ORGANIZATIONS AND STRATEGIES IN ASTRONOMY II

Volume II

ASTROPHYSICS AND SPACE SCIENCE LIBRARY

VOLUME 266

EDITORIAL BOARD

Chairman

W. B. BURTON, *Sterrewacht, Leiden, P.O. Box 9513, 2300 RA Leiden, The Netherlands*
Burton@strw.leidenuniv.nl

Executive Committee

J. M. E. KUIJPERS, *Faculty of Science, Nijmegen, The Netherlands*
E. P. J. VAN DEN HEUVEL, *Astronomical Institute, University of Amsterdam, The Netherlands*
H. VAN DER LAAN, *Astronomical Institute, University of Utrecht, The Netherlands*

MEMBERS

I. APPENZELLER, *Landessternwarte Heidelberg-Königstuhl, Germany*
J. N. BAHCALL, *The Institute for Advanced Study, Princeton, U.S.A.*
F. BERTOLA, *Universitá di Padova, Italy*
J. P. CASSINELLI, *University of Wisconsin, Madison, U.S.A.*
C. J. CESARSKY, *Centre d'Etudes de Saclay, Gif-sur-Yvette Cedex, France*
O. ENGVOLD, *Institute of Theoretical Astrophysics, University of Oslo, Norway*
R. McCRAY, *University of Colorado, JILA, Boulder, U.S.A.*
P. G. MURDIN, *Royal Greenwich Observatory, Cambridge, U.K.*
F. PACINI, *Istituto Astronomia Arcetri, Firenze, Italy*
V. RADHAKRISHNAN, *Raman Research Institute, Bangalore, India*
K. SATO, *School of Science, The University of Tokyo, Japan*
F. H. SHU, *University of California, Berkeley, U.S.A.*
B. V. SOMOV, *Astronomical Institute, Moscow State University, Russia*
R. A. SUNYAEV, *Space Research Institute, Moscow, Russia*
Y. TANAKA, *Institute of Space & Astronautical Science, Kanagawa, Japan*
S. TREMAINE, *CITA, Princeton University, U.S.A.*
N. O. WEISS, *University of Cambridge, U.K.*

ORGANIZATIONS AND STRATEGIES IN ASTRONOMY

Volume II

edited by

ANDRÉ HECK
Strasbourg Astronomical Observatory, France

SPRINGER-SCIENCE+BUSINESS MEDIA, B.V.

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN 978-94-010-3860-7 ISBN 978-94-010-0666-8 (eBook)
DOI 10.1007/978-94-010-0666-8

Printed on acid-free paper

Originally published by Kluwer Academic Publishers in 2001
Softcover reprint of the hardcover 1st edition 2001

Table of contents

FOREWORD

Seated in a sun-lit corner of his 17th century Dutch house, his hand touching a celestial globe, Johannes Vermeer's "Astronomer" seems to ponder about the mysteries of the universe. We might make the trip to Paris and ask him, in the Louvre, what precisely is on his mind. Unfortunately, there will be no answer. But we do know what his mind was not on. It was not on the approaching deadlines for the proposals he would have to write for getting funds and telescope-time, not on the meeting of the observing programs committee, not on his refereeing duty for the journal *Astronomy & Astrophysics*, nor on his university's tightening budget for science.

In the Kapteyn Institute at Groningen I stand face to face with the impressive portrait of J.C. Kapteyn, painted in the year 1918. Seated at his desk he is doing his calculations with pen, pencil and tables, perhaps checking the work of his skilled staff of human computers. Early in his career he had completed his magnum opus, the *Cape Photographic Durchmusterung* in collaboration with his close friend David Gill at Capetown, South Africa. When he wrote to Gill, he knew it would take two months or more before he would receive a reply. And having dispatched a letter to George Ellery Hale, director of Mt Wilson Observatory, he knew the reply would be due at best in four weeks. Ample time to think about the next step. This was the pace of scientific intercourse until well into the 20th century.

And on the frontispiece of a 1929 issue of *Punch*, a British magazine of long standing in pre-World War II years, we meet a plain clothed gentleman, also doing his calculations. His name: Sir James Jeans, one of the giants of 20th century astronomy, whom we owe that monumental volume *Astronomy and Cosmogony.* In his hands, a slide-rule.

Today's astronomer finds himself at the shore of an ocean of observational data accessible à la minute, he/she is amply supplied with information on programs carried out elsewhere, and with references to the work done by others. Calculations are matters of seconds. Perhaps he or she even fancies his or her growing citation index – that monstrous but seemingly unavoidable modern byproduct of research. But there is an other side of the medal, of which the student of astronomy only gradually becomes aware. He or she is immersed in an intricate network of organizations and boundary conditions – all meant to be for his or her good. The present volume reveals the role played in that ambiance at various levels, from consultation between the astronomers themselves, to interaction at European level, to United Nations interests.

There is, first of all, the competition for observing time. Will the OPC pass the proposal and will sufficient observing time be allocated? And, once the work is done, will the editor accept the manuscript? These decisions are made with the collaboration of numerous anonymous colleagues voluntarily sharing in the tasks of OPC and editor. Tasks, so necessary in order to maintain quality and conciseness. The chapters by Abt and by Breysacher and Waelkens on these subjects reveal the size of these important ongoing efforts – shouldn't these chapters be compulsory reading for every astronomy student? A very welcome chapter – at least to me – is also the one by Grothkopf and Cummins. How many astronomers are aware of the scope of librarians' tasks and their mutual contacts when we ask them to get that rare document we urgently want?

"Il faut faire l'Europe". With these words, my friend and colleague Charles Fehrenbach expressed what we felt in the 1950's, the early post-World War II years. The time had come to pool national resources of funds and manpower for astronomy in European countries, and create the European Southern Observatory. It would take nearly a decade, until 1962, to realize our dream. A logical next step was the creation of the European Journal *Astronomy & Astrophysics.*

The examples of, first, CERN and next ESO, were soon followed by EMBO and many other fields of science. But Europeanization was a long and laborious process. The 1950s were the first years of incubation, the years 1960 the first ones of materialization. By now, in the year 2001, the organization and funding of research in European context has grown far beyond what we intended and expected at that time. Mayer's chapter, surveying the panorama from the belvedere of the European Science Foundation describes how far this process has spread. At first sight, his Figure 1 shows a bewildering array of mutual national/European relations. Will science policy and funding gradually shift from national to international level? Haubold's chapter, looking at things from United Nations' point of view, puts the international relations in still wider context.

Eventually, the results of our research will become part of the cultural inheritance we leave for next generations. Dissemination of new insights is a slow process, in which scientists participate with varying degrees of enthusiasm. Those who devote themselves to it, aware of its far-reaching implications, deserve our admiration and support. The description by Jacqueline

Mitton of the Royal Astronomical Society's experience in this field shows numerous aspects of this work and reminds us how important it is that the professional astronomers remain involved or, at least, within reach. Closely connected with this is the project of the *Encyclopedia of Astronomy and Astrophysics*, adjustable on the Web, described by its editor Paul Murdin. It promises to become a main source of information for astronomers as well as laymen.

These and many other interesting items are presented to us under the title "Organizations and Strategies". The fellow on Punch's frontispiece demonstrated the sheer power of the human brain, equipped with a slide-rule. Today's young student of astronomy as well as the advanced researcher will derive pleasure from supplementing these tools with the rich contents of this volume.

Adriaan Blaauw
Kapteyn Astron. Institute
June 2001

INTRODUCTION

Kepler was married twice. On 27 April 1597, he married his first wife, Barbara Mühleck (then 23 years old), who gave him five children of whom only two survived. Arranged by friends and matchmakers, the marriage was rather unhappy, apparently because of the difficult personality of Barbara who died fourteen years later.

Friends and intermediaries interfered again for the second wedding with the difference that, this time, Kepler methodically selected his spouse from among the eleven(!) proposed candidates, explaining his choice in a letter that remains as a surprising document of a dozen printed pages. Thus, in 1613, at the age of 41, Kepler married Susanna Reuttinger (then 24) who gave him seven children of whom three died very young. That union was probably much happier than the first one since little is known of it.

Johannes Kepler, Keppler, Khepler, Kheppler or Keplerus (as he called himself) was born in Weil-der-Stadt in Swabia on 27 December 1571. He studied essentially in Tübingen (mainly theology and, among other disciplines, astronomy) and subsequently lived in Graz (teaching mathematics and astronomy), Prague (succeeding Tycho Brahe as imperial 'mathematicus'), Linz and Sagan.

As exemplified above, Kepler was obviously prone to develop plans and strategies. And he had to devise quite a number of them in his life, for professional and personal reasons.

Towards the end of his life, this led him to travel a great deal in spite of his frail health: to obtain from his august, but greedy, employers the arrears corresponding to his position; to defend his mother accused of witchcraft in Leonberg; to avoid the peasant revolts and the fluctuations of the Thirty Years' War; and also to make sure his books would be properly published. He died during one of those trips, in Regensburg on 15 November 1630.

Kepler was a famous astrologer, but he can be considered as one of the fathers of modern astronomy and his influence went well beyond this. He stated the three basic principles for the planetary motions (Kepler's '*laws*')

A. Heck (ed.), Organizations and Strategies in Astronomy II, 1–8.

which clarified the spatial organization of the solar system; he founded the modern theory of optics by offering a correct explanation of how the human eye worked; he was also the first one to understand what happens to light rays after entering a refracting telescope.

In *Astronomia Nova* (New Astronomy, 1609), he came so close to the concept of gravitation that it is difficult to understand why he did not formulate it explicitly (Newton was to later on). In *Somnium* (Dream of a Trip from the Earth to the Moon), published in 1634, a few years after his death, and which could be regarded as the first science-fiction book in the modern meaning of the term, he even postulated the existence of gravity zero ... at the beginning of the seventeenth century!

⋆⋆⋆⋆⋆

Strategies are naturally devised by people involved in research. They imply objectives. And the achievement of objectives, in turn, implies in turn strategies.

Shall we say that an *organization* is an association (of individuals, of institutions, of other organizations, etc.) with objectives and strategies? This is certainly a definition flexible and convenient enough for our purpose here.

An exhaustive history of astronomical organizations has still to be written. It will certainly illustrate when and how we shifted from personal strategies of isolated scientists, from academic teaching, from general policies of the first professional societies, from the first organized projects and expeditions, often with interested royal sponsors, to the realities of scientific research organizations as we know them today.

It has even become fashionable nowadays to study scientific organizations and research productivity. And this is generally done by specific bodies receiving *ad hoc* contracts and/or subventions from decision makers and takers relying on their conclusions for defining medium- and long-term policies and for motivating immediate critical choices on scientific issues with which they do not feel competent.

The drawback in this approach is that people investigating scientific organizations and research productivity are often not competent themselves in the corresponding fields and therefore their assessment can be seriously biased. Driven by their own internal modes of operation, the sociologists of science might also misevaluate the internal dynamics of the other communities they are investigating (see below) and therefore reach inadequately weighted or nuanced conclusions.

As a fresh member of the *European Association for the Study of Science and Technology (EASST)*, I attended last Fall in Vienna the 4S[1]/EASST

---

[1] 4S = Society for the Social Studies of Science

Conference on *Worlds in Transition*. Let me share with you, as I did with the EASST members[2], a couple of recurrently observed pitfalls from otherwise generally quite interesting sessions at a well-organized and dense conference.

Science and technology are not monolithic

Sociological studies not rarely involve surveys on the perception of science (and/or technology) by layers of society or even by society at large. Science is however frequently presented as a kind of monolithic entity, which it is not, and therefore the corresponding survey results might be seriously polluted or at least might be blending a number of secondary effects. Thus there is a real danger of significantly wrong conclusions being derived, not only by the surveyors themselves, but also by the subsequent users of the survey, for instance science policy makers and deciders.

Running a survey on science in general is roughly equivalent to enquiring about transportation in general. And we do know there are some differences between a bicycle and a jumbo jet or a cruise ship. And those differences are not only effective at the level of the transportation means themselves, but also relevant to the context of specific travels, to the destinations aimed at, and so on. And the differences between scientific disciplines are as varied as between the transportation means above, even if all of them aim at the progress of knowledge.

Part of the problem might arise from the fact that the involved (teams of) sociologists are lacking expertise or enough insight into various fields of science and their respective potential perception (see also below). In any case, we would urge *anyone* enquiring about the perception of science or of scientific issues to record and to state the context in which the survey has been made (the landing of Man on the Moon, the AIDS problem, the 'Dolly affair' or whatever).

Even better, each surveyee should be asked about his/her perception of 'science', in the sense of what that person is thinking of when asked about science in general. It is obvious that some mediatic hype about a specific scientific event might seriously affect the global public perception of science nationally or internationally. For instance, the GMO debate has masked, for a significant number of people, the far-reaching consequences by the completion of the genome project while physics and space sciences remained basically unconcerned by those issues.

In conclusion, when speaking of science in general, the variety of science, the context of the time and the individual perceptions must be taken into account. Hasty generalizations should be avoided in the light of the complexity and nuances of the actual situation.

---

[2] Perceptions of Science, *EASST Review* **19** (December 2000) 8-9.

Perverse perceptions

Astronomy and space sciences are interesting fields in which to investigate public perception. Astronomy has penetrated society remarkably well with an extensive network of associations and organizations of aficionados all over the world. Some of them are well equipped for observing the skies and occasionally become involved with professional research. The deep human need to understand the universe has also led organizations and governments to set up public observatories and planetariums that fulfill academic requirements as well as public educational and cultural interests.

The distinction between professional and amateur astronomers is generally made nowadays on the basis that the former are making a living out of their astronomy-related activities, being paid by some official organization, carrying out some research or participating in some project linked to the advancement of knowledge.

Amateur astronomers are themselves classified in two categories: the active and the armchair amateur astronomers. While the latter have generally a passive interest in astronomy (reading magazines, attending lectures, and so on), the former ones carry out some observing, often with their own instruments, and such activities can be useful to professional astronomy.

Many amateur astronomers have however a limited knowledge of how exactly professional astronomy is carried out and what are the requirements on the professional astronomers themselves. (This is also the case for many potential students in astronomy.) For good amateur astronomers, the 'nec plus ultra' of the achievements would be to know the major stars, the constellations and the visible planets in their share of the sky; and they would expect at least the same from professional astronomers.

Not at all. Many professional astronomers do not know anything about the nightly sky patterns because they conduct theoretical investigations. And those who do carry out observations do not need to be able to point the finger at their pet objects (most of these would be invisible to the unassisted eye anyway): professional observers simply need to know the coordinates of their targets and to enter them into the computers piloting the ground-based and space-borne telescopes.

If such a hiatus already exists between professional astronomers and amateurs who are supposed to know something about the science, one can imagine the breadth of the gap with the public at large. And this gap is again potentially bigger for sciences with less impact on the society. What then can be said on the validity of public understanding of science?

The solution here is education, not through hype and sensationalistic broadcasts or interviews, but through attractive but detailed and informative lectures by patient and non-publicity-seeking experts.

The sports car effect

Car makers (and other manufacturers) know how important it is to have a luxury item in their line of products. Few people will buy it, but most purchasers of the standard items will get something out of it, be it only through the image associated to the brand name – somehow like dreaming (or getting friends and colleagues to dream) of an unaffordable expensive lover.

In that perspective, something interesting can also be pointed out, and again involving astronomy and space sciences. In reader surveys conducted by popular science magazines, subjects such as astronomy and space sciences regularly receive the top rankings in terms of *interest.* Medicine, generally thought as being the primary subject of choice by the public, reaches lower scores.

The difference is that, when it comes to the time of distributing the pennies, the public opinion, and then the policy makers and politicians, go down to pragmatic issues, in line with the fact that – after the end of the Cold War and long after the landing of Man on the Moon – society at large now has other priorities (such as health, environment, security, unemployment) than space investigations or cosmological understanding.

This is when and where the biosciences come first. And this is another reason why public surveys on science perception must be extremely carefully worded, analyzed, interpreted and put into the proper perspective.

⋆⋆⋆⋆⋆

Pushed by the increasingly competitive situation for 'selling' projects and ideas to decision markers/takers, scientists have also felt the need – identified since long by marketers and advertizers – to use imaginative ('sexy') buzzwords. One of these – that we consider most unfortunate – recently appeared in the professional literature world-wide as a label for a number of projects: *virtual observatory.*

The origin and acceptance of the term is in itself an interesting example of sociology and how communities respond to funding systems and to fashion. As explained elsewhere [3], the label is wrong on both counts: 'virtual' and 'observatory'.

Virtuality is indeed nothing new to astronomers.

With the exception of experiments carried out in situ by solar-system spacecraft, our knowledge of the universe is totally derived from photons reaching us from the outer space. And because of the finite speed of light, we do not observe the objects the way they are, but the way they were when the photons we are collecting actually left them.

---

[3] Virtual Observatories or Rather Digital Research Facilities?, *American Astron. Soc. Newsletter* **104** (March 2001) 2.

What we have thus in our data files is nothing other than a huge and complex virtuality of prior stages, differentiated as a function of the distance in space and time of the various sources. Thus the job of astronomers is to work on that space-time mosaicked virtual universe in order to figure out what is exactly the real universe and to understand the place and role of mankind in it.

While highly desirable and commendable, the structures proposed under the label 'virtual observatory' will be quite far from the classical function of an observatory (astronomical or other) devoted to the collection of new data. The label could thus be seriously misleading since additionally a fundamental feature of the actual universe will be disregarded: its omnipresent variability with time.

For instance, the project known in the US as the 'National Virtual Observatory (NVO)' is basically the aggregation of complementary multi-wavelength surveys (of course frozen in time).

There is no doubt that with efficient access and manipulation of immense volumes of data stored at distributed sites, with sophisticated search and cross-correlation methods, and with evolved data visualization tools, results can be obtained if investigations are driven by well-defined science initiatives.

But still, we are not speaking of an observatory per se, but of an advanced digital research facility, well in line with the evolution from data files to information hubs that we have seen over the past decades.

Other projects currently in the air are putting more emphasis on the methodological ways of tackling the existing – and largely dormant – amount of data, not only in astronomy, but also in Earth and environmental sciences.

A related project with a less questionable label (only the 'instrument' here is virtual) has been launched recently: *AstroVirtel*[4] aiming at making accessible the ESO/ST-ECF archive that currently contains more than 7.0 Terabytes of scientific data obtained with the NASA/ESA Hubble Space Telescope (HST) and with several ESO large ground telescopes.

Buzzwords are useful when well introduced and justified. They summarize ideas and projects in an imaginative way and can be excellent vectors to 'sell' them to decision makers and takers, to the community, and to society at large. Some of them might even make it into history. Their semantic substance must however be representative of what they are labelling and not be sources of confusion.

Is there still time for hoping a reversal of usage when wrong labels are already widespread? Probably not and, once again, language might have

---

[4] See for instance `http://www.stecf.org/astrovirtel/` .

to adapt to usage, rather than reason – unfortunately. Even in astronomy now, we'll have to teach kids and students not to believe always what they read ...

★★★★★

This book is the second volume under the title *Organizations and Strategies in Astronomy (OSA).* These OSA Books are intended to cover a large range of fields and themes [5], In practice, one could say that all aspects of astronomy-related life and environment could be tackled in the spirit of sharing specific expertise and lessons learned.

This volume starts with two chapters on astronomy-related research institutions. Marcel Golay shares his experience of the challenges for bringing Geneva Observatory to its current position at the forefront of astronomical research in Europe, while Jayant V. Narlikar details the quite different context of the creation and operation of the Indian Inter-University Centre for Astronomy and Astrophysics.

Then Hans J. Haubold reports on the decade-long activities in the framework of the UN/ESA Workshops on Basic Space Science.

Two European contributions follow: one by Anthony Mayer carefully explaining the complexities of European research and the other by Gerard Gilmore dealing with an ongoing European coordinated project, Opticon.

The next four chapters are devoted to practicalities of astronomical observing. First, Karla A. Peterson and collaborators describe the challenges for coordinating campaigns involving ground-based and space-borne instrumentation, a result of our current panchromatic approach of celestial objects. Second, modern methodologies for efficient observing are analyzed by Ian Robson. Third, Ofer Lahav discusses several sociological issues related to large surveys and associated experiments involving large amounts of collaborators. Finally, the detailed working of the ESO Observing Programme Committee is carefully explained by Jacques Breysacher and Christoffel Waelkens.

Complementing the above series, a chapter by Keith Shortridge pleasantly recalls how the evolution in computing and networking dramatically changed, over the past decades, the way we work and interact.

We then move to evaluation aspects with two chapters. András Schubert introduces both scientometry as a scientific field *per se* and the journal *Scientometrics* he is editing. Next Helmut A. Abt shares his long expertise as Managing Editor and Editor-in-Chief of the *Astrophysical Journal*, offering guidelines for efficient and fair handling of refereeing.

This introduces the subsequent group of chapters centered on publications and astronomical information. Uta Grothkopf and Marlene Cummins

---

[5] See for instance `http://vizier.u-strasbg.fr/~heck/osabooks.htm` .

remind us how astronomy librarians dynamically work and cooperate nowadays, while Paul Murdin presents the way the monumental *Encyclopedia of Astronomy and Astrophysics* has been brought to existence. Noël Cramer then details the "tightrope-walking" publishing of a multilingual magazine for amateurs and public at large in a multilingual and multicultural country (Switzerland).

Jacqueline Mitton then describes her work as Public Relations Officer of the Royal Astronomical Society.

The following chapter by André Heck is devoted to creativity in arts and sciences, offering novel insights from a specific survey showing both similarities and diversity of cases.

The book concludes with an update of the bibliography of publications relating to socio-astronomy and to the interactions of the astronomy community with the society at large.

⋆⋆⋆⋆⋆

It has been a privilege and a great honour to be given the opportunity of compiling this book and interacting with the various contributors. The quality of the authors, the scope of experiences they cover, the messages they convey make of this book the natural continuation of the first volume.

The reader will certainly enjoy as much as I did going through such a variety of well-inspired chapters from so many different horizons, be it also because the contributors have done their best to write in a way understandable to readers who are not necessarily hyperspecialized in astronomy while providing specific detailed information and sometimes enlightening 'lessons learned' sections.

I am specially grateful to Adriaan Blaauw for writing the foreword of this book.

Finally, it is a very pleasant duty to pay tribute here to the various people at *Kluwer Academic Publishers* who are enthusiastically supporting this series of volumes.

The Editor
June 2001

STRATEGIES FOR BRINGING A 19TH-CENTURY OBSERVATORY UP TO THE STANDARDS OF 21ST-CENTURY ASTRONOMY

MARCEL GOLAY
Observatoire de Genève
Chemin des Maillettes 51
CH-1290 Sauverny, Switzerland
`marcel.golay@obs.unige.ch`

Abstract. This article is an account of actual experience that will sound familiar to several European astronomers who began their professional careers during the fifties, and who set out to transform their observatory, generally constructed in the 19th century, into an institution capable of using all the means offered by modern technology to explore and comprehend the phenomena that govern our universe.

1. Astronomy in the 19th century, the reign of logarithmic tables

Most European astronomy students of the fifties received an education based essentially on positional astronomy and celestial mechanics. In some rare occasions an introduction to astrophysics was also given. Practical work was limited to the apparent and true motions of the heavenly bodies, the handling of tabular data found in the *Connaissance des Temps*, *Annuaire du Bureau des Longitudes* or *Nautical Almanac*, as well as the use of logarithmic tables such as the well-known seven-decimal Vega, for example. The latter were unavoidable since the calculating machines (usually cranked by hand) could only add or subtract. Traditionally, some problems regarding cometary orbits also figured in that list.

Practical observational work involved the determination of time by using a meridian circle to check pendulum clocks. That task was, however, not as easy as it may seem. The meridian circle has only one axis of rotation, but the necessary instrumental corrections are many. Here are some of them: corrections related to the inclination of the rotation axis, corrections for collimation of the optical axis (the latter is usually not perfectly

A. Heck (ed.), Organizations and Strategies in Astronomy II, 9–28.

perpendicular to the mechanical axis), and corrections for azimuth, as the rotation axis is not strictly perpendicular to the true meridian. Several of these corrections were made by using levels (which had to be frequently re-calibrated) and micrometric screws that also had to be gauged. The whole procedure had to be repeated every night, sometimes several times per night, in case of large temperature variations causing structural deformations of the telescope and of its mounting.

Finally, human physiology had its word to say with the establishment of each observer's personal equation. Each person evaluates differently the instant when a stellar image crosses the vertical mark of the micrometer in the focal plane.

The foregoing description gives a rather forbidding image of astronomy and of its practice. That impression is still well entrenched in our collective memory and kept alive by the success of some comic strips and cartoons. However, a great number of the astronomers who have contributed to the extraordinary development of the science during the last half century were originally introduced to the thankless subject of positional astronomy, now known as astrometry.

2. Poincaré's arguments do not suffice to ensure the development of an observatory

The activities of young astronomers working at a provincial observatory of that time were not just limited to meridian observations serving to determine local time, or to accurate determinations of longitude and latitude for cartographic or geodesic purposes, or even to measurements of equatorial coordinates for the "Carte du Ciel".

There were many other tasks that make us regret that Poincaré's text cited below did not serve as a guidance for our government economists when establishing research budgets. In his wonderful book *La valeur de la science*, H. Poincaré emphasises the usefulness of astronomy. In an admirable text, he says:

> "Astronomy is useful because it raises us above ourselves; it is useful because it is great; it is useful because it is beautiful; that is what one has to say".

Such arguments are convincing for scientists and philosophers. We must, however, question their efficiency when facing governments, politicians or economists. H. Poincaré refuses to accept any other form of usefulness and adds:

> "One could of course speak about the navy, the importance of which is universally recognised, and for which astronomy is necessary. But that would be tackling the question from its narrow side."

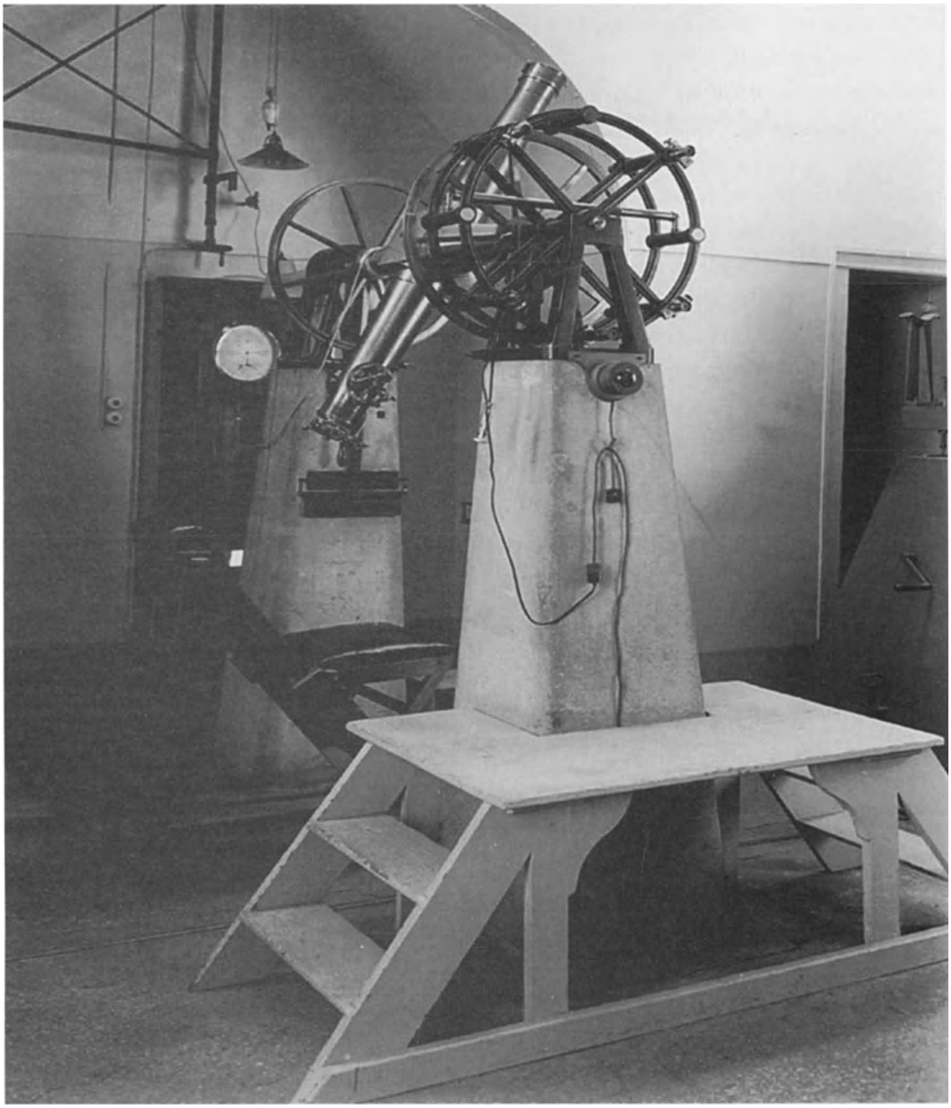


Figure 1. The meridian telescope of Geneva Observatory made in 1830 and improved in 1870.

Maybe, but, as far as I know, most European observatories owe their existence to that narrow side, and to many other ones, still narrower. Those narrow sides had to be faced by the young astronomer of the fifties and he, like myself, had to devote much of his time to them.

The following discussion will show how, in 150 years, observatories became establishments entirely devoted to research. As a concrete example

I shall take the history of the *Observatoire de Genève*. That institute, with which I have been associated for more than 50 years, has encountered throughout its history the same stages as did most of the provincial observatories of other small countries.

I have always been surprised by how the general public, the political leaders, the members of our government and even, which is more serious, our colleagues from non-scientific faculties imagine our activities to be. They are unable to realise that in order of carrying out our investigations we need to organise, plan, manage matters so different as technical developments and staff and, in the same way manufacturers have to do it too, convince numerous organisations to finance our work.

So, to be able to practice astronomy in the sense of Poincaré, we must elaborate policies and strategies for each project undertaken. It is those policies and strategies that I shall discuss in the following on the basis of my own experience linked to the development of Geneva Observatory. The numerous discussions I have had with colleagues of my generation lead me to believe that we have all applied the same methods, save for slight local differences. As mentalities generally evolve very slowly, our successors will be committed to apply similar strategies, though enhanced by the evolution of communication techniques.

3. Statutes and missions of the observatory. From "useful" science to research.

3.1. SUBDIVISION OF APPROXIMATELY TWO CENTURIES INTO DIFFERENT SOCIO-ECONOMIC PERIODS

Geneva Observatory was founded in 1772 and, from then up to this day, its (*de facto*) statutes, means, objectives, have been modified several times apparently in regard to the many social, economic, political, philosophical mutations of our European society during the two last exciting centuries.

We can thus distinguish the following periods:

1. The period of the aristocrats and upper middle class (1727-1830).
2. The State intervenes to develop utilitarian scientific institutions (1830-1870).
3. The State imposes links between the universities and the utilitarian scientific institutions. The new statutes provide some means for fundamental research (1870-1920).
4. The State, some large industries, and the Academies intervene in favour of the realisation of large instruments (telescopes, large refractors, observation sites) (1920-1950).
5. Creation of national organisations for managing the development of fundamental research and the access to international cooperations

(FNRS 1952, CERN 1952, ESRO 1962, ESO 1960, ESA 1972).

6. Information technology is established in university computing centres (1960).
7. Increase of computational capacity at observatories and university laboratories. Establishment of internal networks within universities and between international organisations (1970-1980).
8. Present situation known to all of us.

As listed in the table above, the first Observatory was built and financed mainly by Jacques-André Malet, a member of one of the great Geneva families. After much deliberation, the "Magnifique Conseil" (governing power of the State of Geneva) generously allotted a piece of land close to the town walls while stipulating that the said land could be taken back at any time by their lordships without compensation.

With his refractors and his meridian circle, J.A. Malet made observations of the planets, established a map of the Lake of Geneva, made meteorological observations from the Observatory as well as from his country house. He was often assisted by members of the other patrician families that politically ruled over the city.

As a service in favour of the local watch making industry, J.A. Malet in 1778 calculated the mean time meridian affixed to one of the walls of the cathedral. It enabled the watch makers to set their chronometers with an accuracy of four seconds.

3.2. THE UTILITARIAN OBSERVATORY

The second Observatory was built in 1830 some hundred metres from the first one and was, on that occasion, financed by the government which was still under the rule of the great families.

Official involvement is illustrated by a report that defines the primary mission of the institution. Here is an excerpt:

> "The Observatory is necessary to Geneva within the context of one of the productive sectors of our national industry, namely that of superior watch making (*i.e.* marine chronometry) which cannot be dissociated from a means of determining time exactly and precisely assessing the running of the watches and chronometers made in Geneva."

This report was the basis of an official ruling that was applied from April 7th, 1834 onwards. It was repealed as lately as November 9, 1954. The duration of that ruling reveals to what extent the Observatory was primarily considered as a utilitarian institution.

A similar status is quite representative of the European observatories founded during the 19th century. Since that kind of establishment was permanently occupied by staff (often residing at the Observatory), many additional tasks were added to the primary mission which is the conservation of time. Those mainly consisted of meteorological observations, and observatories were often officially referred to as "Astronomical, Chronometric, Meteorological Observatory".

Moreover, in the vicinity of an area where watch-making industry is of some importance, observatories were required to control the running of chronometers and deliver certificates regarding their performance. All those utilitarian activities were extremely demanding for the staff since meteorological recording instruments were unavailable until the end of the 19th century, and were then often too expensive for small institutions. Often, as was the case in Geneva, those tasks were supplemented by seismography, limnimetry (measurement of lake level) and measurements of the Earth's magnetic field.

The last meteorological observations at Geneva Observatory were carried out in 1966. Activities linked to the time service, the 'speaking clock' and the monitoring of chronometric performance were discontinued in 1968.

3.3. THE OBSERVATORY AS PLACE OF INFORMATION

The 19th-century observatory, as a place where all celestial phenomena were observed, where all atmospheric, terrestrial, fluvial or lakeside data were measured, was also the place where all these recordings were conserved. All these data were gathered in huge registers that adorned the walls of those venerable institutions and contrived to somewhat overpower the visitor with a feeling of respect.

During the 19th and 20th centuries, the information was diffused throughout all social categories. Public schools dispensed knowledge more democratically and, thanks to the variety of its tasks, the Observatory became a popular centre of information. I have seen, in the early fifties, regular visitors coming every day to set their watch by the clock on the Observatories pediment, thereby seizing the opportunity to consult the barometer, noting the air temperature and glancing at the weathervane to know the direction of the wind.

In the event of an eclipse (as it is still the case today) that was perfectly visible in greater comfort from one's own balcony, the public would come in great numbers to observe it from the terrace of the Observatory.

Thus, during the 19th century, the Observatory became an institution that acquired a moral obligation to inform citizens either directly or indirectly – through the daily press, through almanacs and through lectures at the numerous educational societies set up by the various political trends to satisfy the wishes of their electorates. As an assistant in 1950 I used to write a daily press communication which informed the public on the weather of the day past and, sometimes, regarding the probable weather of the morrow and some comments on interesting celestial phenomena.

The director of the Observatory was a man who was supposed to know everything pertaining to climate, auroras, the colours of the sky, earthquakes, stars, planets and comets. Socially, he was the only man of science known to everybody. Personally, he was sometimes attached to the university.

However, after 1890, following the example set by the organisation of the German universities, research laboratories began to be attached to the university. First among these were the laboratories of botany, physiology, chemistry, geology and physics. In the case of Geneva, it was only in 1966 that the Observatory and the teaching of astronomy and astrophysics were totally integrated within the university as a department of the Faculty of Sciences. From 1870 onwards, the successive directors were also full professors of astronomy and meteorology at the university.

As to their means for research, these were financed by sponsors, such as the watch-making industry. There was occasionally a State subsidy (only the State of Geneva; Confederate subsidies were granted only after 1955).

This was how the Observatory received in 1870 a 27cm equatorial refractor, donated by its director E. Plantamour. That instrument enabled systematic research on planets, comets, double stars and variable stars. However, utilitarian activities continued to retain priority, but nevertheless led to important work in climatology and geodesy.

3.4. THE OBSERVATORY, INITIATION OF SYSTEMATIC RESEARCH IN ASTRONOMY

From the beginning of the 20th century onwards, learned societies as well as the university, the State, industry and sponsors financed the acquisition of instruments and the development of sites situated out of town to facilitate astronomical research.

The latter benefited from the considerable progress achieved in the sensitivity of photographic plates which extended their application to stellar spectroscopy. Astrophysics (a term that appeared around 1895 in English and 1906 in French) was introduced to the Observatory by my predecessor, G. Tiercy. Trained as a mathematician and particularly interested in celestial mechanics, he realised that an observatory with modest means could nevertheless venture into a vast program of low-resolution spectroscopy, thanks to the performance of new photographic emulsions. Such a program could be carried out by means of relatively small telescopes provided they were installed in an adequate site far from town light.

During the twenties, the Jungfraujoch site at 3450m in the Bernese Alps became reachable by train, eventually rendering the installation of a telescope possible. Astrophysics interested the physicists and chemists at the University of Geneva, as well as the industries specialised in manufacturing physical instruments. Furthermore, faced by the spectacular photographs made with the large American telescopes, the local press resorted to the competent comments made by the director of the Observatory when publishing the most sensational images.

G. Tiercy skillfully made use of that regain of interest to create an observational station at Jungfraujoch with funds obtained from the "Société Académique", the industry and a popular subscription. The station was built, but was not put into service because its operation was retarded by the financial crises of the thirties and by the war of 1940. In 1945, it became obvious that regional observatories, even if partially attached to a university, could only be transformed into research institutes if the obligations regarding civil services (chronometry, meteorology, climatology, timekeeping, talking clock, geodesy) were severed from those serving the systematic pursuit of astronomical research seconded by an advanced teaching of the subject.

To attain that separation, one had to dispose of financial means that provincial universities generally did not have, and it was not by quoting Poincaré's arguments that we could convince the authorities to finance fundamental research in astronomy and astrophysics – two terms that, by combined use, tended, with time, to become synonyms.

4. Towards an observatory entirely devoted to research

The first years of the last half century, 1950-1960, were marked by a collective arousal in favour of fundamental research. This was primarily stimulated by the achievements of American science and technology. Such great success attracted all young graduated scientists of our universities and, finally, provoked a response from the political and economic circles.

However, realising that they were not competent to manage the development of research, governments created specialised organisms, financed by the State, but responsible for the policy regarding the distribution of the funds among the various scientific disciplines.

This novel situation fundamentally altered the role of directors of research establishments. Until 1950, the director of an observatory such as that of Geneva was answerable to the local government alone and, if need be, to the authorities of the university. The local prestige of the director contributed to simplify all administrative relations. After 1950, our system swung over to the situation that all research institutes now know.

The director and his collaborators have to devote much time not only to the scientific and administrative management of their research projects,

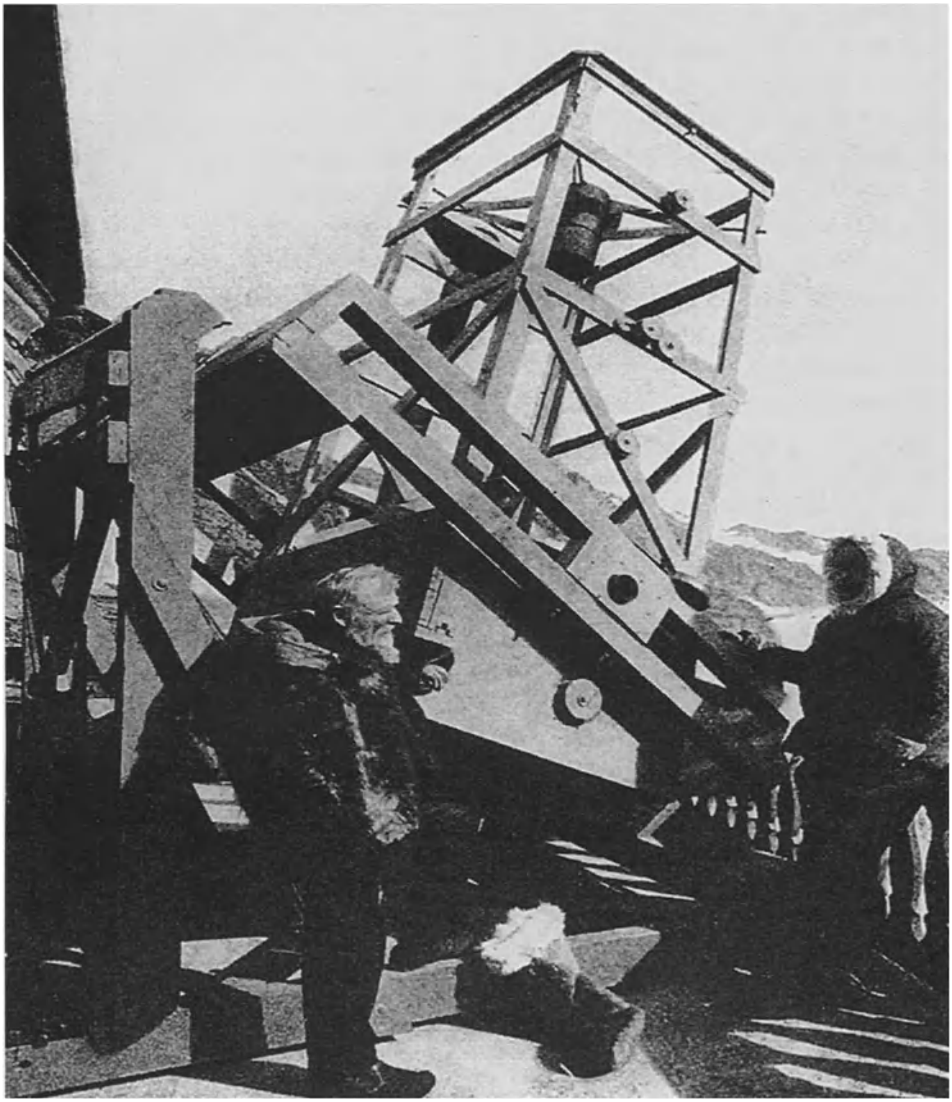


Figure 2. Astronomers of Geneva Observatory with the wooden-mounted 1m telescope set up at Jungfraujoch for observing the 1924 Mars opposition.

but also to the prevalent research management policies on the national and international levels. Although we are astronomers, we are compelled to participate in the activities of organisations which are concerned with, for example, the importance of biology relative to physics, of astrophysics relative to solar physics, and so on. Up to 1950 we were able to pursue freely chosen projects of low cost and to devote all our available time to their implementation.

Nowadays, projects can be defined on a large scale but they have to satisfy a large number of constraints before they may be undertaken. A double strategy has to be applied; one regarding the choice of projects, the other one to impose them upon the community.

Several factors were to guide me regarding the strategies to be developed for attaining the goals I had set to myself in 1956. First, the *Swiss National Science Foundation* was created in 1952 (the director of the Geneva Observatory, G. Tiercy, was one of the founding members) and begins to tentatively fund some research in 1956.

Also in 1952, CERN (European Centre for Nuclear Research) was created in Geneva. A remarkable international organisation, CERN would later serve as model for future research organisations such as ESO for astronomy and ESRO-ESA for space. CERN not only served as an example to be followed, but mainly as a catalyser to incite European astronomers and scientists concerned by space research to unite their efforts in view of achieving intergovernmental agreements leading to the creation of other European research organisations.

Curiously, but in a manner quite indicative of the mentality (and ignorance) of the times regarding fundamental research, and even though Geneva had been chosen as host for the general headquarters of CERN, a popular referendum was launched against the presence of that organisation. The opposition was instigated by the middle-class political parties and academically trained individuals (the latter being generally non-scientific). The arguments used revealed an instinctive fear of science and the confusion of nuclear research with nuclear armament, a confusion upheld by political tensions aggravated by the cold war.

The population was to be more reasonable than the intellectuals and the popular vote turned out very favourably in regard to the construction of CERN. The first local consequence was the construction of an important Institute of Physics at the University of Geneva. Also influenced by CERN, the research worker acquired a professional social status. It is difficult to imagine nowadays that, in 1950, that occupation (research) was subordinated to that of another profession such as professor, engineer, etc. In 1956, I assisted for the first time to the assembly of the professors of the Faculty of Sciences and the dean, while presenting the Faculty to the rector, spoke with much satisfaction regarding the research conducted by the professors *during their free time.*

The decade of the fifties was particularly eventful and witnessed major discoveries. For example, in 1951, astronomers gained access for the first time to radiation unimpeded by Earth's atmosphere, the 21cm line of neutral hydrogen. Within a few months the distribution of H21 revealed the spiral structure of our Galaxy. The result led to the immediate construction of larger and larger radio telescopes that required financial resources of a magnitude exceeding the resources of classical observatories.

This allows me to give another example illustrating how difficult it was for universities of those days to anticipate the importance of large projects. The *Swiss National Science Foundation* was in its beginning stages. The members of the commissions responsible for the preparation of future scientific research in Switzerland were informed of the European projects regarding the construction of radio telescopes by the press. Without conducting any kind of investigation, they imperially decided that no radio astronomy would be done in Switzerland because the necessary means for constructing a radio telescope larger than those already planned would never be available. That decision froze for more than 20 years research projects requiring even a small radio telescope.

Our example shows how difficult is the management of science and that a community of scientists, even though of great reputation, does not necessarily represent an organism capable of making good long-term provisions. Astronomers will often be confronted by such arguments and that compels us to care for the scientific education of our future negotiating partners from the administrations as also of scientists from other disciplines. We all have had to explain that radio telescopes do not automatically render optical telescopes obsolete, that large optical telescopes do not lead to the disappearance of telescopes of lesser diameter, that astronomical satellites do not do away with ground-based optical and radio telescopes.

I have had to struggle against such simplified concepts at all times even when dealing with interlocutors of great scientific reputation, but in a different field (and even, on one occasion, with an astronomer competent in a very narrow field).

The comments above are but a very small sample of the difficulties that must be overcome by a new discipline, or by an older one that has to be modernised. They allow, however, to appreciate the fact that a group desiring to create a new institution aiming at carrying out fundamental research must spend much time convincing even close colleagues (who will, often, swiftly become opponents).

It was with that state of mind and by making use of the dynamics brought to Geneva by CERN that I was able to progress from an Observatory ruled by a law dating to 1834, somewhat modified in 1954, moderately improved in 1956, to an institute able to make good use of the most powerful extant instruments and thus to gain access to all aspects of modern astrophysics.

5. Strategy for creating official and public awareness regarding astronomy

It is first necessary to describe the initial structure.

Initial situation in 1955:

- Operational astronomical instruments: most recent acquisition in 1870.
- Personnel

  One caretaker, working also as assistant and carrying out all routine activities.

  Two half-positions for the control of chronometers, time service, management of meteorological measurements.
- Director

  Professor of astronomy at the Institute of Mathematics at the university (main professional outlook for the graduate students: teaching of mathematics in colleges and technical schools).

The presence of CERN in Geneva encouraged many students to undertake studies in physics and offered graduates true career prospects as mathematicians or physicists. Teaching in a college was no longer the only outlook. Thanks to the recently established *National Science Foundation*, the Institute of Physics at the university could create positions for physicists and carry out research projects making use of CERN facilities. Local industry also hired physicists in order to be able to participate at the required level in the construction of the large accelerator.

Before the advent of CERN, young physicists and mathematicians could only aspire to a professional career by emigrating, generally to the USA. For several years the situation was such that it was impossible to entice our compatriots, who enjoyed well-equipped laboratories and were professionally recognised in the USA, to return to Switzerland.

The preceding comments allow us to sketch the various strategic phases adopted.

- Phase 1

  Introduce astronomy and astrophysics among the subjects taught to physics and mathematics students (later on we would extend teaching to biologists, geologists, chemists, and to the education of teachers at the primary level).
- Phase 2

  Creation of research groups with the help of the first students graduated.
- Phase 3

  Acquisition or construction of the technical means adapted to requirements. Policy of growth.

- Phase 4
  Creation of an autonomous institution possessing the means of developing research within the scope of international co-operations.

6. Phase 1: University teaching of astronomy and astrophysics

Achieving Phase 1 was essential. It was necessary to take advantage of the dynamics generated by the presence of CERN, and to rapidly create a small nucleus of young scientists who would not waver before any of the tasks to be accomplished in view of acquiring the means necessary to practice modern astronomical research.

Thanks to private agreements, the Observatory had access to CERN computers and often also profited from technical support.

In the period 1955-1958, new subjects were offered to physics and mathematics students. These were lectures on theoretical and observational astrophysics, stellar dynamics, astronomical spectroscopy.

From 1952 onwards, I had the opportunity to work with the 120cm telescope at the *Observatoire de Haute Provence (OHP)*. After 1955, my young students were warmly welcomed by the director, Jean Dufay, and by the vice-director Charles Fehrenbach, as well as by Daniel Chalonge and Daniel Barbier from the *Institut d'Astrophysique de Paris (IAP)*. My students were thus rapidly associated with ongoing OHP research projects and, by the same token, acquainted with astronomers coming from all over Europe. OHP was the only European observatory to enjoy a reasonably good climate (according to the criteria of the time). It played the same role for our astronomers as did CERN for the physicists.

This brings us to the action described in the next paragraph.

7. Phase 2: Creation of research groups

In order to stabilise the nucleus of highly-motivated young scientists, it was necessary to create a structure separating the service activities – still essential for the survival of the institution – from research. It was an extremely critical phase which required a redistribution of premises because one needed space for workshops, laboratories, administrative activities, computation (very noisy) and, finally, workspace for the students, assistants and doctoral students.

Such a redistribution was difficult to achieve in a building dating from 1830 (ice-cold in winter). Since the building was State property, we had to follow long procedures to be able to carry out even moderate modifications. We had to act fast and, by using second-hand materials, we undertook to transform the building ourselves, thus putting the State services in a situation of *fait accompli.* Such acts of administrative indiscipline were to be often repeated during the forty following years.

Quite generally, when striving to rapidly develop an institution in a new field, one must be aware that no official administrative structure is adapted to rapid evolution. State structures are generally made to insure the good running of established organisations, but not their rapid mutation. Therefore this entails that those who are responsible for rapid developments must also accept to assume personal responsibilities and risks.

The successful achievement of Phase 2 required that one be particularly careful regarding the selection of the young scientists. It is advisable to surround oneself with young scientists who not only entertain a profound interest for research in astronomy but also for technical implementation and for observational work. Moreover, one must expect from them an acute practical disposition. Our first teams consisted of scientists who were originally educated as engineers.

Starting with nothing, as was our case, I had to define a priority research program. The program needed to involve manufacturing instruments and to open up numerous cooperations with observatories and institutes more advanced than ours. I therefore started a long-term program of multicolour photometry (still running) initially adapted to the work carried out by the group of stellar spectrophotometry led by D. Chalonge. That privileged connection enabled us to convince the *Swiss National Foundation* to finance the construction of a first telescope and photometer, which were installed at Jungfraujoch.

The project led to a long presence at that high-altitude observatory in collaboration with D. Chalonge. Throughout the following years that observatory underwent several phases of expansion associating other astronomers such as the Belgians Migeotte, Neven, Delbouille, and so on.

Following the initial development phase, the research institute that I was setting up had to accommodate scientists interested in some of the many other fields of astronomy and to allow them to develop. Astronomy is a natural science that enables a great variety of types of intelligence to find substance for profitable research. However, in a small-sized institute undergoing its development phase one must select the fields of interest so as to guarantee a cross-fertilisation between the various groups.

In the sixties, we encouraged the study of stellar clusters through their various aspects, stellar photometry, stellar dynamics, interstellar extinction, evolution, stellar spectroscopy, peculiar stars. Subsequently, each of these orientations was to be developed in relation with international progress achieved in each domain.

We may consider that in the sixties astronomy had taken root within the teaching done at the university and within the administrative structures of the State. At the same time, great means of research entered the international stage, such as large telescopes and satellites. Professional prospects opened up for young astronomers. Our needs for equipment and computational capacity increased. A new structure had to be created which could not be set up on the site of an establishment built in 1830.

So enters Phase 3.

8. Phase 3: Implementation of technical means and policy of birth

Phase 3 was extremely critical because the institution, in view of insuring its future development had to re-evaluate the budgetary traditions of all the organisations on which it depended, the budgets of the State services, those of the university, and the contributions of the *National Science Foundation.*

The reflexive action of each organisation is to change nothing. Thanks to the particular status of the Observatory (which will change in 1974), the problems involving construction work and maintenance of the buildings related to the State, *i.e.* the political power. The civil servants of the State managed the budget accepted by the political power which had also defined the priorities over several years. Wisdom counselled me to try and slip my projects within the bounds of the developments foreseen by the university.

One could expect the university was an authority particularly apt to heed the needs of a growing discipline such as astronomy. I nevertheless preferred to confront the political power rather than the conservatism of the university. It was a dangerous gamble!

If one chooses such a course, one must simultaneously convince the high-ranking officials of the State as well as the political leaders of various parties. For the officials, the projects presented by the director of an observatory do not have the same character of urgency as the development of schools, roads, or hospitals. Regarding the political leaders, there is a certain resolve to prepare the future of a region. Once again, CERN has provide me with all the necessary elements to convince the political authorities to support my projects. The creation of the new Geneva Observatory was to be the first realisation of a research laboratory, in Geneva, conceived for long-term research that can only be undertaken within the scope of international cooperation.

The launching of the project benefited from particularly favourable circumstances. It was at CERN that I was to prepare upon invitation of the federal authorities, and with the support of the cantonal authorities, the first meeting of the preliminary committee of the future international organisation for space research ESRO (now ESA). That meeting was also the origin of an intense information campaign – a strategy that was systematically brought into play whenever we had an important development in view.

The launch of Sputnik 1 gave me the opportunity to establish close contacts with all media, newspapers, radio, TV, and to attract the attention of the journalists as to the present and future importance of space research. At that time (up to about 1970), such an act of public information delivered by a university establishment was rather badly perceived by academic circles. The latter had such a high opinion of intellectual activity that my project to equip our university with a computer (it was an IBM 1620) appeared to them as an attack against the spirit of pure thought that should prevail in a university (my main opponent was an eminent theoretical physicist and my greatest supporter was the famous psychologist Jean Piaget).

In the years 1955-1970, journalists were keen for receiving information, all the more so since the other university institutes were difficult to approach. Moreover, each one of them strove to gather a minimum of information before coming to see us (or receiving us). They came to gather more knowledge and very often submitted their articles before publication. The newspapers also gladly received our proposals for articles, corrected them, improved them to suit their readership.

Everything changed after the 1973 “Watergate” affair. All the young journalists considered themselves to be investigative journalists and no longer sought to understand what we were striving to realise but, on the contrary, tried to be – in perfect ignorance – critical and destructive.

The prevailing curiosity regarding all the events related to the conquest of space allowed me to point out how important had been the earlier work of astronomers for the accomplishment of those exploits in space. On the other hand, those exploits opened up extraordinary perspectives regarding a better understanding of our Universe. At the same time that situation allowed me to demonstrate that our institute, in its present or future states, should be equipped so as to take advantage of the powerful new resources of ESRO, ESA, NASA, ESO.

Being under democratic rule, I had to reckon with public resolve that does not hesitate to resort to a referendum in view of opposing a project. I have already mentioned that the presence of CERN in Geneva was at one time threatened by a referendum. As another example, at the time these lines are written, a referendum is holding back the construction of a magnificent museum of anthropology.

Here is a non-exhaustive list of actions, and of their intensity:

1. Local press
    (a) Each week would appear in the general press at least one article concerning an astronomical or space exploration subject.

   (b) In case of an exceptional event, an article would appear in each local newspaper and in the French-speaking press.
   (c) Exceptional situations motivated a press conference, about once a year.
2. Radio Suisse Romande
   (a) Interview or specialised emission and appearance in the news program: on the average, one action per week.
   (b) There were also occasional interviews by the rare private radios.
3. Television
   1955-1970 corresponds to the period when television was present in all families and when the program managers considered themselves to be laden with a cultural mission. It was for us the golden age of the documentary show, and television gladly accepted all our proposals. We were able to introduce three to four emissions per year.
4. Lectures
   Lectures at all levels – learned societies, professional groups, syndicates, industrial sphere (particularly during meetings of the Board of Directors) –, usually about once or twice per week.
5. Presentations and outlines of our future projects during meetings of directive committees, all political parties considered, once or twice per month.
6. Personalised information and comments sent in writing to the most influential personalities with a frequency of about one message per week.
7. Exhibitions
   Presentation of astronomical documents in galleries, show cases in department stores (also in banks) and at fairs and trade shows.

9. Conclusions

In 1956, I was faced by the convenient choice of conserving a utilitarian observatory with a chair of astronomy attached to the Department of Physics or to the Department of Mathematics (at that time one did not speak a department, but of an institute).

I was of the opinion that astronomy was a natural science, an observational science, thus implying the construction of instruments, the installation of those equipments in the Northern and Southern hemispheres, ground-based, at high altitude, or in space. But astronomy was also a science involving the interpretation of data, using physical models, using statistics, with the necessity of having access to powerful computational resources.

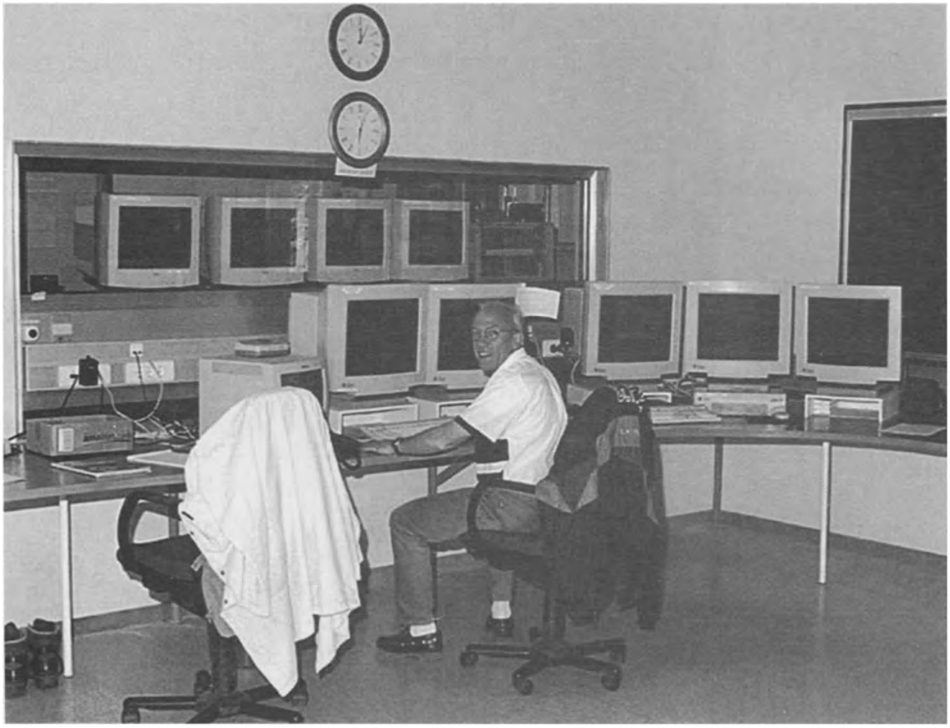


Figure 3. Astronomer in the control room of the 1.2m telescope of Geneva Observatory installed at the ESO La Silla site in Chile in 2000.

It was therefore a science that valued the presence at the university of an important Department of Physics, one of Mathematics, and another one of Computer Science and Statistics. But it was also a discipline that had to be able to choose its goals without having to depend on the traditional ones set by those three other departments. Moreover, at that time – launch of the first satellites, establishment of projects involving large optical telescopes, advent of radio astronomy –, it became obvious to me that the institution I had in mind should withhold the means liable to give access to all those large equipments via international agreements.

Concurrently to the creation of an autonomous Department of Astronomy within the university, I followed a policy of association and collaboration with the University of Lausanne as well as with foreign scientific groups. On the European level, my policy was to drive my country to a participation in the creation of ESA and to adhere to ESO. Starting with an observatory built in 1830 and a staff of four (including director and caretaker), we entered the third millennium with 100 to 120 persons, in a site consisting of several buildings and all necessary services, including lecture halls and seminar rooms. We possess our own stations in Chile, in Haute Provence, and entertain privileged collaborations at Jungfraujoch and on the Canary Islands.

It is interesting to conclude here with the time scales of the different phases since 1956:

- 3 to 4 years
  For the creation of new subjects in astronomy and astrophysics to be taught within the sphere of the faculty of sciences.
- 5 to 8 years
  For creating our stations at Jungfraujoch and Haute Provence and constructing the telescopes and photometers.
- 5 years
  To convince the Swiss federal government to take the initiative and invite to Geneva the European countries interested in creating an organisation similar to CERN, but for space research (ESRO).
- 10 years
  To finish the construction of the main building of the Geneva Observatory and the Institute of Astronomy of the University of Lausanne.
- 18 years
  To pass from ESRO to ESA.
- 19 years
  To install a telescope at La Silla, following an agreement between ESO and Geneva Observatory.
- 26 years
  To finally obtain in 1982 the ratification by the Swiss government of the agreements leading to the participation of Switzerland to ESO.

I may therefore restate the remark made by J.H. Oort in a letter he addressed to A. Danjon in 1962: "Astronomy is truly the school of patience" (quoted by A. Blaauw in 1991).

This time-interval scale shows that during the period 1955-1970 the structures of the university and the State allowed direct discussions and negotiations of projects with the responsible persons.

After 1970, at the Cantonal as well as at the Federal levels, all structures become more complicated. The rapid development of the economy, of the sciences, technologies, universities, institutes of technology, brought about the creation of a considerable number of commissions. These commissions often have no other power than that of transmitting proposals to another commission.

It became very difficult to ensure the advancement of an important project rapidly enough for that project to still be of significance when it finally became feasible.

Today, it is the duty of every astronomer to actively participate at all levels of management in science so as to conserve a certain degree of sovereignty regarding the development of astronomy.

IUCAA:
A NEW EXPERIMENT FOR INDIAN UNIVERSITIES

JAYANT V. NARLIKAR
Inter-University Centre for Astronomy and Astrophysics
Post Bag 4
Ganeshkhind
Pune 411 007, India
`jvn@iucaa.ernet.in`

Abstract. After India became independent in 1947, there was a great thrust for science and technology and a large number of R&D laboratories and research institutes came up. However, this movement was mostly outside the traditional university sector, which as a result suffered in its own development. To redress the balance, the University Grants Commission began creating, in the 1980s, centres of excellence in specific areas which had so far been neglected in the universities. Of these centres, the Inter-University Centre for Astronomy and Astrophysics (IUCAA) is described in this chapter. Founded in Pune in 1988, the IUCAA has centralized research aids and facilities for use by the visiting university academics. To facilitate these visits IUCAA runs an associateship programme and also conducts schools and workshops round the year. It also assists the university academics in formulating guest observing proposals for major observing facilities. The success achieved by IUCAA in the relatively short lifespan of a decade is highlighted as an example of optimization of limited resources in a developing nation.

1. Historical background

In 1947, when India became an independent nation, it already had a reasonable base for higher education, in the form of about 22 universities all over the country. A typical university had departments covering a range of subjects from the liberal arts to sciences. A few universities had faculties of engineering. However, the fraction of the population enjoying the privilege

A. Heck (ed.), Organizations and Strategies in Astronomy II, 29–45.

of higher education was very low and there was a great need for expanding the university system.

Subsequent decades therefore saw not only a rise in the number of universities, but also a growth in the size and membership of a typical university. To give one example, in the pre-independence era, there was only one university catering to the region now identified with the Western state of Maharahtra. Today, the region has ten universities at Bombay (now called Mumbai), Pune, Kolhapur, Nagpur, Aurangabad, Nanded, Jalgaon, Amravati and Wardha, not counting several agricultural universities, specialist universities and other institutions deemed to be universities.

The first Prime Minister of India, Jawaharlal Nehru was a visionary who appreciated the importance of science and technology not only for the development of the new nation but also, through basic research, for developing a measure of self-reliance in the persuit of science. It was with his active support and patronage that scientists like Homi Bhabha and Shanti Swarup Bhatnagar were able to set up a scientific research infrastructure all over the country.

In 1946, a year before independence, Bhabha had started the Tata Institute of Fundamental Research (TIFR), to encourage research in selected fields like pure mathematics, cosmic-ray physics and the theory of atomic nuclei and elementary particles. In the initial few years it was mainly supported by the Dorab Tata Trust, one of the philanthropic trusts set up by the industrial house of Tatas. After independence, within a few years it began to receive major support from the Government of India and as seen by Bhabha it became the precursor of India's Atomic Energy Programme, many of its scientists having earlier worked in the TIFR. Indeed today the Department of Atomic Energy not only manages this programme but also funds, apart from TIFR, several other autonomous institutions carrying out research in basic sciences.

The trend started by Bhatnagar was to evolve into a network of laboratories which would interact with industries and carry out R&D in numerous fields of interest to industry. The Council of Scientific and Industrial Research is the outcome of those pioneering efforts and it now controls the biggest network of scientific laboratories in the world. There are other scientific departments of the Government of India today, like the Departments of Science and Technology, Biotechnology, Space, Defence, etc. which have their own scientific laboratories.

Significantly, all these developments in the post-independence era took place *outside* the university sector. The model of an autonomous research institute (ARI) gradually took shape out of the pattern set by the TIFR. As mentioned above it is funded by a scientific department, and within the guidelines set by the department, it operates with a certain measure of autonomy. It has an apex body (or bodies) like a Governing Board or Management Council to decide the major policies of the institute, to make the main appointments and generally monitor its academic and financial progress. The scientists, who are the prime movers of an ARI, are dedicated to their research projects and *unlike their university counterparts*, can devote all their time to research. This last difference is important. A university academic is expected to carry out teaching as well as research. The typical ARI scientist has practically no teaching commitment except for sharing any teaching in the (usually small) graduate school of the ARI. On the other hand he has access to research facilities set up at ARI.

It is debatable if it was a right decision to so bifurcate the university system from the ARIs. In retrospect the answer seems in the negative. For, by concentrating the limited resources available for research outside the university sector, it deprived the universities of opportunities for high-quality research. Although limited funds were available to the universities for experimental work, their generally low level of infrastructure made it difficult for them to maintain costly equipment, and in general increased their isolation from the mainstream research by making it hard for the university academics to participate in important and topical meetings or to invite experts from other places for discussions and reviews.

The ARIs also suffered, since their scientists had very little contact with the undergraduate population, with the result that they began to find it increasingly more difficult to attract students for their inhouse PhD and postdoctoral programmes. This shortage of motivated young scientists has today become a cause of serious concern for most ARIs.

A solution to this double difficulty lies in increasing collaborations between the ARIs and universities, whereby the staff from the former can lecture to the students of the latter, and the staff from the latter get opportunities to use the experimental equipment of the former. The concept of Inter-University Centres was born out of a desire to forge such symbiotic relationships.

2. The Inter-University Centres

The trend towards sharing and cooperation between universities, institutions, even nations became well established the world over, in the last quarter of the twentieth century. CERN laboratories for particle physics or the European Southern Observatory for astronomy are examples of international cooperation. In the United States, the Association of Universities for Research in Astronomy is a cooperative organization which runs major telescopes, including the Hubble Space Telescope (which it does under contract for NASA).

The reasons for such cooperative enterprises are twofold. Firstly, no single member of the organization can afford to put up the facility on its own. And secondly, even if it did so, it may not be able to generate sufficient usership, to make the facility worthwhile. For this purpose, the shared mode is the best solution.

In the 1980s, the University Grants Commission (UGC), which is the major funding agency for the university sector in India, felt the need to have autonomous centres of excellence of its own to provide access to advance research and developmental facilities to the universities on a shared basis. By a new act of parliament, the UGC acquired powers to create such centres. A typical centre came to be called an 'Inter-University Centre' or briefly, an IUC.

The IUC-experiment started in the mid-1980s and the first IUC to come up was the Nuclear Science Centre (NSC), in 1988, centred around the 15 MV Tandem Van-de-Graaf nuclear accelerator. The machine was unique to the Indian university sector and was set up (along with other follow up facilities) to help research in certain aspects of nuclear physics. The NSC is located in the campus of the Jawaharlal Nehru University in New Delhi.

The second IUC was set up in the campus of Pune University, and was the Inter-University Centre for Astronomy and Astrophysics (IUCAA), which we will highlight in this chapter.

The third IUC was the Inter-University Consortium for the Department of Atomic Energy Facilities (IUCDAEF), set up in the campus of Ahilyabai University, Indore, in central India. Through this centre universities have access to the reactors and accelerators of the Department of Atomic Energy.

Three other IUCs, created in the 1990s, are more in the nature of service providers. The Centre for Educational Communication (CEC) generates educational programmes on TV and also helps run the educational channel. The National Assessment and Accreditation Council (NAAC) provides mechanism for evaluating and grading the performance of universities and other educational institutions. The Information and Library Network (INFLIBNET) is networking library and information databases so as to facilitate access to these by universities. The CEC is in Delhi, the NAAC in Bangalore and INFLIBNET in Ahmedabad.

Having described the IUC-setup in general we now turn to IUCAA, which has brought about a see-change in research, development and teaching in astronomy and astrophysics in the Indian university sector.

3. The setting up of IUCAA

The Project Report (PR) of IUCAA prepared in 1988 gives the initial steps that led to the setting up of the centre, its rationale, modus-operandi, en-

visaged infrastructure, etc. In the PR Foreword, the then UGC Chairman Yash Pal expressed the following desirable characteristics of a typical IUC:
a) The Centre must develop into a world class centre of excellence.
b) Its management, both at the top and at a working level must involve a number of universities.
c) When stable, its core staff should be a minor fraction of the total academic population of the centre at any one time.
d) The Centre should provide a quality of academic and experimental environment which is not easily available to the university community in their own place.
e) The coming and going of university participants should be painless, even pleasurable, with least administrative bottlenecks.
f) The university community should begin to see it as a place to learn, get new ideas, set up collaborations and to develop and use facilities that they and others can benefit from.

These expectations admirably summarize the rationale of setting up IUCAA and also provide benchmarks for judging its performance to date. This account will have occasion to refer to these benchmarks from time to time. But, how did we go about setting up something, the likes of which never existed either in India or abroad? The following calendar records steps which were significant in the historical development of IUCAA, leading to its founding on December 29, 1988.

- In 1984 through efforts of mathematics faculty member Naresh Dadhich, the University of Poona (PU, now University of 'Pune') made a proposal to the UGC to set up an advanced centre for astrophysics.
- In 1986 a decision was made by PU and the Tata Institute of Fundamental Research (TIFR), Bombay to site the centre for the Giant Metrewave Radio Telescope (GMRT) in the PU campus, the GMRT itself being located at Khodad, about 85km from there.
- The UGC Chairman Yash Pal felt that an IUC in astronomy and astrophysics could be located in the PU campus, in lieu of the more limited PU proposal to have an astrophysics centre of its own. Such an IUC would serve to facilitate participation of university academics in the GMRT facility. To this end on September 23, 1987 a brainstorming session was convened at TIFR in which Vice-Chancellor of PU V.G. Bhide, the Director-designate of the GMRT centre Govind Swarup, Naresh Dadhich and a few other scientists from PU and TIFR, including myself, participated. These discussions served to crystallize the basic structure of IUCAA.
- On October 16, 1987, in an informal meeting convened in his chambers and attended by Dadhich and myself, Yash Pal, provided important inputs from the UGC side promising a financial commitment if such a centre came about.

- At its meeting on December 19, 1987, the Executive Council of the PU accorded its approval to setting up such a centre on its campus and to provide administrative support till it became an autonomous registered society under the Societies' act of 1860, under the UGC. Thus, path was cleared for bringing the idea of a centre into reality.
- At the annual meeting of the Indian Science Congress held on the campus of PU, on January 6, 1988, Prime Minister Rajiv Gandhi announced the Government's intention of setting up the centre on the PU campus.
- On January 21, 1988, the UGC agreed to set up the centre and initiated the procedure by appointing a Steering Committee (SC) of scientists to guide the new institution till it became autonomous. A subset of the SC was empowered to act as the Executive Committee (EC), with the Chairman, UGC chairing both committees.
- At the recommendation of the UGC, PU appointed Naresh Dadhich as Project Coordinator and he took charge of this assignment on February 10, 1988. He set up a temporary office in a room in the Golay Bungalow at PU.
- On April 6,1988, the first meetings of the SC and EC of the proposed centre took place in the UGC premises. At this meeting the centre (which was till then called the Inter-University Centre for Astrophysics – IUCA) was formally named the Inter-University Centre for Astronomy and Astrophysics (IUCAA). The draft Project Report of the centre was discussed and approved by the SC. The EC recommended that I be appointed the first Director. This recommendation was forwarded by the SC to PU.
- At its meeting on April 29, 1988, the UGC approved the project report (PR) of the new centre and made a formal budgetary allocation of Rs 1 Crore for the financial year 1988-89. It was decided to approach Charles Correa, distinguished architect and planner, for designing the campus of the centre.
- On July 19,1988, I took charge as Honorary Director of IUCAA. Coincidentally, on the same day the Government of Maharashtra (the State of which the city of Pune is a part) made an allocation of approximately 8 hectares of land adjoining PU and the GMRT Centre, on a lease of 99 years for IUCAA. The PR approved by the UGC was printed for circulation and general information.
- The centre was formally approved by the Government of India on November 18, 1988 and became an autonomous registered society on November 22, 1988.
- The first meetings of the apex bodies of the newly registered centre were held on December 29, 1988, the same day on which Professor Yash Pal, Chairman, UGC, laid the foundation stone of IUCAA.

The march of events mentioned above indicates the rapid progress made by IUCAA during its primordial phase. This was possible because of the help received from UGC, the HRD Ministry, the Prime Minister's Office, the Government of Maharashtra, the local authorities in Pune, the Vice-Chancellor of PU and my own lone colleague at the time Project Coordinator Naresh Dadhich. The next challenge lay in planning an academic strategy that could translate into reality all the brainstorming expectations from the new centre.

4. The Eightfold Way

To meet its various objectives, an 'Eightfold Way' was identified, along which the new centre was expected to function:

1. *Basic Research*: IUCAA was expected to have a small core staff of scientists engaged in frontline research in astronomy and astrophysics (A&A). They were expected to guide research scholars towards their PhD degree, conduct an inhouse postdoctoral programme, and to carry out several other duties not normally assigned to academic staff in a typical research institute. The rest of the items below highlight this unique feature of IUCAA.

2. *Advanced Research Workshops and Schools*: IUCAA decided to hold a number of pedagogical meetings ranging from introductory schools to advanced research workshops so as to bring the latest developments in A&A to the faculty members and students in the university sector.

3. *Visitors and Associates Programme*: Faculty members from universities and colleges who were interested in pursuing teaching, research and developmental activities in A&A were made associates of IUCAA with well laid arrangements to visit the centre a number of times for extended durations during a three year period. In addition IUCAA welcomed visitors from outsde the university sector as resource persons for its pedagogical activities.

4. *Refresher Courses*: IUCAA proposed to arrange refresher courses periodically for A&A teachers in universities and colleges to bring them up-to-date with the developments in the field.

5. *Nucleation of A&A in Universities*: IUCAA proposed to provide a model syllabus for teaching A&A at the MSc level in physics/mathematics departments in the universities, with guidance on books, experimental programmes and lecture notes where necessary. The aim was to introduce A&A as a viable option at the masters level in many universities.

6. *Masters and Doctoral Programmes*: As part of its close interaction with PU, the IUCAA academics offered to teach A&A courses in the MSc Physics of PU. IUCAA's inhouse programme of guiding research scholars to PhD degrees at PU was considered an integral part of its academic activities, and its graduate school was open to research scholars from universities.

7. *Interaction with the GMRT*: One strong reason for bringing IUCAA to the PU campus was to have a close interaction between the university sector and the GMRT facility. To this end the IUCAA hoped to set up a working relationship with the GMRT centre.

8. *Guest Observer Programmes*: Apart from the GMRT usage, the general culture of observational astronomy needed to be introduced to the university sector and to this end IUCAA hoped to involve the faculty and students from the university sector as guest observers in national and international observing facilities.

In addition the PR laid special emphasis on two other aspects: (I) *Astronomical Instrumentation* and (II) *Science Popularization.* This account will outline IUCAA's performance in these areas along the above eightfold way. But before coming to these aspects it is necessary to look at how the facilities and infrastructure of the budding centre were set up at Pune.

5. Buildings and facilities

The following calendar sets out the chronology of how IUCAA's buildings and infrastructure grew up. Considering the many bureaucratic and financial hurdles that exist in a developing country this progress has been considered exemplary.

- To start its activities IUCAA decided to construct a shed of approximately 200 square metres area. Named *Aditi*, it was completed on August 24, 1989. The GMRT Centre made available five office rooms for IUCAA in its newly constructed building. The library of IUCAA initially shared space with the GMRT library. On the above date IUCAA shifted from the Golay Bungalow to these new premises. The old timers recall the relief of a 30-fold increase in working area brought about by this transition.
- Construction of IUCAA's Phase I of the Campus, consisting of staff quarters began with ground breaking on September 4,1989 and was over in 1991. Since the number of houses exceeded the number of staff entitled to occupy them, a decision was taken to move the institutional offices of IUCAA into some of the houses till such time as Phase II was over.
- The construction of Phase II, the main institutional complex began on August 24, 1990 and was completed in December 1992.
- Shifting of academic and administrative offices and the library to the main institutional premises began on June 30, 1992. The library was still in a temporary abode. The computer centre, the library and the instrumentation laboratory moved to their final locations during December 16-25, 1992.
- The IUCAA buildings were dedicated on December 28, 1992 by UGC Chairman G. Ram Reddy with Nobel Laureate S. Chandrasekhar delivering

the Dedication Lecture. The act of 'starting IUCAA' was symbolized by setting its centrally located Foucault Pendulum in motion.

- Work on Phase III (Auditorium) began on January 29, 1992. The Auditorium was completed on August 14, 1993, the occasion being marked with a lecture by the Director to schoolchildren on that day. The auditorium was formally used for the first time with the Sixth Asian Pacific Meeting of the IAU starting on August 16, 1993.

I now return to the academic programmes of IUCAA.

6. Academic programmes

It will be seen from the above time table, that after several shifts and dislocations, IUCAA stabilized its infrastructure late in 1992, and has since consolidated its facilities *in situ.* Its academic programmes however continued right from Day 1, the day it was formally founded.

In the initial stages IUCAA arranged a number of regional meetings in different parts of the country to inform the university faculty of the setting up of IUCAA and its aspirations of generating a strong interaction with those interested in the pursuit of A&A. On January 1, 1990, it launched its quarterly newsletter *Khagol* which has steadily improved in its quality and coverage. The main aim of Khagol has been to give information on IUCAA's activities and also generate interest in A&A through regular columns on A&A topics.

IUCAA's make up and its activities reflect the aims and objectives outlined earlier. It has modelled itself as a composite of several different types of scientific institutions: for example, as a research institute, like the Institute of Astronomy, Cambridge, UK or the Canadian Institute of Theoretical Astrophysics, Toronto, Canada, as a resource centre for schools and workshops and the associateship programme, like the International Centre for Theoretical Physics, Trieste, Italy, as a centre for observational astronomy and instrumentation, like the Kitt Peak National Observatory, as a centre for science popularisation, like the Royal Institution of Great Britain, etc. Thus no single institution has served as a role model for IUCAA. In reviewing IUCAA's work, this important aspect has to be noted.

Keeping the Eightfold Way in view we consider the academic activities in some detail.

(a) *In-house academic activities*

In the early days Yash Pal had set up a Working Group headed by the former UGC Vice-Chairman Rais Ahmed and including physicist N. Mukunda and myself to think of strategies for IUCAA's various academic programmes. In the brainstorming carried out on August 14, 1989, by the

Rais Ahmed Working Group, it was emphasized that IUCAA would command credibility as a resource centre in the university sector only if its core membership were manifestly seen to be highly qualified in research. This perception has played a lead role in the recruitment to IUCAA's core membership.

Although the PR envisaged the ultimate strength of core members to be 20, the march towards this number has been slower than anticipated. IUCAA has consciously been cautious in recruiting core members, as the emphasis is on quality which is not easy to come by. Likewise, the coverage of A&A by the core membership is not exhaustive; again a conscious decision has been taken to cover a few areas well and in depth, rather than cast the net wide and shallow.

The areas covered are Galaxies and Cosmology, Quasars, AGN and High-Energy Astrophysics, Classical and Quantum Gravity, Gravitational-Wave Data Analysis, Stellar Spectra and Astronomical Instrumentation. From pure formal theory, through modelling vis-a-vis observations, to observation-related instrumentation, all different shades may be found in the work coming out of IUCAA's academic programmes.

So far as external recognition of this work is concerned, several positive indicators like being invited to give review talks at well-recognized conferences, invitations to write review articles in good review journals, the extent of international participation in meetings organized at and by IUCAA, invitations to write books by reputed international publishers, responses to its postdoctoral programme, citations and references are heartening indicators.

The postdoctoral programme has been more successful than anticipated. IUCAA's annual advertisement attracts around 30-40 applications from which around 6-8 offers are made and around 3-4 join. Postdocs from Europe and North America as well as Japan, Iran and Korea have worked here, apart from several expatriate Indians who find the place worthwhile to join in order to continue their research interests initiated abroad. Typically postdocs work for a couple of years before finding a more permanent job elsewhere. A very small fraction has been absorbed into the core membership of IUCAA.

Not so successful have been IUCAA's efforts to attract research scholars. The PR had projected about 20 scholars doing PhD in A&A to be in residence at any given time. Given a core faculty of 10 the above number is quite manageable. In fact the number has largely remained between 10-15. This phenomenon is not, however, linked with IUCAA or A&A, but indicates an overall growing apathy towards basic sciences in India as well as abroad.

As in any research institute IUCAA organizes colloquia by distinguished scientists, seminars on A&A, a journal club activity (under the title Informal Discussion Group), after dinner PEP-talks (Perceptions in Emerging Physics), and extramural programmes.

Recently I have introduced a lunchtime forum called MAHFIL (the word means an assembly for cultural activity), an accronym for Midday Astronomy Hour For Interaction and Lunch, where academics, visitors as well as locals, talk briefly over lunch on what research they are doing.

In addition to seminars and colloquia, and the above talks, IUCAA has instituted a Foundation Day Lecture to be delivered by a distinguished personality on the Foundation Day, December 29.

The instrumentation laboratory has a dual role to play. It develops its own research level instruments for use in astronomical observations; it also makes prototypes of instruments for duplication by scientists from the university sector. Since the culture of instrumentation and experimentation is relatively rare in India, special efforts are needed to get scientists interested and involved in R&D activities of this kind.

Against this background, the instrumentation group at IUCAA has made a research level instrument, the *imaging polarimeter* which measures and prepares maps of polarization of optical sources. The polarimeter is being used on the 1m optical/infrared telescope at Guru Shikhar. The instrumentation laboratory also devised testing instruments for testing sites for the IUCAA telescope now under construction. CCD controllers and liquid nitrogen cooled CCD cameras were also made here.

Instruments under the second programme include a 14-inch automated photoelectric telescope, small photometers for use on amateur telescopes, etc. University users are encouraged to come here and build their own instruments as per the prototypes.

In 1996 IUCAA signed a contract with the Particle Physics and Astronomy Research Council (PPARC) of the UK Government to acquire a 2m telescope. The telescope is expected to be installed in the year 2001.

It is expected that with the IUCAA Telescope in the offing the instrumentation laboratory will have more projects on its plate. Already an imager spectrograph has been made by the Copenhagen University Observatory as a first light instrument for the IUCAA telescope.

A major facility most essential for university users is a *well-equipped library.* The IUCAA library has been recognized as the best A&A library in India and has many 'firsts' to its credit, including computerization, e-mail for user service, remote login, etc. It is adapting to the CD-ROM age and is expected to remain at the forefront for use of new information technologies.

The *computer centre* also has many firsts on a national basis, being the first to have a website for IUCAA (February 1993) and a 1-MBps data link (December 1, 1997). Its networking serves academic, administrative and

Figure 1. An inside view of the IUCAA Library. The library houses journals, books and CD-ROMs relating to astronomy, astrophysics and other topics of interest to astronomers.

library needs and is expanding with more workstations of greater power and capacity. Several research-oriented A&A software packages are available. A *data centre* was established in 1992 as a national facility and its volume and efficiency are also being expanded with mirror sites of foreign data centres.

(b) *Interaction with universities and the associateship programme*

In the PR it was anticipated that the *number of associates* in the university sector will eventually reach and stabilize at around 100, a number not too large considering that the number of active members of the Astronomical Society of India is around 300. At present the number of associates is howering around 80.

Those associates who have been actively using IUCAA's facilities have clearly demonstrated that the IUC mode works. There has been an improvement in their quality of work, publication record and range of research interests. IUCAA has encouraged the associates to bring their research students with them, if they feel it would be beneficial to them, and some indeed do with great advantage. One tangible result is the growing interaction between academics from different universities by their getting together at IUCAA. Some associates and other faculty members from universities and colleges have been good users of the *instrumentation laboratory*. Thus scientists from Bangalore University were the first to copy the automated photoelectric telescope made by IUCAA and those from Bhavnagar University were next in line. Several observers have made photometers.

Usage of guest observer programmes on national facilities is now becoming more popular with new observers coming from universities like Ravishankar University, Raipur and colleges like the Sri Venkatesvara College, Delhi. One associate from Raipur has observed galaxies using a telescope at the Las Campanas Observatory in Chile, and it is expected that the trend will grow. This has become possible through the intervention of IUCAA.

The original motivation of interaction and usage of the GMRT facility by the university academics is only now becoming possible because the telescope is becoming functional. IUCAA expects that as the GMRT gets into full swing the interaction will build up.

Since the inception of IUCAA at least ten universities and colleges have *introduced A&A in their MSc curricula*, while several have modernized their existing ones. IUCAA has prepared a model syllabus for such courses, giving it a modular structure, leaving it to the user department to include modules as per their course regulations (which vary from department to department).

IUCAA has organized *introductory schools* at several universities and colleges where A&A are to be introduced or revised substantially. These schools are meant to acquaint the teachers in the region with highlights of these subjects. IUCAA staff have been *teaching A&A courses in the MSc programme* of the Physics Department of Pune University. Occasionally some have taught small capsules of courses at the MSc level at other universities. Although IUCAA would like to get more actively involved in the teaching of MSc courses in universities, the constraints of manpower and distances makes this a rather difficult proposition at present.

Even so, IUCAA faculty have travelled to remote parts of the country from the North East to the deep South in their efforts to plant A&A in universities and colleges. Thus the early credibility gap about IUCAA has been largely bridged and IUCAA activities have been welcomed and actively sought in university campuses.

Schools and workshops as well as *refresher courses* form the core of IUCAA's pedagogical activities for the university sector. Some are organized on the IUCAA campus while about equal number are distributed across the university and college campuses all over India. Certainly the growth in the users of IUCAA has more than met Yash Pal's original expectations.

7. Science popularization programmes

Amongst all scientific institutions in India, IUCAA is probably unique in having an institutional programme for science popularization. The PR stresses this and the general philosophy behind it is as follows. The overall purpose of creating human resources in A&A cannot be fulfilled by simply planting A&A at the MSc level. A coherent strategy which develops an interest for science at school level and then builds on it by introducing some aspects of A&A at the undergraduate level is required. Because astronomy is a subject that excites the human mind even at the layperson level, it provides an excellent opportunity for introducing highlights of astronomy to the general public. Hence IUCAA's science popularization programme aims at the general public as well as at schoolchildren.

Following are the different facets of this programme:

(a) Exhibits in the building

As the IUCAA campus was being constructed several scientific notions or models were built into its overall ambience. These include, for example, the Foucault pendulum, the aperiodic tiling, Sierspinski's gasket, the binary star system, the accretion disc-cum-jet model of a radio source, statues of scientists, Newton's apple tree, the dome with star distribution frozen as on IUCAA's Foundation Day and of course the excellent range of astronomical photographs presented by David Malin. There are also a couple of wall pictures such as Glashow's snake and the Lorentz Spiral, to which more may be added.

(b) Science Park

A series of open air exhibits, some of interactive type are under construction which will illustrate the way scientific laws operate. Some are already in place, like the Samrat Yanrtra model of Jai Singh's observatory and a model of the Hampton Court Maze. A sapling of Newton's Apple is planted here too. The Science Park is located next to the Chandrasekhar Auditorium and will be open to the general public, especially to schoolchildren visiting IUCAA for lectures.

(c) National Science Day

Every year the National Science Day (February 28) is celebrated with a science-oriented programme of lectures, entertainment and quiz for schoolchildren. There is also an open house for the general public with short lectures and lecture demonstrations, exhibits of IUCAA's work, astronomy films, night sky observing, etc. The event receives tremendous response from the Pune public.

Figure 2. The dome which borders the central courtyard at IUCAA has tiny holes right through it. The holes are of varying sizes admitting day light through them so that persons standing underneath the dome see the star studded sky during the day time. The star distribution is arranged to match that prevails at 8:30 pm on IUCAA's Foundation Day, December 29, 1988.

(d) Schoolchildren's Programmes

In 1993, IUCAA began a series of lectures and lecture demonstrations for schoolchildren of classes 8-10 every second Saturday. They are extremely popular with schools in Pune and the Chandrasekhar Auditorium gets filled to capacity at every lecture. Now lectures are also arranged for students of classes 11-12, so that one lot comes on the 2nd Saturday while the other on the 4th.

In the summer vacation schoolchildren from the classes 8-10 do a week-long project with an academic or scientific member of IUCAA and write a report on what they have done. Like day scholars at schools they come in the morning and leave in the afternoon, spending some 5-6 hours working on their project. Nearly 150 students take advantage of this scheme every year.

Additionally IUCAA enthusiastically contributes to the national effort for training gifted children for the international Astronomy Olympiad. I strongly feel that such efforts are worthwhile as they help induce some enthusiastic and motivated children to take up a career in A&A later.

(e) Interface with amateur astronomers

IUCAA has a continuing dialogue with the amateur community and was in fact responsible for convening the first national meeting of amateur astronomers in 1991. The meeting led to the formation of the Confederation of Indian Amateur Astronomers which convenes a national meeting every year in some part of India.

In addition IUCAA has held workshops in areas of interest to amateur astronomers such as telescope making, celestial-globe making, on viewing the total solar eclipse or a meteor shower, etc. A part of the instrumentation laboratory is reserved for amateur activities. There are also public viewing nights regularly on the fourth Friday of the month outside the rainy season.

8. Concluding Remarks

It should be recognized that IUCAA's multi-dimensional programmes could not have functioned at the level of efficiency that they are generally perceived from outside, had it not enjoyed an excellent administrative infrastructure.

In dealing with the core staff requirements, the maintenance of facilities, attention to the visitors' needs, organization of the many workshops on and off campus, and in keeping the campus in a good clean condition, the administrative and support staff have acquitted themselves very well.

It is also to be noted that in comparison to the typical university or a national research institute, the number of such staff is small. This has been achieved by assigning many activities to one staff member and setting premium on quality.

This account is being written as IUCAA just completes twelve years of its existence. It has come a long way from the times of the late 1980s when it was just a concept. The spectrum of its achievements from a public outreach programme to international research reflects the universal appeal that A&A enjoy.

The key to its success lies in making the maximum use of this appeal. For, in the last analysis, a scientific institution should reflect human endeavour and aspirations at all levels.

BACKGROUND AND ACHIEVEMENTS OF UN/ESA WORKSHOPS ON BASIC SPACE SCIENCE 1991-2001

HANS J. HAUBOLD
United Nations Office for Outer Space Affairs
Vienna International Centre
P.O. Box 500
A-1400 Vienna, Austria
`haubold@kph.tuwien.ac.at`

Abstract. Sir Isaac Newton remarked in his Principia (1687) that "the descent of stones in Europe and in America" must both be explained by one set of physical laws. Still, one cannot ignore the peculiar environment in which members of a national group of scientists are trained and carry out their research work. The United Nations and the European Space Agency have jointly organized a series of annual workshops on basic space science since 1991. These workshops have been held for the benefit of astronomers and space scientists in Asia and the Pacific, Latin America and the Caribbean, Africa, Western Asia, and Europe. Additional to the objective of these workshops to review the status of astronomy and space science on a regional basis, the workshops made efforts to implement follow-up projects, particularly the establishment of astronomical telescope research and education facilities in developing nations. The present paper reviews the background and achievements of the workshops for the period of time from 1991 to 2001. The paper is written from the point of view of one of the organizers of the basic space science workshops.

1. The place of science in society

1.1. SCIENCE AND TECHNOLOGY

Basic science is a key to the prosperity of a nation, and it is almost impossible to expect significant economic and social development without a sound research and educational base in the field of basic science. In the 1990's, the correlation between the promotion of basic science and the increase in

A. Heck (ed.), Organizations and Strategies in Astronomy II, 47–64.

industrial competitiveness was frequently discussed among decision-makers of industrialized nations, although the whole process toward a goal would take much time, and as a result, more emphasis was placed on the applications stage in the process of technology development.

However, in every human culture, science and technology, even if the two are often difficult to untangle, work together to create a civilization. Astronomy and space science are no exception to this process. Observing time on large astronomical telescopes, applying the latest scientific and technological achievements in the field, is expensive and competitive and only available in industrialized nations. And yet, the use of small telescopes, often not in heavy demand, offers ways and means to make important discoveries with moderate financial resources (Dyson 1999). As an example, the application of gravitational tomography and techniques of digital image processing enables astronomers to contribute to the detection of invisible mass, one among the most challenging problems of contemporary cosmology, by observing how the light from visible objects more distant than the invisible mass is gravitationally focused or distorted along its way to Earth.

For this purpose networks of small astronomical telescopes, available in developing nations, connected through the Internet, in an international collaborative effort, could be employed. No new telescopes have to be built but efforts could lead to the development of new electronic cameras and new data processing software.

1.2. RECORDING AND MEASURING SCIENTIFIC PROGRESS

The national competency in basic science has often been used as an indicator of potential national technological power. The result of national scholastic aptitude tests in science is considered as one of the measures to determine the national strength in industrial activities in the future. The more the basic research articles published by scientists of a nation are cited by others in academic journals, the more the nation is considered to possess the potential to lead the technological edge, which would result in increase in or maintenance of industrial competitiveness, though such correlation requires careful examination.

Galvez *et al.* (2000) have studied global patterns of scientific progress by surveying scientific productivity in terms of publications in international scientific journals listed in the *Science Citation Index* for 160 nations in the period of time from 1991 to 1998.

Applying certain criteria to the *Science Citation Index*, they looked for the regional distributions of authorship and collaboration exhibited in publications, particularly emanating from developing nations. The overall result of the study shows that 85% of all scientific papers originated from the regions of Western Europe, North America, and Asia. Of the remaining publications, Eastern Europe accounted for the largest share followed by Oceania, Latin America, and Western Asia contributing approximately equal numbers. The region of Africa contributed approximately 1% to the world-wide scientific productivity.

Nations that produce fewer scientific papers generally collaborate with other nations to a much greater extent. Nations from Latin America, Africa, Eastern Europe, and Western Asia have foreign co-authors on at least 50% of all scientific publications. Industrialized nations accumulate the most transnational collaborations; Western Europe alone accounts for almost 45% of all international collaborations. The study clearly indicates that nations with strong economies tend to develop strong scientific communities, and vice versa, and that international collaboration has become the standard of scientific endeavors. Scientific collaboration between developing and industrialized nations benefits both sides of the equation.

1.3. AVAILABILITY OF DATA ARCHIVES AND SYSTEMS FOR RESEARCH AND EDUCATION

In order for a nation to keep its competency in basic science, its scientists should be fully aware of the latest progress made in scientific research. In the competitive world of scientists, who are keen on scientific discoveries ahead of the others, communication and active discussions with scientists from other nations are indispensable. Scientists from developing nations, however, have frequently encountered difficulties in fully participating in the international scientific community, in part due to the limited resources at their disposal for equipment and personnel, but equally because of the difficulties of keeping in touch with the international scientific community.

Access to books, scientific journals, pre-prints of the latest papers, participation in workshops and conferences, and electronic mail contacts with international colleagues have posed particular obstacles for scientists from developing nations. Recent trends toward instant dissemination of the latest results through the Internet and World-Wide Web, taking advantage of computer networks, have improved this situation.

There are two main tools for astronomical research available on the Internet and World-Wide Web (Genova *et al.* 2000), both providing substantive astronomical resources free of charge and accessible from the different regions of the world: *Centre de Données astronomiques de Strasbourg (CDS)* and *NASA Astrophysics Data System (ADS).*

The *ADS* [1] *Abstract Service* allows the searching of four databases with abstracts in Astronomy, Instrumentation, Physics/Geophysics, and

---

[1] `http://ads.harvard.edu/`

the LANL Preprints with a total of more than 2.2 million references. The system also provides access to references and citation information, links to on-line data, electronic journal articles, and other on-line information. The *ADS Article Service* contains the full articles for most of the astronomical literature back to volume one of the respective source. ADS can be accessed through any web browser or, alternatively, an Internet interface is available that allows users to execute queries via e-mail and to retrieve scanned articles via e-mail.

CDS [2] provides electronic access to information about astronomical objects in SIMBAD, catalogue service, reference images and overlays in ALADIN, nomenclature in the *Dictionary of Nomenclature*, yellow pages [3], and the AstroGLU resource discovery tool.

The goals of both CDS and ADS are to collect, homogenize, distribute, and preserve astronomical information for the scientific use of the worldwide astronomical community.

1.4. DEVELOPMENT OF SCIENTIFIC INSTITUTIONS, ENTERPRISES, AND SENSIBILITIES

The importance of basic science for the national development and the existence of obstacles for scientists from developing nations also apply to space activities. Especially since space is seen as the new frontier which promises further economic and social prosperity in the future for successful nations, it is essential, and attractive, for a nation to acquire an independent national capability in space research at the earliest possible stage.

Despite the excellence of the astronomical heritage of many nations, only few of them have access to the full range of astronomy or space research supporting facilities. Efforts to develop indigenous capability in space research in a nation needs to take into account that scientific expression has been allied closely with changes in three distinctive areas of society (Pyenson & Sheets-Pyenson 1999):

1. the institutions that sustain science;
2. the moral, religious, political, and philosophical sensibilities of scientists themselves; and
3. the goal of the scientific enterprise.

Specifically for the case of astronomical observatories, it has been demonstrated, how such institutions are able to create networks of national, regional, and international scientific communities engaged in collecting and exchanging observations and using and perfecting instruments. Such observatories, when established, can support institutions of higher learning to

---

[2] `http://cdsweb.u-strasbg.fr/`

[3] `http://vizier.u-strasbg.fr/starpages.html`

become centres for disciplinary and experimental innovations. Thereby they play an important role in many different societies and they are fundamentally one of the most important activities that connect and even transcend diverse cultures (Dunar & Waring 1999).

2. Scientific Research and National Development

2.1. WORKING AT THE EDGE OF KNOWLEDGE

Space research, of course, is not new. It did not begin with the space age, but goes far back into history. Indeed, people in all parts of the world have speculated about the nature and the meaning of the heavens for as long as traces of civilization have been discovered. Theories of the cosmos and the position of humanity and the Earth within the Universe have always been central elements of cultural beliefs and values. The space research activities, on-going to date world-wide, are part of an intellectual tradition that goes back many centuries and that was the starting point for the development of most of modern science and technology (Hansson 2000). Careful and systematic observations of the movements of the Sun, Moon, and planets among the fixed stars, and the generalization of these observations into mathematical equations still serve as the classical model for scientific research.

Physics and mathematics are the prerequisites for understanding astronomy and space science. Technology is one of the driving vehicles of the field. Four centuries ago, Galileo proclaimed mathematics to be the language of physics and since then it has been customary to celebrate the harmony between them. Only forty years ago, Wigner gave his famous lecture titled "The Unreasonable Effectiveness of Mathematics in the Natural Sciences", including astronomy and space science. The most recent exemplary interplay between mathematics and physics occurs in string theory, a construct to include gravity in the description of the fundamental forces of nature which had been Einstein's lifelong quest for a "unified field theory" (Green 2000).

Among the predictions made by string theory are (i) that gravity fluctuations affect light in a wavelength dependent manner and (ii) that at the end of the cosmological inflation period heavy particles would be generated. Respectively, (i) could be observed by the astronomical satellite mission *Gamma-ray Large Area Space Telescope* and (ii) could be detected with the giant Pierre Auger cosmic-ray arrays proposed in Argentina and the United States, both of them international enterprises.

2.2. BASIC VERSUS APPLIED SCIENCE

Both nationally and internationally, the concept of economic development has generally focused on technology and applications rather than on science and research. And as a result, national and international development programmes, including those of the United Nations (UNISPACE III 1999), have not given adequate attention to promoting scientific research and international cooperation in science. Applications with economic benefit are being considered superior in comparison to research efforts with educational benefits. In the long term, scientific research will remain essential to the intellectual, spiritual, cultural, social, and economic vitality of society at any level. One must not only find technical solutions to the problems he/she understands, but one must also find new ways of understanding his/her world and how it, and the human lives it sustains, can be improved.

There are four aspects of scientific research that make it a vital element in any developing society; and the term "developing" here is used in its proper sense, namely a society at any economic level that is working to improve the lives of its people.

The first aspect of science is its cumulative nature, its commitment to using past knowledge in order to gain new knowledge. While science and technology are often thought of as destroyers of tradition, science is in fact more respectful of tradition than many other areas of human culture in which old beliefs may simply be discarded in favor of new speculations. It does not mean that there are no conflicts between science and tradition, however. When the international culture of modern science, the second aspect, is introduced to a traditional society, the conflict can be quite disruptive culturally, which raises the third element of science. Science has by its very nature a critical aspect. While respecting existing knowledge, science is constantly evaluating that knowledge in order to find ways to improve and extend it. For people who are dogmatically attached to existing knowledge, that critical approach can be disturbing, but it is essential to development.

The fourth aspect of science is its collective or communal nature. Scientists cannot work alone; they must have communications with other researchers. And it is increasingly essential that they have access to worldwide communications. The scientific community is one of the best examples in the world of international cooperation, of people working together toward a common goal of general human interest, and the struggle to maintain and expand that cooperation must be supported. The goal of an independent national capability in astronomy and space research does not preclude international cooperation. On the contrary, international cooperation, formally and informally, has always been central to scientific progress; and scientific research has been a particularly good example of productive international cooperation.

The past decade of the 1990's has experienced a cutting back of spending for civilian research and development, including those devoted to space science, even though economies have shown that the annual rate of social return on investments in research and development is high. Holton (2000) has taken this observation to reemphasize that one of the critical questions of the day concerns the rightful place of science in culture. Comprehensively analyzing Albert Einstein's profound and lasting impact on civilization, the transforming effect of his work on humanity, the analysis confirms, in principle,

- Definition: Science is systematized positive knowledge or what has been taken as such at different ages and in different places;
- Theorem: The acquisition and systematization of positive knowledge are the only human activities which are truly cumulative and progressive; and
- Corollary: The history of science is the only history which can illustrate the progress of mankind. In fact, progress has no definite and unquestionable meaning in fields other than the fields of science.

Einstein's considerations of the meaning of progress and goals for science remain fully applicable today.

3. Cooperation between developing and industrialized nations

3.1. OBSERVATORIES, OBSERVATIONS, AND THE VIRTUAL OBSERVATORY CONCEPT

While all scientific research is based on cooperation that crosses political boundaries, international cooperation is particularly important in space research. Much space research requires access to data from complex astronomical and astrophysical observatories, including observatories in space (for example IUE, COBE, HST, SOHO). Many of these observatories are so expensive and so complex that they can be built only by a few nations or only by cooperating groups of nations. For most scientists in the world, including the great majority of scientists in developing nations, access to ground and space borne data therefore depends on international cooperation. Cooperation in the area of space scientific research has generally been exemplary. The countries and agencies acquiring astronomical and astrophysical data make it widely available to researchers internationally, and many scientific satellites and major ground-based observatories include experiments and instruments designed and built in many nations (Dunar & Waring 1999; Bonnet & Manno 1994).

While such international cooperation in space research has been extensive, however, there have still been many obstacles to the full participation of scientists from developing nations in space research. It is necessary for scientists from both industrialized and developing nations to identify the specific problems faced by scientists from developing nations in order to promote further international cooperation in space science. One more forthcoming opportunity to achieve such a cooperation might be the development of the virtual observatory concept of the United States which may make the data bases from decades of astronomical observations by almost all instruments, both ground-based and space-borne, accessible through computer networks. The practical implementation of this concept will change the way that astronomy is done on a world-wide basis (Schilling 2000; Szalay 2000).

It is also important to consider some of the forms that international cooperation in space research can take. A major form of international cooperation in space science has been advanced education. Advanced education is, of course, essential to the continuing development of space science in any nation, and no nation can provide facilities for advanced study and research in all aspects of space science. The European *AstroVirtel* project [4] will even have educational value readily applicable in institutions of higher learning.

3.2. JAPAN'S TELESCOPE DONATION PROGRAMME

Another form of educational cooperation between industrialized and developing nations, less common but perhaps more important in the long term, is assistance from industrialized nations and international organizations for strengthening educational institutions in developing nations so that fewer students need to go abroad for education. Assistance in the form of visiting faculty, educational equipment and material, can make an important contribution to greater self-reliance in education in developing nations. For example, building on the achievements in the period of time from 1991 to 2001, the Government of Japan, in cooperation with the United Nations, is continuing the establishment of astronomical telescope facilities at universities in developing nations (Kitamura 1999). Japan's initiative is facilitated through Japan's *Cultural Grant Aid* and *General Grant Aid Programmes.* Cooperation between leading astronomers from the *National Astronomical Observatory of Japan*, Tokyo, with their peers in developing nations has been a main driving force for establishing astronomical telescope facilities in developing nations around the world (more recently in Sri Lanka 1995, Paraguay 1999, and the Philippines 2001).

---

[4] `http://www.stecf.org/astrovirtel`

3.3. ASTROPHYSICS FOR UNIVERSITY PHYSICS COURSES AND HANDS-ON ASTROPHYSICS

Advanced education in space science must be built on more basic scientific education. Students must learn elementary physics, chemistry, mathematics, and astronomy at the high school and undergraduate levels before they can go on to advanced graduate studies and original research. International assistance in providing basic textbooks and other educational materials at these more elementary levels could contribute to the long-term growth of space science in developing nations.

Recently, a teaching module was developed, presenting an array of astrophysical problems, any one or a few of which can be selected and used within existing physics courses on elementary mechanics or on heat and radiation, kinetic theory, electrical currents and in some more advanced courses (Wentzel 1998). The module presents an answer to the problem of how to introduce astrophysics in physics courses at the university level, in particular in developing nations. Such astrophysics problems are designed to be an interesting and challenging extension of existing physics courses, to determine the student's understanding in physics by testing it in new realms and to stretch the student's imagination.

The hands-on astrophysics material uses the unique variable star database of the *American Association of Variable Star Observers (AAVSO)* (Mattei & Percy 1998; Mattei & Waagen 2000). It is a curriculum suitable for college and university science, mathematics, and computer science classes and directly involves students and teachers in the scientific process. Hands-on astrophysics helps students acquire fundamental science skills and develop an understanding of basic astronomy concepts; it provides interdisciplinary connections and takes students through the whole scientific process while working with real data. The curriculum also informs students about variable stars and their importance to the professional astronomical community and gives them the necessary information and skills to study variable star behavior or to become amateur variable star observers.

4. United Nations efforts in the promotion of basic space science

4.1. UNITED NATIONS PROGRAMME ON SPACE APPLICATIONS

The Programme on Space Applications of the United Nations Office for Outer Space Affairs was established in 1969 by the General Assembly in order to promote international cooperation in the use of space science and technology for social and economic development. Following the *Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space* in 1999 (UNISPACE III 1999), the activities of the Programme on

Table 1. Overview on the series of UN/ESA workshops on basic space science 1991-2001

Year	*City* *Country*	*Target Region*	*Host Institution*	*Number of Participants*	*Number of Participating Countries*	*Workshop Topic or Sub-topic*	*United Nations GA Report Document*
1991	Bangalore India	Asia and the Pacific	Indian Space Research Organization	87	19	Basic space science	A/AC.105/489
1992	San José Costa Rica Bogotá Colombia	Latin America and the Caribbean	University of Costa Rica University of the Andes	122	19	Basic space science	A/AC.105/530
1993	Lagos Nigeria	Africa	University of Nigeria and Obafemi Awolowo University	54	15	Basic space science	A/AC.105/560/ Add.1
1994	Cairo Egypt	Western Asia	National Research Institute of Astronomy and Geophysics	95	22	Basic space science	A/AC.105/580
1995	Colombo Sri Lanka	Asia and the Pacific	Arthur C. Clarke Institute for Modern Technologies	74	25	From small telescopes to space missions	A/AC.105/640
1996	Bonn Germany	Eastern and Western Europe	Max-Planck-Institute for Radioastronomy	120	34	Ground-based and space-borne astronomy	A/AC.105/657
1997	Tegucigalpa Honduras	Central America	Universidad Nacional Autónoma de Honduras	75	28	Small astronomical telescopes and satellites in education and research	A/AC.105/682
1999	Mafraq Jordan	Western Asia	Al al-Bayt University	95	35	Scientific exploration from space	A/AC.105/723
1999	Vienna Austria	All regions	United Nations Office at Vienna			Basic space science (UNISPACE III)	A/CONF.184/6
2000	Toulouse France	Europe	French Space Agency (CNES)	80	34	Satellites and networks of telescopes - Tools for global participation in the study of the universe	A/AC.105/742
2001	Reduit Mauritius	Africa	University of Mauritius			Exploring the universe - Sky surveys, space exploration, and space technologies	

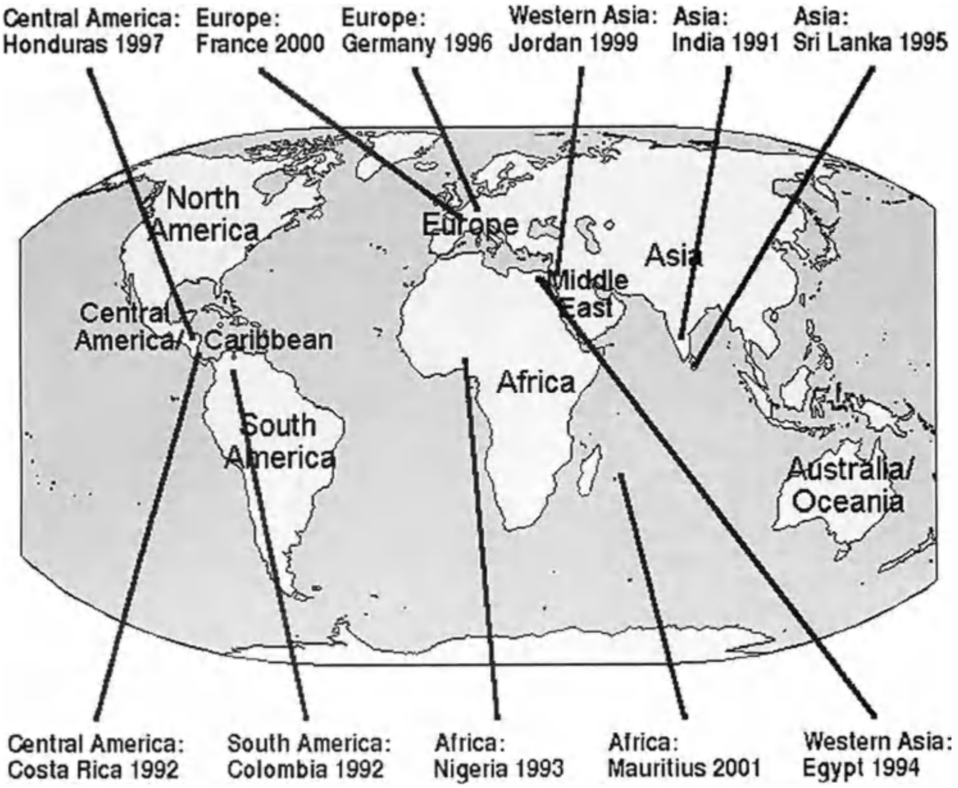


Figure 1. Logo of the UN/ESA Workshops showing the distribution of the workshop host countries on the world map.

Space Applications were expanded and redirected toward the development of self-reliant space activities in developing nations.

4.2. UN/ESA WORKSHOPS ON BASIC SPACE SCIENCE

Since the United Nations and the European Space Agency, under the auspices of the UN programme on Space Applications, took the initiative in organizing annual Workshops in basic space science for developing countries in 1990, each of the workshops in India (1991), Costa Rica (1992), Colombia (1992), Nigeria (1993), Egypt (1994), Sri Lanka (1995), Germany (1996), Honduras (1997), Jordan (1999), and France (2000) yielded a unique set of observations and recommendations for the development of basic space science, reflecting needs of the world-wide development of astronomy and space science (Haubold & Haubold 2001; Table 1; Fig. 1).

Table 2. Regional distribution of nations and number of individuals who contributed to and/or participated at UN/ESA workshops on basic space science 1991-2000

Africa		Asia		Eastern Europe		Latin America & the Caribbean		Western Europe & Other	
ALGERIA	31	BAHRAIN	01	BULGARIA	02	ARGENTINA	06	AUSTRALIA	04
ANGOLA	01	BANGLADESH	01	CROATIA	02	BOLIVIA	01	AUSTRIA	06
BOTSWANA	03	BRUNEI D.	01	CZECH REP.	06	BRAZIL	03	BELGIUM	07
BURKINA FASO	01	CHINA	13	HUNGARY	01	CHILE	03	CANADA	11
BURUNDI	02	INDIA	38	LITHUANIA	02	COLOMBIA	02	DENMARK	03
CAMEROON	06	INDONESIA	08	MACEDONIA	01	COSTA RICA	07	FRANCE	38
CENTR. AFR. R.	01	IRAN	02	POLAND	05	CUBA	05	GERMANY	49
COTE D'IVORE	03	IRAQ	02	ROMANIA	03	ECUADOR	02	GREECE	05
EGYPY	45	JAPAN	13	RUSSIAN FED.	16	EL SALVADOR	06	IRELAND	01
ERITREA	01	JORDAN	14	SLOVAKIA REP.	04	GUATEMALA	04	ISRAEL	06
ETHIOPIA	03	KAZAKHSTAN	03	UKRAINE	02	HONDURAS	24	ITALY	15
GABON	01	KUWAIT	09			MEXICO	13	MALTA	01
GHANA	10	LEBANON	05			NICARAGUA	04	NETHERLANDS	04
GUINEA	04	MALAYSIA	02			PANAMA	03	NEW ZEALAND	01
KENYA	12	MONGOLIA	05			PARAGUAY	01	NORWAY	01
LIBERIA	01	OMAN	04			PERU	04	PORTUGAL	02
LIBYAN A.J.	11	PAKISTAN	07			URUGUAY	06	SPAIN	14
MADAGASCAR	04	PALESTINE	01			VENEZUELA	02	SWEDEN	03
MALAWI	04	PAPUA N.G.	03					SWITZERLAND	03
MALI	01	PHILIPPINES	03					TURKEY	08
MAURITANIA	03	QATAR	05					UNITED KINGDOM	15
MAURITIUS	04	SAUDI ARABIA	12					USA	110
MOROCCO	23	SINGAPORE	02						
MOZAMBIQUE	05	SRI LANKA	06						
NAMIBIA	04	SYRIA	06						
NIGER	02	TAIWAN	03						
NIGERIA	77	TAJIKISTAN	01						
RWANDA	01	THAILAND	04						
SENEGAL	02	U. ARAB EMIR.	02						
SIERRA LEONE	02	UZBEKISTAN	01						
SOUTH AFRICA	113	VIET NAM	04						
SUDAN	04	YEMEN	02						
SWAZILAND	02								
TANZANIA	05								
TOGO	01								
TUNISIA	08								
UGANDA	03								
ZAIRE	02								
ZAMBIA	08								
ZIMBABWE	11								

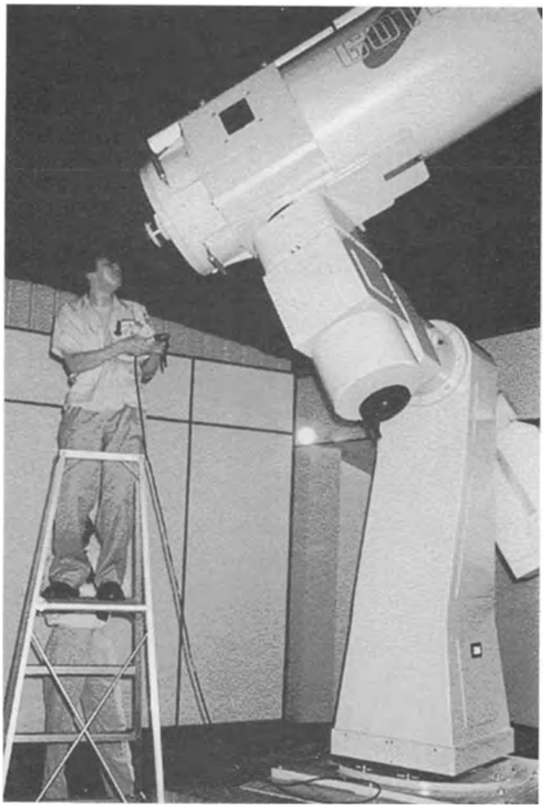


Figure 2. 45-cm Reflecting Telescope from Goto Optical Mfg. Co., Japan, at Arthur C. Clarke Institute of Modern Technology in Sri Lanka at the time of testing its operation (Courtesy of H.S.P. de Alwis).

More than 1000 scientists from 124 nations participated at and contributed to these workshops (Table 2). Some of the workshop recommendations concerned the availability and dissemination of scientific information (Sect. 1.3. & 3.1.), the availability and establishment of astronomical facilities (Sect. 3.2.), the promotion of international cooperation in basic space science through coordination of programmes and projects (Sect. 2.1.), and the introduction of teaching astronomy into education curricula at the university level (Sect. 3.3).

4.3. UN/ESA WORKSHOP FOLLOW-UP PROJECTS

The success of this series of the workshops were highlighted by the special initiatives (Haubold 1998, 2000; Table 3):

- Of Japan to donate astronomical research telescopes;

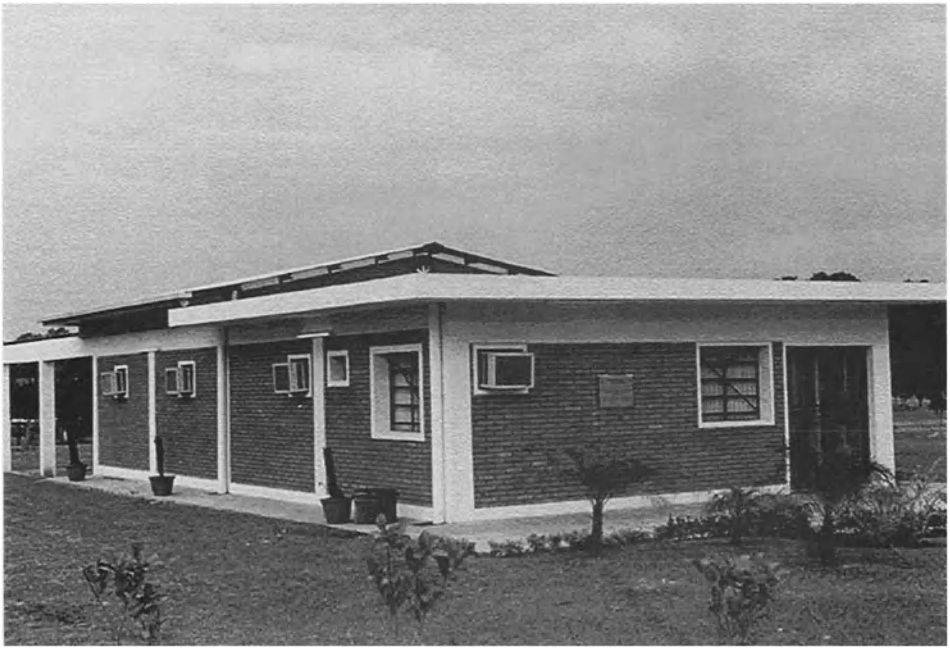


Figure 3. Building of the Astronomical Observatory at National University at Asunción, 2000, showing the sliding roof for the telescope which is, in principle, the same technology developed in Sri Lanka for telescope facilities (Courtesy of A. Troche Boggino).

- Of ESA to provide personal computer systems to research institutes in developing countries;
- Of France and South Africa to publish a Newsletter titled *African Skies/Cieux Africains* for space scientists in Africa;
- Of Egypt to refurbish the Kottamia telescope in Egypt for regional cooperation in West Asia;
- Of Sri Lanka to establish an astronomical telescope facility at ACCIMT (Fig. 2);
- Of Honduras to establish an astronomical observatory for Central American countries;
- Of Colombia to contribute to the operation of a 5.5m radio telescope for galactic emission mapping; and
- Of Jordan to operate an optical telescope facility and to envisage the conversion of the 32m Baaqua communications dish into a radio telescope.

Similar initiatives are currently pursued, through support from the *United Nations Office for Outer Space Affairs* in Paraguay (Fig. 3) and the Philippines in cooperation with the Government of Japan and astronomers

Table 3. Projects pursued through the series of UN/ESA workshops on basic space science 1991-2000

Year	*Country*	*Project World Wide Web Site*	*Projects Addressed at the Workshop*	*Recommended Follow-up Projects*
1991	India		Telescope donation programme of Government of Japan	Establishment of astronomical facility at Arthur C. Clarke Institute of Modern Technologies in Sri Lanka
1992	Costa Rica Colombia	Galactic Emission Maps Project in Colombia: aether.lbl.gov/www/projects/GEM/	Computer equipment donation by European Space Agency	Establishment of an astronomical observatory for Central America Establishment of a radiotelescope in Colombia
1993	Nigeria	Inter-African astronomical observatory and science park in Namibia: home.t-online.de/home/a.masche/ www.mpia-hd.mpg.de/Public/PUBREL/booklet01.html Southern African Large Telescope (SALT) in South Africa: www.salt.ac.za	Inter-African Astronomical Observatory and Science Park on the Gamsberg in Namibia Southern African Large Telescope	Establishment of an Inter-African Astronomical Observatory and Science Park on the Gamsberg in Namibia (terminated)
1994	Egypt	Kottamia Telescope in Egypt: www.sti.sci.eg/scrci/nriag.html	Egypt's Kottamia Telescope Egyptian drill project for Mars Mission	Refurbishment of Kottamia Telescope Participation of Egypt in the United States/Russia Mars Mission 2001 (terminated)
1995	Sri Lanka	ACCIMT Telescope Facility in Sri Lanka: www.slt.lk/accimt/	Inauguration of telescope facility in Sri Lanka World Space Observatory (WSO)	Establishment of World Space Observatory
1996	Germany	Working Group on Space Science in Africa: www.saao.ac.za/~wgssa/ Network of Oriental Robotic Telescopes: www.saao.ac.za/~wgssa/as2/nort.html	Assessment of the achievements of the series of UN/ESA workshops Foundation of Working Group on Space Science in Africa Network of Oriental Robotic Telescopes (NORT) Education and research using small astronomical telescopes Developing astronomy and space science world wide	Establishment of Network of Oriental Robotic Telescopes
1997	Honduras	Observatorio Centroamericano de Suyapa in Honduras: www.unah.hn Space Guard Foundation (NEO Observation) in Italy: spaceguard.ias.rm.cnr.it/	Newsletter African Skies/Cieux Africain published Inauguration of Central American Astronomical Observatory in Honduras NORT Observation of Near-Earth Objects	
1999	Jordan	Maragha Astronomical Observatory in Jordan: www.aabu.edu.jo/ Hands-on Astrophysics: www.aavso.org/	WSO/UV Operation of Maragha Observatory in Jordan Baaqua radio telescope Hands-on Astrophysics	Operation of astronomical telescope facility at Al al-Bayt University Planning of 31-m Baquaa radio telescope at University of Jordan
2000	France	World Space Observatory/UV: www.seas.columbia.edu/~ah297/un-esa/wso.html Astrophysics for University Physics Courses book manuscript: www.seas.columbia.edu/~ah297/un-esa/astrophysics/index.html	WSO/UV NORT Astrophysics for University Physics Courses	

Table 4. Contact addresses and published results of UN/ESA workshops on basic space science 1991-2000

Year	*Principal Organizer's*	*Reviews of Workshop*	*Working papers Published in Seminars of the UN Programme on Space Applications: Selected Papers of Activities*	*Workshop Proceedings*
1991	S.C. CHAKRAVARTY INDIA scc@isro.ernet.in	Astrophysics and Space Science 193(1992) 161	One working paper each in volumes 3(1992) and 4(1993)	AIP Conference Proceedings 245(1992)1-350
1992	W. FERNANDEZ COSTA RICA wfer@cariari.ucr.ac.cr	Earth Space Review 2(2) (1993)25-26 COSPAR Information Bulletin 149(2000)82-84	No working papers published	Earth, Moon, and Planets 63(1993)93-179
1992	S. TORRES COLOMBIA verada@earthlink.net	Earth Space Review 2(2)(1993)25-26 COSPAR Information Bulletin 144(1999)13-15	No working papers published	Astrophysics and Space Science 214(1994)1-260
1993	P. N. OKEKE NIGERIA misunn@aol.com	Earth Space Review 3(3)(1994)26-27 COSPAR Information Bulletin 144(1999)28-30	Three working papers in volume 5(1994)	AIP Conference Proceedings 320(1992)1-320
1994	J. S. MIKHAIL EGYPT	Earth Space Review 4(2)(1995)28-30 COSPAR Information Bulletin 148(1995)1-405	Three working papers in volume 6(1995)	Earth, Moon, and Planets 10(1995)1-233 Astrophysics and Space Science 228(1995)1-405
1995	P. DE ALWIS SRI LANKA asela@slt.lk	COSPAR Information Bulletin 136(1996)8-11 ESA Bulletin 81(1995)18-21	Three working papers in volume 8(1997)	No workshop proceedings published
1996	R. SCHWARTZ GERMANY rolf@mpifr-bonn.mpg.de	COSPAR Information Bulletin 138(1997)21-24 AAS Newsletter 79(1996)18-19	Two working papers in volume 8(1997)	Astrophysics and Space Science 258(1998)1-394
1997	M. C. PINEDA DE CARIAS HONDURAS mcarias@hondutel.hn	COSPAR Information Bulletin 141(1998)9-10 Annals of the New York Academy of Sciences 822(1997)621-630	Six working papers in volume 9(1998)	No workshop proceedings published
1999	H. M.K. AL-NAIMIY JORDAN alnaimiy@yahoo.com	COSPAR Information Bulletin 146(1999)9-10	Six working papers in volume 11(1999)	Astrophysics and Space Science 273(2000)1-343
2000	F. R. QUERCI FRANCE fquerci@ast.obs-mip.fr	COSPAR Information Bulletin 136(1999)66-67 AAS Newsletter 100(2000)21 AAS Newsletter 102(2000)14	Thirteen working papers in volume 12(2001)	No workshop proceedings published

from the *National Astronomical Observatory of Japan* in Tokyo.

Since 1991, the results of each of the workshops have been reported and evaluated in reviews, working papers, and proceedings of the workshops (Table 4). The principal organizers of the workshop have made efforts to sustain the momentum and spirit of the workshops for the benefit of astronomy and space science.

4.4. CONTINUATION OF THE WORKSHOPS

As part of the 2001 activities of the UN Programme on Space Applications, the *Office for Outer Space Affairs* of the United Nations will organizes from 25 to 29 June 2001 a *Workshop on Basic Space Science*, in cooperation with the Government of Mauritius and the European Space Agency (ESA), at the University of Mauritius, Reduit, Mauritius.

It is the tenth in the on-going series of regional and international workshops dedicated specifically to space science in developing nations. Preparations for the eleventh Workshop in Argentina in 2002 have also been initiated. While most activities of the Space Applications Programme focus on practical space applications, such as remote sensing, satellite communications, and satellite meteorology, these workshops on basic space science constitute a recognition of the importance of space research as part of space activities that contribute to national development.

DISCLAIMER

Any opinions, findings, and conclusions expressed in this paper are those of the author and do not necessarily reflect the views of the United Nations.

ACKNOWLEDGMENT

The author greatly acknowledges the cooperation of colleagues who participated at and/or contributed to the UN/ESA Workshops on Basic Space Science.

References

1. Bonnet, R.M. and Manno, V.: 1994, International Cooperation in Space: The Example of the European Space Agency, Harvard University Press, Cambridge, MA.
2. Dunar, A.J. and Waring, S.P.: 1999, Power to Explore: A History of Marshall Space Flight Center 1960-1990, National Aeronautics and Space Administration, Washington DC.
3. Dyson, F.J.: 1999, Miracles of Rare Device, *The Sciences* **39/2**, 32-37.
4. Galvez, A., Maqueda, M., Martinez-Bueno, M. and Valdivia, E.: 2000, Scientific Publication Trends and the Developing World, *American Scientist* **88**, 526-533.
5. Genova, F. *et al.*: 2000, The CDS and NASA ADS Resources: New Tools for Astronomical Research, *Astronomy and Astrophysics Supplement Series* **143**, 1-143.

6. Green, B.: 1999, The Elegant Universe – Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory, Vintage Books, New York.
7. Hansson, A.: 2000, Cosmic Genesis and Interstellar Exploration, Proceedings of the Third International Academy of Astronautics Symposium on Missions to the Outer Solar System and Beyond, Aosta, Italy, July 3-5, 2000, pp. 67-73.
8. Haubold, A. and Haubold, H.J.: 2001, UN/ESA Workshops on Basic Space Science web site `http://www.seas.columbia.edu/~ah297/un-esa/`
9. Haubold, H.J.: 1998, UN/ESA Workshops on Basic Space Science – An Initiative in the World-Wide Development of Astronomy, *Journal of Astronomical History and Heritage* **1**, 105-121.
10. Haubold, H.J.: 2000, A Challenge for International Cooperation in Astronomy and Basic Space Science, in *The Future of the Universe and the Future of Our Civilization* (Eds. V. Burdyuzha and G. Khozin), World Scientific Publishing Co. Pte. Ltd., Singapore, 366-373.
11. Holton, G.: 2000, Einstein, History and Other Passions – The Rebellion Against Science at the End of the Twentieth Century, Harvard University Press, Cambridge, MA.
12. Kitamura, M.: 1999, Provision of Astronomical Equipment for Developing Countries Through ODA of the Government of Japan, Seminars of the UN Programme on Space Applications: Selected Papers from Activities Held in 1999, No. 11, UN Document ST/SPACE/3, p.1-2.
13. Mattei, J.A. and Percy, J.R. (Eds.): 1998, American Association of Variable Star Observers: Hands-On Astrophysics, Cambridge, MA.
14. Mattei, J.A. and Waagen, E.O.: 2000, An Example of a Large Organization of Amateur Astronomers, in *Information handling in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 205-222
15. Pyenson, L. and Sheets-Pyenson, S.: 1999, Servants of Nature – A History of Scientific Institutions, Enterprises and Sensibilities, WW. Norton & Company, New York.
16. Schilling, G.: 2000, The Virtual Observatory Moves Closer to Reality, *Science*, 289, 238-239.
17. Szalay, A.: 2000, National Virtual Observatory, in *Astronomical Data Analysis Software and Systems X*, in press
18. UNISPACE III: 1999, Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999, UN Document A/CONF.184/6.
19. Wentzel, D.G.: 1998, Astrophysics for University Physics Courses, College Park, MD, University of Maryland.

ORGANISING AND FUNDING RESEARCH AT A EUROPEAN LEVEL

ANTHONY E.S. MAYER
European Science Foundation
1, quai Lezay-Marnésia
F-67080 Strasbourg Cedex, France
`amayer@esf.org`

Abstract. It is difficult to organise research at a European level and the reasons for this are examined. Although an international collaborative activity, research is frequently perceived in nationalistic terms, primarily because it is viewed as leading directly to economic benefit. Despite this, a number of initiatives have been established at the European level since the 1950's. Their history is somewhat erratic and is now dominated by the European Union's Framework Programme.

Research infrastructures need to be considered at the European level and have been the reason behind many of the collaborative European developments in the past. They are essential for the development of research and are frequently beyond the capabilities of any single nation to finance them. Here, there is a clear case for a European approach. The problems of organising research at a European level arise from the complex structures which exist and the many conflicting interests. In addition, there is the paradox of science itself which is both collaborative and an intensely competitive activity. The case of the European Science Foundation demonstrates these difficulties in developing "European" research.

Finally, the proposal for a European Research Area is discussed with the conclusion that new structures are needed in Europe in order to support globally competitive basic research.

1. Introduction

The Americans have developed a reputation for apt and pithy sayings. When one considers the title of this chapter, then the saying that "this is like herding cats" immediately comes to mind. One has to ask why this

A. Heck (ed.), Organizations and Strategies in Astronomy II, 65–82.

should be so when scientific research is an international endeavour and particularly when we function in an increasingly global environment?

Another question which also needs to be addressed is why there is such a complex web of structures to promote European cooperation in science and technology and which, in turn, leads to further problems in creating an efficient means of organising and funding research in Europe?

2. Historical perspective

As scientific research, especially in the understanding-driven part of the scientific spectrum, relies heavily on public patronage (*i.e.* through the use of resources ultimately derived from the taxpayers), then perhaps the key driver is the structure and policy of Europe itself. Depending on the definition of Europe, whether this be the restricted view of the European Union of 15 Member States or the concept of 40 or more states stretching from the Atlantic to the Urals, one can build different constructs to deliver common actions with varying degrees of conformity or centralisation. In mapping the structures which support scientific research, a number of models may be defined.

These models reflect political history with regional tendencies being evident. Grant agencies/research councils are the norm in northern Europe. Southern Europe tends to prefer the national research organisations while in Eastern Europe, the old Soviet-style academy with a range of in-house institutes may remain. Of course, it is not always as simple as this. Many countries mix their structures to provide for major national laboratories and grant functions, especially in support of university research, as it is the case, for example, in Germany and Spain (Table 1).

Even where structures may appear culturally similar, with similar titles, there may be subtle differences in the detail of the operation and the relationship with the research community. This is often a reflection of the independence or distance from Ministerial control. On top of that must be added the directly-funded government laboratories seated within ministries and owing a direct responsibility to government. This picture of research structures in Europe demonstrates both the complexity of organisation and its reliance on *national* budgets. There is obviously a perceived and accepted view that the support of research, wherever it is performed, is in the national interest.

This may be expressed in the extreme view of the former Communist central economies where every detail of activity is accountable to central planners or in the increasing acceptance in Western Europe and the rest of the developed World of the so-called "linear model". In this it is assumed that advances in basic research fairly rapidly move into applications and innovation and hence into job-creation and economic development. This rather naïve view is used both by politicians to justify funding research from the public purse and by scientists in making the case for continued investment. In reality, the interaction between research investment and economic development is far more complex consisting of a number of feedback loops and the diffusion of knowledge, especially through knowledge transfer by people, as argued by Martin *et al.* (1996).

Nevertheless, the link between research investment and economic development figures in most of the key policy initiatives accepted by government and it is for this reason that the development of European research in any area, which, *par excellence*, relies on international collaboration and exchange is seen in such nationalistic terms.

Even when we pool defence systems in NATO or the Western European Union or have common markets and economies in the EU or more to a single currency in the Eurozone, science remains apart as a fundamentally nationally-driven activity.

3. A short history of European research integration

Although scientific research is primarily a national activity, the past fifty years have seen very substantial changes and increases in European-level collaboration. Initially, and this is still the case, the "driver" for such collaboration is the scale of investment as the cost and sophistication of equipment increases and investment decisions have to be taken at a level above that of the nation state.

It is pertinent to examine the history of European collaboration and to analyse some of the underlying reasons for its development.

Table 2 shows some of the main dates of the development of European collaboration in research. The first observation is that some of the collaborations are now very long-standing and date from the early fifties. CERN is perhaps the best-known example which has developed not only into a very comprehensive European collaborative action but into a global centre. Secondly, most of the collaborations have been "driven" by the need to provide expensive instrumental infrastructures. Thirdly, the organisational initiatives have been dominated from 1985 onwards by the "political" development within the European Union which brought together previous European activities and provided a structure and funding such that the European Commission can take its place alongside national structures as a major research funder, albeit with strictly-defined political objectives. Detailed histories of these European collaborations have been compiled by Krige & Guzzetti (1997).

Astronomy is a discipline where its very essence and context demand an

Table 1

CLASSIFICATION OF ESF MEMBER ORGANISATIONS

Country	Grant Agency (*senso stricto*)	Grant Agency with Institutes	National Research Organisations	Academy (learned society model)	Academy with Institutes	Other (incl. Agencies located in Ministries)
Austria	FWF				Acad. of Sciences	
Belgium	FNRS (Wallonia) FWO (Flanders)					
Czech Rep.	GACR				Acad. of Sciences	
Denmark	Research Agency & incl. 6 research councils			Acad. for Sciences and Letters		
Estonia	Estonian Science Foundation			Acad. of Sciences		
Finland	Academy of Finland			Del. of Acads. for Sciences and Letters		
France			CNRS INSERM CEA IFREMER INRA IRD			
Germany	DFG		HgF MPG	Union of Acads of Sci. & Humanities		
Greece			NHRF			
Hungary	OTKA				Acad. of Sciences	
Iceland	Rannis					
Ireland	IRCHSS	HRB		Royal Irish Acad.		Enterprise Ireland

Italy			CNR INFM INFN			
The Netherlands		NWO		KNAW		
Norway	Norwegian Research Council			Acad. for Sci. and Letters		
Poland					Acad. of Sciences	
Portugal	FCT			Lisbon Acad. of Sciences		ICCTI
Slovakia					Acad. of Sciences	
Slovenia	Slovenian Science Found			Acad. for Sciences and Arts		
Spain			CSIC			OCYT
Sweden	Research Council of Sweden			Acad. of Sciences Acad. of Letters & History		FAS FORMAS
Switzerland	SNSF			CASS		
Turkey		Tübitak				
United Kingdom	ESRC EPSRC PPARC	BBSRC MRC NERC		Royal Society	British Acad.	

Table 2

Some key dates in European scientific integration

50s	60s	70s	80s	90s
CERN 1952	EMBO 1964	ESRC & EMRC 1971 leading to ESF 1974	EISCAT 1982	
EC-JRC 1958	ESO 1962		EUREKA 1985	Treaty of Union (Maastricht) 1992
	ILL 1967		ESRF 1988	
Treaty of Rome 1957		COST 1971		FP III 1990-94
		EMBL 1974	Single European Act 1985	FP IV 1994-98
		ESA 1975	FP I 1984-87	FP V 1998-2002
		JET 1976	FP II 1988-92	Treaty of Amsterdam 1996

international collaborative approach and is probably one of the first sciences to have truly involved such collaborations. One only has to think about such topics as a 'planetary' approach to the study of the Universe, the necessity of having observations in both Northern and Southern hemispheres and the need for establishing coordinated observations of phenomena in order to provide every long baselines to realise why astronomy may be ahead of the other disciplines in this respect.

It is also instructive to see that the seventies was a period when attention shifted from specific infrastructural collaboration to the initiation of systems being put in place to foster European collaboration *per se*, such as the establishment of COST and the merging together of various informal groupings which existed to form the European Science Foundation (ESF).

4. Research infrastructure in Europe

In "Towards a European Research Area" (see later), it was recognised that "research infrastructures play a central role in the progress and application of knowledge". The aim of any European action must be to ensure that European research is properly equipped, that this is efficiently managed and providing a magnet for the best students and researchers from all over the world.

The concept of European research infrastructure has extended from its origins in the physical sciences including, in particular, astronomy and nuclear physics to encompass the biological and biomedical sciences, as well as the social sciences and humanities. Research infrastructure covers both instrumentation and software, systematic and well-documented collections of cultural artefacts or natural specimens in museums, and social science data archives; it can also include animal houses, aquaria or green houses. Rapidly evolving database technology now enables researchers to store, sort, compare and analyse data with an efficiency unimagined a few years ago.

Electronic communication networks have eased access to many infrastructures, substantially enhancing research collaboration in many disciplines, and allowing internationally comparative research in, for example, the social sciences and humanities. In addition, the growing emphasis on systemic thinking, leading to more interdisciplinary and transdisciplinary research, has also changed the profile of many infrastructure users. Visualisation centres are now being established which facilitate interpretation of large multicomponent data sets. True three-dimensional immersive interactive databases bring a human dimension to any mathematically formulated problem or data set. Combinations of multi-dimensional visual data can be fused with multi-dimensional audio data to produce a knowledge landscape that approximates the real world.

Given this new and broader definition of research infrastructure, it is clearly important to establish criteria to identify those facilities which would qualify as important elements in a European system of research infrastructures.

European research infrastructure, therefore, must:

- operate at an internationally recognised level of excellence;
- demonstrate a substantial, measurable impact on the quality of research undertaken;
- be evaluated at appropriate time intervals by an international group of experts;

- grant access for national and international researchers under identical rules (merit, peer review);
- reach a clearly visible European dimension;
- be able to demonstrate a European "added value".

An important opportunity for added-value is in the elimination of unnecessary resource duplication. Specifically, large-scale European-level research infrastructures may diminish or even eliminate the need for the creation of similar infrastructures at the national level and thereby optimise investments.

Astronomy, by its very nature and its demands for expensive observatories on a global basis, common observation campaigns, long-baseline interferometry and the combination of Earth-based and space-based activities is an example, perhaps above all others, of the need to take a European and a global collaborative approach.

Europe, over the past 50 years, has built and operated, with great success, a large variety of research facilities serving various scientific communities. What have been their strengths? Among these are flexibility and diversity. Most infrastructures have been built on an *à la carte* system or according to an unwritten principle of "variable geometry", reflecting the will of national agencies and, thus, their research communities which bear the financial consequences of their choices and which, for most of their time, are involved in decisions regarding their operation and future development and improvement.

However, in looking at the provision of research infrastructure within Europe, it is useful to compare the situation to that in the USA. There are important differences, of which the most significant is that the USA has a coherent system, both politically and in its support for science. The capital investment in the USA is also considered greater. There are also similarities, in that regional and local rivalries exist as hosts for infrastructure, sometimes leading to wasteful investment. The most important difference, however, is the lack of national "labels" on infrastructure in the USA and so the issue of "juste retour" between the various nations of Europe does not arise. A further consequence is that Europe falls behind the USA when it comes to the speed of decision-taking and implementation. Nevertheless, Europe has a generally good record of cooperation on infrastructures despite these apparent difficulties.

The cost and technical imperative to come together for major facilities and efforts such as CERN has been an outstanding success. CERN has engendered a scientific cooperative system that it has been a model of its kind, a flagship of Europe an collaboration and has enabled this facility to grow from a limited European cooperation to a global leader in particle physics. At the same time CERN has pioneered new methods of working, including the World-Wide Web, and is a driving force behind moves to establish a Europe-wide computer grid. Similar cost imperatives have driven broad European cooperation in provision of space missions and launchers, telescopes and other high-cost infrastructure, while EMBL has brought together the relevant intellectual resources in Europe to focus on common research targets. Successive Framework Programmes, in addressing infrastructure needs and access on a continent-wide basis, have undoubtedly enhanced the effectiveness of Europe's investment in research.

It is clear that shared infrastructure works well when there exists a highly focused research community. A good example of this is EISCAT which brings together several countries whose atmosphere physics communities are both strong and have a tradition of cooperative working (these are in the bigger EU countries and the Arctic nations). Similarly, Europe has successfully assembled the infrastructure and communities to sustain several major observational campaigns, such as the Arctic and sub-Arctic ozone measurement campaigns and continent-wide geophysical traverses. It is not essential to enforce a continent-wide approach, but to take into account diverse needs while encouraging cooperation and taking advantage of the economies of scale which European cooperation can offer.

In other endeavours, the record is more patchy. Service facilities serving a large community have provided several outstandingly successful examples (*e.g.* ILL and ESRF). Synchrotron beamlines, originally built to meet the demands of the chemistry and physics communities, have now become essential analytical tools in many sciences, especially in the biological and biomedical sciences. However, while clearly at a level well beyond that of the "well found" laboratory, synchrotron sources and similar facilities frequently retain "national" labels, thereby weakening the European system. Critically, within Europe there is difficulty in providing a mechanism for taking decisions on such facilities at a European-wide basis, following an objective analysis of the demands and an assessment of the existing provision. This is certainly a case for European coordination and collaboration to realise the objectives of "better, cheaper, faster".

5. The complexity of European collaborative structures

One consequence of the nationally-based research systems in Europe is that each new initiative to create multi-lateral collaboration tends to be created *ab initio*. The result is a complex "spider" web of organisational structure, scientific or infrastructure collaborations and responsibility links. Figure 1 is an attempt, from an ESF viewpoint, to map these relationships. Another outcome is that one finds a whole series of political arrangements, now "cast in stone", which are difficult either to stop or to develop and adapt in combination with others. So, we have the supra-national arrangement of the EU Framework Programme and then a series of other agreements – inter-governmental (*e.g.* CERN), inter-ministerial (*e.g.* COST), inter-agency (*e.g.* ESF) at varying levels of multilateral collaboration. Again, to quote examples, CERN, COST and ESF are multi-lateral arrangements at a very broad level while ESA, ESO and EISCAT represent differing levels of multi-lateralism, some more restricted than others.

The lack of any systematic approach or central "clearing house" structure means that there is a tendency for such collaborations not only to be created *ab intro* but to involve, with varying degrees, ministries and governments rather than agencies. Again this is a throwback to a more nationalistic policy framework and to the Cold War when every collaboration was viewed within the context of national foreign policy. The result, as stated previously, is a complex web of relationships, each jealously guarded by a particular part of government machinery and reluctant to give up its area of influence, even if this would be to the greater good of European science.

6. The science paradox

Science is both intensely competitive while being, at the same time, collaborative. Research can be a lonely occupation and one needs to communicate with one's peers and test ideas. At the same time, the nature of research is one of incremental advance and again communication is vital. As Kai Simons (2000) said in referring to experimental biology:

> "There is an outstanding paradox in experimental biology: the existential urge for scientists to shine as individuals and the necessity to work together as a collective. We not only stand on the shoulders of past scientists but also have to use and develop a number of new and different methods ... no single individual can be a jack of all tracks ... and (we) have to work together in teams ... But the fact remains that any real breakthrough today is the result of an amazing weave of experimental strategies that demands collective efforts."

Although written in terms of modern experimental biology the same sentiments may be applied to almost all subjects, and especially as we push against the borders of traditional disciplines.

So there are the pressures on the individual to further her/his career and reputation and the increasing necessity to collaborate. Similarly, this may apply to groups, laboratories and institutes. As we saw under infrastructures, the need and desire to collaborate is driven frequently by economic necessity.

Table 3

European research coordination mechanisms - a comparison

European Union Framework Programme	**EUREKA**	**COST**	**ESF**
1987	1985	1971	1974
Established by Treaty Supranational	Inter-governmental agreement	Inter-ministerial agreement	Inter-agency organisation
EU + EEA + Accession States + others			
30 countries	26 countries	32 countries	67 organisations in 24 'national groups' (countries)
Policy driven RTD support for industrial competitivity and policy	Pre-competitive near market industrial research	Applied and fundamental research	Fundamental research spanning humanities to nuclear physics
Shared-cost research funding and concerted actions	Coordination with national support	Coordination of funded researchers	Coordination of funded researchers and other actions Coordinated Research funding Science policy
FP V has 7 major programmes with 23 Key Actions	692 actions	approx. 200 actions	approx. 180 actions

Then there is the need to compete, as a discipline, to defend whole areas of science within the restricted budgets which are available. Here there is an alliance between the research practitioners in the laboratories and the research managers in the funding agencies to maintain and defend budget lines. A good example is that of the Atacama Large Millimetre Array (ALMA). This global project involves Europe, Japan and the USA with an estimated cost of 750 MEuros. Such an instrument is one of the highest priorities in astronomy. To succeed it must compete not just against other astronomical projects but against projects of equal merit in other scientific disciplines as, for example, the Integrated Ocean Drilling Project (IODP). Both are, in their way, basic, curiosity-driven activities. Here we see the paradox of collaboration and competition within and between disciplines. It also shows that such projects are certainly beyond the capacity of the largest nations, thus necessitating global partnerships.

In other words there is a paradox of competition versus collaboration existing at all levels of organisation and within all scientific disciplines.

7. Need for change

Hopefully, the sections on research infrastructures, and on the complexity of present arrangements have demonstrated that there is both a need to consider the benefits of working together at the European level and a need for reform and consolidation of European structures.

Very often, in such a debate, people raise the question of "subsidiarity". This concept, originally put forward by Pope Leo XIII, says that a central authority should only perform these tasks not best carried out at a more local level (in other words, have a subsidiary function). This is often used to advocate maintaining national or regional systems. The countervailing argument is that of Occam's Razor which says that one should not do with more what can be done with less. How then may these two principles be reconciled in relation to European scientific research?

There are no doubts that the research activity itself must be carried out by individuals, laboratories or institutes *i.e.* that subsidiarity and 'bottom-up' actions and ideas should prevail. Certainly, to quote Peter Swinnerton-Dyer "Questions may be asked both 'top-down' and 'bottom-up' but answers always come 'bottom-up' ". This does not apply to the organisation and funding of research and it is here that one must surely apply Occam's Razor. This is not to say that one should have a single, centralised and unitary system. Diversity is also an important factor. But, scientific research has now reached a scale, a cost and a complexity that is beyond most national capacities and new solutions working together at a European level are necessary.

8. The European Science Foundation (ESF) – An example of a European approach

Table 2 shows that the period when there seemed to be the greatest impulse to create European collaboration was in the early 1970's. At that time, the only instrument of the then European Economic Community (EEC), now the EU, was to encourage collaboration between nationally funded research, through support of coordination costs - so-called "concerted actions". This was organised through a scheme known as Cooperation in Science and Technology in Europe (COST), set up by inter-ministerial agreement. Although covering all sciences it nevertheless gave emphasis to issues of concern to the EEC in terms of strategic and applied research.

The coming together in Europe, first of medical research councils and then of natural sciences research councils eventually led to their combining, in 1974, with the support of the European Commission and the Council of Europe, within a formal body, the European Science Foundation (ESF), with its seat in Strasbourg. The ESF was deliberately set up to act as an opposite to the European Commission and COST in that it is an inter-agency organisation, legally not an inter-governmental organisation but a non-government not-for-profit organisation registered in Alsace, concentrating in developing and supporting research in the basic part of the research spectrum. In many ways, the model of operation was more that of a learned society than a research council, ESF was seen as the antithesis or counterweight to the European Commission and COST.

Since its conception, ESF has grown to cover most of the different types of organisation listed in Table 1 in a majority of European countries[1]. Initially restricted to Western Europe (with Greece, Turkey and former Yugoslavia), it now involves many organisations from central and Eastern Europe and sees itself as a European "voice of science". It has very much operated on a "bottom-up" approach but needs to combine this with the "top-down" priorities of its Member Organisations from whom it derives its funding. Therefore, it can be said to need to be responsive to the demands of both its groups of stakeholders, the European research community at large and its Member Organisations.

Funding, which is small and supports coordination or networking costs, is achieved in two ways. First of all, there is the General Budget, the "subscription fees" of its Member Organisations which supports schemes of common interest and an *à la carte* approach in which initiatives are supported by a variable constellation of Member Organisations, dependant on their

---

[1] The online database StarBits (`http://vizier.u-strasbg.fr/starbits.html`) is a useful tool for deciphering acronyms. (Ed.)

interests and priorities. Thus, ESF is an example of both central action and variable geometry.

In the intervening years since its establishment, the EEC and EU has developed the Framework Programme with a system of direct research funding as well as support for concerted actions of its own and of COST. What, therefore, is the ESF role? Some comparisons between the EU Framework Programme, COST and the ESF are given in Table 3.

In many ways, it is able to act as complementary to these EU actions in that it works in the basic part of the research spectrum and also includes the humanities and social sciences, which were, until the later nineties, largely neglected by the other bodies. It can act in an independent manner, especially in the matter of providing scientific advice, in a way not open to inter-governmental structures. This role, based on the weight of the scientific community and on its Member Organisations, had become increasingly important and the advice more authoritative. ESF has not sought to interfere itself in areas where there is successful existing collaboration such as these working through CERN, EMBL, ESA, ESO, etc. although the sciences represented by those activities may also seek ESF support.

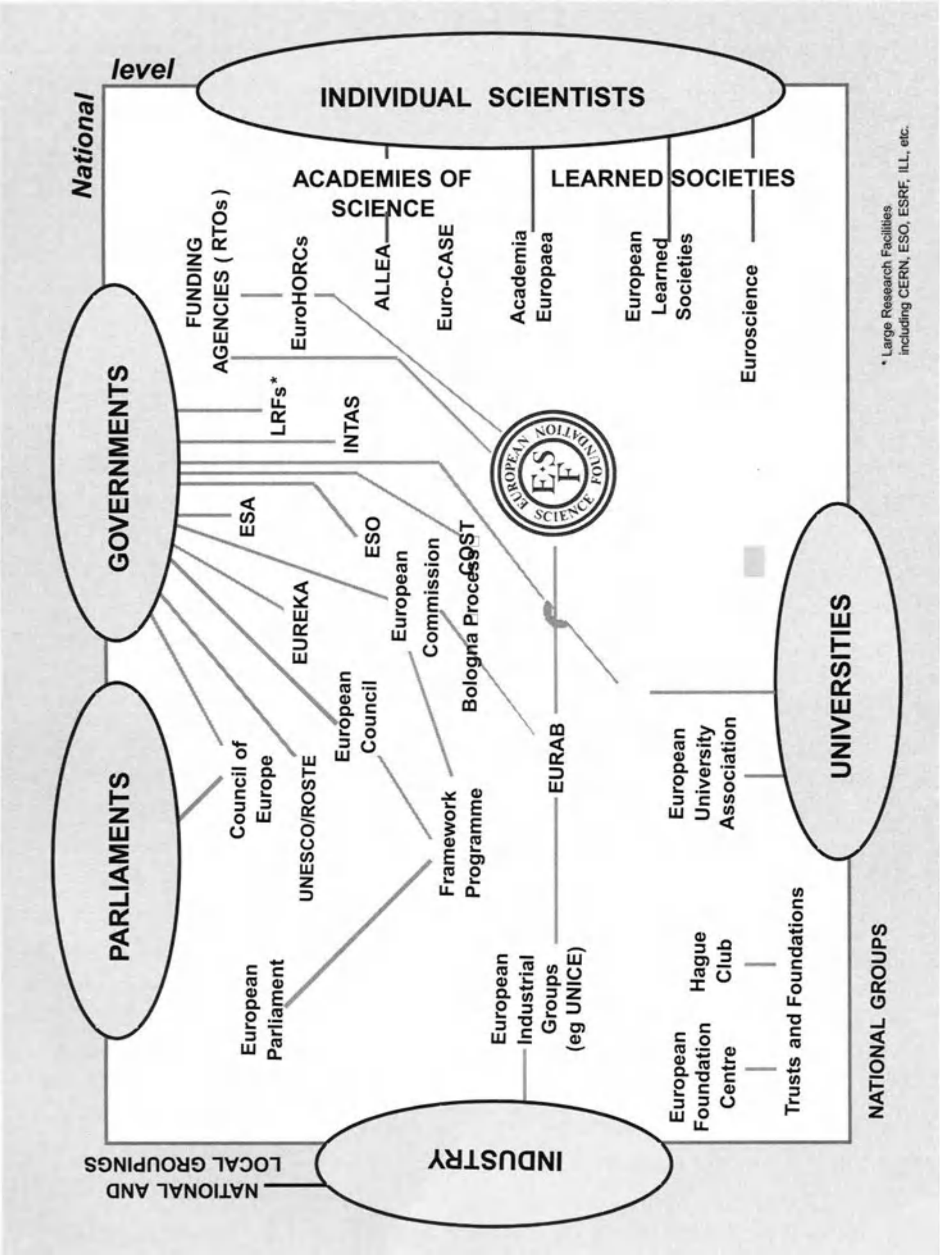
More recently (past-2000) it has endeavoured to move more into a funding mode, not by bringing funds together within ESF, but by "assembling" funds from within its Member Organisations to provide a common funding approach. This scheme, the EUROCORES scheme (European Science Foundation Collaborative Research Programmes) effectively is networking funding agencies as distinct from the ESF established function of networking scientists.

The strengths of ESF are its high level of actions based on its Member Organisations and its independent status (Banda 1999). The latter is also its weakness as its funding is modest, derived from its Member Organisations and subject to budget restrictions applied at the national level. Furthermore, it has no statutory role and this may at times make it difficult to interpose itself on key debates on European research or to insist on common actions by its Member Organisations.

9. The European Research Area and future perspectives

In February 2000, the European Commission (through Philippe Busquin, Commissioner for Research) proposed the creation of a European Research Area (ERA). This was considered as somewhat of a new inspiration although the idea, in different forms, had been proposed in a number of different quarters.

In proposing the ERA, Busquin justified this move by examining global comparisons of scientific productivity, patent productivity and public in-



* Large Research Facilities including CERN, ESO, ESRF, ILL, etc.

vestment in research between the EU, the USA and Japan as being the three principal economic competitors in the World. While some of the comparisons, especially those between the EU and Japan are somewhat debatable (as one is not really comparing like with like), these between the EU-15 and the USA do make a strong case for a more unified approach to organising and funding European research.

The idea is not new (Barré *et al.* 1997, Ruberti & André 1995). In March 1998, the author proposed a new model for European research based on three distinct pillars of industrial and strategic cooperation through the Framework Programme (Mayer 1998), bringing together all coordination activities within the ESF "umbrella" and developing a European basic grant agency by the step by step transfer of funds from national agencies to the new grant agency. The location of this agency, whether in ESF or elsewhere was left open. In October of the same year, there appeared a significant editorial in *Nature* which argued for the creation of a European Research Council, ideally formed from the evolution of ESF into such a body. Although arguing in this way, *Nature* concluded that bodies such as ESF lacked the required strength due to the lack of enthusiasm from its own Member Organisations and national governments, who feared the transfer of funds and authority to a European body.

In 1995 Ruberti and André published their book "Un espace européen de la science" in which they argued for what has now become the European Research Area.

What is indisputable, regardless of the economic arguments, the case regarding patents and the informal acceptance of the linear model is that, with comparable populations and economies, the EU-15 is less competitive than the USA. Certainly, in terms of share of science publications, the USA is the world leader with 32.9%, the UK is a poor second with 9.4% closely followed by Germany and France (1998 figures). Singly, none of these nations is competitive with the USA but together, and with the other states of the EU, then Europe becomes a true competitor with 37.8% of world publications. These figures also belie the argument that it is only the smaller states that gain from European integration[2]. However, when it comes to public patronage of research, the usual index (GERD or the percentage of GDP devoted to funding research) is significantly lower and gradually declining in Europe.

It is against this background that Busquin proposed the ERA. Maybe it and its logical consequences will lead to a fully collaborative ERA, which, in turn, will lead to a European great agency, maybe evolving from ESF. However, if one takes the analogy of economic union, then there needs to be

[2] This is often the argument put forward by the larger countries when not wishing to participate in a European action.

a common political will and convergence criteria. Although within months of the formal proposition of ERA, the concept was endorsed by Heads of Government meeting in the European Council, the "devil" is always in the detail. Despite such a grand, high-level declaration, it is from the working level in ministries and national research agencies that resistance will come with the reluctance to lose control, particularly of the peer review process and funding allocations. However, maybe ERA and its consequences is "an idea whose time has come" as national authorities struggle to match needs against available resources.

Another input to the debate comes from the Europolis Project (funded by the EU Fifth Framework Programme) which identified four possible scenarios for the future. These are:

- "Lampedusan" Europe in which nothing changes other than minor cosmetic alterations,
- "Swiss" Europe in which must actions take place at a regional and national level with only a few matters left at European level – science not being one of them,
- "Federal" Europe which envisages a significant shift of authority to the European level and
- "Round Table" Europe with the gradual concertation of national policies including research.

The Europolis Project rejected the "Lampedusan" model and advocated what may be thought of as a mix between the "Federal" and "Round Table" models.

In the short term, this may be the way forward (after all this is politics and politics is the "art of the possible") but cannot be a long-term solution.

Europeans should regard scientific research as the key activity at the European level. Europeans should not be afraid of change (certainly, change needs to be carefully managed) or of losing "control". After all, to quote the Formula 1 driver Mario Andretti, "if you are in control then you are not going fast enough". Movement to a European approach must be transparent and with accountability to the European research community and its is this which will provide the various checks and balances.

Science needs the European approach and science should be in the vanguard of such collaboration and not be trying to apply the brakes to collaboration at all levels. If, by 2017 or 60 years on from the Treaty of Rome, we will not have come together to form efficient structures for the future development of science at a European level, then we will have betrayed the future generation of researchers.

References

1. Banda, E. 1999, Putting Science at the heart of Europe – The European Science Foundation's next 25 years, *European Review* **7**, 385-394
2. Barré, R., Gibbons, M., Maddox, J., Martin, B. & Papon, P. (Eds.) 1997, Realignment of Research Systems: Science in Tomorrow's Europe, Economica International
3. Busquin, Ph. 2000, Towards a European Research Area, European Commission – COM (2000)6
4. Europolis 2001, Four scenarios for Europe – Report of the Europolis Project *La Lettre de l'OST* **22** (special issue)
5. Krige, J. & Guzzetti, L. (Eds.) 1997, History of European Scientific and Technological Cooperation European Science and Technology Forum, EC Reports
6. Martin, B., Salter, A., Hicks,D., Pavitt, K., Senker, J., Sharp, M. & von Tunzelmann, N. 1996, The relationship between publicly funded basic research and economic performance – a SPRU review for H.M. Treasury, SPRU Report (July 1996)
7. Mayer, A.E.S. 1998, 2017 – A science funding model for Europe, Science Funding – The European Dimension, Science and Society, Royal Society Report
8. Nature 1998, Opinion, *Nature* **395**, 623
9. Ruberti, A. & André. M. 1995, Un espace européen de la science, Presses Universitaires de France, Paris, 185 pp. (ISBN 2130470793)
10. Simmons, K. 2000, Why work together? (Editorial), *Journal of Cell Science* **113/44**

OPTICON:
EC OPTICAL INFRARED COORDINATION NETWORK FOR ASTRONOMY

GERARD GILMORE
Institute of Astronomy
Madingley Road
Cambridge CB3 0HA, UK
`gil@ast.cam.ac.uk`

Abstract. OPTICON[1], the ICN Optical Infrared Coordination Network for Astronomy, brings together for the first time the operators of all Europe's medium to large optical-infrared telescopes, the largest corresponding data archives, and several user representatives. The OPTICON partners work with their communities to identify those major challenges for the future development of European optical-infrared astronomy which require Europe-wide collaboration. OPTICON sponsors and coordinates developments towards these goals, involving the entire astronomical community through workshops and meetings targeted towards these agreed common goals of general importance.

1. Introduction

OPTICON, the Co-ordination Network for optical and infrared astronomy, is an EC funded *Infrastructure Cooperation Network (ICN)* under the *Enhancing Access to Large Infrastructures* part of the Framework 5 (FP5) Human Potential Programme. Such networks are funded to bring together infrastructure operators and 'typical' users. OPTICON brings together Europe's multinational, national and major regional providers of astronomical infrastructures, together with four 'representative' research institutes. The classes of infrastructure of direct relevance to OPTICON include optical and infrared telescopes, their instrumentation, existing medium-sized observatory infrastructures, data archives and their relevant communication

---

[1] `http://www.astro-opticon.org/`

A. Heck (ed.), Organizations and Strategies in Astronomy II, 83–102.

infrastructures, and optimization of the scientific development and exploitation of these facilities. By identifying and encouraging common approaches to those challenges which require Europe-wide collaboration, the OPTICON partners work to enhance both the quality and the quantity of access to those research infrastructures across the whole EU community.

2. Brief history

In 1999 the EC 5th Framework Program funded the thematic network Optical and Infrared Co-ordination Network for Astronomy (OPTICON: HPRI-1999-40002). This network brings together 14 partners, representing the major astronomical funding and management organizations within the European Union. The OPTICON network is sponsored to facilitate co-ordination of key developmental issues in European astronomy.

As part of its FP5 initiative, the EC made a deliberate effort to encourage improved coordination and collaboration in the development of, and access to, European-scale and internationally competitive research infrastructures. In practise, this meant extending the established system of *Infrastructure Cooperation Networks*, which existed in many branches of science which received significant EC funding support.

The role of these networks was described at the time as:

> *INFRASTRUCTURE COOPERATION NETWORKS*
>
> *The objective of this scheme is to catalyze the self-coordination and the pooling of resources between infrastructure operators in order to foster a culture of cooperation between them, to generate critical mass for research into higher performance techniques, instrumentation and technologies, to spread good practice, to promote common protocols and interoperability, to encourage complementarity, and to stimulate the creation of "distributed" and "virtual" large facilities.*
>
> *Participants in these networks will be operators of research infrastructures, research teams in universities, in research centres and in industry, representatives of users of the infrastructures, and equipment manufacturers. Each network will contain at least three mutually independent legal entities which operate research infrastructure and which come from at least three different countries of the Member States and Associated States (one of which at least must be a Member State) and must be co-ordinated by one of these legal entities.*
>
> *Infrastructure cooperation networks will be implemented as thematic networks.*

One such network, EVN-JIVE, was in place supporting radio astronomy, and in particular Very Long Baseline Interferometry (VLBI), and its central data processing facility at JIVE, the Joint Institute for VLBI in Europe, based in the Netherlands. JIVE/EVN has as partners all the facilities (including several outside the EU geographical borders) which manage radio telescopes in the VLBI network. Many of the users work in the same Institutes, so that user representation is provided naturally.

To establish a comparable scale network in the rest of astronomy, ensuring full community participation and support, is not easy: there are very many Institutes in Europe active in astronomy, very many observatories, and many major data centres. In order to ensure that OPTICON had validity from its start, the EC invited to meetings in Brussels one or more representatives from every major astronomy-related funding agency, as well as the PIs of every EC-funded astronomy-related network and grant. Over 100 people were involved in these meetings. By February 1999 clear agreement had been reached that establishing such a network was desirable, the major infrastructure operators in Europe had all agreed their support, identified the issues which they wished the network addressed as a minimum, and the present author was asked to write and coordinate the proposal.

The proposal was submitted to the early May 1999 proposal round, and approved. Funding for travel and workshops over four years was provided to ensure open community-wide participation in agreed goals. The OPTICON partners met formally for the first time in April, 2000.

Identification of the partners was, in most cases, self-evident. Organizations which operate observatories and large data centres are readily identifiable. There was only one existing grant holder under the extant Access Program, and that Institute (Instituto de Astrofisica de Canarias, manager of the European Northern Observatory Access grant), while not yet an operator of medium sized or large telescopes (pace GRANTECAN), or a data centre, does operate an observatory site, the Canarian Observatories.

One issue which arose at once, and which remains subjective, was selection of the 'representative user groups'. Clearly no such selection has any meaning when hundreds of comparable Institutes exist. In practise however, the role of the users among the partners has been restricted to hosting open scientific workshops, and to scientific support for a single item in OPTICON's activities, development of the science case for future Extremely Large Telescopes. Since this role provides no direct benefits for the user representatives, the relevant organizations do indeed act on behalf of the wider community. The user Institutes were in fact recommended for inclusion, by the EU meeting, to be the European Association for Research in Astronomy members, as being an available, independently-defined, European-wide group of major research Institutes with a tradition in international collaboration.

The European Association for Research in Astronomy (EARA), was founded in December 1991, joining the CNRS astrophysics laboratoire, Institut d'Astrophysique de Paris, with the astronomy departments of the Universities of Cambridge and Leiden, in the frame of a CNRS initiative for "Associated European Laboratories". EARA was later extended to include the Instituto de Astrofisica de Canarias, and the Max-Planck-Institut für Astrophysik, all five of whose members are OPTICON partners.

TABLE 1. The OPTICON Partner Organizations

Contact Individual	**Partner Organization**
COORDIN. ORGANISATION Dr Paul Murdin	Particle Physics and Astronomy Research Council
CHAIRMAN/CONTACT Professor Gerard Gilmore	Institute of Astronomy The University of Cambridge
Professor Françoise Genova	Université Louis Pasteur - Strasbourg CDS
Professor Piero Benvenuti	Space Sciences Division European Space Agency
Professor Alvio Renzini	European Southern Observatory
Professor Alain Omont	CNRS/Institut d'Astrophysique de Paris
Dr Geneviève Debouzy	Institut National des Sciences de l'Univers Centre National de la Recherche Scientifique
Professor Francisco Sánchez	Instituto de Astrofisica de Canarias
Professor Marcello Rodono	Consorzio Nazionale per l'Astronomia e l'Astrofisica
Professor George Miley	Universiteit Leiden/Astronomy Department
Professor Simon White	Max-Planck-Institut für Astrophysik
Professor Hans-Walter Rix	Max-Planck-Institut für Astronomie
Professor Dr Tim De Zeeuw	Netherlands Research School for Astronomy (NOVA)
Dr Leo Takalo	Nordic Optical Telescope Scientific Association

3. Organization and funding

The Opticon Network includes 14 formal participants and a number of associated partners. The formal participants include the major European and National astronomical agencies plus representative user institutes. The five EARA institutes are among the latter.

The contract partners are independent national agencies or research institutes, and multi-national organizations. Each partner is represented by national research and funding directors, research group directors or the equivalent.

Overall Network coordination is provided largely by the science co-ordinator assisted by the OPTICON Administrator and secretary. This small team ensures adequate information and administrative support for the working groups' and partners' meetings, enhances reliable and effective communications across the network, maintains the webpage and enhances Europe-wide information about the OPTICON activities.

The OPTICON management board meets twice a year with the inaugural meeting being held at the National Maritime Museum, Greenwich, London in April 2000. The schedule of future meetings is given in our diary available on the Opticon webpage.

The Network operates a two-level structure. This means that the contract partners meet to specify timely areas of common interest and opportunity for development and cooperation. These areas of mutual interest are developed and quantified where appropriate by specialist working groups, chaired by a partner, bringing together relevant complementary expertise and users from the whole European astronomical community, explicitely including countries and Institutes not explicitly included in the present partners.

Each working group is led by a delegated partner, who is responsible for specific management, and for reporting to the network overall. In practise, there is a considerable degree of overlap in membership of the working groups, so that informal communications are excellent. Regular communications are utilized on a daily basis with more permanent, and public, information being provided on a series of web sites. Beyond the dedicated network homepage, each working group also has its own home page[2,3,4,5,6].

[2] `http://www.roe.ac.uk/atc/elt/workshop/index.html`

[3] `http://www.ip.de/Euro3D/`

[4] `http://www.stecf.org/ jwalsh/OPTICON3D`

[5] `http://ecf.hq.eso.org/astrovirtel/`

[6] `http://www.roe.ac.uk/ifa/surveys`

3.1. PROFILES OF THE OPTICON PARTNERS

A summary profile of the fourteen Opticon partners is provided below:

3.1.1. *Particle Physics and Astronomy Research Council*

The Particle Physics and Astronomy Research Council (PPARC)[7] funds UK research, education and public understanding in its four broad areas of science – particle physics, astronomy, cosmology and space science. PPARC has three scientific sites: the UK Astronomy Technology Centre (UKATC) in Edinburgh, the Isaac Newton Group of telescopes (ING) in La Palma and the Joint Astronomy Centre (JAC) in Hawaii.

3.1.2. *Institute of Astronomy, University of Cambridge*

The Institute of Astronomy[8] is a department of the University of Cambridge. It is the largest centre for astronomical research in the UK and is among the oldest scientific research departments of the University. The 120 staff, students and visitors are drawn from many countries making it an international research centre dedicated to teaching and research in many areas of observational and theoretical astronomy.

3.1.3. *Centre de Données astronomiques de Strasbourg*

The Centre de Données astronomiques de Strasbourg (CDS)[9] is a data centre dedicated to the collection and worldwide distribution of astronomical data and related information. It is located at the Strasbourg Astronomical Observatory, France.

The CDS develops reference databases and tools, widely used by the astronomy community, and collaborates actively with other data centres, ground and space-based observatories and electronic journals to build links between distributed on-line resources.

3.1.4. *European Space Agency – Space Sciences Division*

The European Space Agency (ESA)[10] provides a vision of Europe's future in space, and of the benefits for people on the ground that satellites can supply. It also develops the strategies needed to fulfil the vision, through collaborative projects in space science and technology.

Most OPTICON-related activity is organized through the ESA/NASA Space Telescope-European Coordinating Facility (ST-ECF)[11,12].

[7] `http://www.pparc.ac.uk/`

[8] `http://www.ast.cam.ac.uk/`

[9] `http://www.astro.u-strasbg.fr/obs-E.HTML`

[10] `http://www.esa.int/`

[11] `http://www.stecf.org/`

[12] `http://www.stecf.org/astrovirtel/`

The Science Archive Facility has over twelve years of experience in the management and development of astronomical archives and databases. Throughout this period the Archive has pursued a steady and effective collaboration with the CADC (Canadian Astronomy Data Centre) and has implemented a number of innovative features. These additions have all proven so useful and popular that they have been adopted by other archive sites and have become part of a set of 'minimum requirements' for modern astronomical archive systems.

3.1.5. *European Southern Observatory*

The European Southern Observatory (ESO)[13] was created in 1962 to establish and operate an astronomical observatory in the Southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy.

It is supported by eight countries: Belgium, Denmark, France, Germany, Italy, the Netherlands, Sweden and Switzerland; the United Kingdom is to join ESO in 2002. Portugal has a cooperation Agreement with ESO, leading to future membership.

ESO operates at two sites. It operates the La Silla observatory in the Atacama desert, 600km north of Santiago de Chile, at 2,400m altitude, where fourteen optical telescopes with diameters up to 3.6m and a 15m submillimetre radio telescope (SEST) are now in operation. In addition, ESO has built the Very Large Telescope (VLT) on Paranal, a 2,600m high mountain approximately 130 km south of Antofagasta, in the driest part of the Atacama desert. The VLT consists of four 8.2m and several 1.8m telescopes. These telescopes can also be used in combination as a giant interferometer (VLTI). "First Light" of the first 8.2m telescope (UT1) occurred in May 1998. UT1 became available on a regular basis for astronomical observations from April 1999. Over 1000 proposals are made each year for the use of the ESO telescopes.

The ESO Headquarters are located in Garching, near Munich, Germany. This is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the La Silla and Paranal observatories with the most advanced instruments. There are also extensive astronomical data facilities. In Europe ESO employs about 200 international staff members, Fellows and Associates; in Chile about 50 and, in addition, about 130 local Staff members.

---

[13] `http://www.eso.org/`

3.1.6. *Institut d'Astrophysique de Paris*

The Institut d'Astrophysique de Paris (IAP)[14] is a laboratory of the Centre National de la Recherche Scientifique (CNRS). Founded in 1938 with the development of modern astrophysics and the foundation of CNRS, IAP has a long history of prominent activity in observation and theory and of international collaboration. Its present activity focuses on extragalactic astronomy and cosmology, including stellar populations and star formation in galaxies, and specific aspects of stellar physics.

The IAP hosts data reduction centers for several major international experiments, including the infrared survey of the Southern sky (DENIS), French participation in the NASA ultraviolet mission FUSE, TERAPIX, the data reduction center for the $1^\circ \times 1^\circ$ MEGACAM camera to be installed on the Canada France Hawaii Telescope (CFHT), and participation in the data analysis of the ESA PLANCK cosmic microwave background space mission.

3.1.7. *Institut National des Sciences de l'Univers*

The Institut National des Sciences de l'Univers (INSU)[15] is part of the Centre National de la Recherche Scientifique (CNRS), the main scientific public research organization in France. INSU has the responsibility in three scientific areas: ocean-atmosphere, earth science and astrophysics. Its 128 research and service units (most of them associated with Universities) represent a total staff of 5608 individuals. INSU is also strongly involved in large international collaborations and participate to the funding and operation of some of the major large ground-based infrastructure facilities.

3.1.8. *Consorzio Nazionale per l'Astronomia e l'Astrofisica and Istituto Nazionale di Astrofisica*

The Italian "National Consortium for Astronomy and Astrophysics" (CNAA)[16] is based in Rome and was established in 1996 by the 12 Italian Astronomical Observatories of the Ministry of Universities and Research (Arcetri-Florence, Bologna, Brera-Merate, Cagliari, Capodimonte-Naples, Collurania-Teramo, Catania, Padua, Palermo, Rome, Turin, Trieste) as a temporary Institution devoted to the promotion and management of national projects, primarily the newly completed "Telescopio Nazionale Galileo" at the Roque de Los Muchachos Observatory (La Palma, Canary Islands), and of coordinated research activities carried out at different institutions in Italy. The CNAA has also served as a forum for debating questions related to the national science policy in Astronomy.

---

[14] `http://www.iap.fr/accueil.html`

[15] `http://www.insu.cnrs-dir.fr/`

[16] `http://w3c.ct.astro.it/cnaa`

The Italian Observatories and the CNAA are now being restructured into a single national institution, the "Istituto Nazionale di Astrofisica" (INAF), which is based in Rome and will take over all legal and management responsibilities starting from mid 2001.

3.1.9. *Instituto de Astrofíca de Canarias*

The Instituto de Astrofisica de Canarias (IAC)[17] is a highly internationalized research centre and comprises: the Instituto de Astrofisica, which constitutes the headquarters, based in La Laguna (Tenerife, Spain); the Observatorio del Teide, in Izaña (Tenerife); and the Observatorio del Roque de los Muchachos, in Garafia (La Palma).

The IAC's headquarters is located on the campus of the University of La Laguna, where it has become a meeting point for the international astronomical community, a centre for research, technological development and training of researchers, engineers and technicians. The Grantecan 10m telescope is the major undergoing technological project. IAC is also an active promoter of science education.

The IAC Observatories (the Observatorio del Teide, on Tenerife, and the Observatorio del Roque de los Muchachos, on La Palma), together with the research facilities from 18 different countries, constitute the European Northern Observatory (ENO)[18], Europe's organization for Astronomy in the North.

3.1.10. *Leiden Observatory*

The Institute of Astronomy at Leiden University, the Sterrewacht Leiden (Leiden Observatory)[19], has a long tradition and an internationally acknowledged reputation for education and research in astronomy.

The Institute offers all the facilities needed to participate in top level research. The research interests of the Sterrewacht Leiden cover many aspects of modern astronomy, ranging from stars and the interstellar medium, to galaxies and cosmology.

3.1.11. *Max-Planck-Institut für Astrophysik*

The Max-Planck-Institut für Astrophysik (MPA)[20] is one of more than 70 autonomous research institutes within the Max-Planck-Gesellschaft (MPG). These institutes are primarily devoted to fundamental research. Most of them carry out work in several distinct areas, each led by a senior scientist who is a "Scientific Member" of the Max-Planck-Gesellschaft.

---

[17] `http://www.iac.es/`

[18] `http://www.iac.es/eno/`

[19] `http://www.strw.leidenuniv.nl/`

[20] `http://www.mpa-garching.mpg.de/`

Research at MPA is devoted to a broad range of topics in theoretical astrophysics. Major concentrations of interest lie in the areas of stellar evolution, stellar atmospheres, supernova physics, astrophysical fluid dynamics, high-energy astrophysics, galaxy structure and evolution, the large-scale structure of the Universe, and cosmology.

3.1.12. *Max-Planck-Institut für Astronomie*

The Max-Planck-Institut für Astronomie (MPIA)[21] in Heidelberg operates the Calar Alto Observatory[22] as well as conducting research in different areas of astronomy and astrophysics. It is one of the Max Planck Institutes in Germany within the Max-Planck-Gesellschaft (MPG) and one of the five astronomically-orientated institutes in Heidelberg.

3.1.13. *Netherlands Research School for Astronomy*

The scientific program of the Netherlands Research School for Astronomy, Nederlandse Onderzoekschool voor Astronomie (NOVA)[23], is based on three multiply-connected inter-university networks. It is built around key researchers with international reputations, who lead groups in their respective institutions (at the Universities of Amsterdam, Groningen, Leiden and Utrecht), and who already have ongoing collaborations.

Nova's mission is two-fold: i) to carry out front-line astronomical research in the Netherlands and ii) to train young astronomers at the highest international level.

3.1.14. *Nordic Optical Telescope Scientific Association*

The Nordic Optical Telescope (NOT)[24,25] Scientific Association (NOTSA) was founded in 1984 to construct and operate a Nordic telescope for observations at optical and infrared wavelengths.

The associates members are: Statens Naturvidenskabelige Forskningsråd (Denmark); Suomen Akatemia (Finland); Háskói Íslands (Iceland); Norges Forskningsråd (Norway); Naturvetenskapliga Forskningsrådet (Sweden).

The executive bodies of NOTSA are the NOT Council and the Directorate.

---

[21] `http://www.mpia-hd.mpg.de/`
[22] `http://www.caha.es/`
[23] `http://www.strw.leidenuniv.nl/nova`
[24] `http://www.astro.utu.fi/`
[25] `http://www.not.iac.es/`

4. OPTICON activity: What and how?

Since the start of the network, six major aspects of European astronomical research in which there are clear benefits from international cooperation, and where inadequate cooperation currently exists, have been identified. These are:

Activity 1: EU Elite Fellowship Program
Activity 2: The Astrophysical Virtual Observatory
Activity 3: Improved Coordination on Common Infrastructures
Activity 4: The Future of Medium-sized Observatories in the enlarged EU
Activity 5: The Science Case for Extremely Large Telescopes
Activity 6: Joint Activities with the radio astronomy ICN (JIVE).

Working groups, with full representation across the whole EU astronomy community, have been established to implement these common objectives, with substantial progress being made.

4.1. ACTIVITY 1: EU ELITE FELLOWSHIP PROGRAM

The working group responsible for Elite Fellowships operates to ensure that the best European fellowships on offer are of comparable status and duration to those on offer in the US and through some European National Programmes. The goal is to make European astrophysics as attractive a career option for the most talented young scientists as options which are available in other communities.

This scheme should enhance the production of excellent science within Europe and help identify research leaders of the future.

4.1.1. *Overview of progress*

A proposal for six, three-year postdoctoral fellowships, namely the J.H. Oort Fellowships, had been submitted to the EU Marie Curie scheme, but these had not been immediately supported. EU feedback strongly supported the scientific goals of the proposal, but implied that the application was not suitable for the programme to which it had been submitted.

The failure of present EU structures to provide internationally competitive fellowship and career opportunities for the most able astrophysicists was identified, with the specific limitations in current schemes being successfully localized.

Following a meeting between the Director General of ESO and the head of DG-XII, the working group chair had put together a new generic proposal for an *elite* fellowship scheme which was hoped could be considered as an *Accompanying Measure* in Framework VI. The scheme could initially be run as a pilot in two or three disciplines, including astrophysics.

The EU had said that it did not have the resource or facility to manage such a scheme and would seek to allocate this responsibility to a suitable Agency if the scheme was supported, though it was not clear who this might be for astrophysics. Consequently, a proposal to investigate possible management structures in several disciplines was submitted to the Call for Accompanying Measures, approved and funded, and is underway.

Efforts continue to create and implement a scheme whereby EU-funded Europe-wide fellowships for the most able astrophysicists will be competitive with US opportunities.

4.2. ACTIVITY 2: THE ASTROPHYSICAL VIRTUAL OBSERVATORY

The OPTICON partners agreed to coordinate their efforts towards the realization of an Astrophysical Virtual Observatory for all European astronomy. An Astrophysical Virtual Observatory (AVO) would allow all European astronomers to partake in, and utilize, the technological advances of the future internet (GRID) initiatives that have already been recognized by the EC as critical to the development of the European Research Area. Similar efforts are under way in the US, in response to an NSF decadal report on astronomy, and in other subjects.

4.2.1. *First step*

The ASTROVIRTEL Project[26], supported by the European Commission and managed by the ST-ECF on behalf of ESA and ESO, was the first stage in the fruition of the AVO. ASTROVIRTEL was aimed at enhancing the scientific return of the ESO/ST-ECF Archive and offers to European users the opportunity to exploit it as a virtual telescope, retrieving and analyzing large quantities of data with the assistance of the Archive staff.

ASTROVIRTEL is primarily concerned with implementation of science-driven query tools spanning multiple extant databases, and means to label the scientific integrity of databases. The approach taken consists of building from specific astronomer led queries starting with a few high-quality and well-understood databases. At present this includes the HST and ESO/VLT archives followed by the rest of the ESA mission archives.

A first call for proposals was announced in mid-2000, with 11 proposals received and 5 selected for further assessment and implementation.

The advantages of the ASTROVIRTEL approach are that: the "scientific interoperability" of different archives will be enhanced on the basis of specific scientific requirements as contained in the approved proposals, the "mining tools" and the procedures for the management and analysis of the

---

[26] `http://www.stecf.org/astrovirtel/`

retrieved data sets. These will then become part of the archive and offered to the community.

It is envisaged that ASTROVIRTEL will naturally evolve into a part of the larger AVO. In the meantime ASTROVIRTEL, with 3 years funding, is providing an essential learning experience.

4.2.2. *Second step*

With the background of ASTROVIRTEL, European-wide efforts are now in place by the working group responsible for implementing an AVO. They are specifically preparing for the following:
1)A complete science case and set of science requirements;
2)A demonstration of interoperability using a small set of existing archives with varying degrees of VO-readiness;
3)An assessment of GRID technologies for astronomy including prototyping, testbeds and the development and assessment of scalable storage and processing facilities;
4)Implementation of active links to similar international initiatives (*e.g.* NVO in the US) to prepare for the possibility of global VO activities.

OPTICON established three working groups to investigate practical implementation of these goals, and definition and implementation of the Astrophysical Virtual Observatory: one to focus on the scientific utilization of archives; one on the interoperability of archives; and one on the necessary IT infrastructure for the exploitation of an ever-increasing astronomical data flood. A meeting of the OPTICON partner organizations in Strasbourg in October 2000 made explicit recommendations to these working groups to prepare, by early 2001, proposals to the 5th Framework RTD program for developments leading to the Astrophysical Virtual Observatory, in such a way as to benefit the entire EC-wide astronomical community.

Six key organizations were identified as members of the AVO Phase A proposal in order to meet the requirements of the RTD program and the aims outlined. The UK ASTROGRID consortium was an existing collaboration that was seeking e-Science funds from the UK government to deploy GRID technologies for several astronomical programs. The joining of the ASTROGRID consortium into the AVO proposal was a major step in order to form an important unification of the European VO effort and to optimize the return on available funds, together with forming a unified interface to international efforts.

The RTD proposal was submitted in February 2001 and identified a 6.2 MEuros work program over three years consisting of 718 man months of development, testing and deployment, 1 MEuros in hardware and 100,000 Euros in travel expenses. The immediate goals have been achieved. The RTD proposal has been approved.

4.2.3. *An illustration using the OPTICON Working Group on Interoperability*

Among the tasks of the OPTICON network are to ensure improved efficiency of access to and enhanced exploitation of ground and space observations, together with the development of virtual access to large data archives. One key element for increasing scientific access to multi-wavelength, heterogeneous data is interoperability of data archives and information services. This allows scientists to retrieve the data of interest for their research among the large variety of possible information sources and be able to formulate queries to these distributed on-line resources. On the service provider side, metadata describing the service contents have to be implemented, and data exchange mechanisms have to be defined and used to allow the implementation of links between services and the integration of data of different origins in common user interfaces.

This analysis was presented at the first general meeting of the OPTICON network at Greenwich in April 2000, where it was agreed that a Working Group to tackle these questions should be created. The Interoperability Working Group aims at studying cost effective tools and standards for improving access to and data exchange from data archives and information services. One important specification was to keep to a minimum the additional workload on data providers. A pragmatic bottom-up approach will be used, with e-mail discussions, targeted meetings to define and promote basic standards and generic tools, short technical visits if necessary, and eventually prototype implementation in some cases. Working Group members are managers of European public databases and archives proposed by the OPTICON collaboration.

The Interoperability Working Group's goals were presented at two major international meetings: Virtual Observatories of the Future (Caltech, June 2000), and Mining the sky (Munich, July-August 2000), where numerous contacts and discussions took place with potential participants and international partners (USA, Canada). The list of participants was further discussed after the second OPTICON general meeting with the OPTICON collaboration members. Exchanges of information took place with the proposed members, to explain the Working Group's goals, to acquire confirmation of their willingness to participate, and identify a first set of information to be distributed and of subjects to be discussed. A Web page is in preparation and a meeting is foreseen in the coming months, with presentations of problems and possible solutions by the Working Group members, together with a few round-table discussions on specific topics of general interests.

A targeted meeting was held in Strasbourg with the ECF-ESO Astro-Virtel managers in December 2000, to discuss the usage of common tools taking into account their scientific requirements.

The importance of early partnership with other communities was recognized from the beginning with contacts being immediately taken with the European Radio Network and an OPTICON/EVN discussion organized during the International Astronomical Union General Assembly in Manchester. The "Astronomy Information Network" was presented at an EVN meeting in Madrid in November 2000. The radio network nominated a representative to participate in the Working Group activities and to diffuse the information in the radio community. Data archive managers from Australia, Canada and USA were invited to participate in the Working Group activities and have fully contributed.

From these meetings and more generally to present the "Astronomy Information Network" at which to discuss generic tools at the first AstroGRID meeting in Belfast, January 2001, a coherent Interoperability work program was thus established for the AVO proposal.

Joint EU and US meetings have identified several key coordination points and milestones for the future. A regular series of open international and Europe-wide workshops, conferences, and scientific meetings are scheduled, with OPTICON sponsorship. The committees also submitted a joint proposal for an IAU Symposium on VO Science to be held in conjunction with the IAU General Assembly in Sydney 2003.

For the future, OPTICON will continue to coordinate EU-wide development of the Virtual Observatory (VO) and implement the RTD aims.

A Review Paper 'OPTICON and the Virtual Observatory'[27] is available further describing these activities.

4.3. ACTIVITY 3: IMPROVED COORDINATION ON COMMON INFRASTRUCTURES

4.3.1. *ASTRO-WISE: OPTICON Working Group on Wide Field Imaging*

The aim of this programme is to provide a European astronomical survey system, facilitating astronomical research, data reduction, and data mining based on the new generation of wide-field sky survey cameras. By joining the efforts of several National data centres established in support of these cameras and of the ESO, the programme establishes, through common standards, a European wide shared computing infrastructure. The huge, many Terabyte, wide field imaging data volumes call for a coordinated effort: the programme coordinates the development of software tools and will support the derivation of survey system products, such as Public Survey results, calibrated images and catalogues of astronomical objects. These products will be used for astronomical research, made available to archive facilities

[27] `http://xxx.soton.ac.uk/multi astro-ph/0011464`

to be addressed by parallel activities such as AVO, and are crucial for the exploitation of the new very large telescopes.

Following a successful OPTICON meeting on Survey systems in Edinburgh, the National data centers involved in wide-field imaging in the Netherlands (NOVA), Italy (Capodimonte), France (TeraPix) and Germany, together with ESO and the UK-VISTA community have taken the initiative to prepare for a joint effort. A full account of the talks and program of the workshop can be found at the workshop web site[28].

A new consortium has been founded with all partners being prepared to contribute significantly by providing both hardware and human resources for a new European-wide-field-imaging initiative. An RTD proposal has been prepared and submitted, seeking funding for this international collaboration. This proposal has been approved and supported by the EU.

This remarkably swift development after the OPTICON meeting marks the common needs and the appreciation of partners' expertise in the consortium. Several meetings between individuals from the data centers have taken place and exchange of personnel is planned. All short-term intentions have been realized, most importantly building a new Europe-wide collaboration.

Long term plans include the implementation of the RTD proposal goals, together with continuation of common work towards agreed common goals.

4.3.2. *EURO-3D: OPTICON 3D-Spectroscopy Working Group*

One of the crucial ways in which European astronomy has acted in coordinating Europe-wide community has been identified by the OPTICON partners. This has been in the development of common software tools to address data challenges common to major instrumental developments. Following recommendation, the OPTICON partners considered the case for 3-Dimensional spectroscopic developments in European astronomy. The partners concluded 3-Dimensional spectroscopy as one of the most technologically challenging developments in optical-infrared astronomy at present, yet is one in which the scientific returns are immense. It is one in which the European scientific community holds a significant and currently world-leading role. It has also been recognized that an essential requirement for European excellence in this technologically challenging field is improved coordination in development of the common infrastructure tools.

In response to this agreed priority need, and to meet the EC recommendation for a coordinated Europe-wide response, OPTICON established a Working Group, with the following remit:

To bring together representatives of all the European groups working in 3D spectroscopy; to share experience, software and expertise; to enhance

---

[28] `http://www.roe.ac.uk/ifa/surveys`

common working methods; and to consider ways in which to apply for EC funding; to support developments of clear common benefit to the whole European astronomical community.

The working group accepted the OPTICON remit, and agreed to develop a proposal to the EC Research, Training Networks programme (RTN). In addition, the instrumental, software and future plans of all the groups were reviewed, and a critical item for progress agreed.

The aim of the RTN proposal, called Euro3D, is to coordinate and underpin the ma ny potentially complementary activities underway in Europe, concentrating on pro viding software while training young researchers to scientifically exploit the m any 3D spectroscopy instruments which are coming available on large telescopes. However, the data from these instruments is large and complex and expertise in the community to exploit the scientific potential is not yet sufficiently widespread.

The working group had met twice during 2000 to discuss and review the instrumental, software and future plans of all the groups. Two open and widely advertised meetings were also held in Garching in December 2000 and in Potsdam in February 2001.

4.3.3. *Activity 4: The Future of medium-sized observatories in the enlarged EU*

The existing medium sized (2-4metre telescope aperture on good mountain sites) observatories have an enormous potential for improved international cooperation, with particular opportunities in enhanced training for the young and for scientists in Central Europe. Additionally, considerable scientific benefits to the whole European scientific community, together with financial benefits to the national operating agencies, can follow from improved coordination of operational facilities, instrumentation, and procedures.

A working group has been established to achieve these training and common operational aims.

Two working group meetings brought together, for the first time, the operators and observatory directors of every 2-4m telescope in which an EU country has a major financial partnership. These historic occasions led immediately to an appreciation of common requirements, opportunities and challenges.

Facilities already in existence cover a wide range of science and training applications, but there is little co-ordination with respect to operation or development. It has also been noted that access to some facilities was already open to the entire international community, but no financial support was available for observers to reach the telescopes.

Four sub-groups were established to consider different areas of possible co-operation and collaboration. One of the aims of these groups is to set out the principles for proposals which could be taken to the wider community and funding agencies.

These groups have prepared a working document, which is now being used as the basis of discussions between telescope operators, national funding agencies, and extant user communities. When agreed with all these communities, a joint proposal to the EU FP6 Access to Large Infrastructures, together with related training and PHARE programmes, will be developed. Various bi-national and multi-national cooperative arrangements have already been stimulated by these meetings.

An extremely ambitious programme, bringing together for the first time all of Europe's national telescope operators, has succeeded admirably.

It is proposed to develop, in detail, methods to enhance the scientific and research training roles of extant 2-4m telescopes; to implement bi-national and multi-national coordination of operations and developments, and to propose to the EU FP6 programme a Europe-wide training and research capability.

4.3.4. *Activity 5: The science case for extremely large telescopes*

An immediate goal of this working group is to develop the science case for future large telescopes, as that would form the basis for specific technological developments. An ancillary goal was to bring together the European astronomy community to support an agreed future program of major infrastructure developments, aimed at putting Europe at the head of the world.

This science case will do the following:

i) define the technological studies and developments which are necessary to build the telescope; ii) form the basis for future proposals for national and EU funding support for development and construction of a world-leading facility.

A major international workshop was held in Edinburgh, September 2000, resulting in the 58 participants identifying and outlining key scientific challenges which enhances the case for future technologies.

The material was assembled into a web-based "skeleton science case", including technical background and performance comparisons between space-based and ground-based facilities. The science sessions (planets and stars, stars and galaxies, galaxies and cosmology) were summarized by the session chairs, and other contributions from participants were included or linked. A software performance simulator is under development, while the whole web-based information package forms the basis for further development at the next planned workshop in the series during Summer 2001.

The current text is available on the web[29].

The early intention, to initiate development of the science case for future extremely large telescopes, has been admirably achieved. A draft science case exists, based on full international participation, which will be further developed in the near future. A pleasing outcome which exceeded intention was the very high degree of international interest and involvement in the planning and implementation of next generation facilities.

4.4. ACTIVITY 6: COMMON ACTIVITIES INVOLVING ALL OF ASTRONOMY

Multinational organizations, such as the EU, and national funding agencies, expect research communities to agree their priorities internally. Competing proposals to national/international agencies from inside a sub-discipline are mutually destructive. Conversely, where several subsdisciplines can benefit from a similar infrastructure investemnt, the case for that investment is strengthened. A topical example in investement in high-bandwidth communications infrastructure (the internet, GRID, and their successors), where all science will benefit.

Coordinated approaches to funding agencies and strategy forums for major projects are thus both necessary and desirable. There is at present no natural forum in Europe to coordinate such approaches. Thus, joint efforts by OPTICON and JIVE/EVN are underway, to establish relevant communications. This will be initiated with public meetings at the Joint European Astronomy Meetings.

5. Publicity, and public awareness

A challenge for any new organization, especially for one involving funding agencies from many countries, is to ensure that the wider community is both fully involved and fully informed of activities and opportunities.

For OPTICON, a conscious decision was made that the first major effort to disseminate results of OPTICON's activities had to await those activities. That is, wide advertising would await some positive results. This rather non-commercial approach has been followed.

The first major successes of OPTICON are now in place:

- The Astrophysical Virtual Observatory developments and initial funding have been obtained;
- Coordinated developments of common infrastructures have been agreed, and funded;

---

[29] `http://www.astro-opticon.org/ELT.html`

- Substantial development work towards an Elite Fellowship programme is funded, and underway;
- The science case for a large telescope is under multi-national development;
- Europe's operators of existing telescopes are meeting and working together;

All these successes have been achieved under the sponsorship of OPTICON. All have been achieved in the first year of activity. Now is the time to address wider questions, and inform the wider community. This is the next challenge for OPTICON.

COORDINATING MULTIPLE OBSERVATORY CAMPAIGNS

KARLA PETERSON, BETH PERRIELLO AND PEG STANLEY
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218, USA
`peterson@stsci.edu, bethp@stsci.edu, pstanley@stsci.edu`

JERRY BONNELL
Compton Gamma-Ray Observatory Science Support Center
NASA Goddard Space Flight Center
Mail Code 661.0
Greenbelt, MD 20771, USA
`bonnell@grossc.gsfc.nasa.gov`

EVAN SMITH
Rossi X-Ray Timing Explorer Science Operations Center
NASA Goddard Space Flight Center
Mail Code 664.0
Greenbelt, MD 20771, USA
`esmith@ucephei.gsfc.nasa.gov`

NANCY REMAGE EVANS
Chandra X-Ray Observatory Center
Smithsonian Astrophysical Observatory
Mail Stop 4
Cambridge, MA 02138, USA
`evans@head-cfa.harvard.edu`

PAUL HILTON
Institute for Space and Astronautical Science
3-1-1 Yoshinodai
Sagamihara-shi
Kanagawa-ken 229-8510, Japan
`hiltonp@saic.com`

AND

BRYCE ROBERTS
Department of Physics and Astronomy
Johns Hopkins University
3400 North Charles Street
Baltimore, MD 21218-2686, USA
`broberts@pha.juh.edu`

A. Heck (ed.), Organizations and Strategies in Astronomy II, 103–120.

Abstract. Available ground and space-based astronomical observatories now cover the electromagnetic spectrum. Combining these resources, astronomers are finding powerful ways to probe the physical processes behind variable astronomical phenomena. However, the wide variety of instrumentation employed, and the resulting operating constraints, can make it challenging to coordinate observations among multiple observatories. Astronomers should be involved in the coordination process from the beginning, but this is not always sufficient. Professional observatory schedulers have learned that contacting each other directly can increase the likelihood that the astronomer's goals will be met. Schedulers are also helping with the evolution of processes and tools to facilitate coordinated observations and maximize the scientific return.

1. The variety of space telescopes

Astronomers have long coordinated observing campaigns using multiple ground-based telescopes. With the advent of telescopes in space, the range of wavelengths that can be observed has increased. Scheduling a space-based telescope, though, is more complex and mostly out of the hands of the observer. So when a team of astronomers has time on multiple space telescopes to study a time-dependent phenomenon, they face the daunting task of trying to get their observations done at the same time.

Beginning around 1995, the requests for closely coordinated space-based observations went up dramatically. Schedulers for several telescopes found that it was necessary to contact each other directly in a grass roots effort to overcome the challenges of the observations. This chapter represents the authors' experience with coordinating observations among the following space-based observatories:

These space telescopes together cover a very large swath of the electromagnetic spectrum, from the infrared to gamma-rays (Fig. 1). They also represent two decades of observing from space including the most recent decade in which observing from space became routine (Fig. 2).

2. The history of coordination with space telescopes

Coordinated observing has been occurring in astronomy for many years, especially between ground-based telescopes. During the early years of IUE, their coordinations were dominated by satellite-to-ground-based projects, since there were far fewer satellites, especially those with guest observer programs. For IUE-to-ground-based coordination, organizing the ground-based observations was left to the observer, with IUE operations personnel

TABLE 1. Space-based observatories

Observatory Name	Observatory Acronym
Advanced Satellite for Cosmology and Astrophysics	ASCA
Beppo Satellite per Astronomia X	BeppoSAX
Chandra X-ray Observatory	CXO
Compton Gamma Ray Observatory	CGRO
Extreme Ultraviolet Explorer	EUVE
Far Ultraviolet Spectroscopic Explorer	FUSE
High-Energy Transient Explorer	HETE-2
Hubble Space Telescope	HST
Infrared Space Observatory	ISO
International Ultraviolet Explorer	IUE
Roentgen Satellite	ROSAT
Rossi X-ray Timing Explorer	RXTE
Solar and Heliospheric Observatory	SOHO
X-ray Multi-Mirror Mission	XMM-Newton

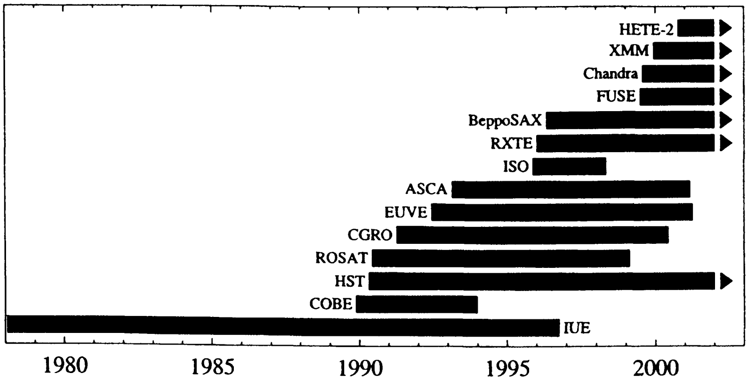


Figure 1. Energy coverage for observatories in space

committing to specific days a number of months in advance. But this was the case for most guest observers anyway since they typically travelled to one of the two IUE control centers (as one would use a ground-based telescope). So observing schedules were set in time for observers to make travel arrangements.

The earliest example of extensive coordination between space telescopes known to the authors was the ROSAT - IUE All Sky Survey (RIASS) program, conducted from August 1990 through January 1991. RIASS took advantage of the survey mode observations in the extreme ultraviolet (EUV) and soft X-ray performed early in the ROSAT mission to acquire simulta-

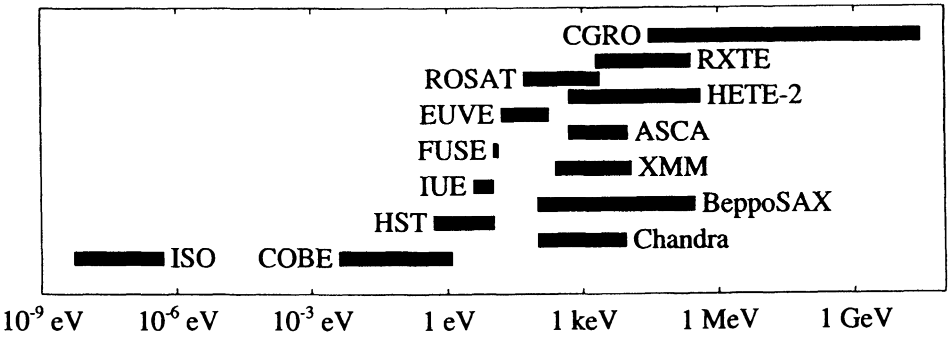


Figure 2. Time line for observatories in space

neous ultraviolet (UV) coverage for preselected sources with IUE's spectrographs. Operationally, the observing schedule for RIASS was largely driven by the ROSAT survey time-line.

The IUE satellite was maintained in an orbit which allowed continuous contact from ground stations at Goddard Space Flight Center in the US and the Villafranca satellite control station in Spain. The tremendous scheduling flexibility offered by this arrangement was used to good effect in the RIASS program. Depending on ecliptic latitude, sources were within ROSAT's relatively wide field of view for two or more days during the ROSAT survey. IUE schedulers took all of the requested targets approved for the RIASS program and attempted to schedule observations at roughly two day intervals to acquire UV spectra during a target's window of visibility in the ROSAT survey. Coordinated ground-based observations arranged by the individual astronomers were also conducted.

Ultimately 454 observations of 128 targets were made during the RIASS program. Over 20 percent of the IUE observing time during the six month period was devoted to RIASS, and the vast majority of RIASS IUE observations were made by staff astronomers (including one of the authors, JTB) as opposed to the individual astronomers who had requested the observations. The sheer variety of targets was impressive and included planets, cool stars, interacting binaries and active galactic nuclei. This broad scope is a testament to the importance of multiwavelength investigations to a wide range of astrophysical problems.

In the post-IUE era, requests for coordinated observations continue to be popular. Between 1996 and 1999, there were about 20 observations closely coordinated per year among the observatories represented by the authors.

There were also a fair number of requested coordinated observations that did not work out each year due to scheduling difficulties. The number of requests is increasing with about 50 requests for coordination in 2000. What is striking about the more recent requests is the large number of observatories involved in the campaigns. Many three, four, and even five-way coordinated observations were requested.

The growth in coordinated observing drove the observatory schedulers to work together to accomplish the science objectives. In 1995 an informal meeting was held among the schedulers for RXTE, ASCA, and HST to define a means of communicating between observatories. This was a process in which no one observatory immediately took precedence and there was no single authority for setting priorities and making decisions. The goal of achieving the science was clearly the driver and the satellite scheduling constraints defined the order of scheduling.

Since that time the schedulers have kept in routine contact: exchanging e-mail, holding meetings, writing papers, and attending conferences together. Chandra sponsored a workshop on multiwavelength campaigns at the May 1996 American Astronomical Society (AAS) High Energy Astrophysics Division meeting. A group of schedulers created a poster aimed at astronomers (with a take home brochure and web page) about the process of coordinating observations for the June 1996 AAS meeting. And the authors of this chapter created a poster paper for the March 2000 SPIE (International Society for Optical Engineering) meeting (Peterson *et al.*, 2000). The excitement of opening new horizons in space-based astronomy and the spirit of cooperation among the schedulers have been the key elements in the success of multiple observatory coordinations.

3. The challenges of very close coordination

Many observers will state in their proposal that they need their observation to be "coordinated" with another telescope. What this actually means can vary, so it is important that the observer explain this in more detail. How tightly coordinated depends on the science being done. It could indicate that the two observations need to be done in the same month or week. Other observations require the same day, same hour or complete simultaneity. Yet other observations are coordinated but sequenced, *i.e.* one satellite observation follows another with a time delay appropriate to (for instance) the different energy ranges. While space-based observatories have much in common, there are differences that make tightly coordinated observing difficult. Here is a look at those differences.

3.1. TERMINOLOGY

If observations must be scheduled within a day of each other, it helps to have the schedulers in direct contact with one other. If the observer has to pass information back and forth, a lot will be lost in the translation. However even when schedulers are in direct contact, there can still be miscommunication and frustration. Each observatory has a different vocabulary.

Historically, astronomy terms were based on observers looking through ground-based telescopes, so terms were defined based on looking up at the sky. Space-based telescope terms are often defined by the motion or action of the spacecraft. An example of this was overheard at a meeting between an astronomer and an engineer discussing onboard target acquisition algorithms. The astronomer referred to an action as "move the target into the aperture" while the engineer responded, "We can't move the target, we have to move the spacecraft". While the engineer is correct, the resulting action is what is important to the astronomer. The astronomer wants to put the target into the field of view!

Some effort has been made by observatories to make the language used to define observations appropriate for astronomers, but the engineering words seem to still show up here and there. Difficulties arise when astronomers are talking directly to schedulers and each lapses into their natural lingo. The astronomer is worried about the placement of the target in the field of view and the scheduler is worried about what the spacecraft has to do to get it there. Compounding the problem is that the space-based observatories are built upon different spacecraft platforms and are flown in different orbits, resulting in different terms for the same general physical concept. Take for instance the HST term "orientation" which in their shorthand is just "orient". The same concept is called "position angle" by FUSE, "roll-bias" by RXTE, and "roll angle" by Chandra.

While we have encouraged the observer to remain involved in the planning and scheduling of their observations, learning the different languages of the various observatories is an added burden. A common language between observatories would definitely be beneficial for multi-wavelength observers, but without a governing body directing this, it is unlikely to occur.

The difference in terminology for common concepts can cause problems for the operations staff attempting to communicate with each other to plan and schedule the observations. Understanding the constraints and restrictions for the other observatories allows the schedulers to hone in on available overlapping times more quickly and the different terminology can hamper these discussions.

3.2. OBSERVING CYCLES

Astronomers requiring coordinated observations face the task of reviewing the schedule of various "calls for proposals" and developing a proposal sequence strategy. They have to decide which observatory to propose for first, once they develop their idea. They must then propose to other observatories without knowing if they have been allocated time on the "first" observatory. Allocation committees do not award time simply because another observatory has already done so, but the question often arises during peer review about whether or not a proposer has successfully gotten time on another observatory. The statement is made that the committee does not want to award time on Observatory A unless they also have time on Observatory B. Given the timing of the calls for proposals, it is often impossible for proposers to clearly address this question.

One reason that an intended coordination falls through is that the observing team applies for time on two telescopes, but only receives time on one. Since some types of variable phenomena can only be studied with coordinated observations, it makes sense for the observatories to find a way to enable these types of programs.

Interestingly, because of the way IUE was run (part of the day commanded by NASA and part by ESA), IUE actually had this problem all by itself. Observers who needed to make a long contiguous observation had to apply independently to the separate NASA and ESA review panels. In some cases one was accepted but the other rejected and the observatory directors had to reconcile these mismatches after the review.

Once coordinated observations have been approved, the observatories have demonstrated significant flexibility in their ability to address proposals out of cycle boundaries as "targets of opportunity" or "director's discretionary" observations. These are usually reserved for specific events that could not be predicted ahead of time, so most of the coordinated observing does come in with the regular cycle. The observatories often must execute programs before or after their nominal annual cycle in order to coordinate these observations.

3.3. SCHEDULING POLICIES AND PROCEDURES

Astronomers tend to view coordination as a technical constraint problem that has a mathematical "best" solution. But in reality policies and procedures play a very large role. Each observatory has different policies and procedures for long-term planning, short-term scheduling, and placing something on the schedule at the last minute.

For instance, normal HST observations are assigned an eight-week planning window at the beginning of an annual observing cycle. The observer

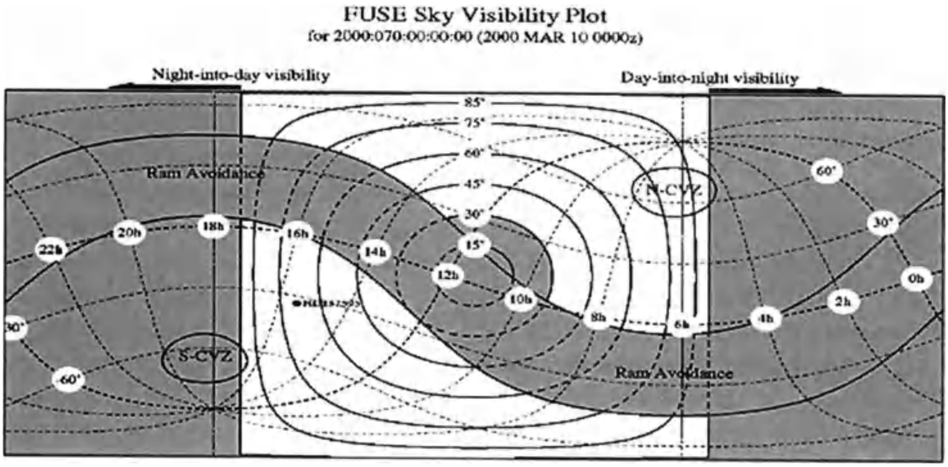


Figure 3. Graphical summary of what area of the sky FUSE can observe

is told about two weeks ahead of time that an observation has been scheduled in a particular place. Trying to add an observation only a week in advance is highly disruptive and is therefore generally limited to proposals that requested "target of opportunity" status when originally proposed. The procedures have been more flexible with observatories such as RXTE, ASCA, FUSE and EUVE. The schedulers have in many cases been able to accommodate observers who need an observation done within a day by waiting until the spot on the schedule is announced by HST, and then placing their observation on the same day. Chandra's scheduling process is similar to HST's, but planning ahead for a time that is good for both these observatories is made easier by Chandra's long uninterrupted target viewing periods.

It would be a mistake, though, to depend on the more flexible observatories to simply follow HST or Chandra's schedule. As the next two sections make abundantly clear, space-based telescopes cannot simply observe on demand. There are whole months that particular targets cannot be observed by a particular telescope, times when the data are not as good, and times that conflict with other high-priority observations. A good example is FUSE. Fig. 3 shows how little of the sky (in white) is available to FUSE on any given week. (The shaded areas are excluded because of proximity to the sun, and the prohibition against observing close to the plane of the telescope's orbit.)

Choosing a good week or day for both telescopes far in advance greatly increases the likelihood that the two observations will be able to be done as closely as desired. And once an agreement for a week or day has been reached, it is critical that any changes be communicated back to the other participating telescopes.

3.4. SPACECRAFT ORBITS

Many space-based observatories are in circular, low-inclination, low-Earth orbits with periods of about 95 minutes. Notable exceptions include IUE which was in a circular geosynchronous orbit (period of one day) and XMM-Newton and Chandra which are in highly elliptical orbits with 2 and 2.6 day periods respectively.

In order to coordinate truly simultaneous observations between two observatories in low-Earth orbit one essentially needs to compare the satellites' orbits. In low-Earth orbits, the earth blocks (occults) the target for a little less than half of each orbit. If the two satellites' positions in orbit were exactly out of phase one could schedule observations for the same three hours and get very little simultaneous data! For example, RXTE and HST have similar orbits and their target visibility periods currently go from in to out of synchronization in about four days. Clearly this makes it difficult to schedule observations that require absolutely simultaneous observations.

Another scheduling constraint that can cause greatly reduced simultaneous observing time is the "South Atlantic anomaly" (SAA). This is an area of high charged particle radiation and most telescope instruments cannot operate while passing through it. For HST, the SAA interrupts about half of the 15 target visibility periods in a day. For RXTE, it is two thirds of the orbits. Ideally both spacecraft would pass through the SAA at the same time of day and avoid the SAA together. RXTE and HST's orbits precess slowly at such similar rate that they only line up every two and a half years. (See Fig. 4 for an example of how the orbits change with respect to one another.)

It can be difficult to find a time when both target visibility and SAA passages for the telescopes are in phase. Two of the authors (EAS, KAP) previously worked at Goddard Space Flight Center doing satellite orbit determination and used their previous experience to compare the orbits more directly. This clearly is not a solution for other schedulers faced with a simultaneous observation.

Each telescope has a different suite of tools available to the observer and a more complete suite for the scheduler. Since each has been developed independently there is no way to compare the results except to highlight plots or read times out of reports. When tight coordination occurred only

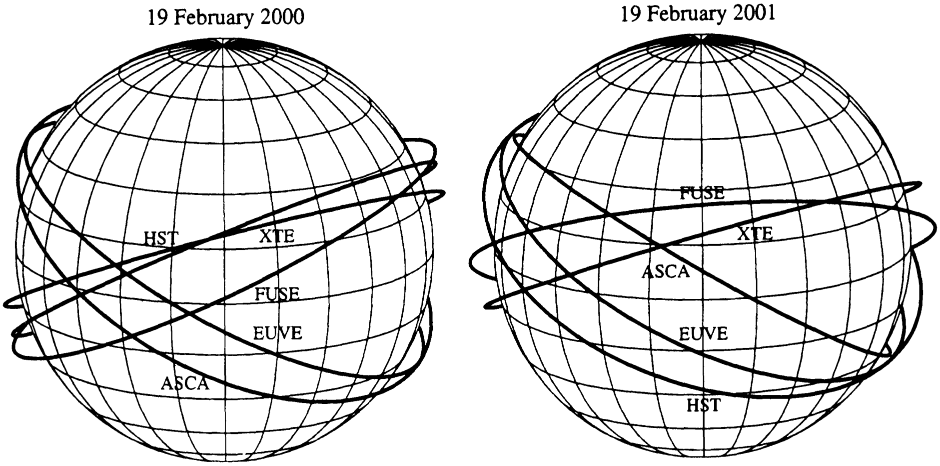


Figure 4. Comparing low-Earth orbits

several times a year this was reasonable. However, as more and more observers ask to tightly coordinate observations it is important to have tools to help with the process.

3.5. OBSERVATIONS LENGTHS

It takes a long time to collect enough light in the EUV and X-ray compared to other wavelengths. So telescopes like EUVE and Chandra tend to have much longer observations than other telescopes (as long as days rather than hours). Stopping and restarting an observation to accommodate a coordination can be inefficient for scheduling, and may also be detrimental to the interrupted observation's science goals.

3.6. UNIQUE OBSERVATORY CONSTRAINTS

All telescopes which are in low-Earth orbits have some scheduling constraints in common. In addition to earth occultation and SAA passages, each telescope has a different tolerance for how close the target can be to the Sun. There are other constraints that are unique to a particular observatory. For example, ASCA had a constraint called "cut-off rigidity" (COR) which measured the ability of the geomagnetic field to repel cosmic rays. Data could be taken when COR is high, but it was generally not usable. This affected up to 10 orbits per day.

3.7. PERIODIC NATURE OF THE TARGETS

In addition to attempting to satisfy the scheduling constraints of two orbiting telescopes, a further complication can be the periodic nature of the target itself. For example, targets which vary periodically or have definite orbital phases, like cataclysmic variables (CVs), may require a further constraint of the observation to a specific phase of the system. Particularly difficult are those targets which must be repeatedly observed at a particular phase to obtain sufficient data. This was the case with some CVs observed in the RIASS campaign. IUE had to do repeated short (several minute) exposures of the same target at a particular phase of the system. And this had to be done when ROSAT had returned to observing that area of the sky.

3.8. FAST RESPONSE TIMES

A different type of coordination between observatories is necessary when the goal is to react quickly to a discovery made by another observatory. The study of gamma-ray bursts (GRBs) requires this type of coordination. As noted above in the section on policies and procedures, it can be difficult for traditional space observatories to react quickly to a request for immediate response. But the scientific benefit of studying the afterglow of GRBs is so great that it pushes observatories to reduce their response time.

For example, CGRO could detect GRBs, but with large positional uncertainties. In 1997 RXTE developed a procedure for scanning an area CGRO identified to accurately locate the associated X-ray afterglow. The RXTE response time was only about seven hours, but to detect afterglows, this had to be shortened to two hours or less. This required bypassing the normal scheduling software, and directly editing the final delivered scheduling files. Although RXTE GRB chases were a long-shot, in more than 20 attempts, there were only a couple of successes.

4. The rewards of coordination: Case studies

While the observers in these case studies have generally had positive experiences, it should be noted that there are also astronomers who have not gotten what they intended because of poor communication or bad luck with scheduling constraints. While reading these remarks, note the comments about the high level of effort required to make these observations happen.

4.1. INTERACTING BINARY SYSTEMS

Multi-wavelength observations are absolutely indispensable to Dr. Carole Haswell and her science team (Haswell 2000, personal communication). The interacting binary star systems they study have several components, each predominantly emitting in different parts of the electromagnetic spectrum. In order to derive a realistic picture of their complex behavior, and the interdependence of the various components, they needed to observe across as wide a range of wavelengths as possible. And since these systems exhibit variability on all observable time-scales it is essential that this multi-wavelength coverage be simultaneous, or as close to simultaneous as possible (Hynes *et al.*, 1998b).

According to Dr. Haswell, "The multi-wavelength target of opportunity campaigns we execute on outbursting soft X-ray transients are the ultimate in inconvenience: we need to quickly take observations of a variable target of unknown spectrum without prior knowledge of the position. Despite the obvious difficulties this causes, we have been extremely lucky in obtaining good simultaneous coverage with the HST and RXTE satellites [see the first figure in Hynes *et al.*, 1998a], due to the laudable efforts of the scheduling and support staff of both satellites. Our 1999 campaign on J1859+226 benefited from similar heroic efforts at the many ground-based facilities which contributed."

Dr. Haswell's science obviously stretches the planning and scheduling capabilities of the observatories due to its target of opportunity nature and she offers that "The success of our program has largely been due to the diligence, helpfulness, and cooperation of the staff involved." She also reports that it is often tricky to get ground-based supporting simultaneous data. In practice, they have to wait until the space-based observatories are scheduled, then try to arrange appropriate ground coverage. Often there is no suitable telescope available at the appropriate longitude. She anticipates that robotic or queue-scheduled ground-based telescopes such as Hobby Eberly and the Liverpool Robotic Telescope should make their task easier.

4.2. ACTIVE GALACTIC NUCLEI

Dr. Greg Madjeski's main field of research is active galactic nuclei, objects that are variable on relatively short time scales. His science relies upon the availability of simultaneous observations (Madjeski 2000, personal communication). Dr. Madjeski states that this "was usually possible thanks to the satellite schedulers, and in most cases, quite successful." One example provided by Dr. Madjeski is that they were able to measure, for the first time, the broad band X-ray through gamma-ray spectrum of the bright Seyfert 1 Galaxy IC 4329a, measuring the extent of the spectrum. This allowed an accurate determination of the broad band continuum, and led to the inferences that thermal comptonization models provide the best description of the processes responsible for the observed data. Dr. Madjeski adds that for his research, "the next major advances can only happen via simultaneous monitoring of these objects with multiple satellites, to establish the relationship of the time series observed in all bands. This has promise of determining the location of the matter responsible for various parts of their spectra."

4.3. CATACLYSMIC VARIABLES

In many astronomical research fields, multi-wavelength observations are powerful but they need not be closely coordinated. In Dr. Koji Mukai's field (CVs) it is the simultaneous multi-wavelength observations that have the real power (Mukai 2000, personal communication). For example, UV emission lines in CVs are created because there is X-ray photoionized plasma. Therefore, a quantitative understanding of the UV lines cannot be obtained without X-ray observations. Since CVs are variable on all time scales, the observing has to be simultaneous to be truly useful. Dr. Mukai reports that "Once you have the basic understanding of the UV line emission region, then simultaneous X-ray/UV data can be used to map the emission regions."

Dr. Mukai was "very impressed with the coordination among the mission schedulers." For both of his major campaigns, "we gave the parameters to the schedulers and they did the rest. I'm particularly impressed that the HST/ASCA campaign on OY Car could be carried out. ASCA was approaching the end of the mission, and was scheduled to enter a reduced mode of operation in mid February 2000; HST was just coming back for general use after a servicing mission. Yet the simultaneous observations were carried out in late January, in what turned out to be a very narrow window."

4.4. GAMMA-RAY BURSTS

GRBs represent one of the most extreme astrophysical sources observed. Their apparently random and transient nature poses some of the most severe problems for simultaneous multiwavelength coverage. Still the scientific rewards have been huge and the determination of the distance scale to the bursters is perhaps the most dramatic example of a breakthrough in modern astrophysics that has been made by a multiwavelength campaign. Starting in 1997, nearly thirty years after the discovery of these high-energy transients, space-based detections of GRBs and and their afterglows at gamma-ray and X-ray energies by BeppoSAX were successfully combined with observations of optical counterparts to the burst sources, at long last leading to the identification of GRB host galaxies and redshift determinations (Galama *et al.*, 1997, Metzger *et al.*, 1997). Large collaborations now exist to follow the bursters fading afterglows across the electromagnetic spectrum. These coordinate prime space and ground-based facilities such as HST, Chandra, Keck (a ground-based optical observatory), and the Very Large Array (a ground-based radio observatory), in part utilizing target of opportunity style observing programs.

While well over 2,000 GRBs have been detected, to date truly simultaneous observations of the burst emission at optical and gamma-ray energies have been achieved for only one burst (Ackerlof *et al.*, 1999). The observation was accomplished by the automated GRB Coordinates Network (GCN) established by Scott Barthelmy in 1997 (Barthelmy *et al.*, 1998) which rapidly transmitted coordinates derived from CGRO observations to the Robotic Optical Transient Search Experiment (ROTSE) capable of imaging the GRB field within seconds, while the event was still in progress at gamma-ray energies.

5. The future of coordinated observing

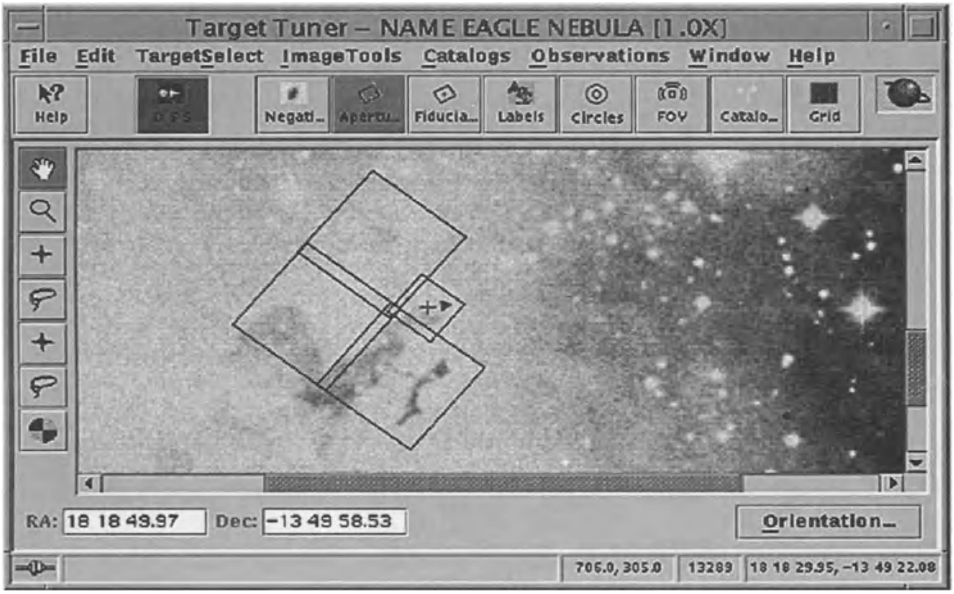
The observatory community has learned a lot over the years about scheduling coordinated observations. Some of the challenges that have been discussed in this chapter are being addressed in a variety of creative ways.

5.1. MORE ASTRONOMER-ORIENTED LANGUAGE AND TOOLS

As was discussed in Sect. 4.1, terminology can be an impediment to the observers communicating their needs to the observatories. In addition to trying to provide observers with a language that is closer to their own, another approach is to present a picture to the astronomers to ensure that their observing requirements and constraints are being met. Fig. 5 shows a tool graphically representing an HST camera's field of view positioned on the Eagle Nebula. This type of tool allows the astronomer to place the field of view of an instrument on the target and manipulate the position and orientation until the desired placement is obtained. There is less need to be familiar with the terminology of HST. Tools of this type will help overcome some of the difficulties faced by observers learning the languages of different telescopes (Jones *et al.*, 2000a).

5.2. MULTIPLE OBSERVATORY TAC ALLOCATIONS

As was discussed in Sect. 4.2, it can be a difficult process for an observing team to request and get time on multiple observatories. In an effort to



RA: 18 18 49.97 Dec: -13 49 58.53

706.0, 305.0 13289 18 18 29.95, -13 49 22.08

Figure 5. Example of a graphical planning aid (the Visual Target Tuner)

overcome this problem a new cooperative program allows HST and Chandra to award time in packages (Blacker *et al.*, 2000). Proposals of a multi-wavelength nature clearly requiring both HST and Chandra data can be submitted to either the HST or Chandra proposal review panel. Now the committee making the selection has the full scientific information on which to base its decision. Each review panel can allocate about one week of observing time for the other observatory. This exchange is now in its second year, and is working well.

When the infrared satellite SIRTF is launched, the plan is to include it in the joint award program. In addition, since the ESA satellite XMM-Newton is an X-ray facility like Chandra, but with different capabilities, active consideration is being given to how these two facilities can be used in a coordinated fashion.

5.3. MULTIPLE OBSERVATORY SCHEDULING TOOLS

As was discussed in Sect. 4.4, without the proper tools, it can be very difficult to find times to plan a closely coordinated campaign between several observatories. Furthermore, what may be difficult for mission schedulers is impossible for the astronomical community at large, which does not have access to the specialized tools available to the planning community. As a result, astronomers do not have the ability to experiment with and optimize coordination strategies without requiring the assistance of the observatory schedulers.

A prototyping effort at Goddard Space Flight Center (Jones *et al.*, 2000b) seeks to address these difficulties by developing a multi-mission visualization tool for both schedulers and observers alike. The Visual Observation Layout Tool (VOLT) project's stated goal is to produce advanced visualization software which is powerful enough to graphically represent the interaction between scheduling constraints of many different telescopes, while being flexible enough to allow the addition of new observatories without extensive modification. Though VOLT designers worked with HST, Chandra, and FUSE schedulers during the initial design, the project aims to add other space-based observatories, as well as ground-based telescopes.

Beyond just being a graphical tool for analyzing the overlap of scheduling opportunities for a single observation across multiple telescopes, VOLT allows a user to define observation sequences. Relative constraints can be laid down between members of each sequence, and VOLT will attempt to generate a recommendation for observation times which will satisfy all the user supplied constraints.

Fig. 6 shows an example screen of VOLT analyzing a coordinated observation scenario between Chandra, FUSE and HST. Each black and white line represents a time line; black represents "good" times to schedule the observation while white represents "bad" times to schedule. The first, second and last lines depict the overall schedulability of the observations for each of the three telescopes. The third to sixth lines depict the individual constraints (both telescope driven and user supplied) for FUSE, which when added together make the overall schedulability for the FUSE observation.

While the generation of complete long-range plans and short-term schedules still requires a high degree of observatory-specific control and expertise, the VOLT prototype has abstracted the information essential to simultaneous observations into a publicly available tool, and has excellent promise to simplify the design of coordinated observing campaigns.

5.4. NEW TYPES OF SPACE OBSERVATORIES

The results of coordinated observations have been so compelling that new classes of space observatories have been created to facilitate the process for certain types of science.

Though GRB observational programs are challenging, the tremendous physical insight into the nature of the bursters provided by the still sparse multiwavelength studies has inspired new space-based observatories dedi-

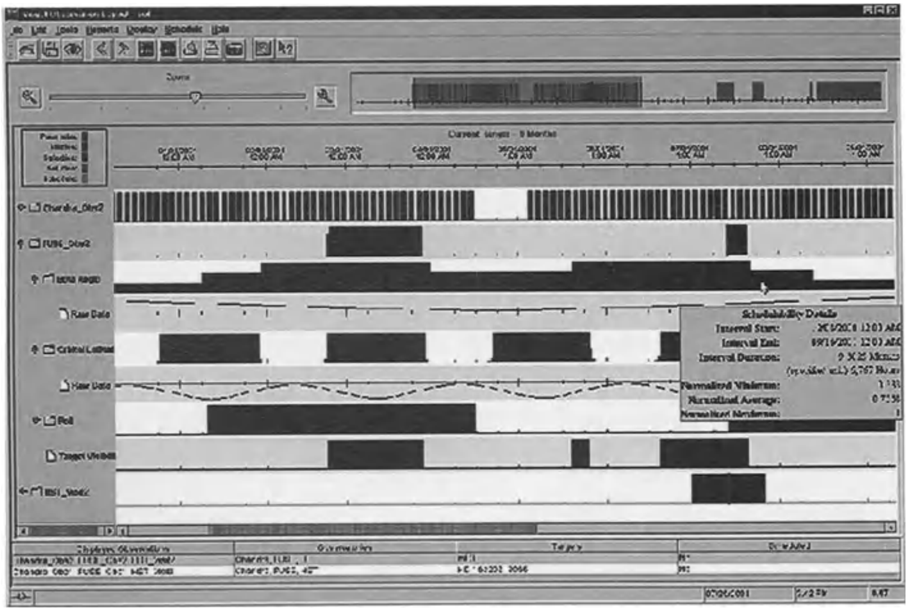


Figure 6. Example screen from the Visual Observation Layout Tool

cated to panchromatic observations. Some examples include XMM-Newton which has both UV/optical and X-ray detectors, and Swift a yet-to-be-launched observatory which will detect GRBs and then quickly train X-ray and optical telescopes on board in the correct direction, along with a proliferation of automated rapid reaction ground-based telescopes suitable for transient studies.

There is also a class of satellite that has grown up in response to the need for another kind of coordinated observations. The need for a long and continuous series of photometric observations to measure the frequency spectrum of flux variations of stars has resulted in carefully organized campaigns involving telescopes spaced in longitude, named the Whole Earth Telescope (WET). But satellites can obtain much longer strings of observations than ground-based observatories. Three satellites with this purpose (COROT, MONS, and MOST) will be launched soon.

5.5. CONTINUED COOPERATION OF SCHEDULERS AND OBSERVERS

Telescope time exchange programs, panchromatic observatories, and new tools will help. But there will continue to be many small and unique telescopes and inventive astronomers will make interesting proposals to use them in new combinations. Support of deep space probes such as Galileo or IUE participation in campaigns of Halley's comet or SN1987a, and HST observations of comet Shoemaker-Levy's impact on Jupiter are examples of types of events that will continue to produce novel multiple observatory campaigns. Schedulers and astronomers involved in coordinated observing must continue to cooperate and communicate with each other closely to make multiple observatory campaigns a success.

References

1. Akerlof, C., Balsano, R., Barthelemy, S., Bloch, J., Butterworth, P., Casperson, D., Cline, T., Fletcher, S., Frontera, F., Gisler, G., Heise, J., Hills, J., Kehoe, R., Lee, B., Marshall, S., McKay, T., Miller, R., Piro, L., Priedhorsky, W., Szymanski, J. & Wren, J. 1999, Observation of contemporaneous optical radiation from a gamma-ray burst, *Nature*, **398**, pp. 400-402.
2. Barthelmy, S., Butterworth, P., Cline, T., Gehrels, N., Marshall, F., Takeshima, T., Connaughton, V., Kippen, R., Kouveliotou, C. & Robinson, C. 1998, The GRB Coordinates Network (GCN): A Status Report, *American Institute of Physics Conference Proceedings*, **428**, p. 99.
3. Blacker, B., Macchetto, D., Urry, C. & Wilkes, B. 2000, Multi-wavelength Time Allocation, the Wave of the Future, *Proceedings of SPIE*, **4010**, pp. 118-126.
4. Galama, T., Groot, P., Vanparadijs, J., Kouveliotou, C., Robinson, C., Fishman, G., Meegan, C., Sahu, K., Livio, M., Petro, L., Macchetto, F., Heise, J., in 't Zand, J., Strom, R., Telting, J., Rutten, R., Pettini, M., Tanvir, N. & Bloom, J. 1997, The Decay of Optical Emission from the gamma-Ray Burst GRB970228, *Letters to Nature*, **387**, p. 479.
5. Hynes, R., O'Brien, K., Horne, K., Chen, W. & Haswell, C. 1998a, Echoes from an irradiated disc in GRO J1655-40, *Monthly Notices of the Royal Astronomical Society*, **299**, pp. L37-L41.
6. Hynes, R., Haswell, C., Shrader, C., Chen, W., Horne, K., Harlaftis, E., O'Brien, K., Hellier, C. & Fender, R. 1998b, The 1996 outburst of GRO J1655-40: the challenge of interpreting the multiwavelength spectra, *Monthly Notices of the Royal Astronomical Society*, **300**, pp. 64-82.
7. Jones, J., Burkhardt C., Fishman, M., Grosvenor, S., Koratkar, A., Ruley, L. & Wolf, K. 2000a, Lessons Learned from the Scientist's Expert Assistant Project, *Proceedings of SPIE*, **4010**, pp. 107-117.
8. Jones, J., Fishman, M., Grella, V., Kerbel, U., Maks, L., Misra, D. & Pell, V. 2000b, Tools for Coordinated Planning Between Observatories, *Astronomical Society of the Pacific Conference Series*, in press.
9. Metzger, M., Djorgovski, S., Kulkarni, S., Steidel, C., Adelberger, K., Frail, D., Costa, E. & Frontera, F. 1997, Spectral constraints on the redshift of the optical counterpart to the gamma-ray burst of 8 May 1997, *Nature*, **387**, pp. 878-800.
10. Peterson, K., Eckert, M., Evans, N., Hilton, P., Perriello, B., Roberts, B., Smith E. & Stanley, P. 2000, Coordinating multi-wavelength campaigns between observatories, *Proceedings of SPIE*, 4010, pp. 279-286.

NEW STRATEGIES IN GROUND-BASED OBSERVING

IAN ROBSON
Joint Astronomy Centre
660 N. A'ohoku Place
Hilo HI 96720, USA
`i.robson@jach.hawaii.edu`

Abstract. As ground-based observatories fight to ensure maximum efficiency in terms of scientific delivery, the actual mode of observing has been thrown into sharp relief. Historically, optical, infrared and submillimetre astronomers travelled to the telescope to take up their allotted nights, booked well in advance, and in so doing took their chances that the weather would co-operate. The obvious drawback is that there is no guarantee that the most scientifically ranked programmes will be completed. New observing modes addressing how to overcome the uncertainty of the weather have been investigated over the past five years. These, along with other modes where observing is difficult (high-altitude sites) are now being implemented on the world's major facilities.

1. Introduction

Observing modes for ground-based telescopes have become a hot topic over the past decade, as telescopes become more expensive and funding agencies demand higher levels of scientific return and overall efficiency. Indeed, an entire conference was devoted to "New observing modes for the next century" (Boroson *et al.* 1996). This review describes the great progress that has been made over the past few years in making ground-based observing more efficient, delivering more and better science in the process.

This resulted from a serious rethink of the observing modes and the move away from the so-called classical mode, to a more flexible mode in which the best science programmes are guaranteed to be completed. This all sounds very laudable, but it does not come free. It carries a price, either to the telescope facility, the visiting scientists or both. Furthermore, and

A. Heck (ed.), Organizations and Strategies in Astronomy II, 121–137.

perhaps most importantly, it requires a culture change on behalf of the astronomers themselves.

The topic of observing modes and operational efficiency and scientific output is especially important for those wavelengths where the atmosphere plays a major part in the collected data quality, and so is very pertinent to the optical-infrared-submillimetre regimes of ground-based astronomy. Radio astronomy is largely insulated from the problems and pressures and will not be discussed further.

One of the difficulties of this topic is that although significant work has been undertaken, much of it is buried in internal reports or obscure publications. I have attempted to give a broad overview and to point the interested reader to a small number of publications (*e.g.* Quinn 1998) from which detailed work can be obtained. To begin this review I will first describe the traditional mode of observing and then take some time to describe the atmospheric effects that cause this mode to be inefficient. I will then proceed to cover the topic of new modes of observing, describing their nature, their advantages, possible disadvantages and the difficulties of policy implementation.

2. The classical observing mode

The traditional mode of observing for ground-based astronomers in the optical-infrared disciplines is to travel to the telescope on scheduled dates to undertake their allocated observing programme. Unfortunately, the best-laid plans are often thwarted due to the vagaries of the Earth's atmosphere, the weather. This sometimes results in the scientifically highest-ranked programmes failing to be completed due to adverse conditions, resulting in a major loss of science benefit to the scientists, the telescope and the funding agencies.

The great advantage of the classical mode is that everything is simple. The telescope schedule for the coming six months can be constructed and set in a tablet of stone. While there is always horse-trading between the telescope scheduler and the observers regarding suitable dates, once the schedule is fixed, the facility just has to ensure that the required instruments are available on the required nights and the systems function as they should. The visiting astronomers can plan their observing schedule with their other responsibilities, book their airline tickets, and travel to the telescope for their fixed allocation of nights. Easy all round.

However, as we shall see, unless the conditions are suitable for their programme, then their entire visit can be wasted. This is far more serious than just the waste of time. Astronomy is a highly competitive discipline and for the observer, telescope data are lifelines for research publication and future funding. Positions and promotions are also intimately linked with the ability to obtain the best data and make the best use of it. Therefore, classical observing becomes a lottery, whereby one takes ones chance with the weather. In the most galling situation, two back-to-back observing runs, one with the highest-ranked proposal for the semester is weathered out, only to see the adjacent lowest-ranked proposal obtain spectacular weather. Clearly this cannot be right.

Astronomers have recognised this for many years, but have often been very reluctant to take the obvious step of moving away from the classical mode to something else. Why is this? Because there are always winners and losers. While the classical mode is a lottery, everyone gets an equal chance of the weather. With a mode that looks to guarantee that the best programmes are completed, then to make headway for the extra time that this will surely take, the losers will be those in the lowest quartile of those applications that in the classical mode would have been awarded time. Now they would not even get to take their chance with the weather and so their ability to obtain data is severely restricted. This is the much sharper focus of the survival of the fittest nature of non-classical scheduling modes.

In this review, the words observing and scheduling will be used somewhat interchangeably. The key to scientific efficiency is to how the programmes are scheduled. How they are observed is a separate matter, as we shall discover. Although flexible observing is a frequently used term, the key is the scheduling. The observing is merely the implementation of an agreed philosophy. Without flexible scheduling there cannot be flexible observing, hence the description of classical observing above relies on the scheduling of fixed blocks of time on set dates to an astronomer in advance of the semester and these dates are not changed.

The situation for space telescopes is interesting. In general, there is no, or little, weather in space, and although the schedule is often fixed (hard-wired in the jargon) for a number of months ahead, this is not allocated to the astronomer on a number of nights basis. Rather, individual observations from all the awarded programmes are slotted together to give the most efficient operation of the telescope. This has to take account of instrument configuration, targets, exposure time, telescope slew times and Sun-Moon-Earth angle for example. Therefore, although the schedule is fixed and rarely disturbed (only for special targets of opportunity), this is actually a good example of a queue-scheduled system, but the queue is based on operating efficiency rather than a weather-match efficiency. A further simplifying factor is that the astronomers do not generally have to travel to the centre to observe in real time, the data are eventually electronically fed back to them for further processing.

3. The effects of the atmosphere

Before launching into observing modes it is instructive to see how the Earth's atmosphere affects ground-based astronomy. The Earth's atmosphere may be a life-saving protection blanket for the human race, shielding us from harmful solar radiation, but it is a serious impediment to astronomy. Indeed, for some wavelengths, especially those where the atmosphere is so protecting, such as the X-ray and ultraviolet, astronomy can only be undertaken from space-based observatories. The situation is the same for the far-infrared and although gamma-ray astronomy can be undertaken from the ground, this is the detection of secondary effects of the astronomical gamma-rays on the atmosphere, rather than the gamma-rays themselves.

The absorbing limitation noted above means that ground-based astronomy is restricted to the optical to mid-infrared and submillimetre to radio regions. Optical (wavelengths from 0.3 micron – one thousandth of a millimetre – to 0.7 micron) can be undertaken from sea-level sites, while infrared (1 to 30 microns) and submillimetre (wavelengths between 0.3 mm to around 1 mm) can be undertaken at certain wavelengths from very high mountain tops. There are seven infrared and four submillimetre transmission 'windows'. The region from 30 to 300 microns (0.3mm) is only accessible from airborne or spaceborne platforms. Radio, from $\sim$1 cm longward can be undertaken from sea level.

Although telescopes can be flown in space, their collecting apertures are small in comparison to their ground-based counterparts; they are extremely expensive and have much shorter lifetimes. Nevertheless, they have advantages in escaping the atmosphere's limitations as we shall see.

An absorbing body also emits; hence the Earth's atmosphere is a source of emission with an effective temperature of around 20°C. A blackbody of this temperature has peak emission at around 10 microns (0.01mm), and so for wavelengths from $\sim$2.5 microns to 1 mm, the atmosphere represents a tremendous source of emission, as do the telescope optics of course. Therefore, even in the transmission 'windows' the atmosphere still radiates strongly, emitting enormously more energy than the sources astronomers are trying to detect. The Earth's atmosphere is therefore the limiting factor on ultimate sensitivity in these wavelengths.

Even in the near-infrared (1-2.5 microns), while thermal emission is negligible, the atmosphere is not completely transparent. High-altitude lines of OH emission blend together to create a pseudo-continuum background, which is absent from space. This can be overcome from the ground when undertaking spectroscopy because high-resolution spectrometers can look between or even blank out the OH lines. Indeed, this technique is used for spectroscopy for all large ground-based infrared telescopes.

Atmospheric thermal emission also causes another problem for the mid-infrared through submillimetre, that of skynoise. This is caused by blobs of atmosphere of differing density moving through the beam of the telescope. This causes variations in the atmospheric background that is much harder to remove than a perfectly stable and radiating atmosphere. Techniques are available to remove most of this by oscillating the secondary mirror of the telescope, known as 'chopping', but ultimately this can be a limiting factor for sensitivity at these wavelengths.

A crudely similar phenomenon is apparent in the optical and near-infrared and this is called atmospheric 'seeing'. Although this is due to density variations, this does not cause emission noise but a refraction difference as light rays are bent by different amounts. This is apparent as the twinkling of stars that we see with our eyes. Atmospheric seeing puts a natural limit on the spatial resolution of telescopes of around 0.5 arcseconds at the ground-based best sites. (The diameter of the Sun and Moon is 30 arcminutes and there are 60 arcseconds in an arcminute). However, a telescope of diameter of only 0.05 m can achieve this spatial resolution. So while the 8- and 10-m telescopes of today can, in theory, resolve features as small as 0.01 arcseconds, much of the power of these giant telescopes seems wasted as far as spatial resolution is concerned.

Indeed, this is one of the prime reasons why the very much smaller Hubble Space Telescope does so well – it is in space, which has no seeing. Therefore, its spatial resolution of 0.05 arcseconds is limited by the size of the mirror (2.2m) alone. The HST is truly diffraction limited. However, new techniques for ground-based telescopes, called active and adaptive optics can overcome the seeing, enabling these large telescopes to be almost diffraction limited in the optical and fully diffraction limited in the near-infrared. Spatial resolutions of 0.05 arcseconds can now be achieved, equalling Hubble and going much fainter, but only when looking at certain bright objects or where there is a bright object in the field of view.

I have gone to the length of pointing out the problems of the atmosphere because this lies at the heart of observing strategies for ground-based strategies. The atmosphere is unpredictable, and often limits the observations being undertaken. We cannot control the atmosphere, and so unless we fly telescopes in space, to maximise efficiency, we must control the observing mode, specifically we must match the scientific programme to the prevailing conditions at the time.

4. The telescope locations

Given the above, in considering where to place an expensive telescope, one looks for a very stable atmosphere (to minimise seeing), to be very distant from cities (to make the sky dark), and for the atmosphere to be very dry (to improve the transmission for infrared and submillimetre). Also, for financial reasons, one would prefer a site that is already well developed rather than having to construct the infrastructure from scratch. All of this suggests high and isolated mountain peaks are the preferred option, and indeed, the current best site in the world is that of Mauna Kea, a 14,000ft volcanic summit on the Island of Hawaii in the mid-Pacific. This is the location of most of the world's foremost optical, infrared and submillimetre telescopes, the largest in their fields. In the optical and infrared we have the two Keck telescopes with 10-m diameter segmented mirrors, plus Gemini North and Subaru with 8-m diameter mirrors, while in the submillimetre there is the James Clerk Maxwell Telescope with a 15-m dish.

Hawaii is very distant from anywhere, therefore, travel to and from the observatory location becomes a non-trivial factor, both in time and cost. The journey to the telescope from the US West Coast takes at least a day, *i.e.* at least 12 hours, while from Europe one is talking about two days of travelling. An obvious alternative is to have astronomers located at the telescope undertake the observations on behalf of the distant astronomers, a technique known as service observing. We will return to this later.

5. The Observing process

The observing process is the crux of the matter, and within it lies the relationship of the astronomer to his or her data. Over most of the last century, astronomers were trained by visiting the telescope to learn how observations are made. The training included understanding the scientific decisions to be taken regarding progress of the programme, appreciation of the prevailing conditions such as seeing, modifying the programme accordingly and deciding when to curtail an observation and move on to the next target. This was all highly valuable training, and was the 'real thing'.

Seeing a massive telescope do just what you want it to do was a memorable experience, and a valuable aspect of the training medium. On the other hand, astronomers were rarely actually allowed to drive the most important telescopes, this was in the hands of specialists, often called telescope operators. Indeed, as the telescopes and instruments became more sophisticated, software control of instruments and a telescope specialist became the norm. The astronomer's role was solely to command the sequence of observations, undertake the on-line analysis to determine the scientific progress, and make decisions accordingly. All of which had to be tempered by monitoring of the atmospheric conditions pertaining.

Over the years astronomers have jealously guarded their right to undertake their own programmes. This was for a variety of reasons. The idea of relying on someone else to take your observations and do it correctly is somewhat alien for cut-throat researchers. Furthermore, the opportunity to get away from the tedium of normal work and the ever-ringing telephone is also a bonus (now removed with global e-mail of course). Additionally, having the opportunity to spend time in a sunny climate such as Hawaii in the depths of a Northern Hemisphere winter is not unappealing. But another aspect that is not so tangible is the sheer excitement of being at the telescope, driving ones' own programme and seeing your data come in on the computer. This is a powerful stimulant, almost like an addiction. The fact that a significant effort has been expounded in the travel just to be at the telescope serves to heighten this anticipation.

Nevertheless, this was far from satisfactory. In this classical mode, obtaining excellent data is very much a 'pot-luck' situation in that telescope time is usually allocated in blocks of 2-5 nights, and during that time the weather could do anything. So being stuck atop a 14,000ft mountain with poor weather and zero data definitely offsets the bonus points of the visit. Of course allocation committees anticipate this might happen and often require a 'backup' programme to be undertaken if the weather does not co-operate for the primary programme. For many astronomers this 'backup' programme was never taken very seriously, and data obtained were often stuck away in a drawer never to see the light of day.

This of course was a total waste of telescope time, because there may well have been a number of scientifically important primary programmes that could have been done in these conditions, but were not. So the obvious solution (in theory) was to have the visiting astronomer undertake these alternate observations rather than their own backup programme. However, without some incentive this was never going to be popular. Who wants to travel halfway around the world to undertake observations for someone else? It might be acceptable if they were colleagues or friends, but what if they were key competitors, or worse. Furthermore, for those whose programmes were going to be undertaken by someone else, we are back to the problem of 'service observing', and in this case potentially even worse suspicion. At least when a staff astronomer undertakes the observations there should be a very good chance will be done correctly, because in the end the support astronomers job depends on the ability to carry them out professionally.

The alternative to classical observing is to have some form of flexible scheduling and observing strategies that match programmes to the weather in some form of ranked queue.

6. Flexible scheduling and observing

6.1. SERVICE OBSERVING

Flexible scheduling aims to match the science programmes to the conditions pertaining at the telescope at the time. The simplest way to do this is to staff the telescope with support astronomers and to undertake the entire observations in 'service' mode. Programmes are broken down into smaller elements rather than tackled piecemeal. Each element can then be matched to the weather at the time. This is the typical model for space telescopes with the support staff at the ground control centre.

The key to service observing for ground-based telescopes is that the entire scientific programme has to be written down in some form of words or algorithm that can be easily interpreted at the telescope and executed as if the astronomer were present. For simple programmes this is rather easy. Crudely speaking it could be to go measure a bunch of objects and for each object either spend x amount of time integrating, or, for any object that was very bright to curtail the observations and move on. Alternatively, if the objects turn out to be fainter than expected, the astronomer might require longer exposures but for fewer objects in the sample within the total allocation of time. This is where the scientific decision making comes into play. If suitable words can be produced that are not too complex to follow, then a serviced programme should, in theory, be as well carried out by the service astronomer as the primary astronomer. A good example of this can be found by Maoli *et al.* (2000).

On the other hand, when the programmes are more speculative, such as "go map this region and then let me figure out what I want to do next because I am looking for certain types of phenomenon and I need to decide what to do after seeing the picture", this is more difficult in real-time without interaction with the primary astronomer. With rapid data analysis software and good communication links, this is quite possible, and is an example of "remote eavesdropping" (see below).

However, when this is impractical, the solution in very simple. The map is only the first stage of the observation programme. The map is taken first and it is then shipped back to the astronomer, who subsequently submits a second set of observational requirements based on the results. For complex programmes this becomes an iterative solution. The problem here lies in the requirement to track the status of the programme: how much time has been allocated, how much has been done, how much remains, what has been achieved. This is very expensive in staff effort and requires software to produce an automatic accounting system. It should be noted that in considering this example we have already slipped into some form of flexible mode of observing and an undefined queue.

Another little wrinkle to the above is that for all the observations the service astronomer would also be expected to do the necessary calibration. When there are a number of programmes during a night the question of who owns the calibration is readily solved by the policy that all calibration and instrument set-up observations are the property of the observatory and available to everyone. How the time spent on each is included in individual programme is a little more complex but solvable. At the end of each night the data sets are separated, packaged up and e-mailed off to the respective astronomers.

6.2. REMOTE EAVESDROPPING AND REMOTE OBSERVING

The problem of complex programmes can be countered to some extent by allowing "remote eavesdropping". In this mode, the astronomer can be located at some remote site (anywhere in the world with Internet access) and can watch the data being taken and can undertake the analysis and make decisions in almost real-time. This works well, especially when the telescope is offset from the remote astronomer by 10-12 hours. Night-time observing is normal daytime for the absent astronomer, who can remote eavesdrop and advise on the programme as if they were present.

As long as the networks are reliable and the bandwidth is adequate, this works fine. To guarantee this however, really requires leased lines of high bandwidth rather than relying solely on the Internet. This in turn usually means having a single central data centre located remotely from the telescope.

We can go one stage further by having entirely remote observing. This is an extension of remote eavesdropping, but in this case the telescope and the instrumentation (and hence the observations) are controlled remotely. While the telescope could be totally unstaffed, there may be a telescope operator present to ensure safety or to take over if the communication link goes down or something breaks. Remote observing requires a much higher level of facility reliability, software integrity and guaranteed bandwidths, for the obvious reasons that there may be no expert support at the telescope if anything goes wrong. Therefore, everything really has to work to maintain the efficiency that remote observing is meant to bring.

One of the first experiments in remote operation and observing was pioneered in the early 1980's by the United Kingdom Infrared Telescope on Mauna Kea, being remotely operated from a control centre at the Royal Observatory Edinburgh in Scotland (Longair *et al.* 1986). However, although this worked, it was expensive because of the unreliability of the Internet and the consequent need to hire dedicated communication links. On the other hand, a halfway measure was to abandon the remote operation and to have most of the observing team in Edinburgh and a telescope operator and a team member at the telescope in Hawaii. This produced some interesting experimental results pertaining to the sociological problems of remote eavesdropping. I remember the huge degree of frustration felt in Edinburgh at seemingly stupid decisions being made at 14,000ft, but because the electronic communications were so poor one had to resort to the telephone to stop an observation being queued up. I should point out that I took my turn at being at the telescope and this also came with its own stress factor. All of which showed that if the absent observer was to be 'in-charge' of the observations, fast and reliable communications and continuous voice contact were essential. This trial mode was soon abandoned.

There has been notable progress since these early days. The European Southern Observatory, which operates a number of telescopes in Chile, including the four, 8m Very Large Telescope (VLT), is one of the leading exponents of remote eavesdropping, remote observing and flexible scheduling. A remote observing centre has been developed in Garching in Germany. ESO has dedicated satellite links to ensure communication integrity and has expended a huge amount of effort on the software needed to make this system operate efficiently (see *e.g.* Quinn 1998). The 3.5m NTT telescope pioneered much of this work and a visit to the web-site[1], particularly the section under "observing", provides an excellent description of the modern method of performing observations including observing templates and scheduling tools. The NTT has a long track record of successful work in this field.

So, is remote eavesdropping and/or remote observing the perfect solution? As usual there are pros and cons. If the travel to the remote control centre is trivial it looks appealing. However, once the travel time becomes comparable to visiting the telescope, the attraction and benefit would appear to diminish. But, there is an excellent example of when the travel to the remote centre is extensive and almost equivalent to travel to the telescope itself, remote observing has taken off and been both tremendously popular and a huge success. This is for the W.M. Keck Observatory on Mauna Kea. Because of the high altitude, human performance suffers in terms of stamina, alertness and decision making. In general, an astronomer at sea-level (or a site where there is little or no altitude effect) will perform much better than one at the 14,000ft summit, where the oxygen content is only 60% that at sea level. The Keck Director, Dr Fred Chaffee, introduced remote observing as an experiment, with astronomers observing from the base facility in Waimea, some 50 miles by road from the telescope (Conrad *et al.* 1997).

---

[1] `http://www.ls.eso.org/lasilla/Telescopes/NEWNTT/`

To make this a success a number of changes had to be implemented. High-bandwidth fibre optic lines were installed between the two Keck telescopes and Waimea; the telescope and instruments are all controlled remotely through software; 'night personnel' are at the telescope to take action in case of problems (but a much reduced number); and not least, purpose-built accommodation had to be provided at Waimea for astronomers to be able to sleep in peace during the daytime. Astronomers were given the choice between the summit and Waimea and very rapidly, and to many people's surprise, most astronomers elected to observe remotely from Waimea. To be sure, they could still see the telescope, well actually they could see the dome, but only as a white blob on top of Mauna Kea at sunset when the weather was fine. Currently, around 90% of astronomers observe on Keck remotely from Waimea.

This is a very important breakthrough because for many years there have been arguments against the benefits of remote observing. One was the training element. This said that sitting at a computer terminal on a different continent is just like being at a simulator, and so the training is diminished because it is not the same as being at the telescope. But of course this is not so. The observing is the real thing. All that is missing is the telescope in the next building.

But again it has to be pointed out that for all modern telescopes the astronomer does not venture into the dome, good heavens no. The astronomer is a very unwelcome source of heat, potential dome seeing, and is totally useless in the dark. Besides which, there is nothing to do in the dome unless something breaks; everything is remotely controlled these days. Astronomers are banished to a control room remote from the telescope. In fact for most facilities the actual telescope cannot even be seen from the control room. Therefore, one could readily argue that the astronomer might as well be anywhere as long as the communications function well. And as we have seen from the example of Keck, this has worked very satisfactorily. Therefore, the arguments against remote observing based on the training requirements are certainly overblown.

A second argument against remote observing was that the local weather at the telescope could not be appreciated by the absent astronomer and the data may be untrustworthy. There is a lot of old folklore in this. The experienced astronomer who goes out on a moonless night and claims to be able to detect thin cirrus has either superhuman eyes, or a good imagination. On Mauna Kea for example, the extreme altitude means that the lowered oxygen content in the eye results in a much reduced sensitivity than at sea-level and so cirrus is even harder to see! The solution of course, is to install remote weather monitors that can do all that the human eye can do, except far better, all the time, and give quantifiable outputs that are stored for reference. Hence most large observatories spend significant sums on constructing weather monitors and all-sky cameras that work through the night. An example of the work being done for Mauna Kea on behalf of all the facilities can be found on our web site[2]. Therefore this aspect can also be rebutted.

So we now have good evidence from a number of facilities that remote eavesdropping and remote observing have advantages. It saves time and effort, and for high-altitude sites, brings observing efficiency. However, we need to be very clear that by itself, it does not overcome the weather problem. It can, and often is, still mated to the classical scheduling mode, which bring with it the weather lottery inefficiencies.

For a remote centre that does not require much travel for astronomers, then a further attraction is that it is much easier to have two sets of observers located in the remote control room. In this case each will undertake their own programme depending on the weather conditions prevailing. This is a first step towards complete flexible observing. A variation on this theme is for the prime observer to be at the remote centre, but if the weather is too poor (or perhaps too good), then a support astronomer can undertake a different programme in service mode, one that is matched to the weather conditions.

In terms of cost benefit for remote eavesdropping/observing, there are additional costs for the facility. These include the need for more support astronomers at the telescope to undertake the observing, support astronomers at the remote centre, additional costs of leased satellite links or communications infrastructure, the setting up and staffing of the remote centre itself. But, probably the major cost is the software effort to make all this seamless, reliable and user friendly. Although most of this will be in a one-off investment, the maintenance and inevitable regular upgrades will continue to be a non-trivial on-going cost.

6.3. QUEUE-RANKED FLEXIBLE SCHEDULING – THE PRINCIPLE

As noted above, the most efficient observing mode is that where the observations undertaken in the weather conditions that match their requirements. This is flexible scheduling and is a policy decision. How the observations are subsequently taken is a matter of practice, but is often the sticking point in being able to implement the policy.

In terms of the policy, the simplest method is to first divide the weather into a number of bands ranging from excellent to poor. For example, this could be based on seeing, transparency, or phase of the moon (for sky brightness). Because of the enormous problems of the submillimetre atmo-

[2] `http://hokukea.soest.hawaii.edu`

sphere, the JCMT has been operating this system for over four years and has opted for five transparency bands, which seem to serve the scientific purpose. Bands 1 and 2 are the driest and are reserved for the short-wavelength spectroscopic programmes and the continuum deep imaging and photometry work. Once the weather moves into Bands 4 and 5 this is the territory of the long-wavelength spectroscopic programmes.

One of the experiences from this work is that it is better to have a smaller number of broad weather bands than many more finely divided categories. This only works where the atmosphere is relatively stable. Where there are notable fluctuations, then attempting to change between a number of weather bands during a night becomes a source of great inefficiency due to differing instruments and calibration changes. Therefore, some form of time-average for the selection of a weather band is necessary and some experience and common sense required. This is also where weather prediction becomes extremely valuable.

Given the weather bands, then one can construct a series of observation queues for each band. Within each queue proposals are ranked scientifically, usually by the Time Allocation Committee. All the observatory then has to do is to execute them in the best order. But this is where the difficulty starts. The JCMT, and Gemini, are international telescopes, with a number of partner countries participating. So one needs to have the weather queues set up for each country. The principles are the same but the complexity increases, especially in terms of the time tracking and accounting.

So now we come to the implementation, which is at the heart of queue-based flexible scheduling. Returning to our discussions above, the reader will have grasped that a simple mode of undertaking this is through pure service observing. Service astronomers undertake all the observations in the queue along with calibration and system checks. The data are sent-off to the astronomer at the end of the night. This requires that there is a process for programme selection and programme tracking to make sure that sources are either not missed or are not repeated. Undertaking this by hand is a huge staff intensive operation (as the JCMT has verified). Sophisticated software systems are clearly the solution, as many observatories such as ESO, Gemini and the Joint Astronomy Centre (which operates the JCMT and UKIRT) have made huge investments in this area.

While this mode of observing ensures that the best science programmes are undertaken and the telescope is operated in the most efficient manner it comes at a price. One price is that of staffing the facility with enough support astronomers to undertake all the observations, although this can be offset against the reduced travel costs for the visiting astronomers. But there is another price to pay: that of removing astronomers from the data-taking process. As we saw above, this has been a long cherished ‘right’ for ground-based astronomers, and many see relinquishing this to be fought over.

6.4. THE ARGUMENTS AGAINST SERVICE OBSERVING

While there are powerful arguments for service observing for the major facilities, arguments against this mode revolve around two aspects; the use of service observers to take the data at the telescope in lieu of the astronomer whose programme was awarded time (no eavesdropping), and the training of students.

We have already touched on the first, but let us expound on this for completely service observing (with no eavesdropping) for queue-based scheduling. It is certainly the case that unless the world's best observers are undertaking the service observations, there will come a time when a mistake will be made and a 'better' astronomer who was not able to come to the telescope will get a raw deal. However, with highly competent staff this will be a very rare event indeed, and one that is easily countered by the fact that once trained up and with some experience, the service observers will almost certainly be more experienced in observing with that specific instrument than most visiting astronomers. They will know the foibles of the telescope and instruments, the latest software and best ways of obtaining data. So on balance, as long as the absent astronomer can communicate the scientific requirements in the observation recipe, the service astronomer should be able to do just as good job, if not better, than the visiting astronomer. So this argument can be discounted.

The argument posed by the training element and fully queue-based flexible scheduling and service observing is subtler. In this mode, the training a student receives is now different. The student becomes accomplished in writing proposals, observing recipes and data analysis, but not on the hand-on instrument control and real-time decision making at the telescope. The scientific decision-making regarding the observational programme is not undiminished however, and it can be taken with much more time and consideration than the frantic scramble at the telescope as sources set. But, are they any different from their colleagues who use space telescope? Indeed, if they are all-round students they will use all facilities to obtain their science. However, having said that, there is a worry that totally divorcing students from the facility, its operation and instrument control and knowledge, may have a long-term damaging effect to the health of the community, perhaps of the next generation of service and support astronomers for example.

The answer is to allow students to go to the telescope, or the remote control centre, and to spend an extended period there, working with a support astronomer and being trained, not only on one's own science programme, but the decision-making process of a range of observing techniques. This brings additional knowledge and also seeing how other programmes are undertaken.

There is final aspect to pure service observing that is usually ignored. This is the impact on the staff at the remote telescope. It is very clear that a visiting astronomer is the most aggressive proponent of their own programme. It is possible, that over time, a sense of isolationism could creep over an observatory that became cut-off from its customer base of astronomers. There is something very vibrant and vital from having visiting astronomers passing through the facility, through the interchange, science seminars and general astro-gossip. Without this I have a concern that it could be much harder to maintain the cutting edge thrust of competition and total efficiency, clearly a management challenge.

7. Where we are today

While the telescopes were being constructed, the Gemini project invested notable efforts in investigating the best mode for its operations with regard to overall scientific productivity (*e.g.* Puxley & Boroson 1997). Detailed simulations of programmes and the weather conditions on Mauna Kea predicted that a minimum factor of three improvement in completion rate (from 10% to 30%) could be attained for those programmes requiring the rarest conditions by operating one particular queue-based scheduling mode rather than from classical scheduling (Boroson 1996).

Observing has just commenced with Gemini North and this is a combination of 50% in the classical mode, and 50% queue-scheduled, implemented by service astronomers, who in due course will undertake most of the observations remotely from the sea-level site. It will be very interesting to monitor how this progresses and how astronomers' attitudes adapt to the requirements, given this telescope is starting from scratch and is not trying to change an old-established pattern for the facility.

The JCMT has been operating queue-based flexible scheduling for three years but has never been able to staff the facility to undertake fully serviced observing. So how did the implementation work in this case? The telescope operators were trained to be able to execute 'fallback' programmes using observing templates or scripts compiled by the absent astronomers. The scientifically highest-ranked programmes were allocated more time than would be required to complete the programme if the weather was perfect. The astronomers from these programmes agreed to visit the telescope for this extended length of time and if the weather was suitable for their work, they would carry it out their observations. However, once they had completed their programme, or, if the weather moved out of their allocated band, they would then either undertake the fallback programmes selected from the queue, or act as a buddy to the telescope operator who would carry them out (there is a requirement for two people to be always present in the domes on Mauna Kea).

This clearly is a compromise but has a lot to commend it. The observers still need to travel to the facility, but with this they bring excellent interactions to the local support astronomers. The staffing levels of the facility remain modest. The training element is still undertaken by having students at the telescope, where they undertake their own programmes or help with the backups, gaining valuable experience. However, without the software tracking, the burden on support staff has been high and a sophisticated software observing management system is now nearing completion for both the JCMT and UKIRT. In the future there is the option of undertaking some of the observing remotely from the telescope, which would be left unstaffed, providing further operational savings that are always welcomed (or demanded) by funding agencies.

In terms of scientific efficiency gains, for the JCMT this can be quantified, although it is not trivial and a long-term analysis is currently underway. The data suggest that the completion rates for the highest ranked first quartile programmes (which have a very close correspondence to the requirement for the best two weather bands) improved from less than 25%, to well over 50%.

8. Conclusion

Gone are the days when classical observing alone could really claim to satisfy the demands of getting the maximum science out of a ground-based optical-IR-submillimetre facility. Queue-based flexible scheduling is the complete solution, but its implementation comes with a number of price tags. Various facilities have tackled these differently and no doubt much experimentation will produce even better solutions. Its is also clear that no single solution fits all. The next few years will be a time of further experimentation and change, both technically and in terms of how ground-based astronomers change their well-established habits of always going to the telescope to do their observations on their nights. It will also be very important to monitor the scientific gains in a quantifiable manner. This will not be easy, but the Gemini Observatory is perfectly placed to be able to do this.

However, one thing is very clear. To achieve the anticipated scientific gains through efficiency of operations and observing modes, high-quality software and support staff are critical. Both are in short supply in the modern world.

References

1. Boroson, T., Davies, J. & Robson, I. (Eds.) 1996, New observing modes for the next century, ASP Conf. Series **87**.
2. Boroson, T. 1996, Queue schedling, gains and drawbacks, in *New observing modes for the next century*, Eds. T. Boroson, J. Davies, & I. Robson, ASP Conf. Series **87**, p. 13.
3. Conrad, A.R., Kibrick, R.I. & Gathright, J. 1997, Remote observing with the Keck Telescopes, in *SPIE Proceedings* **3112**, 99
4. Longair, M.S., Stewart, M.J. & Williams, P.M. 1986, *Quart. J. Roy. Astron. Soc.* **27**, 153.
5. Maoli, R. *et al.* 2000, Cosmic Shear with ANTU/FORSI: An Optimal Use of Service Mode Observation, *The Messenger* **101**,10.
6. Puxley, P.J. & Boroson, T. 1997, *SPIE Proceedings* **2871**, 744.
7. Quinn, P.J. (Ed.) 1998, Observatory Operations to Optimize Scientific Return, *SPIE Proceedings* **3349**.

LARGE SURVEYS IN COSMOLOGY: THE CHANGING SOCIOLOGY

OFER LAHAV
Institute of Astronomy
Madingley Road
Cambridge CB3 0HA, UK
`lahav@ast.cam.ac.uk`

Abstract. Galaxy redshift surveys and Cosmic Microwave Background experiments are undertaken with larger and larger teams, in a fashion reminiscent of particle physics experiments and the human genome projects. We discuss the role of young researchers, the issue of multiple authorship, and ways to communicate effectively in teams of tens to hundreds of collaborators.

1. Introduction

The field of observational cosmology is going through an 'inflationary phase'. Galaxy redshift surveys will soon register millions of galaxies, imaging surveys will soon record Terabytes per observing night, and Cosmic Microwave Background experiments will map the sky at very high resolution and sensitivity.

These technological developments have immediate effects on the human interaction. We commonly hear at conferences statements like "to make a big impact in astronomy, a new survey must be 10-1000 times better in sensitivity and/or resolution and/or number of objects", and "it takes at least 2-3 times the most pessimistic estimate to begin/complete/analyse a survey". This indicates that conducting large surveys in this competitive field is becoming more demanding, and that the new technology heavily relies on human resources. While improving the technology of the big surveys, the human aspects should not be neglected. This raises some questions about the changing sociology of doing research in modern astronomy:

- What is the individual's contribution in a big collaboration (cf. the particle physics experiments and the human genome project)?

A. Heck (ed.), Organizations and Strategies in Astronomy II, 139–147.

- How to communicate effectively (via e-mail, web, meetings) in a team of 20-200 collaborators?
- What skills should be acquired by the next generation of astronomers?
- Will the increase in projects and data sets be followed by more jobs for young astronomers?
- How should the community deal with public-domain data (*e.g.* HDF and the proposed Virtual Observatories)?
- How to communicate the knowledge resulting from the surveys to the tax-payer?

Here we examine some of these issues. I happen to be involved in several large collaborations, and I have chosen to illustrate some of the points by using as an example the ongoing 2-degree-Field Galaxy Redshift Survey (2dFGRS). Needless to say, the points made below are my own views, and they do not necessarily represent a 'party line'.

2. Large surveys, large collaborations

Astronomy has been unique among the sciences in allowing small teams (of 3-8 people) to compete for time on world-class telescopes. Although the telescopes are built by hundreds of people, time is allocated (via competition) among the community at large, and only those involved in the science appear on the resulting paper (with the facility acknowledged and the instrument builders referenced). This made astronomy more attractive to some young researchers than say particle physics, where papers include hundreds of authors. However, the new big surveys in astronomy require many more participants.

We shall first discuss the big redshift surveys. Multi-fibre technology now allows us to measure redshifts of millions of galaxies. Two major surveys are under way. The US Sloan Digital Sky Survey (SDSS [1]) will measure redshifts of about 1 million galaxies over a quarter of the sky. The Anglo-Australian 2-degree-Field (2dF) survey [2] will measure redshifts for 250,000 galaxies selected from the APM catalogue. Over 150,000 2dF redshifts have been measured so far (as of April 2001).

By the standards of the new millennium, the 2dFGRS is a medium-sized collaboration (20-30 people). For reference, the QSO 2dF survey [3] has only six collaborators. On the other hand, the ambitious SDSS involves a formal list of roughly 100 'builders', people who have put at least two years effort into the project (York *et al.* 2000). The SDSS home page on the collabora-

---

[1] `http://www.sdss.org/`

[2] `http://www.mso.anu.edu.au/2dFGRS/`

[3] `http://www.2dfquasar.org/`

tion [4] mentions 150 scientists at the eleven participating institutions, but there are about 400 people with data rights. The SDSS is coordinated by a Collaboration Council ('CoCo') which helps to manage the affairs of the collaboration. Examples of other large 'ground-based' collaborations are micro-lensing experiments (*e.g.* Machos) and imaging surveys (*e.g.* Vista, which involves 18 universities in the UK).

The Cosmic Microwave Background (CMB) experiments also require large collaborations with new management strategies. While recent and ongoing experiments like Boomerang [5], Maxima [6] and MAP [7] have 'only' 20-40 collaborators each, the Planck project is of a different order of magnitude.

In the Planck project [8] (to be launched in 2007), there are several degrees of involvement (without counting the people involved from industry). There are 50-100 people on the management level, some 100-200 people involved with the instrumentation, and at least 30 people who are involved with data analysis on a day-to-day basis [9].

When it comes to considering the optimal size of a collaboration, it is worth recalling some remarks from the autobiography of Fred Hoyle (1994):

> "The essential point – the overriding point – is that the number of people with whom we need to interact in our daily lives should not exceed about one hundred, and preferably, on any enterprise of difficulty, not more than twenty-five. This is because twenty-five was the typical size of the hunting parties of pre-history. It is the scale of the medieval village, the scale of the modern cabinet in government, ... More or less everything that lies within it will be successful, and more or less everything that lies outside it will not".

3. 2dFGRS as a test case

The 2dFGRS (*e.g.* Folkes *et al.* 1999; Peacock *et al.* 2001) includes about 20 core members and in addition about 10 students and post-docs who are heavily involved in the survey. Most of the collaborators are in various institutions in the UK and in Australia, so there are in fact two sub-teams, with principal investigators in each of the countries. This geographical distribution has led to regular 'half-team' one-day meetings (about two-three per

---

[4] `http://www.sdss.org/collaboration/index.html`

[5] `http://www.physics.ucsb.edu/ boomerang/team.html`

[6] `http://cfpa.berkeley.edu/group/cmb/maximapeople.html`

[7] `http://map.gsfc.nasa.gov/html/institutions.html`

[8] `http://astro.estec.esa.nl/Planck/`

[9] For the big projects like SDSS and Planck it was actually difficult to find accurate estimates for the number of people involved. This is by itself an interesting fact.

year) in the two countries, and to regular e-mail/WWW exchanges. The 2dFRGS group web site has proved useful for exchanging data, results, and minutes of meetings among the team members.

Since the time the 2dFGRS team formed (around 1995), some members have left and others have joined. Also, the scientific goals have somewhat changed given the rapid progress in other areas of Cosmology (*e.g.* the CMB). This requires frequent updates on 'who is doing what', with careful attention to protecting the work of PhD students and post-docs.

The 2dFGRS is not complete yet, so it is too early to assess its overall performance, but on the whole one can make the following observations:

- It has taken some time for all involved to get used to the 'loss of individuality' and to the structure of the big collaboration, to agree on the division of labour, and to develop appropriate communication channels.
- The regular meetings in the UK and in Australia are very useful in focusing attention on technical issues and progress with papers.
- The e-mail/WWW exchange is quite efficient, even if daunting at times (see below).
- Decisions on papers and authorship have usually reached reasonable agreement after iterations among the relevant people.
- Requests for external collaborators have been dealt with in a democratic way, by consulting the entire team.

4. The role of PhD students and post-docs

Young researchers may find themselves in big collaborations, co-authoring papers with tens of authors, and with collaborators they have never met. Although there is a danger that individuals (junior as well as senior) might be 'lost in the crowd', there are some benefits for a young person to be involved in a collaboration at the forefront of research.

However, it is crucial to identify a niche, which is not already taken by other senior members of the collaborations, or by other students. When a PhD student or a post-doc has such a territory, his/her work, if of high quality, is recognized by a large number of people well ahead of publication. There is also a constant exchange of ideas and cross-fertilization with collaborators who are leaders of the field. This means that the young person can get exposure and can form an international 'network' at an early stage of his/her career. Being appreciated by a number of senior people also improves the chances of getting post-doctoral and faculty positions.

There is however, at least one problematic issue related to long-term projects. Some post-docs are employed for a period of 2-3 years primarily to develop algorithms and pipe-line software for future experiments. This means that when they next apply for jobs, it would be difficult for them to present 'real' scientific output. The 'reward system' for those who put in several years of hard work on technical aspects of the surveys varies from country to country and from one institution to another. In some places more can be done to improve it.

There are a number of solutions to this problem (heard occasionally in Cambridge pubs):

- To assign some of the development task to national laboratories, where PhDs with permanent positions can develop long-term projects without the worry of 'publishing or perishing'.
- To enable post-docs who are working on software development etc. to spend say 50 % of their time on science of their choice.
- To change the rules of assessment for positions from being based entirely on listed journal papers to other products such as software packages or management achievements. There should be career paths for such people which are as highly regarded as the standard academic university track. This assessment would of course heavily depend on references from senior members of the collaboration.

Another aspect of the large surveys is that the skills required for some of the tasks are quite different from the PhD qualifications of the previous generation. While there is still great need for post-docs and students with analytic skills and deep knowledge of the Landau & Lifshitz volumes, we see a new generation of successful post-docs who have stronger emphasis on numerical and computational work. The group dynamic of the large collaborations also suggests that those with good communication skills have better chances of succeeding.

It remains to be seen if the growth in projects and 'soft-money' positions will eventually lead to more tenured positions in astronomy. This issue is beyond the scope of this article, but it is clear that the probability of a young researcher eventually getting a permanent position also affects the research patterns in the large collaborations.

5. E-mail traffic and the WWW

Joining big teams also means spending a large fraction of the day on e-mail. The e-mail and the World-Wide Web (WWW) media make the interaction between people in different institutions and countries easier, but it consumes time and energy. The ethics of using e-mail have not yet been structured in the society (see *e.g.* Wallace 1999), and one can experience daily different style of e-mail communications.

In a large collaboration most of the e-mail messages circulated are relevant to only a subset of the team. One may choose to send an e-mail only to a subset of the team, but then others may get upset about not being informed! I found it helpful when a message circulated to the entire team gives in 1-2 sentences at the top a summary of the main point, with clear indication of who might be directly interested in it, and who is expected to act upon it. It is also helpful if the sender points to material such as tables and plots in his/her web home page, instead of sending huge files to the e-mail boxes of numerous collaborators.

In the SDSS collaboration there are different (about 40 in total) e-mail exploders for all aspects of SDSS (*e.g.* photometric pipeline, galaxy science, etc.), which are archived on the web. This allows people to choose to pay attention to just those aspects they find important.

Other problematic issues related to e-mail are well known, *e.g.* misunderstanding over language, style and terminology. For example, from time to time messages with sensitive 'political' issues make it (by chance or by design!) to those who were not supposed to see them. In certain circumstances it is worth remembering to use, instead of e-mail, the good old telephone!

6. Multiple authorship

We examined the number of authors in volumes of the *Astrophysical Journal (ApJ).* Of the 32 papers published in the first volume of the ApJ in 1895, 31 (97%) were written by a single author. On the other hand, in the first volume of ApJ 2000, only 15% were written by a single author, 70% written by 2-5 authors, and 15% written by 6 and more authors.

The recent 2dFGRS papers (*e.g.* Folkes *et al.* 1999; Peacock *et al.* 2001) have about 25-30 authors. This long list of authors attempts to reflect the division of labour regarding instrumentation, observations, data reduction, analysis and theory. The author-list is usually led by the 5-6 authors who contributed most to that particular paper, and the rest are listed by alphabetical order. The credit for people is complicated even more by the fact that the big surveys are stretched over many years, so some participants leave the project (or quit astronomy) and others join in.

In the SDSS collaboration there are formal rules about authorship, *e.g.* a first list of people who did the immediate work on a given paper, and everybody else alphabetically (similar to 2dFGRS), but also that no-one is automatically put as a co-author on a paper; one must explicitly request co-authorship.

Paczynski (2000) raised the question (in the context of monitoring the whole sky for variability of objects) "should the whole effort be combined in a very large team, with all papers having several dozen authors listed alphabetically, and no way to find out whom to credit and whom to blame for different parts of the project?".

This problem arises as the big projects involve individuals who worked hard on the instrumentation and data reduction, and they deserve credit for their efforts. However, one alternative would be to have technical papers (or web sites) written by those who contributed to the infra-structure of the project, which will later be quoted by any paper resulting from the survey.

The same holds for more scientific aspects of the collaboration, *i.e.* apart from core papers, to break the publications down into specific studies with the authorship of those who directly contributed. In the case that two (or more) groups within the team attempt to address the same question by analysing the data differently, it seems most logical to simply publish two separate papers.

Another possible solution for large collaborative papers is to have authorship by section as well as a global author list of the paper. This would allow a more precise assignment of credit/blame to be apportioned. It will no doubt take some time for the astronomical community to develop 'rules' regarding authorship and publications.

7. Public release, virtual observatories and data mining

Time allocation committees oblige survey teams to release the data within a given period. Perhaps the most successful example is that of the Hubble Deep Field (Williams *et al.* 1996), where the data were made available to all over the WWW, and resulted in a remarkable scientific output by groups not necessarily involved in conducting the survey. We shall no doubt see similar trends with future publically available data sets such as 2dF, SDSS, 2MASS [10] and 6dF [11].

There are in fact plans to establish Virtual Observatories and Astrogrid (distributed CPU) facilities. This is an interesting concept where the data produced by large teams go eventually to the individuals, and allow small groups to do their own data-mining and analysis. The exact nature of these new digital research facilities still needs to be defined (*e.g.* Heck 2001). Another aspect of these public domain data is of course that anyone else in the world, not only professional astronomers, can access the data, or at least enjoy some pretty pictures.

8. Discussion

In recent years the astronomical community has experienced an enormous growth in the number of projects and photons collected by ground-based

---

[10] `http://www.ipac.caltech.edu/2mass/`

[11] `http://www.mso.anu.edu.au/ colless/6dF/`

and space observatories. This has led to a new style of work in large teams, and competition between big projects.

As discussed above, these trends could be positive if the large projects are divided into smaller tasks that allow the individuals (in particular young researchers) to identify their niche.

The astronomical community will have to define rules and ethics related to authorship of papers, and e-mail and other communication channels in collaborations of tens to hundreds of people. While these issues are occasionally discussed informally, a more open and frank discussion could help to shape the sociology of the new astronomy.

Acknowledgments

I thank A. Heck for suggesting to me to write this article, S. Bridle, A. Bunker, M. Colless, M. Diemling, F. van Leeuwen, J. Nicholas and M. Strauss for providing information and suggestions, as well as the participants of the round-table tea at the IoA for helpful discussions.

References

1. Folkes, S., Ronen, Sh., Price, I, Lahav, O., Colless, M., Maddox, S., Deeley, K., Glazebrook, K., Bland-Hawthorn, J., Cannon, R., Cole, Sh, Collins, Chr., Warrick, C., Driver, S.P., Dalton, G., Efstathiou, G., Ellis, R.S., Frenk, C.S., Kaiser, N., Lewis, I., Lumsden, St., Peacock, J., Peterson, B.A., Sutherland, W. & Taylor, K. 1999, *Monthly Not. Royal Astron. Soc.* **308**, 459-472
2. Heck, A. 2001, *Amer. Astron. Soc. Newsl.* **104**, 2
3. Hoyle, F. 1994, *Home is where the Wind Blows*, University Science Books, Mill Valley, 443 pp. (ISBN 0-935702-27-X)
4. Paczynski, B. 2000, *Publ. Astron. Soc. Pacific* **112**, 1281-1283
5. Peacock, J.A., Cole, Sh., Norberg, P., Baugh, C.M., Bland-Hawthorn, J., Bridges, T., Cannon, R.D., Colless, M., Collins, Chr., Couch, W., Dalton, G., Deeley, K., De Propris, R., Driver, S.P., Efstathiou, G., Ellis, R.S., Frenk, C.S., Glazebrook, K., Jackson, C., Lahav, O., Lewis, I., Lumsden, St., Maddox, St., Percival, W.J., Peterson, B.A., Price, I., Sutherland, W. & Taylor, K. 2001, *Nature*, **410**, 169-173
6. Wallace, P. 1999, *The Psychology of the Internet*, Cambridge University Press, Cambridge, 264 pp. (ISBN 0-521-63294-3)
7. Williams, R.E., Blacker, B., Dickinson, M., Van Dyke Dixon, W., Ferguson, H.C., Fruchter, A.S., Giavalisco, M., Gilliland, R.L., Heyer, I., Katsanis, R., Levay, Z., Lucas, R.A., McElroy, D.B., Petro, L. & Postman, M. 1996, *Astron. J.* **112**, 1335-1389
8. York, D.G., Adelman, J., Anderson Jr., J.E., Anderson, S.F., Annis, J., Bahcall, N.A., Bakken, J.A., Barkhouser, R., Bastian, St., Berman, E., Boroski, W.N., Bracker, St., Briegel, Ch., Briggs, J.W., Brinkmann, J., Brunner, R., Burles, S., Carey, L., Carr, M.A., Castander, F.J., Chen, B., Colestock, P.L., Connolly, A.J., Crocker, J.H., Csabal, I., Czarapata, P.C., Davis, J.E., Doi, M., Dombeck, T., Eisenstein, D., Ellman, N., Elms, B.R., Evans, M.L., Fan, X., Federwitz, G.R., Fiscelli, L., Friedman, S., Frieman, J.A., Fukugita, M., Gillepsie, B., Gunn, J.E., Gurbani, V.K., De Haas, E., Haldeman, M., Harris, F.H., Hayes, J., Heckman, T.M., Hennessy, G.S., Hindsley, R.B., Holm, S., Holmgren, D.J., Huang, C.H., Hull, Ch.,

Husby, D., Ichikawa, S.I., Ichikawa, T., Ivezić, Ž., Kent, St., Kim, R.S.J., Kinney, E., Klaene, M., Kleinman, A.N., Kleinman, S., Knapp, G.R., Korienek, J., Kron, R.G., Kunszt, P.Z., Lamb, D.Q., Lee, B., Leger, R.F., Limmongkol, S., Lindenmeyer, C., Long, D.C., Loomis, C., Loveday, J., Lucinio, R., Lupton, R.H., MacKinnon, B., Mannery, E.J., Mantsch, P.M., Margon, B., McGehee, P., McKay, T.A., Meiksin, A., Merelli, A., Monet, D.G., Munn, J.A., Narayanan, V.K., Nash, Th., Neilsen, E., Neswold, R., Newberg, H.J., Nichol, R.C., Nicinski, T., Nonino, M., Okada, N., Okamura, S., Ostriker, J.P., Owen, R., Pauls, A.G., Peoples, J., Peterson, R.L., Petravick, D., Pier, J.R., Pope, A., Pordes, R., Prosapio, A., Rechenmacher, R., Quinn, Th.R., Richards, G.T., Richmond, M.W., Rivetta, Cl.H., Rockosi, C.M., Ruthmansdorfer, K., Sandford, D., Schlegel, D.J., Schneider, D.P., Sekiguchi, M., Sergey, G., Shimasaku, K., Siegmund, W.A., Smee, St., Smith, J.A., Snedden, S., Stone, R., Stoughton, Chr., Strauss, M.A., Stubbs, Chr., Subba Rao, M., Szalay, A.S., Szapudi, I., Szokoly, G.P., Thakar, A.R., Tremonti, Chr., Tucker, D.L., Uomoto, A., Vanden Berk, D., Vogeley, M.S., Waddell, P., Wang, S.I., Watanabe, M., Weinberg, D.H., Yanny, B. & Yasuda, N. 2000, *Astron. J.* **120**, 1579-1587

THE ESO OBSERVING PROGRAMMES COMMITTEE

JACQUES BREYSACHER
European Southern Observatory
Karl-Schwarzschild-Straße 2
D-85748 Garching, Germany
`jbreysac@eso.org`

AND

CHRISTOFFEL WAELKENS
Instituut voor Sterrenkunde
Katholieke Universiteit Leuven
Celestijnenlaan 200B
B-3001 Leuven, Belgium
`Christoffel.Waelkens@ster.kuleuven.ac.be`

Abstract. The Observing Programme Committee (OPC) of the European Southern Observatory (ESO) is the body which evaluates the proposals and recommends to the Director General which programmes are scientifically most valuable to be scheduled. We give a historical overview on how the OPC evolved with the organisation, describe in detail its present structure and procedures, and reflect on the challenges of the OPC and of evaluations processes in general in an evolving environment.

1. The early days

The history of the Observing Programmes Committee goes back to June 1967 when the ESO Council decided to establish a Scientific Programmes Committee (SPC) meant to advise the Directorate and the Council on general scientific policy matters, and to evaluate the observing proposals submitted by the visiting astronomers. The SPC held its first meeting on May 2, 1968 at the Bergedorf office of the ESO Directorate. Each of the member countries had a representative, and the Scientific Director of ESO acted as secretary.

The SPC proposed rules of procedure which were formally adopted by the ESO Council in July 1968: telescope time allocation was to be arranged

A. Heck (ed.), Organizations and Strategies in Astronomy II, 149–162.

for periods of six months (March–August and September–February)[1] ; observing proposals had to be submitted six months before the beginning of these periods; final allocation was to be done by the Directorate following the recommendations of the SPC; and the applicants were to be informed on the allocations about four months in advance. One third of the observing time was to be alloted to the ESO staff; the SPC was not supposed to advise on these programmes but merely to be kept informed.

The first official **Announcement of the ESO Directorate** inviting applications for the use of the **1m Photometric Telescope** for the period March 1 – September 1, 1969, was published in the ESO Bulletin No. 4 of July 1968. It was also distributed to all astronomical institutes in the ESO member states. According to the ESO numbering system of the observing semesters, in which October 1 – April 1, 2001, corresponds to **Period 68**, this early announcement refers to **Period 2**. In the call for proposals corresponding to **Period 3** (September 1, 1969 – March 1, 1970), 4 instruments were advertised: the **1m Photometric Telescope**, the **1.52m Spectrographic Telescope**, the **Radial Velocity Objective Prism Astrograph**, and a **Small Photometric Telescope** only partly at the disposal of visiting astronomers.

In these early days, potential applicants were informed that *"Observing periods granted may range from several weeks to several months."*, a somewhat unusual length for a run nowadays ..., but were also warned that *"Defrayal of travel expenses of accompanying wifes is foreseen to a limited extent and only in the case the observers will have to stay in Chile for a period of at least six months."*

This last statement reveals an interesting sociological fact. It is indeed to be understood that, at that time, a visiting astronomer could evidently only belong to the stronger sex!

The dates corresponding to the first ten ESO observing periods for which time was allocated to visiting astronomers are specified in Table 1.

By Council decision of June 1971, the SPC split into the Observing Programmes Committee (OPC) and the Scientific Policy Committee.

2. The "classic" era

For about 20 years, from the early 1970's till 1994, the structure and working procedure of the OPC remained remarkably stable, in strong contrast to the huge changes which occurred during that period in the number and size of the telescopes available at the La Silla observatory, and to the resulting increase in the number of observing proposals submitted to ESO

---

[1] They were later on, in 1971, shifted by one month: April–September and October–March.

TABLE 1. The first ten ESO observing periods

Observing period	Dates	
1	Nov. 1, 1968	May 1, 1969
2	May 1, 1969	Sept. 1, 1969
3	Sept. 1, 1969	March 2, 1970
4	March 2, 1970	Sept. 1, 1970
5	Sept. 1, 1970	March 2, 1971
6	March 2, 1971	July 1, 1971
7	July 1, 1971	Oct. 1, 1971
8	Oct. 1, 1971	April 1, 1972
9	April 1, 1972	Oct. 1, 1972
10	Oct. 1, 1972	April 1, 1973

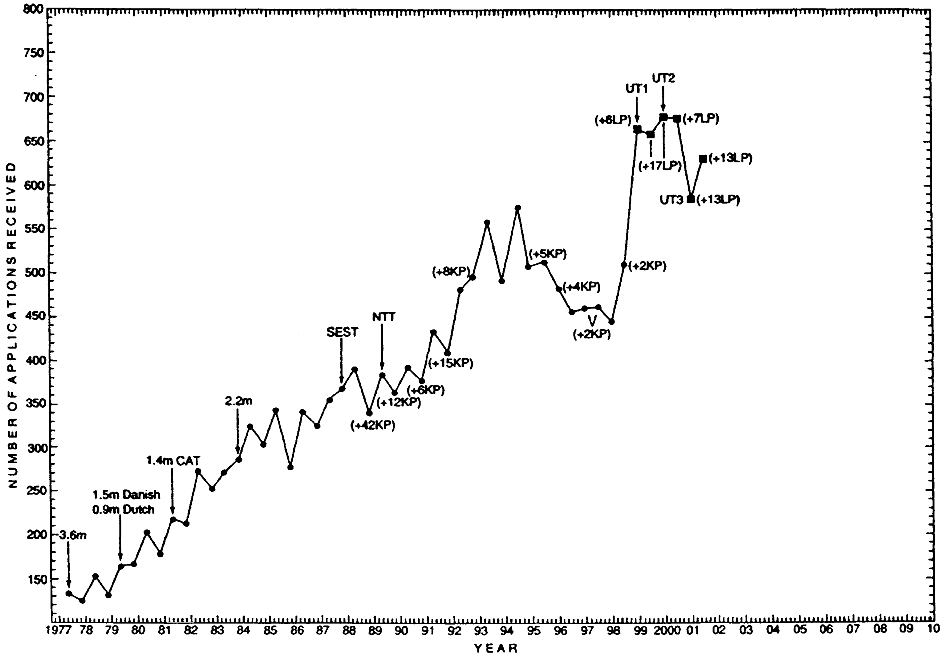


Figure 1. The half-yearly evolution of the number of proposals received at ESO since 1977. The steady increase is well linked to the increased amount of telescopes available; the dip during the late 90s corresponds to the closing of facilities at La Silla before the advent of the VLT.

(cf. Fig. 1). During these two decades, the system was regularly improved but never fundamentally called into question.

The OPC rules of procedure stated that the committee has *"the function to inspect and rank the proposals made for observing programmes at La Silla, and thereby to advise the Director General on the distribution of observing time"*. Every member state, through its national ESO committee, nominated one OPC member and a substitute for a five-year term not immediately renewable. The terms were staggered so that each year one or two persons could be replaced. The OPC chairperson, appointed annually by the Council, was invited to attend Council meetings and to report to its members.

The OPC meetings were systematically attended by the Director General, the Head of the Visiting Astronomers Section, and one ESO staff astronomer (usually the Head of the Scientific Group) fully involved in the review process of the proposals. At the beginning, each application for observing time was evaluated by one OPC member only who then presented his rating and conclusions to the committee for discussion and final decision. The applicants were treated in alphabetical order. In 1976, it was agreed to have all ESO staff proposals evaluated exactly in the same way as for visiting astronomers. From Period 23 (April 1 – October 1, 1979) it was decided to have two referees assigned to the programmes presented for execution at the 3.6m telescope. This was extended to the 1.5m- and 1m-size telescopes from Period 25. At that time three days were necessary to examine the about 160 proposals submitted.

The review procedure of the proposals submitted for Period 32 (October 1, 1983 – April 1, 1984) greatly benefited from the implementation of computer support for the OPC activities. From then on, after completion of the refereeing work[2] and about a week before the OPC meeting, working documents were distributed in a systematic way to the committee members.

The information contained in the data base was used to generate a set of tables giving, for each telescope, the preliminary ranking of the programmes according to their average grade, and showing the distribution of the programmes above the cut-off line over the months and the moon phases, as well as the resulting frequency of change-overs of instruments at each telescope. At the time of the meeting, after a careful examination of the above-mentioned documents, discrepancies in the judgement of applications were clarified, and proposals near the cut-off line were discussed

---

[2] Each application was evaluated by three referees selected among the OPC members. The rating scale consisted of nine grades extending from "outstanding" to "useless", expressed by numbers 1 to 5 with half-integer steps. In order to avoid any bias in judgement the referees assigned to a given applicant were changed from one observing period to the next.

in particular detail. The discussion was based on the scientific merit of the proposals alone, the nationality or affiliation of an applicant being of no concern to the OPC. As final product of the meeting, a list of proposed allocations was submitted to the ESO Directorate.

Following a preliminary enquiry carried out in 1988, the **Key Programme** scheme was introduced as from **Period 43** (April 1 – October 1, 1989). The addition of the **3.5m New Technology Telescope** to the La Silla telescope park motivated this initiative. The aim was to give to astronomers having a Key Programme accepted, the security to receive over a significant period of time (e.g. two or three years) a substantial number of nights to achieve a project, without the obligation to re-submit the same proposal every six months.

Originally, the small telescopes were not offered for Key programmes. Indeed, it was the Director General's idea to have Key Programmes started to prepare the **Very Large Telescope** (VLT) era, and to foster extragalactic research which essentially requires the use of large telescopes. Later on, it was considered that allocation on small telescopes was also acceptable depending on the quality of the proposals. Once a year, the principal investigators of Key Programmes had to submit progress reports to the OPC.

As from **Period 50** (October 1, 1992 – April 1, 1993), a major technical change in the proposal submission process was introduced with the possibility of sending the applications for observing time by e-mail, using the ESOFORM LaTeXpackage.

The scientific categories used by the OPC for the classification of the proposals during the "classic" era are listed in Table 2. It is only from **Period 28** (October 1, 1981 – April 1, 1982) that the proposals were systematically grouped in pre-defined categories.

Interestingly, during all that period the OPC strongly opposed to have any information forwarded to the unsuccessful applicants. An indication of the relative position of their programmes with regard to the cut-off line, possibly complemented by some comments directly communicated by the OPC national representative, was deemed to be a satisfactory solution.

3. The modern times

The steady increase in the number of observing proposals submitted to ESO for the use of the La Silla facilities led to adopt in 1994, from **Period 54** on, a panel structure for the OPC in order to keep at an acceptable level the amount of work for each committee member. The nine scientific categories previously used for the classification of the proposals were abandoned and replaced by six new ones. One panel was appointed for each of these categories:

TABLE 2. The OPC scientific categories in the "classic" era

From Period 28	From Period 43
1 – Galaxies	1 – Galaxies, clusters of galaxies
2 – Quasars, Seyferts, Radio galaxies	2 – Quasars, Seyferts, Radio galaxies
3 – Magellanic clouds	3 – Magellanic Clouds
4 – Infrared	4 – Interstellar matter
5 – Interstellar matter	5 – Star clusters, galactic structure
6 – Clusters & galactic structure	6 – X-ray sources
7 – X-ray-sources	7 – Stars
8 – Binaries	8 – Solar system
9 – Stars	9 – Miscellaneous
10 – Solar system	

- Galaxies, Clusters of Galaxies & Cosmology,
- Active Galactic Nuclei & Quasars,
- Intergalactic & Interstellar Media,
- High-mass and/or Hot Stars,
- Low-mass and/or Cool Stars,
- Solar System.

At its 61st meeting, in November 1997, the OPC concurred with the definition of a Large Programme as proposed by the *VLT Key Programme Working Groups*, and recommended the abolishment of the term "Key Programme" which had led in the past to some confusion.

In 1998, it was decided to enlarge the number of OPC panels by introducing an Observational Cosmology panel. In addition, the above three first OPC categories were revised as follows:

- Nearby Normal Galaxies & Stellar Systems,
- Physics of AGNs, QSOs & Starburst Galaxies,
- Interstellar Medium & Star Formation.

Discussions in the OPC revealed however the need for a further improvement of the functionning and working procedure of this committee in the VLT era. There was in particular a consensus on the fact that panels with rather broad scientific profiles may evaluate more efficiently and objectively the general impact of proposals on astrophysics.

Following a decision of the Director General, for the June 2000 meeting of the OPC, a new committee structure and revised working procedure was implemented. The seven previous panels were replaced by the following four new panels:

- Cosmology,
- Galaxies & Galactic Nuclei,
- ISM, Star Formation & Planetary Systems,
- Stellar Evolution.

each of them being divided into two sub-panels having the same expertise. This allows to maintain the workload at an acceptable level for every panel member, and also offers a better way to handle conflicts of interest by mere exchanges of proposals between the two related sub-panels.

44 astronomers are currently involved in the review process of the proposals: 16 *"OPC members"*, i.e. members nominated by the respective National Committees in the ESO member states and members-at-large nominated by the Director General in consultation with the OPC chairman; 28 *"expert advisers"* selected by the Director General in consultation with the OPC chairman. The OPC representatives serve for three years with a possible extension of one year, the advisers are appointed for a two-years-term. The chairperson of the OPC is necessarily chosen among the national delegates, for the vice-chair there is no constraint with this respect. Both of them are appointed annually by Council.

Twice a year the complete OPC meets for five full days to discuss and rank the about 650 proposals submitted by the astronomical community. The various activities can be summarized as follows:

- Day 1: First OPC session, attended by OPC members only, and mainly devoted to the discussion and pre-selection of the large programmes;
- Days 2 & 3: Review of all the applications by the sub-panels;
- Day 4 (morning): Discussion of overlaps by sub-panel chairs and preparation of final documents by ESO Visiting-Astronomer Team;
- Day 4 (afternoon) & 5: Second OPC session for final selection of the large programmes and normal programmes to be recommended for time allocation to the ESO Directorate.

In the new system, it is the responsibility of the "prime referee" to summarize in a short report, for the proposals assigned to him, the sub-panel final comments and recommendations to be communicated later on by ESO to the applicants. The sub-panels work in an independent manner, their respective members review exclusively the proposals assigned to the sub-panel they belong to. It is the responsibility of the sub-panel chairs to check for possible duplications among the selected proposals in their category, and if necessary to discuss them with their panelists before the final OPC session. Experience shows that the issue is more academic than real. Moreover, it is a fact of life that individual biases affect any kind of evaluation if one wants this evaluation to be done by experts. The only solution is to average out these biases by rotating panel members regularly, and a dual panel system also effectively contributes to this.

Although implemented on rather short notice for Period 66, at the June 2000 meeting of the OPC, the above-described reorganisation of the OPC is now unanimously regarded as a significant improvement with respect to the previous composition and working procedure of this committee.

4. The evaluation process

4.1. ACTIVITIES BEFORE THE OPC MEETING

Within two weeks after the deadline of submission of proposals, the Visiting Astronomers Office ships the proposals in the relevant sub-panels to the OPC and sub-panel members. To each proposal three referees are assigned, from which the primary referee is expected to summarize the proposal at the meeting; all proposals in a sub-panel are expected to be read by every member, however. Two weeks are then given to the referees to identify unnoticed conflicts of interest and proposals that have been submitted to the wrong panel. When the replies have been received, corrections are made, and report cards are mailed electronically to the referees on which these should write their grades and comments.

TABLE 3. Time table for the OPC activities

Date	Event
April 1, October 1	Deadline for submission of proposals
April 15, October 15	Proposals arrive at the referees
May 1, November 1	Proposal cards are issued to the referees
May 23, November 23	Deadline for evaluations to be sent to ESO
June 1, December 1	Start of OPC meeting
June 20, December 20	Finalization of comments on proposals

Before the meeting, documents are produced which summarize the evaluations by the referees. It should be stressed that these documents are of a preliminary nature: they essentially serve to prepare the sub-panel meetings, during which all members are expected to intervene on every proposal. In order to minimize the bias introduced by a specific referee, it is recommended to the sub-panel chairs not to discuss the proposals in the order of the average preliminary grades. Technical assessment about proposals is provided by ESO staff upon request.

4.2. WORKING PROCEDURE FOR LARGE PROGRAMMES AND TARGET OF OPPORTUNITY PROGRAMMES

The VLT Science Policy document recommends that up to 30% of the telescope time should be attributed to large programmes, and this policy has since been extended to the La Silla telescopes. The idea behind is that experience with HST has shown that real breakthroughs often result from programmes, such as the Hubble Deep Field and the Hubble Constant projects, to which large amounts of time have been devoted. Large programmes are also felt as a way to foster collaborations within the ESO community: not only many data but also much expertise helps to make progress! For the 2.2m telescope, which is particularly demanded for surveys and other programmes which are preparatory for VLT science, more than 30% of the time may be awarded to large programmes.

Before an OPC meeting, 30% of the time available on each telescope is set aside as a pool for large programmes, so as to make sure that the awarding of a large programme has no adverse effect on the fraction of time reserved for the regular programmes of a sub-panel. The selection of large programmes is then the responsibility of the full OPC.

On the other hand, a selection of such programmes by the OPC without the advice of the sub-panels where the experts in the field reside, is clearly not wanted. Therefore, the first day of the OPC meeting is devoted to a discussion within OPC of the large-programme proposals, which results in a pre-selection which is then presented to the sub-panels during Days 2 and 3 of the meeting. During the last two days of the OPC week, the reports by the sub-panels are discussed, and the OPC proceeds to the final selection of large programmes.

A similar procedure is followed for the selection of Target of Opportunity (ToO) proposals. Such programmes by definition get override status and thus need to be of high scientific priority in order to be recommended for scheduling. Moreover, by nature they most often concern the 'Stellar Evolution' panel, and if considered as regular programmes would bias too much the time allocation for this panel. During the first day of the OPC meeting, the ToO proposals are pre-discussed within OPC, and their final allocation is decided upon after them being reviewed in the relevant sub-panels.

4.3. WORKING PROCEDURE FOR REGULAR PROGRAMMES

The main task of the sub-panels is to provide grades and a ranking per telescope for the applications they received. During the two-day panel meetings, each proposal is summarized by the primary referee and then discussed by the whole sub-panel. After the discussion of each proposal, a grade is given by every sub-panel member, and the amount of time to be recommended is settled. Only when all proposals for a particular telescope are discussed, average grades are computed, and a listing of the proposals ordered according to their average grade is produced. On the basis of this listing, the sub-panel is then free to discuss the achieved ranking and to change it.

Especially the unsuccessful applicants are eager to know what the rationale behind the recommendations were. An issue with which OPC has struggled since a long time, and which the Users Committee has often put on its agenda, is the formulation of exhaustive comments for every proposal. It may be useful information for brain researchers to know that it is not easy for the mind of a panelist to formulate a detailed comment immediately after the discussion of a proposal: analytical and synthetic thinking appear to reside in other places in the brain!

The precise formulation of comments slows the sub-panel discussions, which already occur under some time pressure, considerably. But, clearly, the request by the community of detailed explanations is sound. The solution which is adopted, is to charge the primary referees with noting the remarks by the individual referees and to summarize them by editing comments after the meeting, in time for ESO to include them in the email messages to the applicants.

While in principle sub-panel members have an idea about the total observing time they can dispose on, the essential result of their deliberation is the ranking of the proposals. During the final selection of the proposals during days 4 and 5, the OPC respects the ranking of the proposals made by the sub-panels. The main task of the OPC is then to determine the cut-off line which delimits recommended from not recommended proposals.

The word 'recommended' deserves to be repeated, since the final attribution of time is the full responsibility of the Director General, who has to take into account scheduling constraints and other technical issues, application of the Agreement with Chile, etc. On the VLT, about half of the programmes are carried out in service observing mode[3]. The final execution of these proposals depends on the conditions on Paranal. The highest rated proposals are safe, but proposals lower in the list often can be executed only partially. Conversely, it is useful to know that service proposals not recommended in the first place, but which are not demanding on seeing constraints, have a fair chance to be partially successful after all.

---

[3] The rationale behind service observing is in the first place the opportunity this mode offers to carry out demanding programmes under the required atmospheric conditions, and conversely also to take maximal advantage of periods of e.g. less optimal seeing circumstances.

However, about half of the time is reserved for 'visitor mode' programmes, for operational reasons, but also to ensure a healthy familiarity of the scientific community with the instrumentation and observing conditions.

The amount of time which is available for regular proposals in the different sub-panels, is initially set as proportional to the total time requested for the proposals in these sub-panels. Clearly, merely attributing telescope time to sub-panels proportional to the total time requested, can appear to be an abdication with respect to discussing the real science issues in the OPC. Moreover, institutionalizing such a procedure might contain an incentive to introduce fake proposals; experience shows, however, that the community is most reasonable in this respect, and that people understand that such an attitude would rapidly become self-destructive.

Ideally, then, in order to recommend the highest-quality science, an OPC discussion should be held on the relative merits of the proposals in the sub-panels, and the cut-off lines should be modified accordingly. This final adjustment of the cut-off lines is not an easy issue, however. OPC members, who lively remember the thorough discussions they had in their sub-panel, tend to refrain from reshaping the picture from much shorter discussions with less involvement from the experts in the field. Moreover, with eight sub-panels, any formal voting procedure which is systematically applied for each telescope, tends to be cumbersome, and for this very reason often hardly influences the result.

But it remains true that OPC members should strive, to the extent possible, towards gauging the quality of the science in their (sub-)panel to that in the others. If this did not happen, the system might degenerate into four or even eight independent OPCs, a situation which should definitely be avoided! It should be pointed out, however, that thorough multidisciplinary scientific discussions occur within the OPC for the large and ToO proposals, which concern the full OPC, and that the very fact of living a full week together entails many opportunities for cross-fertilizing. Also, when more nights become available for regular programmes, because of the non-selection of large programmes, discussion naturally arises within OPC on which sub-panel presents the best case for this additional time.

Finally, if a panel definitely feels it needs more time than the preliminary amount, it is able to fight for it and thus to trigger an agreement on some redistribution of time, involving a discussion within the OPC on the scientific quality of the cut-off proposals. Experience shows that from the moment that a fair quantitative distribution of the proposals over the different sub-panels is achieved, the need for a final redistribution of observing time is felt as being less stringent: the broad scope of the new panels seems to have led to a beneficial redistributing effect on quality as well.

5. Lessons learned

Cosmologists need the cosmological principle to make sense of the evolving Universe. A credible assessment of observing proposals also needs isotropy and homogeneity: it is essential that every proposal gets a fair chance, and also that adequate ways are found to gauge proposals which cover a wide range of science domains. Aiming at a fair distribution of observing time has of course always been the main goal of the OPC, but putting this into practice within an environment characterized by changing possibilities and constraints, has induced rethinking of the process at about every OPC meeting.

Nevertheless, the change has been a continuous one, which builds on the experience of several generations of OPC members. The dual panel system, which was adopted with some hesitation, passed its first test very well. It would be naive, however, to anticipate that no new evolution of the procedures should occur in the future, with new instrumentation becoming available, probably again leading to an increase of the amount and a widening of the scope of the proposals.

Readers familiar with the procedures adopted for the selection of HST proposals, may notice several similarities with the ESO system. Indeed, experience obtained with the HST proposal evaluation process has often helped to refine the procedures at the ESO OPC.

One difference is the more regular character of the process at ESO, which implies that panel members serve for several semesters, and hence only the composition of the OPC - not that of the sub-panels - is made public. A second, and major, difference is that the OPC recommends observing time for several telescopes. Even with the advent of the VLT, ESO has never deviated from its policy to organize its OPC panels according to scientific categories rather than implementing different panels for different telescopes. In this way also, the VLT is one 'Very Large Telescope' with complementary components and instrumentation!

In order to cope with the steady increase of projects and particularly of data, not only the OPC but also the community should respond positively to the challenge of accepting to evolve. The large-programme concept was designed to increase the efficiency with which the VLT could achieve the fundamental science issues for which it was built. Its success will also rely, however, on the capacity of the fairly dispersed ESO community to coordinate the expertise which exists in the member states. Some efforts are clearly needed to foster collaborations between institutes in the different countries, and the community is large enough to achieve this while maintaining a healthy competition.

In fact, collaborations on projects at ESO have been increasing steadily throughout the years, and single-institute proposals nowadays represent a small fraction of the total. A proposal is considered to be a 'non-member-state proposal' if more than 60% of the applicants are from non-member states. Such proposals are also treated by the OPC according to scientific merit only, and only when a 'competing member-state proposal of equal scientific merit' occurs does the ESO policy foresee to give preference to the latter. The allocation of observing time to the "Host State" proposals is regulated by the "Interpretative, Supplementary and Amending Agreement" to the 1963 Convention between the Government of Chile and ESO, signed on April 18, 1995.

A major way to involve the ESO community in the rich potential of the telescope park in Chile, is the OPC itself. Several experts, asked to join a panel, decline the offer because they fear the high workload. They are right that the workload is high, but by declining miss an opportunity to be part of a most inspiring process. There is no reserved time for OPC or panel members, but participating to the discussions is a unique way of enlarging one's scientific culture and is very helpful to learn how best use is made of the ESO instruments.

This way, the panel members can exert a positive feedback on the dynamism of research in their home institutes and contribute to inspire their colleagues in their home country. Since the panel system, involving much more than before the community in the evaluation process, was installed, the average quality of the proposals has been increasing significantly indeed.

By all means, it should be kept in mind that evaluation of research which still has to be carried out, remains an ambiguous issue. When the pressure on a telescope is high, an average panelist tends to be hesitant to recommend time to 'risky' proposals and prefers proposals of which the scientific outcome is more secure. Also, it is well known that proposals which get observing time, do so because of the high scientific level of the proposers, while unsuccessful applicants tend to blame the incompetence of the evaluators!

As a possible check on the quality of the work carried out by the OPC, it may be of some interest to revisit the ranking obtained by proposals which finally resulted in a *Nature* or a *Science* paper or in an ESO Press Release, even realizing that also these 'quality tests' are not watertight. It is encouraging to note that currently several of the large programmes rapidly passed these tests. When browsing through the ESO press releases on research carried out at the VLT, one remarks several projects the high value of which was anticipated with a top ranking, but also a few which ended close to the cut-off line. This should remind us that all human endeavors are flawed to some extent, for which we humbly apologize, and encourage the community to continue to exert its creativity!

References

1. Blaauw, A. (1991) ESO's Early History, European Southern Observatory, Garching
2. Breysacher J. (1988) The Observing Time Distribution in Major Ground-Based Observatories: A Complex Task, in *Coordination of Observational Projects in Astronomy*, eds. C. Jaschek & C. Sterken, Cambridge University Press, p. 211
3. Breysacher J. (1994) The New Observing Programmes Committee, *ESO Messenger* **75**, p. 43
4. Breysacher J., Andersen J. (1993) Proposal Statistics, *ESO Messenger* **74**, p. 30
5. Césarsky C., Breysacher J., Kudritzki R. (1994), Meeting on Key Programmes, *ESO Messenger* **75**, p. 45
6. Huber M.C.E., Breysacher J. (1986) The Work of the ESO Observing Programmes Committee, *ESO Messenger* **45**, p. 2
7. Waelkens C. (2000) The ESO Observing Programmes Committee – An Evolving Process, *ESO Messenger* **101**, p. 37
8. Westerlund B.E. (1982) The ESO Observing Programmes Committee, *ESO Messenger* **28**, p. 1

ASTRONOMICAL SOFTWARE STRATEGIES

KEITH SHORTRIDGE
Anglo-Australian Observatory
P.O. Box 296
Epping, NSW 1710, Australia
`ks@aaoepp.aao.gov.au`

Abstract. This chapter presents an overview of astronomical software development. It looks at the sort of software that is needed for astronomy, at how it is produced, and at how things have changed over the years. Rapid technological change has led software developers to attempt to design and build increasingly ambitious systems. As the complexity of systems increases, and as their production starts to involve international collaboration, so the way projects are managed has to change, and software developers have had to abandon some of their old habits and learn new styles of working.

1. Introduction

Technology changes the way people work. It changes things on a small scale, replacing blackboards with overhead projectors and overhead projectors with Powerpoint laptops. It also changes things on a large scale, first collecting individual researchers into small self-contained teams, then grouping small teams into international collaborations as the cost and scale of research projects increase.

This is true of astronomy in general, and it is also true of astronomical software development. Shepherds in fields abiding, staring at a night sky sparkling free of city lights, gave way to Renaissance thinkers peering through newly invented instruments and conceiving dangerous thoughts about the solar system. The instruments grew larger, and small private observatories emerged. Governments became interested in the commercial possibilities of reliable navigation, and observatories became national facilities. Now, technology's march forward has led to the modern observatory – a small bureaucracy with dozens of staff, backed up by attendant sub-

A. Heck (ed.), Organizations and Strategies in Astronomy II, 163–178.

bureaucracies such as boards of management and time-assignment panels that dole out observing time, on occasion to vast teams whose resulting papers have abstracts that are dwarfed by the list of authors.

None of this is, per se, a bad thing. Quite the opposite. But it has sociological consequences – the types of people who thrive in the new environment are not necessarily those who stood out in earlier times, and everyone has to work in different ways.

On a smaller scale, and in a shorter time, the role of astronomical software, and the way it is written, has also changed dramatically. This chapter presents a view of the astronomical software development process. It looks at how it has changed over the years, and how the various systems we use now have evolved. Some of what follows is, naturally, coloured by my own experiences and in places I may concentrate unduly on the systems I know best. I hope the reader will bear with this.

2. Computers in Astronomy

Originally, of course, software had no astronomical role at all. In the first half of the 20th century the only 'computers' found in an observatory were people performing tedious astrometric calculations. Even when computers as we know them came into astronomy in the 1950s their first application was to the automation of these same astrometric calculations.

Consider just how computers are used in astronomy.

Ask people what computers do and many will think of 'number-crunching', or of huge databases or of the error in their last bank statement. Someone with a home PC may think of computer games, or of surfing that swamp of information called the Web. Many observational astronomers will of course think of data reduction – which combines aspects of most of the above. Few people – other than instrumentalists – will think of the computer as a device to control equipment.

And yet a major use of computers in astronomy is to control instruments. Computers control telescopes, setting them accurately and tracking precisely. They provide the interface between the observer and the instrument. They link one instrument to other instruments and to the telescope. In many cases, an 'instrument' is itself a hierarchy of sub-systems – a spectrograph, an autoguider, a detector, perhaps.

Instruments have only been like this for a relatively short time, and it took a synergy between two (not entirely independent) developments to make this both possible and necessary.

The first was the development of the mini-computer. The mainframes of the '50s and early '60s were all very well, but you were hardly going to put them in an electronics lab or an observatory control room. But once computers could fit into a 19" rack, and once they were no longer out of the question as items in a funding application, the way was open for their use as instrument controllers. (A computer is after all, just a piece of electronics. Open one up and you see a jumble of electronic components and wires. It is a relatively simple matter to connect such a device and another piece of electronics, such as the control system for a detector or spectrograph.)

The other half of this was the increasing use of electronics for instrumentation. Control systems based on falling weights and detectors built around photographic emulsion are unlikely candidates for computer control. But once electronic control systems came into use there was a place in the middle for the computer. And once detectors began to produce data in electronic form – TV-based cameras on optical telescopes, CCDs, any radio receiver – computers became essential.

So electronic data needed electronic processing, electronic detectors needed electronic control. Enter the computer. And, tagging along with it, a necessary if awkward adjunct, enter the computer programmer.

3. Small Machines, Small Systems

Minicomputers and digitally recorded data brought an eruption of computing into astronomy in the early '70s. It became possible to control a telescope completely via a computer. The Anglo-Australian Telescope (AAT) had a control system that computed the distortion in the telescope structure as it moved around the sky and provided unprecedented pointing accuracy, setting the standard for later large telescopes (Straede and Wallace, 1976).

What were these computers like to program, and how was that programming organised? Here again, the technology drives the way one works.

The first draft of this chapter has been written with a pencil and paper, because that is how I happen to like to work. (Deep down, I do not like using computers.) The second draft, however, has been typed into a word processing program running on a relatively inexpensive home computer with a 180 MHz processor, 64 Mbytes of memory and 6 Gbytes of disk space – it is three years old and due for an upgrade. By comparison, the minicomputer used to control the AAT had a 4 Mhz processor, 64 Kbytes of memory, and 5 Mbytes of disk space. That is a thousandfold less memory – both disk space and RAM – and a far slower processor.

Writing software for these early systems was not a large-scale undertaking. This was partly a natural consequence of the limitations of the machines themselves, and it was partly the result of the generally immature state of astronomical software as a field of endeavour.

Programming as a discipline was relatively new; as a profession it was completely in its infancy, and its tools were both new and primitive. Arguably the first 'real' computer – ENIAC, completed in 1945 – had its logical functions under the control of a set of switches and dials; a 'program' was a list of switch settings that could take a couple of days to set up (McCartney, 1999). 'Stored-program' machines, where the program was held in a section of the computer memory (the so-called 'Von Neumann' architecture) had come in with the design for EDVAC, ENIAC's intended successor.

The stored programs consisted of machine code, instructions for the machine's processor encoded into the 0s and 1s to which computers are said to have reduced the world. Since they were data, they could be produced by other programs. The 'assembler', which took a symbolic textual expression of the program and created the equivalent machine code, emerged as the first program development tool.

Assembler programming is a vanishing art now, but in the mid-'60s it was the fundamental way to program minicomputers for control systems. It insists that you think the computer's way, far removed from the way the problem was originally posed. The continual progression towards 'higher-level' languages can be seen as a series of faltering steps towards a Nirvana where the problem to be solved can be written down in its most natural form (whatever that may be) and this form can be fed directly into a computer.

It used to be that from time to time computing pundits would predict the imminent demise of programming as an activity, on the grounds that advances in higher-level languages would soon enable the users to submit their problems in a natural form directly to the computer. This refrain is heard less often nowadays, for the perfectly simple reason that up until now it has always proven to be complete nonsense. (The cynical might wonder if programmers have a real interest in making themselves redundant. The generous might point to such things as high-level command languages, to high-level scripts written in IRAF CL or Glish as evidence that it has actually happened to some extent.)

The first dramatic step on this path had been taken in 1954, when IBM introduced FORTRAN, the first high-level language. Having this made it much easier to write the theoretical computations, data reduction sequences, and ephemeris calculations being run on the larger machines. By the mid-'70s, implementations of FORTRAN and other languages such as BASIC and FORTH were available for mini-computers. However, FORTRAN made heavy demands on the limited mini-computer memories, and was not a natural control language (it had no facilities to control hardware directly) which is why assembler was still a main part of the programmer's repertoire.

4. Software's Lone Rangers

Most programmers with long memories would say that the astronomical programming environment of those days was quite different to that of today. This is true for a number of reasons, not all of them directly technical in nature. Not completely different – operating systems were reasonably capable, high-level languages were available, as were most of today's peripherals such as disks, tapes, terminals.

But there were some obvious technical differences:

- Networking was almost unknown. All machines were stand-alone systems.
- Graphical displays were rudimentary – the graphical user interface was still 10 years in the future.
- Available memory was much smaller. 16-bit computers could only address up to 64 Kbytes of memory directly, and virtual memory was essentially unknown.

The effect of all these was to make for simple, stand-alone systems with simple, text-based, user interfaces.

There were sociological differences too, mainly reflecting the immature nature of the whole astronomical software endeavour. Very little code was portable between different machines, so there was little code sharing between programmers. It was, in any case, physically hard to send a program (which was usually a deck of cards, or a reel of tape) between distant machines. Observatories might have a small team of programmers; instrumentation groups at universities might have one or two graduate students who knew how to program; data reduction programs would be written by astronomers (or more likely, by their students) as one-off applications.

These were frontier days – perhaps not quite the lawless 'everyone for themselves' days of the TV western, but certainly days where programmers were on their own, often only answerable to themselves for the quality of what they produced, and with few rules to be followed. They were Lone Rangers.

The feeling that every program is a one-off production colours one's attitude considerably. Nobody else has had this precise problem to solve (this is often untrue, of course), and nobody else has had to solve it in this precise environment (this is more likely to be true), so you may as well just get down to it and solve it for yourself.

A mainframe computer might be something one had to queue up for at a computer center, but even a mini-computer was a scarce resource. These were usually single-user systems, and you often queued up for them too. Observatories would run booking systems for them.

International communications would be by telex, usually through some centralised office. (Standing by an organisation's telex machine reading the Director's messages was, however, more straightforward than hacking in to read their e-mail.)

So one operated in isolation, on problems one regarded as isolated, and solved these problems in an environment where 'any solution that worked was fine'. Software was only just developing good practices such as structured programming. The mini-computer programmers knew the execution time of each instruction (and knowing just how fast a `GO TO` instruction was coloured one's attitude to the structured programming directive that they should be avoided). They also operated in an environment where memory was at a premium. 64 Kb was not very big, even in those days, and programmers spent much more effort in trying to work around memory restrictions than on secondary questions such as portability of code, sharing of resources, use of common subroutine libraries and the like.

Consider one example: on the Interdata mini-computers used for the AAT, the standard FORTRAN formatted I/O library took up 8Kb. This was a major incentive to avoid its use. So a lot of people implemented their own quick, dirty, and above all small, equivalent routines. Why did not they get together and share them? Because there were not the mechanisms available to facilitate such sharing. In any case, each one would have been a purpose-built, tailored package that only solved a subset of the general problem. A program that solved the whole problem, that anyone could use, would probably have been as big as the standard library.

Memory limitations are much more severe than limitations imposed by processor speed. These old machines did not necessarily feel slow, even compared to modern ones, mainly because modern ones feel obliged to use all and more of the power available to do a job. In those days you entered text into an editor that could always keep up with your typing. Now, you type into a word processor that, as you type, corrects your spelling into US English and criticises your grammar. But sometimes it cannot keep up with your typing. (Later versions on still faster machines will maintain a database of your opinions from previous documents and will automatically replace "Of course, I have always held a high opinion of your work" with what you really think as expressed in an earlier e-mail to someone else. But I digress ...)

Data reduction of mainframes was often run in a 'compile, link, and go' mode, where you submitted a processing job that included the program source, usually on punched cards. Since you recompiled the program each time, one easy way to control the program's operation was just to change it each time. Instead of some interactive dialogue to control the program (impossible anyway, in a batch system), you could insert judiciously positioned

`GO TO` lines into the card deck to invoke or omit parts of the processing. I once saw a card deck where the control system involved reversing selected cards. One way round they had a `GO TO`; the other way around they started with a comment character and the card was ignored. It was very effective, but it was not a style that made for common-user, shared software.

Taking an instrument, developed perhaps at a university, to an observatory was done the obvious way. You took its control computer too. This represents, in a way, the ultimate in software transportability – you know it will run properly on the machine at the observatory, because that is the machine you developed it on and brought with you. This technique is still seen on occasion today, and still works well, as should be expected. (One has to be careful with the local mains voltage, or the machine will crash spectacularly, but operating system compatibility is not a problem.) What is a problem, of course, is that you end up with a stand-alone system that cannot communicate with the rest of the observatory systems. Sometimes that matters, sometimes it does not.

5. Larger Machines

In time, the computing environment changed under the feet of the software Lone Rangers. Arguably, there were two big changes; memory addressing, and networking. Memory addressing had a huge effect. It may not seem that dramatic – machines appeared that used 32 address bits instead of 16. However, this was a qualitative change, not just one of scale.

A 32-bit machine can address 4 Gigabytes of memory, as against 64 Kilobytes for a 16-bit machine. Even in the mid-'70s, 64 Kbytes imposed a constricting limit on the size of a program. A quarter of a century later, 32-bit addressing is still not a serious limit on the complexity of most programs – a gigabyte is still a huge amount of code. (It is, however, no longer a huge amount of data, which is why 64-bit machines will eventually take over. But although 64-bit machines are available now, there is no all-trampling rush to use them for everything. Not yet.)

Obviously, even now, very few 32-bit systems have 4 gigabytes of memory (or even the 2Gb that is the effective limit for machines that use half the address space for other purposes). But once the 16-bit address barrier was broken it became possible to implement virtual memory systems that gave the effect of having large amounts of real memory by switching data (or programs) in and out between disk and real memory as required.

Although 32-bit virtual memory machines removed a huge constraint on the design of programs, there had been a number of quite elaborate data reduction systems built on 16-bit machines. The AAT machines had SDRSYS, running on Interdata 70 machines. ESO had IHAP, running on

H-P systems. Groningen had GIPSY running on a PDP 11/70. The general structure of all these systems had a master control program running a series of individual applications as required by the user – splitting up a large amount of code into small units that a machine of this type could handle. The production of systems such as these required some coordination. Clearly, some of the Lone Rangers had been corralled, at least as far as data reduction software was concerned.

Nevertheless, it was the introduction of the 32-bit machines, particularly the DEC VAX 11/780 in 1978, that galvanised the data reduction software architects. The VAX was extremely successful, particularly in astronomy. Its ubiquity almost wrecked the concept of software portability – if everyone had VAXes, VAX-specific software was portable. (Similar arguments are occasionally used for both Windows and UNIX now; one should beware of them.) Fortunately, while most people ran DEC's VMS operating system on their VAXes, others ran the upstart UNIX system, thereby keeping portability as an issue.

With a VAX, there was little need to resort to assembler, and FORTRAN inefficiencies were relatively unimportant (the VAX had a very good optimising FORTRAN compiler), so it was reasonable to consider writing portable code – code written in a standard high-level language that would run on other machines as well. DEC, naturally, introduced a number of tempting extensions to their FORTRAN and seduced rash programmers into using them, just as one now finds Java programs that only run on Windows.

6. Enter the 'Environment'

It was now possible to think seriously about just what an ideal data reduction system would look like.

An interesting set of snapshots come from the series of data reduction conferences held in the Sicilian spring, at Erice, from 1984 to 1991. By the time of the first, in May 1984 (Di Gesu *et al.*, 1984), VAXes were well established and programmers had had a chance to get used to what they could do.

The question was, what did astronomers want them to do? Could a system be built that could cater for the different needs of all astronomers – those that wanted efficient pipeline processing of large data sets; those that wanted to experiment with different tentative algorithms on smaller amounts of data? How did you combine efficiency with flexibility? If you build a system out of a set of applications each implementing a relatively primitive operation (add two images, display an image, etc) and a command language of some sort, will people find the command language sufficiently powerful, or will they want the primitive applications aggregated into larger modules? If so, how will they interact with them? What about really esoteric schemes, such as manipulating data as icons, the way the newly-released Apple systems handled files?

Is it the role of the programmers to provide complete packages, ready-built to do everything the astronomer needs, or should they provide a structure in which astronomers could write their own programs?

These questions were important then, and remain important now.

Discussions centered around the concept of an 'environment' – what might nowadays be called a component software model. In this, there is a central core of software that provides the 'environment' in which the programs that does the real astronomical work (the 'applications') can run. The environment provides services that handle all the tasks common to most applications – starting them up, accessing data files in a standard format geared to astronomical needs, communication with the user, etc. Given such an environment, it should be easy to write an application. All the applications should work together, using the same data format, and they should present a uniform interface to the user.

As a minimal example, you can just use the native operating system provided by the computer as an environment. This is familiar (if you know the system) but applications are highly unlikely to run unchanged on other systems. It also led to a proliferation of incompatible data formats, whose only common denominator was the use of standard FORTRAN read and write facilities to produce them. At the other extreme, you can have an elaborate environment that provides, in a portable way, all the operating system facilities, including a programmable command language. You can even invent your own programming language, as IRAF did, in order to guarantee that all language features work identically on all machines. Applications written for such an environment are highly portable (which does not necessarily mean that it is trivial to port the environment itself to other systems – IRAF has not been ported to Windows, for example). However, until one becomes well practiced with the system, writing an application is an unfamiliar task.

A trap is that complex environments can represent a huge expenditure of high-quality software effort – effort that is therefore not available to write the applications programs, which ultimately are what matter. They also can be fun to write, particularly for computer scientists, which can be another trap. Because they introduce at least one additional layer of complexity, they can also introduce significant inefficiencies.

Many questions arose at that first meeting at Erice, which had panel discussions on such topics. The participants had some interesting experiences to draw on, with a number of new systems available or about to appear.

7. Developing Larger Systems

AIPS, developed at NRAO, Charlottesville, for radio data processing, and MIDAS, ESO's replacement for the 16-bit IHAP, were now well developed. Both had been developed centrally, at one location. In the UK, the STARLINK project had been set up from the start as a distributed system, a number of VAXes at scattered sites, linked by DECNET. For many, this was their first introduction to networked computers – copying data from remote machines, the joy of communicating via e-mail. Some (not all?) never looked back.

This provided the possibility of distributed software development, and an introduction to its pitfalls. From the beginning, STARLINK determined to produce a 'STARLINK' environment, for all the usual (and very valid) reasons. The center of this was to be a very flexible hierarchical data file system, HDS. STARLINK's programmers were scattered geographically from the start, and one lesson learned was that e-mail is a poor substitute for walking into the next office when something complicated has to be discussed. It is also particularly hard to corral cowboys when they work a long way away and are paid by someone else.

A major part of the STARLINK environment was written at a distance by talented people who were less concerned with efficiency than with elegant design principles. (In time, increasingly powerful systems rescue you from the inefficiencies and the elegance may be appreciated, but until then elegance tends to be invisible and inefficiency all to apparent.)

STARLINK, a victim of distributed, slightly undisciplined development and an ambitious, under-resourced design, found itself with a splendid file format and an environment that was slow and had few of the all-important applications.

Indeed, a crucial question is: who writes the applications? In the eighties, many astronomers, certainly their students, were reasonably competent FORTRAN programmers. Given an easy environment in which to write, they could produce applications suited to their own use, if not for use by others.

Astronomers are often puzzled by the time and effort astronomical software developers have to put in to writing an apparently simple program. Most of the answer can be found right at the start of 'The Mythical Man-Month' (Brooks, 1975), still one of the most interesting books on software development. Brooks looks at how long it takes to dash off a program for one's own use, then how long it takes to make it useful for a slightly more general case, and finally at how long it takes to produce a properly documented, reliable, general-purpose version of the program. The last requires, according to Brooks, about ten times the effort of the original program.

Astronomers frequently feel they have let an evil genie out of the lamp when they ask for a simple program. It is not enough that it do what they asked for: it suddenly needs to be written in an esoteric language (to be more portable, to interface with the environment); it needs to be made completely general and controlled through some parameter system; it has to allocate all data space on the fly (large arrays declared in programs are seriously unprofessional); it has to get the data from the standard file format via an exotic data access layer (and the original data files will have to be converted to the standard format); and of course, it has to test for every conceiveable error and one or two inconceiveable ones.

Standard subroutine libraries are another aspect of software sharing, on a much smaller scale than the big environment. A standard library is just a set of subroutines that together provide some commonly used facility. A good example is the PGPLOT graphics package written by Tim Pearson at Caltech. The astrometric routines written by Pat Wallace became available as SLALIB. The FITSIO package can be used to access data in FITS format. It is possible to put together a relatively straightforward program using code from such subroutine libraries. (There are also commercial subroutine libraries, such as the mathematical packages NAG and IMSL, which, although expensive, will often be available at large institutions.)

It can be argued that a big environment can be seen as just something that provides a set of such subroutine packages, and an application for such an environment is just some specialised code making a set of calls to such packages. The difference is that the libraries provided by such environments are designed to work together, and only within the environment – they often rely on internal aspects of the environment and on the presence of the other environment packages. If you try to use such a library in isolation, you become entangled in what Pat Wallace has called the 'big sticky lump syndrome' – to use one superficially attractive library, you end up needing most of the environment. By contrast, libraries such as PGPLOT are intended to work more or less in isolation. This is not always true; STARLINK's excellent HDS library used to be only loosely entangled with the STARLINK environment, and was used as the basis of my own FIGARO system, for example.

8. Data Acquisition Systems

As the '80s slipped into the '90s, AIPS established its hold on radio data reduction, MIDAS continued to be developed at ESO, and IRAF began to establish a dominant position in optical data reduction. Writing in the IRAF-specific application language required the negotiation of a significant learning curve, but there was a critical mass of applications available for use and it was well-supported. Although there were aspects to IRAF that one might dislike, it was there, it did the job, and that was what really mattered. STARLINK, interestingly, abandoned its ambitious environment, and after a proposal to adopt IRAF surprisingly failed to get general support, adopted the ADAM environment instead.

ADAM is interesting (not just because I was connected peripherally with its development), but because it was a data acquisition environment, not one designed for data reduction. It had the same basic concepts as the data reduction environments – that you built a system out of component applications – but in ADAM's case a component application usually controlled a particular piece of hardware (on a large scale, like a telescope or a detector or a spectrograph, not just a single mechanism like a shutter). And so, where a data reduction system might have component applications running sequentially, ADAM tasks ran in parallel, would usually need to communicate with one another, and were designed to be always ready to accept new commands and cancel old ones – unlike most data reduction applications which just start doing something and carry on regardless until they have finished.

ADAM was originally written for Perkin-Elmer 32-bit machines at RGO, but was substantially re-engineered at ROE to produce a VAX version. It was adopted by most of the UK-connected telescopes and was maintained on an ad hoc basis by various observatories loosely coordinated by ROE. Occasional 'ADAM workshops' were held for technical discussions. There was even an 'ADAM Management Committee' which held one meeting in Edinburgh, realised it had no power to manage an ad hoc development effort and took only one decision, to rename itself the 'ADAM Steering Committee'. Surprisingly, ADAM worked reasonably well, although working within its constraints was awkward for some of the cowboys.

In principle, running a straightforward data reduction application was nothing compared to what ADAM was designed to do, and using it for data reduction looked very attractive. In practice, there is a noticeable difference in emphasis between data acquisition and data reduction, and resources tend to be allocated to doing one side well at the expense of the other. Also, one generally wants data reduction systems to be regularly updated, while one wants data acquisition systems to be stable. This tended to lead to an observatory running a number of ADAM versions – you could not switch an existing instrument to a new version without a thorough test and that needed precious observing time, it being a well-known effect that bugs in observing software only come out at night when the skies are clear and the seeing is good.

9. UNIX on the Rise

The dominance of VAXes did not last far into the '90s. UNIX systems, relatively cheap and powerful, based on the new RISC processors, began to proliferate. At the same time, networking became universal, and the isolated computer was soon a thing of the past. For the first time, it became feasible to share software directly across continents, and this had a profound effect on software development collaborations.

IRAF, although highly portable, had always had its roots in UNIX, and the rush UNIX-wards merely emphasised its dominance, at least in the optical. MIDAS development continued, and it was used throughout Europe but made few inroads into the USA. AIPS continued in use, but was starting to show its age, and an elaborate development effort was started with the aim of producing a new system, AIPS++.

With UNIX, the dominant language moved from FORTRAN to the C that was UNIX's natural language (UNIX itself being written in C). The ousting of the VAX showed that portability really had been important.

ADAM, which had not been written with portability as a prime requirement, moved to UNIX, but diverged in the process. The UNIX port was undertaken by STARLINK, who naturally concentrated on the data reduction aspects. A complete reworking of the ADAM concept, in C and designed from the outset for networked systems, had been begun at AAO, and the new system, DRAMA, has replaced ADAM for data acquisition at many UK-connected observatories.

The series of meetings at Erice ended, but a new series under the ADASS banner (Astronomical Data Analysis Software and Systems) began on a yearly basis, the first being in 1991 at Tucson (Worrall *et al.*, 1992). Attending ADASS meetings regularly, sharing software through ever faster international networks, astronomical software developers have more contact than ever before, and yet are still working in a variety of different software environments.

10. The Current State of Play

All major observatories now base their data acquisition software around some sort of environment. The days of the stand-alone instrument are long gone. To get the most out of a telescope, instruments must now cooperate – they need to communicate with the telescope itself, often with some master scheduler, with the data archiving sub-system – and to do this they need to run within the observatory's environment. It is also the only way an observatory can impose some uniformity upon the software for a disparate set of instruments, and this is essential if they are to be maintained.

A number of the new 8-meter telescopes have moved away from the ADAM-type model where a hierarchy of relatively large tasks send commands and requests to one another. GEMINI, and to a lesser extent ESO, have adopted a database design, where database entries correspond to physical elements of the system, so the system state can be monitored by looking at the database, and changing a database value changes the state of the corresponding physical part of the system. These systems are usually layered, with a UNIX workstation handling user interaction and less time-critical tasks, while a real-time layer, generally a VME system running a real-time kernel such as VxWorks directly controls the instruments. Of course, this sort of inhomogeneous environment makes for inhomogeneous software, with implications for development and testing.

While optical observatories were developing their data acquisition environments, the radio observatories were combining for a new and ambitious project, AIPS++. AIPS++ was to be written as an object-oriented system, where a program is built up as a set of cooperating 'objects'; the behaviour of each software object encapsulates the behaviour of some logically distinct part of the overall system. The object-oriented programming language, C++, encourages programmers to carefully define the capabilities of each object – to specify its interfaces – and then its internal implementation is a matter for that object only and can be developed in isolation from the rest of the system. In principle, careful design is encouraged by C++, and pays dividends in maintainability and clarity of code.

AIPS++ was doubly ambitious, however, since it was to be developed by an international collaboration. Although networking had come a long way from the days of STARLINK's first effort in this direction, such ambition places huge demands on the management of the project, and AIPS++ has had its problems in this regard. Ultimately, complicated software projects, like all complex projects, need to be carefully planned and managed, and this is difficult in such collaborations, where people serve different masters with different priorities. Above all, it seems to be essential for designs to be agreed in the same room. (Get together to define the interfaces, go home to create the black-boxes that implement them.) International phone meetings help here (ESO makes considerable use of video-conferencing, another case where technology affects the way one works), but nothing seems to be able to replace regular live face to face contact, and it may be that the jumbo jet is the most important technological development of all.

So, now, we still have a disparate set of software environments. This may be a necessary thing. Computing is still evolving too fast for anyone to know the best way to do anything, and what is best now will soon be outdated. In these circumstances, new designs have to be tried, and inevitably they will overlap both existing designs and other, new and different designs being tried at the same time. We need to monitor general software developments too; the distributed object systems such as DCOM and CORBA have many similarities to the distributed data acquisition environments such as ADAM and DRAMA, and it may be that eventually these environments can be replaced by some standard system. Already, a number of new observatories, such as ALMA, are planning to use CORBA.

No matter what the underlying environment, one question remains, still not completely answered from when it was posed in Erice. Who will write the applications? Astronomers are generally keen to write data reduction code, but they need the environment to make it easy for them. We need to remember that astronomy graduates are probably not going to be experts in C++, or CORBA, or whatever. (FORTRAN is still used by astronomers, long after the software professionals have moved on to better things, and this sort of mismatch may increasingly represent a problem.) Similarly, while the observatories adopt complicated systems based on distributed databases, or DRAMA, or whatever, they are increasingly resorting to the use of external contractors to build their instruments. Such contractors are unlikely to be experts in the esoteric environments they will have to work in, and this is another potential mismatch. It takes a long time to become proficient in a new and complex system. It is hard to design an environment; it is hard to maintain it, and hard enough to document it in the necessary detail. It is even harder (and needs a different type of skill) to produce the sort of 'The XXX Environment for Idiots' books and training courses that are what new programmers need.

And finally, a reminder of one triumph for standards in astronomy. Data files are still being transmitted around the world using the FITS format, first specified in 1981. The original FITS paper (Wells *et al.*, 1981)[1] has a long discussion of word sizes and how they affect the choice of tape block size used. All of this is largely irrelevant to a FITS file sent across an Internet that was almost inconceiveable in 1981, but FITS has lasted. Good standards can last. We need more of them.

References

1. Brooks, F.P., *The Mythical Man-Month*, Addison-Wesley.
2. Di Gesu, V. Scarsi, L., Crane, P., Friedman, J.H., and Levialdi, S. (eds.) (1984), *Data Analysis in Astronomy*, Plenum Press.
3. McCartney, S. (1999), *ENIAC*, Walker and Company.
4. Straede, J.O. and Wallace, P.T. (1976), The Anglo-Australian 3.9-Meter Telescope: Software Controlled Slewing, Setting, and Tracking, *Publ. Astr. Soc. Pacific*, **88**, pp. 792-802.
5. Wells, D.C. (2000) The FITS Experience: Lessons Learned, in *Information Handling in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dodrecht, pp. 65-72

---

[1] See also Wells (2000). (Ed.)

6. Wells, D.C., Greisen, E.W., and Harten, R.H. (1981), FITS: A Flexible Image Transport System, *Astron. Astrophys. Suppl. Ser.*, **44**, pp. 363–370.
7. Worrall, D.M., Biemesderfer, C., and Barnes, J. (eds.) (1992), *Astronomical Data Analysis Software and Systems I*, A.S.P. Conf. Ser., **25**.

SCIENTOMETRICS: THE RESEARCH FIELD AND ITS JOURNAL

ANDRÁS SCHUBERT
Library
Hungarian Academy of Sciences
P.O. Box 1002
H-1245 Budapest, Hungary
`schuba@helka.iif.hu`

Abstract. After a brief overview of the aims, methods and directions of scientometrics, the research field, a quantitative introduction of its leading journal, *Scientometrics* is given. Statistical characteristics of its authors, co-authors, references and citations are used to reveal the structure and dynamics of the research community and the intellectual environment of the field. An outlook to the expected future challenges concludes the review.

1. Introduction

It is common understanding that the term "scientometrics" has been first used as a translation of the Russian word "naukometriya" (measurement of science) coined by Nalimov & Mulchenko (1969). The term gained a wider acquaintance for the public through the second edition of De Solla Price's "Science Since Babylon" (1975)[1].

It was, however, the launching of the journal *Scientometrics* [2] that persuaded all those concerned that a self-contained research field under this name really exists. Actually, the founder and present Editor-in-Chief of the journal, Tibor Braun, meant the journal to provide a common umbrella for

---

[1] See particularly the Postscript to Chapter 8.

[2] *Scientometrics – An International Journal for All Quantitative Aspects of the Science of Science and Science Policy*, ISSN 0138-9130, Vol. 1, No. 1, September 1978, Elsevier Science Publishing Co., Amsterdam and Akadémiai Kiadó, Budapest. Latest available issue (as of April 2001): *Scientometrics – An International Journal for All Quantitative Aspects of the Science of Science, Communication in Science and Science Policy*, Vol. 50, No. 3, March-April 2001, Kluwer Academic Publishers, Dordrecht and Akadémiai Kiadó, Budapest.

A. Heck (ed.), Organizations and Strategies in Astronomy II, 179–195.

all kinds of quantitative science studies – as it is stated to this very day in the subtitle of the journal. It seems, therefore, reasonable to give a joint overview of the research field and the journal if the developments of the past decades are considered.

As a researcher in the field of scientometrics for some 25 years and a member of the editorial staff of the journal *Scientometrics* for almost 20 years, I cannot guarantee an unbiased and objective overview. What I can offer is a concise formulation of my personal views on the aims, scope, directions and achievements of scientometrics and a collection of facts and figures about the journal. To counterbalance this partiality, please refer to Anderl (1993), Callon *et al.* (1993), Cronin & Atkins (2000), De Solla Price (1986), Glänzel & Schoepflin (1994), Schoepflin & Glänzel (2001), Van Raan (1988) and Wouters (1999) as a selected readings representing various views on the state-of-the-art both of the research field and the journal.

2. Fundamentals of scientometrics

2.1. DEFINITION

According to its name-giving parents, Nalimov and Mulchenko (1969), scientometrics comprises "those quantitative methods which are dealing with the analysis of science viewed as an information process". In my opinion, in spite of the numerous attempts of broadening or sharpening the formulation, this is the most pertinent and concise definition given ever since.

As a working definition in the editorial practice of the journal, scientometrics is considered the quantitative (mainly statistical) study of any measurable aspect of scientific activity (mainly those reflected in the scientific literature), with the aim of understanding and, if possible, improving its operating mechanism.

The only substantial addition in the latter definition is the reference to the purpose of the research, which has particular significance in distinguishing scientometrics from the very closely related fields of bibliometrics and informetrics. These latter two share both their subject and their methodology with scientometrics, but the main aim of bibliometrics is improving library and information services (Pritchard 1969), while informetrics has its main interest in pure theoretical and methodological issues (Egghe & Rousseau 1990). It should be stressed that there is no general consensus in the literature on the dividing lines between the different "metrics" fields; there is a significant overlap among them, even they are sometimes used almost as synonyms.

2.2. MAIN AREAS OF SCIENTOMETRIC RESEARCH

Scientometric research can be classified into subareas according to various criteria. The following classification seems to be a reasonable choice:

2.2.1. *Structural scientometrics.*

Its purpose is the mapping of the structure of scientific communities, sets of documents, cognitive ideas, etc. Its typical techniques are, among others, graph theory, network analysis, cluster analysis.

There are various options for establishing structural links among scientometric objects to be mapped.

Co-authorship connects researchers jointly authoring scientific works. An interesting example of co-authorship-based quantification is the Erdős-number (named after Paul Erdős, the late great Hungarian-born mathematician), which is defined to be one for the co-authors of Erdős (about 500 researchers from all over the world), two for the co-authors of his co-authors and so on. A rather comprehensive collection of Erdős-numbers can be found on the Internet [3].

Bibliographic coupling (Kessler 1963) relates documents sharing bibliographic references. Its basic assumption is that overlap in the reference lists reflects similarity in technical contents. Bibliographic coupling forms the theoretical background of the "related record" concept in the *Science Citation Index (SCI)* database (provided by the Institute for Scientific Information (ISI), Philadelphia, PA) and its successor, the ISI's *Web of Science.*

Co-citation (Small & Griffith 1974; Griffith *et al.* 1974) is, in a sense, the reverse of bibliographic coupling. Two documents are now connected if they appear together in the same reference list. Co-citation-based clustering was the basis of ISI's monumental venture: the *Atlas of Science.*

Co-occurrence of words in certain bibliographic units (title, keywords, abstracts, etc.), *i.e.* co-word links, have been extensively used by French researchers (see *e.g.* Callon *et al.* 1993) to build epistemological maps of science.

2.2.2. *Dynamic scientometrics.*

Its purpose is to describe the space-time behaviour of scientific information through scientometric objects (authors, publications, citations, etc.). Its typical methodological tools are ordinary and partial differential equations, stochastic models and computer simulations.

The prototype of dynamic scientometrics is the model of exponential and logistic growth of science in De Solla Price's classics (1975, 1986).

---

[3] `http://www.oakland.edu/grossman/erdoshp.html`

Another influential model was the epidemiological analogue by Goffmann & Newill (1964). The epidemic model patterns the transmission of ideas after the transmission of infectious diseases.

Not only the dynamics of the total population but also that of certain probability distributions defined on them *e.g.* productivity distribution of authors can be modelled (Schubert & Glänzel 1984) . Recently, attempts have been made to combine structural and dynamic scientometrics by studying the time evolution of scientometric networks with the aid of statistical physical models (Barabási *et al.* 2001).

2.2.3. *Evaluative scientometrics.*

Its purpose is to establish evaluative statements about participants of the endeavour called scientific research (geographic, institutional, etc. units, publishers, journals, groups and individuals).

Although evaluative scientometrics is just a narrow subarea of scientometrics, it provokes the most vehement debates, and has a definitive role in forming attitudes toward the whole research field.

Evaluative investigations (assessments) are performed on three levels:

- macro (countries, science fields);
- meso (institutes, "invisible colleges");
- micro (small groups, individuals).

It is generally understood that there is a certain kind of complementarity between reliability *versus* relevance as results of evaluative scientometrics on different levels are considered. Macro-level results are obviously the most reliable in statistical sense but their relevance is largely limited by the complete "impersonality" of the findings. Micro-level results are undoubtedly the most intriguing but they are usually based on samples statistically insufficient in size. This dichotomy is the main source of objections concerning the use of scientometric methods as evaluation tools in science policy and research management.

There is, of course, no magic device to resolve this dichotomy; the idiosyncratic warning is: use them but with extreme caution! Wise as it is, this advice is not really operative. A somewhat more followable guiding principle is: use scientometric methods as antidiagnostic tools, that is, not to detect signs or symptoms of disease (what would be the diagnostic use) but to detect signs or symptoms of health. In other words, scientometric (*i.e.* publication- or citation-based) merits are always worth being rewarded but the lack of them should, in itself, never be penalised.

2.3. PERSPECTIVES OF SCIENTOMETRICS

During the past decades, from the hobby of a few eccentrics, scientometrics turned to be (i) a legitimate area of scientific research, (ii) a regular element of national science policies, and (iii) a business venture. These three facets of the field have conflicting standards and interests. The future of scientometrics hinges on the ability and willingness of the scientometric community to resolve these conflicts.

3. Scientometrics: The journal

The journal *Scientometrics* was launched in 1978 as a joint venture of Elsevier Science Publishing Company, Amsterdam and Akadémiai Kiadó, Budapest.

Several of the most prominent members of the "invisible college" of scientometricians (G.M. Dobrov, E. Garfield, D. De Solla Price, M.J. Moravcsik) assumed honorary or active roles in the Editorial Board, but the motor of the new journal was the then Managing Editor (now Editor-in-Chief) Tibor Braun of the Library of the Hungarian Academy of Sciences, Budapest, Hungary. He and the Information Science and Scientometrics Research Unit (ISSRU) at the Library have made constant efforts to keep the journal in the forefront of research and development in scientometrics.

The material of practically all major international conferences in the field was published here, and several national issues related the world-wide developments (beside the US and the major European countries India and Latin America were represented, as well).

As a result, *Scientometrics* obtained and maintained a leading role not only in its immediate field but also in the broader field of Library and Information Science. As the representative communication channel of its field, it reflects the characteristic trends and patterns of the past decades in scientometric research, that is why this study – like several of its predecessors (Anderl 1993; Schubert & Maczelka 1993; Wouters 1999; Schoepflin & Glänzel 2001) – uses the journal as embodying model of scientometrics research.

3.1. SUMMARY STATISTICS

The statistical overview given in what follows is based on the first 50 volumes of the journal published between September 1978 and April 2001. Citations were retrieved from ISI's *Science Citation Index (SCI)*, *Social Science Citation Index (SSCI)* and *Web of Science (WoS)* databases for the period 1978-2000.

All *Scientometrics* articles, letters, notes, reviews and bibliographies were considered independently of their length, as well as other documents types provided that they were more than 2 pages long. Meeting abstracts, corrections, editorials, obituaries and other personal items were thus not considered.

A total of 1443 items were published written by 1223 authors from 60 countries. They contained 25200 references to about 16500 different items (the exact number is practically impossible to determine because of a certain number of incomplete or erroneous bibliographic data of the referred items). 1061 *Scientometrics* papers received 7242 citations in the 1978-2000 period (*i.e.* 382 papers remained uncited).

3.2. GEOGRAPHIC VIEW

As mentioned, authors from 60 countries contributed to the first 50 volumes of the journal (the authors' nationality was determined according to their institutional affiliation as given in the by-line of the publication). Fig. 1 presents a proportional map of the 29 countries with more than 8 papers. The area of the countries is proportional to the number of the publications while their relative position is intended to resemble to the natural topography.

It is striking at first sight that otherwise small countries like the Netherlands, Belgium and, most remarkably, Hungary (the birthplace and homeland of the journal) compete with the superpowers USA, England, Germany, France, Russia and India. A rather aborted Italy, and the completely absent Switzerland and the African continent are on the losing side.

3.3. THEMATIC VIEW

In their paper, Schoepflin & Glänzel (2001)classified the papers published in *Scientometrics* into six thematic categories, and studied the change in the weight of these categories by selecting three sample years: 1980, 1989 and 1997. The distribution of the papers over the categories is given in Table 1.

There are two obvious developments: an impressing and steady growth of case studies and methodology and the loss of position of articles on sociological and science policy issues.

3.4. AUTHORSHIP CHARACTERISTICS

3.4.1. *Author productivity.*

The 1223 authors contributing to the journal shared in 2443 authorships, that means almost exactly two papers per author. The productivity distri-

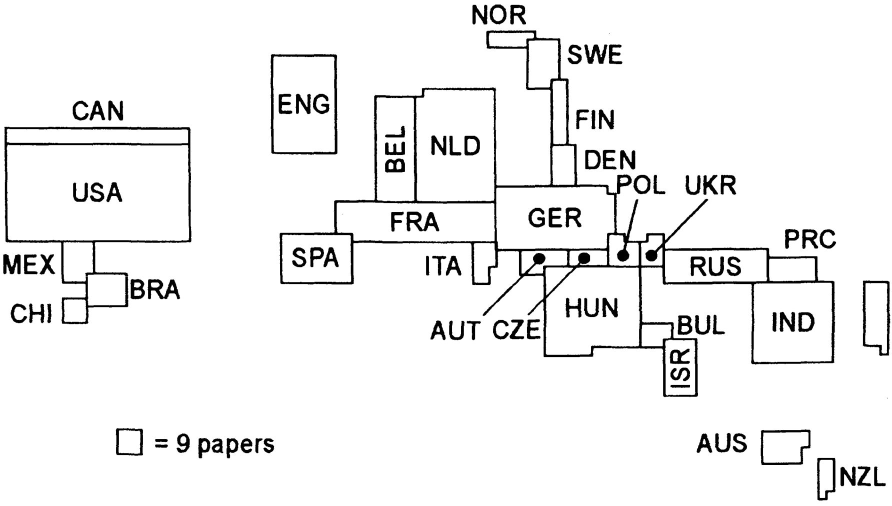


Figure 1. Proportional map of countries according to their publication activity in the journal *Scientometrics.*

TABLE 1. Thematic distribution of papers in the journal *Scientometrics.*

	1980	1989	1997
Total number of papers	31	67	75
Theory, mathematical models and formalisation	3.2%	9.0%	4.0%
Case studies and empirical papers	16.1%	31.3%	46.7%
Methodological papers including applications	19.4%	35.8%	33.3%
Indicator engineering and data presentation	6.5%	9.0%	1.3%
Sociological approach	16.1%	13.4%	8.0%
Science policy, science management	38.7%	1.5%	6.7%

bution, as usual, rather skew: 874 authors (71.5%) contributed one single paper each, while 26 authors (2.1%) published 10 or more papers. One or more of these highly productive authors were co-authors in about 1/3 of the papers published in the journal.

3.4.2. *Author turnover.*

One of the potential dangers of running a journal in a relatively narrow research field is the tapering of the author population, forming eventually a kind of inbred, clannish community. To check the situation in the journal *Scientometrics*, the annual share of newcomers (authors publishing their

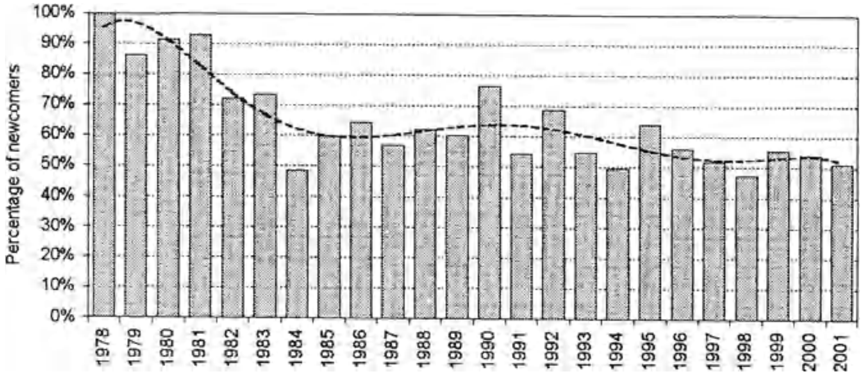


Figure 2. Percentage share of newcomers among the authors of the journal *Scientometrics* (dashed line: polynomial smoothed trendline).

first ever *Scientometrics* paper) in all authors in the given year is shown in Fig. 2.

Obviously, in the first few years most of the authors were "new". The emergence of a "new wave" of the early 90's came to a standstill by the second half of the decade, but even in the last few years, the share of newcomers is above 50%. The fears of loss of supply in active researchers in the field thus appear to be unfounded.

3.4.3. *Co-authorship characteristics.*

The ubiquitous trend of scientific collaboration does not avoid scientometrics, either. In this respect, however, scientometrics resembles rather to the social sciences (or, maybe, mathematics) than to the sciences: 55.1% of the papers published in the first 50 volumes of *Scientometrics* is single-authored and only 5.4% of them are multi-authored (more than three authors). The average number of authors per paper is 1.61. In the past decade, nevertheless, there is a slight tendency of growing collaboration.

International collaboration is even less favourised in the scientometrics community. There is a modest 7% of *Scientometrics* papers having more than one country in the authors' affiliation section in the by-line of the publication. Nevertheless, the tendency is unambiguous: the fraction of internationally co-authored papers more than doubled from the first to the second 25 volumes.

Fig. 3 presents the international co-authorship network of the journal indicating all co-authorship links between pairs of countries with more than one joint publication. No distinction has been made according to the strength of the links, since they are rather weak (representing typically 2-3 joint papers) and somewhat accidental. Yet, the diagram provides a

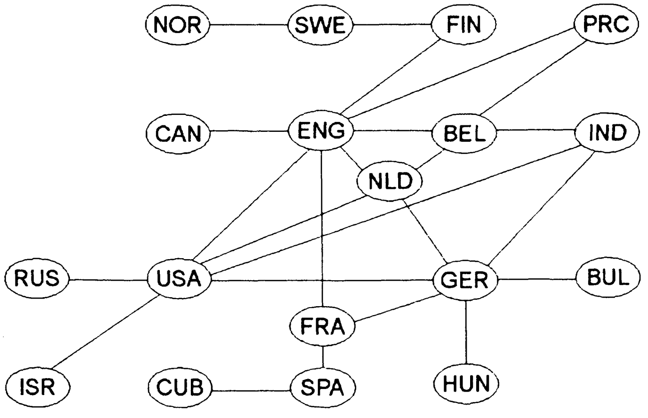


Figure 3. International co-authorship network of the journal *Scientometrics*.

surprisingly good picture on which countries are located in central (USA, England, Germany, France, the Netherlands, Belgium) and which in peripheral position.

3.5. ANALYSIS OF REFERENCES

The 25200 references of the papers form, as it were, the intellectual "hinterland" of research reported in *Scientometrics*. Clearly, they constitute a vast treasury of information about the history, sociology, epistemology of the field and its journal, and several attempts were made to make the most of this information (Schubert & Maczelka 1993; Wouters & Leydesdorff 1994; Schoepflin & Glänzel 2001).

3.5.1. *Age of references.*

The age of references reflect the up-to-date nature of the research reported in a paper. De Solla Price (1970) introduced an index, later named after him, with the aim of distinguishing between "harder" and "softer" sciences. The Price Index is defined as the percentage share of references to items not older than five years at the time of publishing the citing paper. Typical "soft science" journals (*German Review*, *American Literature*, *Studies in English Literature*, *Isis*, in Price's original study) have an index value less than 10%, while some research front physics journals may reach 80%. The Price Index of the journal *Scientometrics* is around 45%, *i.e.* it occupies a medium position on the hardness scale.

In a previous paper (Schubert & Maczelka 1993), it was conjectured that the Price Index of *Scientometrics* has an increasing tendency, thereby supporting the assumption that "the research field of scientometrics – as reflected in the journal of that name – has undergone a crystallization

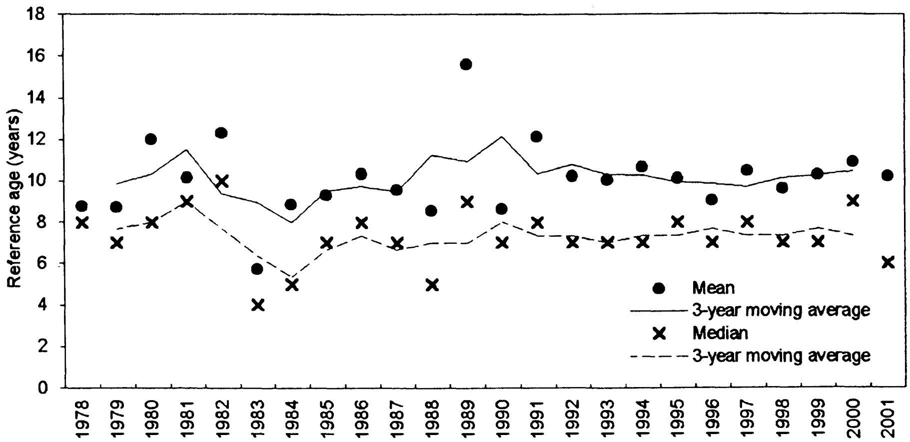


Figure 4. Mean and median reference age of the journal *Scientometrics.*

process, and moved from the 'soft' towards the 'harder' sciences" and "that the underlying research field is increasingly codified – although, in some aspects, it is still in a 'preparadigmatic' state." That study was based on the comparison of the reference patterns of the journal *Scientometrics* in two two-year periods: 1980-81 and 1990-91.

The validity of this argument (although by no means that of the main inferences) was later questioned (Wouters & Leydesdorff 1994) by showing that the two periods under study were just two random points in a strongly fluctuating series, where no definite tendency whatever can be uncovered. The validity of this criticism is hereby readily admitted with a penitential presentation in Fig. 4 the time series of two much more commonly used statistics, the mean and median reference age. Apparently, the hardening of scientometrics is still to be awaited.

3.5.2. *Sources of references.*

Almost half of the 25200 references (namely, 12137) were made to articles of 762 journals covered either by the SCI or the SSCI database of the ISI. About 2000 references were made to a similar number of non-SCI or SSCI journals, the rest to other reference sources (books, non-periodical literature, proceedings, reports, etc.).

3.5.3. *Most cited sources.*

The 15 most cited reference sources – SCI/SSCI-covered journals with the sole exception of Price's classic book – are given in Table 2. References to the journal itself (journal self-references) constitute 13.6% of all references – it is a typical value for a consolidated primary journal.

TABLE 2. Most cited reference sources in the journal *Scientometrics*.

Rank	Title	Times cited in Scientometrics
1	Scientometrics	3425
2	J. Am. Soc. Inform. Sci.	930
3	Soc. Stud. Sci.	616
4	Res. Policy	524
5	Science	488
6	J. Documentation	382
7	Nature	308
8	J. Inform. Sci.	288
9	Czech. J. Phys.	226
10	Current Contents	214
11	Am. Sociol. Rev.	185
12	Am. Psychol.	181
13	Inform. Proc. & Manag.	172
14	Little Science Big Science (Price)	167
15	Nauchno-tekhnicheskaya Informatsiya	156

3.5.4. *Most cited references.*

Table 3 lists the top 12 most cited references in the journal *Scientometrics*. Among the cited references, the weight of books becomes prevalent: 6 of the 12 most cited items are books.

TABLE 3. The most cited references in the journal *Scientometrics*.

Rank	First author	Publ. year	Source data	Times cited
1	Price D.D.	1963, 1986	Little Science Big Science	167
2	Garfield E.	1979	Citation Indexing	90
3	Schubert A.	1989	Scientometrics 16:3	77
4	Narin F.	1976	Evaluative Bibliometrics	66
5	Lotka A.J.	1926	J. Washington Academy 16:317	59
6	Callon M.	1986	Mapping the Dynamics of Science	56
7	Cole J.R.	1973	Social Stratification in Science	53
8	Martin B.R.	1983	Res. Policy 12:61	52
9	Price D.D.	1965	Science 149:510	51
10	Schubert A.	1986	Scientometrics 9:281	51
11	Kuhn T.S.	1962	Structure of Scientific Revolutions	49
12	Small H.	1974	Sci. Studies 4:17	46

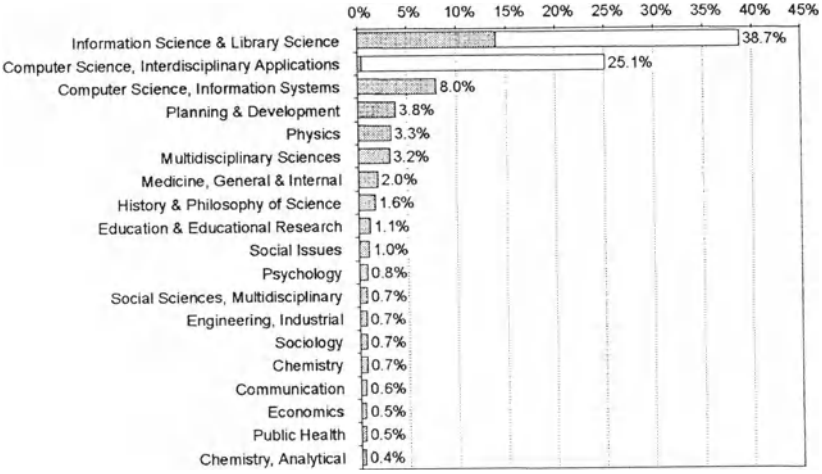


Figure 5. The subfield profile of references in the journal *Scientometrics.*

3.5.5. *Disciplinary distribution of references.*

The 12137 references to articles of journals covered by the ISI databases could be categorised into science/social science subfields according to the subfield categorisation of journals given by ISI. Papers in journals categorised into more than one subfields were evenly divided among the subfields in question. The subfield profile of Scientometrics references is shown in Fig. 5.

The journal *Scientometrics* itself is categorised into two subfields: Information Science & Library Science and Computer Science, Interdisciplinary Applications. The share of the journal's self-references is indicated by the unshaded part of the corresponding bars in the chart. It can be seen that Information Science & Library Science would remain the main source of information for the journal even if self-references were disregarded, while Computer Science, Interdisciplinary Applications would disappear from the chart without them.

Among science journals, those from broader-scope subfields (general physics, general chemistry, general medicine, multidisciplinary sciences) contribute the most to the reference base of *Scientometrics.* The presence of Analytical Chemistry among the top cited fields may be connected with the fact that this is the original and main profession of the Editor-in-Chief of the journal.

3.6. ANALYSIS OF CITATIONS

Just like the references cited in Scientometrics hinted on the information sources of the research reported there, the citations to the journal indicate the diffusion of the reported information into the literature. Citations were retrieved from ISI's SCI, SSCI and WoS databases for the period 1978-2000. No adjustment for author self-citations has been made.

3.6.1. *Sources of citations.*

Unlike in the case of references, we have no information about citations in journals not covered by the ISI databases or in non-journal sources. The 7242 citations were found in 442 journals. 182 of them cited *Scientometrics* only once; 47.3% of the citations are from the journal itself, another 28.6% from the other 14 journals in Table 4. The journal self-citation rate is rather high (47.3%), particularly if compared with the self-reference rate of 13.6%. It indicated that the "outside world" pays less attention to the journal than vice versa. This is particularly true for the high prestige journals like *Science* and *Nature* ranking only 50th and 26th in the citing journal list, respectively. There is, nevertheless, an inevitable similarity between the cited and citing journal lists (Tables 2 & 4), showing a consistent "core" journal network around the topic.

TABLE 4. Journals most frequently citing *Scientometrics*.

Rank	Title	Number of citations to *Scientometrics*
1	Scientometrics	3425
2	J. Am. Soc. Inform. Sci.	481
3	Res. Policy	253
4	Czech. J. Phys.	225
5	J. Inform. Sci.	218
6	Inform. Proc. & Manag.	141
7	Ann. Rev. Inform. Sci.	114
8	Current Contents	113
9	Soc. Stud. Sci.	92
10	Int. Forum Inform. Doc.	88
11	J. Documentation	77
12	Interciencia	75
13	Med. Clin. - Barcelona	67
14	J. Sci. Ind. Res. India	62
15	Libri	62

3.6.2. *Most cited papers.*

Scientometrics papers most frequently cited within the journal were included in Table 3. In order to complement them, Table 5 lists the top 12 *Scientometrics* papers cited most frequently in journals other than *Scientometrics.* It appears that the diffusion of the information is rather slow: only one of the top cited papers was published after Vol. 10, and not a single one in the second half of the 50 volumes.

TABLE 5. *Scientometrics* papers most frequently cited in other journals.

Rank	First author	Volume:page	Number of citations
1	Schubert A.	16:3	57
2	Garfield E.	1:359	56
3	Pavitt K.	7:77	50
4	Small H.	7:391	44
5	Small H.	1:445	42
6	Haitun S.D.	4:5	39
7	Small H.	8:321	39
8	Rushton J.P.	5:93	37
9	Haitun S.D.	4:89	35
10	Narin F.	7:369	33
11	Yablonsky A.I.	2:3	32
12	Beaver D.D.	1:65	29

3.6.3. *Disciplinary distribution of citations.*

Analogously to the subfield profile of references in Fig. 5, Fig. 6 shows the subfield profile of the 7242 citations. The unshaded area of the first two bars represents the journal self-citations.

4. Challenges of the 21th century

Undoubtedly, the greatest challenge – not only for scientometrics, but for the whole scientific publication system – is the advent of electronic publication and communication, in short, the Internet. Scientometrics, may I say, is multiply challenged, not only – similarly to all other areas of science and social science research – by getting somewhat confused about the most effective way of communicating its own results, but also by being compelled to properly describe, analyse and evaluate the new forms of communication in other science and social science fields.

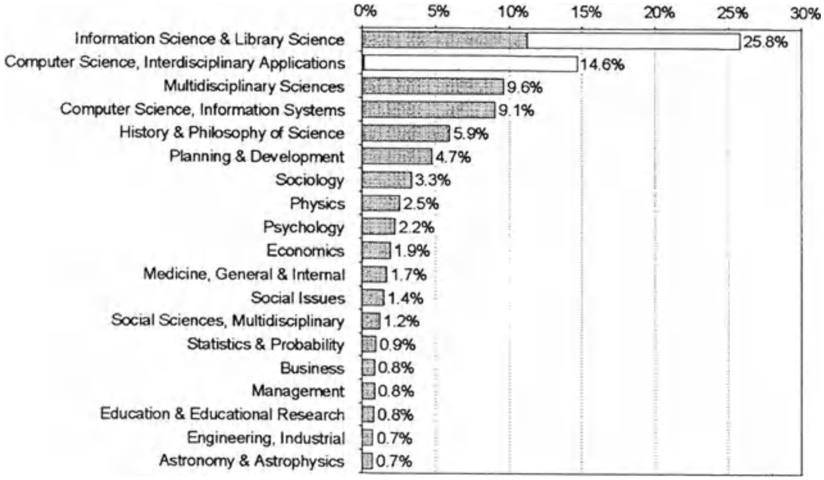


Figure 6. The subfield profile of citations to the journal *Scientometrics.*

As to the first part of the problem, the research community of scientometrics launched its own web-based fora: the electronic journal *Cybermetrics* [4] and the discussion forum *SIGMETRICS* [5].

Cybermetrics is both an electronic-only journal and a virtual forum devoted to the study of the quantitative analysis of scholarly and scientific communications. From 1997 the editors are organising a series of conferences to disseminate results from quantitative analysis of the Internet. *Cybermetrics* also maintains a series of directories of electronic resources, including secondary archives of interesting web papers in pdf format. The topics covered are the methodologies and results of scientometric, bibliometric or informetric research; emphasis is placed on aspects related to Internet. *Cybermetrics* is an international peer-reviewed journal published in English and distributed free-of-charge in the World-Wide Web by the Centro de Información y Documentación Cientfica (CINDOC) of the Consejo Superior de Investigaciones Científicas (CSIC) in Madrid, Spain. *Cybermetrics* is maintained by Isidro F. Aguillo.

SIGMETRICS is a listserv discussion group that covers bibliometrics, scientometrics and informetrics, but also metrics as related to the design and operation of digital libraries and other information systems interpreted broadly. The listserv also serves as the official "channel" for the American Society for Information Science Special Interest Group on Metrics. Bibliographic records, articles, web resources, and other news items of interest

---

[4] International Journal of Scientometrics, Informetrics and Bibliometrics, ISSN 1137-5019, `http://www.cindoc.csic.es/cybermetrics`

[5] `http://web.utk.edu/ gwhitney/sigmetrics.html`

are routinely forwarded to the list, at a rate of approximately 8-10 items per week as they become available. Bibliographic notes from established databases are included as relevant. As of 26 July 2000, *SIGMETRICS* was not moderated, and anyone can post to the list, whether subscribed or not. The listserv included 216 members, and representatives from 31 countries. *SIGMETRICS* is maintained by Gretchen Whitney, School of Information Sciences, University of Tennessee, Knoxville, TN, USA.

Various research findings and opinions on the whole Scientometrics–Internet relationship complex were compiled in a recent special issue of the journal *Scientometrics* [6].

Let me close this overview with Van Raan's conclusion (2001):

> "Bibliometrics and the Internet: Plus a change, plus c'est la mme chose. 'Real time' web-based reporting and commenting about research results will be not 'replacing' but an additional facility in the whole of scientific communication. A much more revolutionary change in science will be the increasing availability and sharing of research data, *i.e.* the emergence of a real-time web-based collective use of research materials."

References

1. Anderl, E.H. 1993, Scientometrics – Eine Zeitschrift als Spiegel einer Disziplin – Eine Inhaltsanalyse der wissenschaftlichen Fachzeitschrift Scientometrics für die Jahre 1978-1990, MA Dissertation, Univ. Vienna.
2. Barabási, A.L., Jeong, H., Néda, Z., Ravasz, E., Schubert, A. and Vicsek, T. 2001, Evolution of the Science Collaboration Network, submitted to *Physical Reviews E.*
3. Callon, M., Courtial, J.P. and Penan, H. 1993, La scientométrie, Presses Univ. France, Paris.
4. Cronin, B. and Atkins, H. (Eds) 2000, The Web of Knowledge – A Festschrift in Honor of Eugene Garfield, Information Today, Medford, NJ.
5. De Solla Price, D.J. 1963, Little Science, Big Science, Columbia Univ. Press, New York.
6. De Solla Price, D.J. 1970, Citation Measures of Hard Science, Soft Science, Technology and Non-Science, in *Communication among Scientists and Engineers*, Eds. C.E. Nelson & D.K. Pollak, Heat, Lexington, MA, pp. 1-12.
7. De Solla Price, D.J. 1975, Science Since Babylon, Yale Univ. Press, New Haven.
8. De Solla Price, D.J. 1986, Little Science, Big Science... and Beyond, Columbia Univ. Press, New York.
9. Egghe, L. and Rousseau, R. 1990, Introduction to Informetrics – Quantitative Methods in Library, Documentation and Information Science, Elsevier, Amsterdam.
10. Glänzel, W. and Schoepflin, U. 1994, Little Scientometrics, Big Scientometrics... and Beyond?, *Scientometrics* **30(2-3)**, 375-384. This discussion paper is followed by 29 commenting articles.
11. Goffman, W. and Newill, V.A. 1964, Generalization of Epidemic Theory – An Application to the Transmission of Ideas, *Nature* **204**, 225

[6] Scientometrics on the Internet – Internet in Scientometrics. Scientometrics 50(1) (2001) 3-98.

12. Griffith, B.C., Small, H.G., Stonehill, J.A. and Dey, S. 1974, The Structure of Scientific Literature II: Toward a Macro- and Micro-structure for Science, *Science Studies* **4**, 339-365.
13. Kessler, M.M. 1963, Bibliographic Coupling between Scientific Papers, *American Documentation* **14**, 10-25.
14. Nalimov, V.V. and Mulchenko, Z.M. 1969, Naukometriya – Izucheniye razvitiya nauki kak informatsionnogo protsessa, Nauka, Moscow – English translation (1971): Scientometrics – Studying Science as an Information Process, US Air Force Systems Command, Foreign Technology Division, Washington DC.
15. Pritchard, A. 1969, Statistical Bibliography or Bibliometrics?, *Journal of Documentation* **24**, 348-349.
16. Schoepflin, U. and Glänzel, W. 2001, Two Decades of Scientometrics – An Interdisciplinary Field Represented by Its Leading Journal, *Scientometrics* **50(2)**, 301-312.
17. Schubert, A. and Glänzel, W. 1984, A Dynamic Look at a Class of Skew Distributions – A Model with Scientometric Applications, *Scientometrics* **6(3)**, 149-167.
18. Schubert, A. and Maczelka, H. 1993, Cognitive Changes in Scientometrics during the 1980's, as Reflected by the Reference Patterns of Its Core Journal, *Social Studies of Science* **23**, 571-582.
19. Small, H.G. and Griffith, B.C. 1974, The Structure of Scientific Literature I: Identifying and Graphing Specialties, *Science Studies* **4**, 17-40.
20. Van Raan, A.F.J. (Ed.) 1988, Handbook of Quantitative Studies of Science and Technology, North Holland, Amsterdam.
21. Van Raan, A.F.J. 2001, Bibliometrics and Internet: Some Observations and Expectations, *Scientometrics* **50**, 59-63.
22. Wouters, P. 1999, The Citation Culture, PhD Dissertation, Univ. Amsterdam (Particularly, Chapter 7: Scientometrics).
23. Wouters, P. and Leydesdorff L. 1994, Has Price's Dream Come True? Is Scientometrics a Hard Science?, *Scientometrics* **31**, 193-222.

COMMENTS ON REFEREEING

HELMUT A. ABT
Kitt Peak National Observatory
P.O. Box 26732
Tucson, AZ 85726-6732, USA
`abt@noao.edu`

Abstract. On the basis of 29 years of editorial experience, I suggest ways of confronting refereeing problems that seem fair to the authors, and that produce efficiently a reliable and clear publication. The purposes for reviewing manuscripts and the need to do so are given. The advantages and disadvantages of the two refereeing systems (parallel and series) are presented. Policies for selecting referees, their qualifications, how long to wait for reports, how to handle controversial manuscripts, and whether the referees should be open or anonymous are explained.

1. Introduction

In 29 years (1971-2000) of being Managing Editor and Editor-in-Chief of the *Astrophysical Journal*, I have overseen, or witnessed associate editors oversee, the review of thousands of manuscripts. I would like to share some of our experiences in hopes that it will help other editors to consider, at least, various approaches. I cannot claim that these techniques are the best for all situations and are the only ones that work, but through some trial and error, we settled on the general policies given below. Doubtless each reviewing situation is slightly different or has a different mix of conditions, so policies may necessarily vary somewhat for different situations.

The goal of refereeing is to produce the most-accurate and worthwhile publication that is fair to the authors and user-friendly to the readers, produced economically with the well-recognized help of associate editors, referees, and the editorial staff. The reviewing need not be confrontational; rather because we all aim for the prompt and accurate publication of important scientific results, we work together to achieve that goal. We strive to

A. Heck (ed.), Organizations and Strategies in Astronomy II, 197–205.

have all the participants satisfied with the final product and the procedures needed to obtain that.

There have often been questions raised about whether refereeing is necessary, how thorough it should be, whether referees should be identified to the authors, how controversial papers should be handled, etc. I will try to comment on each of those and other questions.

2. The purposes of refereeing

The reasons for reviewing a manuscript are:

1. To help determine whether a manuscript has sufficient content to justify its publication,
2. To find and correct obvious errors,
3. To learn if important elements are missing, such as pertinent information, references and relevant data,
4. To ensure that the presentation is clear to the readers, especially to those who normally speak other languages, and that the authors' scientific intentions are understood, and
5. To find out if there is controversial or antagonistic material in the manuscript.

The first purpose is the most subjective one. It is especially important for those journals and books, often in the social sciences, whose acceptance rates are only 10-20%. In the physical sciences most papers are eventually accepted (the acceptance rates tend to be 70-90%) unless the referees can show that the content is scientifically wrong or misleading or if the results are not new or substantial. In most journals the referees advise the editor and the editor makes the final choices. But just as in other aspects of the scientific method, the reasons for acceptance or rejection should be clear to the authors and referees.

With regard to errors, the editor, referees, and editorial staff try to minimize them, but some one said that a book had never been published that did not contain some errors. The referees and editor are responsible for discovering the scientific errors; the editorial staff is concerned with the grammatical, spelling, and formatting errors because those staff members are usually not scientists. We should not expect the referees to discover the grammatical errors, insofar as they do not affect the scientific logic; their time is better spent on a study of the scientific content.

However, scientific papers, even in the most-respected journals, should not be trusted to be completely error-free, if for no other reasons than that in the months between acceptance and publication, some parts of the papers may have become obsolete. Every scientist should always be skeptical of what he reads. I have often found that ideas for new research projects occur when I read and question whether the stated results seem consistent with what I have previously learned.

With the recent growth in the scientific literature it has become nearly impossible to read or even become aware of all of the many papers related to our work. People entering a field, or those changing fields, have even a harder time absorbing the huge literature of the past. We will have to rely in part upon search engines, although they remain imperfect and misleading. Therefore the role of the experienced referee, who can point out omissions, is becoming increasingly important. Nearly all referees mention possible pertinent papers and data that might be added to a manuscript. In fact, there are currently as many referee requests to add material as there are requests to shorten text.

Regarding the need for a clearly-worded text, this has become increasingly important as the authors and readers come from scores of different countries. Many authors writing in English are not using their native languages and we must admire their fortitude in doing so. It is important to warn English-speaking authors not to use English slang; all authors should not use excessive acronyms and specialized vocabulary, even though some slang expressions can convey our intentions better or "hit the nail on the head". Authors, referees, editors, and editorial staffs all need to work to ensure clarity. If an expression is used only a few times in a paper, its acronym slows the reading while saving very little space.

Regarding the fifth purpose, the referees should alert the editor and authors about criticisms or controversial statements. For instance, it is alright to say "our results do not agree with those of Jones (1995)". But if the authors say "the results of Jones (1995) are wrong", the editor must give Jones the opportunity to defend his work. The method used will be discussed in Sect. 7.

3. The ideal referee

The ideal referee is one who is currently working in the specific area of the manuscript in question and using the same techniques. An observational paper is not expected to provide theoretical insight; such a paper usually should not be reviewed by a theoretician. Similarly, one cannot expect a optical astronomer to be an ideal reviewer of a paper in radio astronomy. People who have worked in the area of the manuscript years ago may not be familiar with the recent literature, so editors should consult a current researcher in the field of the manuscript.

Further, there are some fields that have developed differing points of view. The ideal referee should be a neutral person, or one who does not have a strong adherence to one of the viewpoints or "camps."

The referees and authors should usually be members of the same population, namely currently active researchers. This means that the referee may not be much more experienced than the authors. There are no "Popes" in science whose judgments are invariably regarded as the right ones. This also means that the referee is not always infallible. In the reviewing, the authors and referee should each strive to convince each other by scientific logic and evidence. If that does not succeed in some cases, the editor should consult another referee for arbitration unless he happens to have enough experience in the area of the manuscript to do the arbitration himself. However, arbitration takes much time, and the editor may not want to take the time, even if he/she has the knowledge.

Because the referees and authors are members of the same population, they each can expect to be called upon to review roughly one manuscript for each one they submit. That has the advantage that the authors benefits by having their papers corrected and improved, so that they morally can expect to do the same for other papers. Of course students are usually not expected to be referees, so the practicing scientists will have a little larger share of the reviewing. Strongly-biased referees may be called upon less frequently.

Experienced referees have found that criticisms are more readily accepted by authors if they follow some compliments, *e.g.* "the authors have accumulated some excellent observations that will be of great value in future studies, but I have some questions about their interpretations ...". Criticisms should never be personal, *e.g.* never say, "the authors are stupid to think....", but rather say "I have serious questions about ...". Editors should watch for violations of politeness and statements that can cause resentments.

4. Two refereeing approaches

There are two methods that editors may use:

1. *Parallel reviewing.* This involves two or more referees working simultaneously but independently. The editor reads both reports and sends one or two consistent reports to the authors for their consideration.
2. *Series reviewing.* Only one referee reviews the manuscript at one time. If the authors and referee do not come to an agreement after a reasonable set of exchanges, the editor consults a second referee, often for arbitration.

Parallel reviewing gives the most thorough reviewing, but:

1. it means roughly double the work for the scientific community because a scientist can expect to review two manuscripts for each one that he/she writes;

2. it is much more work for the editor because the two reports will usually be partly inconsistent and he has to decide which parts of the two reports to transmit to the authors, *e.g.* one may ask for more information while the second may complain that the manuscript is too long; if the editor is not an expert in the field of the manuscript, he will have to ask a third referee to arbitrate the differences;
3. each review will usually take longer since it will depend upon the reviewing time by the slowest referee plus the editor's deliberation time.

Series reviewing works well if good referees are selected. If not, a substandard paper can slip through. The editor must understand the manuscript or he/she should delegate the manuscript to another editor who understands the field well enough to select the right referees. In our complex science it is apparent that many, not just one or two, editors should oversee the reviewing because few of us understand many subfields.

After how many reviews should an editor give up on a referee and consult a second one? Sometimes it is apparent after one report and one reply that the authors and referee will never come to an agreement. Typically it takes two cycles before it is obvious that there is an impasse. Some referees may be biased, perhaps subconsciously, and they will not admit that. Every set of authors deserve a hearing by a neutral expert.

5. Reviewing times

About 20 years ago (Abt 1987) the average reviewing time was 28 days for a normal paper. Very long papers might take longer while Letters manuscripts took about 14 days. Now many manuscripts, referee reports, and replies are transmitted between authors, editors, referees, and the publishers by Internet so the long postal times are avoided. Nevertheless the reviewing times have not decreased because astronomers have ever-increasing demands on their time, and they find it harder to find the many hours to devote to a review.

If a referee has not sent a report in 60 days despite reminders from the editor and promises by the referee, the editor should give up. In consulting a second referee he should mention the delay by a previous referee in hopes that the second will act more quickly than normal. The editor can thank the first referee and express understanding that he may be unusually busy, or he can say nothing at that time. In the latter case the editor might wait to see which referee sends a report first. If the first referee does comes through, the editor can phone or e-mail the second that a report is not needed from him/her. If both referees produce reports at the same time, he can use both reports.

It is important to maintain excellent relations with the referees by (1) always being polite and understanding, (2) express gratitude for their work, whether the editor thinks that the reports are good or mediocre, (3) not overwork individuals, even if certain ones invariably produce excellent and prompt reports. We found that almost all referees appreciate personal pertinent notes, which may take only a few minutes for the editors to write, rather than a form letter, card, or recognition in an annual list of referees. After all, if a referee takes, for example, six hours to review a manuscript, the editor can spend 10 minutes to thank him/her.

Regarding frequency, the *ApJ* has a policy to not send a new manuscript to a referee for review within two months of the previous one, except for revised papers, and not to consult a person more than four times per year. The *ApJ Letters* consults a person not more than once a year. Needless to say, editors should reserve the best referees for the most important papers.

6. Acceptance rates

It sometimes surprises people to learn that for astronomical journals the final acceptance rates are 85-90% (Abt 1988). It is that high for two reasons. One was given above in Sect. 2, namely that a referee must produce reasons for rejection, rather than a subjective evaluation that a manuscript is not as good as some others. The second is that there are few journals in astronomy, so that submitting a manuscript to another journal, rather than revising it to satisfy the referee and editor, is not always an option. I was told by another editor that in medicine, where there are scores of suitable journals, each author has mentally ordered those in a hierarchy and, after assessing his own manuscript, will submit it to the highest journal in that list that might accept it. Because of their low acceptance rates, the manuscript will usually be rejected. Then he submits the same version of the manuscript to the next journal in the list. Only after receiving three rejections does he revise it.

For the *ApJ* only about 5% of the submitted manuscripts are accepted after one review. Another 85% are accepted after one or more revisions; 10% are never accepted. Some of those are published elsewhere (Abt 1988).

Because the referee is not always initially right – I have seen many cases where the authors convince the referee to change his initial objections – most negative referee reports are not accompanied by a letter of rejection. The editor does not need to take a stand after the first or second report, but simply to send the report for his "consideration". If the authors can satisfy the referee's objections, fine. If they wants to disagree with the referee, that is their right. However, the editor should not send a referee more than two replies regarding a manuscript that disagree with the referee. Some referees get tired of the dialogue and simply give in against their better judgment. The author should have the right to disagree once with major aspects of a referee's report and, if the editor feels that the scientific dialogue is still productive, he may allow a second reply that disagrees. But after two, an arbitrator should be consulted.

People do not like to admit that they have made a mistake, so that if they receive a negative referee's report and realize that they cannot rebut it, they will simply put the manuscript in a lower drawer and never reply. That is alright, except that it leaves the editor wondering whether a revision will be submitted at a later time; his files will become filled with possibly-inactive manuscripts. Our record time for a resubmission, not after a negative report but a generally positive one, was 11 years. But the editor's inconvenience of having a filled file (in the days of computer storage this is less bothersome) is more than overcome by his politeness in not forcing the authors to admit that their manuscripts are inferior.

7. Controversial manuscripts

How should an editor handle a manuscript that states that a published paper is wrong? No one would like to read in a journal a criticism of his published work without having been alerted in advance. Also, many critical manuscripts are wrong because the authors misunderstood what was published or they use the results in inappropriate ways.

A person whose published (or unpublished) work is being criticized in a new manuscript should receive a copy of that manuscript first for his comments to allow him to defend his own work. Then his comments should be sent to the author of the criticism for his reply, which should be shared with the person being criticized. Finally, the new manuscript, comments from the person whose work is being criticized, and the author's response should be sent to a neutral referee for reviewing. The person being criticized should be shown all the reports and responses, but after his first reply, he should not necessarily be allowed to intervene in the further exchanges.

This process takes longer, but it most cases it avoids later manuscripts that continue to argue the points of disagreement. Most of those disagreements should be resolved in the initial exchanges between the two authors, neutral referee, and editor. Some journals publish the response of the person being criticized, but I have rarely found that to be useful.

8. Compensation for the referees?

The referee often spends much time in reviewing a manuscript – sometimes several days of work. Should he be compensated for that work? That does not seen necessary because other referees have helped him in similar ways in improving his own papers. About 95% of the published papers have been revised in major or minor ways, so it is fairly safe to assume that the referee has already benefited from this system.

9. Is reviewing necessary?

Of course editors receive obviously inferior manuscripts, sometimes called "crank" papers, and those are returned to the authors without external reviews but with polite letters from the editor explaining the main objections to the manuscripts. For instance, non-scientists often do not understand that every definite statement made in a paper must follow from previous ones in a clear and logical way or be substantiated by a reference to published results; non-scientists sometimes mistakenly think that dogmatic statements alone will suffice.

But should manuscripts that are written by experienced scientists and that the editor does not recognize immediately as being flawed be accepted for publication without review? The fact that 95% of the published manuscripts have been revised in major or minor ways demonstrates that reviewing is necessary in producing a fairly reliable journal.

That then raises the question of whether censorship occurs in scientific publication. Of course there are some biased or dogmatic referees and even editors; we cannot deny that humans are fallible. We all know of famous papers that were initially rejected or heavily revised against the wishes of the authors. I think that we are more sensitive today than in the past about the rights of authors. The referees are expected to produce substantial or quantitative objections to acceptance, or the paper is accepted. Sometimes it is recognized that to produce such evidence against the author's conclusions may be a research project in itself and therefore too much to expect the referee to do at that time. An honest referee will say, "I do not believe that the author's result is true, but I cannot prove that, so he should be allowed to publish his evidence". Also an editor should be patient with such papers in allowing more than the normal number of reviews by multiple referees and resubmissions if their material present unconventional viewpoints on seemingly important matters.

10. Should all referees be identified to the authors?

In the small society of astronomy most individuals may be asked to review grant proposals, make recommendations for new positions or promotions or committee memberships, make recommendations for prizes and honors, etc. Most of those requests are confidential. Therefore if a referee finds it necessary to recommend rejection of a paper or major revisions, some less-ethical authors may retaliate against an identified referee by secretly recommending against the referee's grant proposal, promotion, etc. Sadly not all of us are objective. I therefore recommend that younger astronomers not routinely identify themselves, but that senior astronomers who are no longer seeking promotions and whose reputations are not easily blackballed be open. An open relationship often allows the more-efficient direct discussions between authors and referees. But the choice as to whether the reviewing is open or secret should be the referee's; only they can guess whether openness may place them in a vulnerable position.

I have provided suggestions on how to handle various reviewing procedures. They seem to be fair to the authors, whose whole careers sometimes depend upon the publication of their papers, yet maintain a quality journal. Editors should never be capricious, biased, stubborn except in maintaining high standards, secretive, impatient, or prone to temper flares. Are there such people? Fortunately there are some who are nearly ideal.

References

1. Abt, H.A. 1987, *Publ. Astron. Soc. Pacific* **99**, 1329
2. Abt, H.A. 1988, *Publ. Astron. Soc. Pacific* **100**, 506

COMMUNICATING AND NETWORKING IN ASTRONOMY LIBRARIES

UTA GROTHKOPF
European Southern Observatory
Karl-Schwarzschild-Straße 2
D-85748 Garching, Germany
`esolib@eso.org`

AND

MARLENE CUMMINS
University of Toronto
Astronomy Library
60 St. George Street
Toronto, ON M5S 3H8, Canada
`library@astro.utoronto.ca`

Abstract. This chapter reviews communication strategies applied in contemporary astronomy libraries. It focusses on contacts of individual librarians with colleagues, library users and publishers, as opposed to more formal methods of communication. While the most appropriate strategy may vary according to the librarian's function and role within an organization, communicating and networking among astronomy librarians in general is excellent and has led to numerous cooperative projects during the past two decades. We describe successes, problems, and trends around the world as well as barriers to effective communication. Some comparisons are made between developing and developed countries.

1. Introduction

An important part of the librarians' mission is to keep their users informed about suitable information resources. By nature, this requires that the librarian herself be well-informed about what is available and what potential value lies in a resource. In our rapidly growing world of information resources, one person alone will not succeed in obtaining knowledge of all available products, all services that may be needed by our users, or on

A. Heck (ed.), Organizations and Strategies in Astronomy II, 207–219.

the entire range of options we can offer. Communication among fellow librarians therefore is critical in carrying out librarians' professional duties. Participating in mailing lists, attending conferences and other continuing education events, and discussing issues with library users as well as with publishers and vendors are all important activities for staying informed about latest developments.

Personal communication with colleagues, be it through electronic or traditional methods, is also vital. Astronomy libraries often are small entities; a solo librarian at an observatory library or at a geographically remote university institute is a common situation. In somewhat isolated settings that don't lend themselves to regular personal encounters with colleagues it is even more important to stay in close contact with fellow librarians through all available means. Fortunately, distance can be bridged far easier than previously in this era of electronic mail.

In the following, we look at various forms of communication and review their advantages, disadvantages and possible positive outcomes.

2. Survey methodology

When contemplating this chapter on communicating, it was felt that a survey of astronomy librarians would be useful in assessing problems, successes and trends around the world. The focus was on communications of individual astronomy librarians with their colleagues, their library users and publishers, as opposed to formal communication through publications, professional development courses, resource sharing projects etc.

The survey was done completely by e-mail and circulated in a focused manner. In January 2001 it was posted to three electronic discussion lists where we knew that astronomy librarians were concentrated: Astrolib, PAMnet and PAM-APF (addresses and contact persons see below).

We received a total of 69 responses from 24 countries; with the exception of the USA (33 replies) 1-4 responses came from each country. It is difficult to assess our response rate. One way is to look at the number of subscribers to "Astrolib", a highly specialized electronic distribution list. There are currently 216 subscribers to that list. Making the rash assumption that the list represents all astronomy librarians (it certainly represents most astronomy librarians) our 69 responses represent a rate of 32%.

There are several caveats to the results of the survey. The fact that it was done only by e-mail filters out those who do not readily communicate that way and therefore biases the results towards e-mail. This bias can be discounted to some extent in consideration of the large response we got and the degree to which e-mail was favoured. The large number of countries (24) represented in the responses also ameliorates concerns about bias.

The narrow focus of our target group might bias the results, for example towards specialized astronomy libraries and away from science libraries at universities which nevertheless support astronomy. However, 19 of the 69 responses came from librarians at university libraries covering two or more disciplines. At 27.5%, this is a respectable percentage of the whole.

It is interesting to note that within 24 hours we had almost half of the final tally of respondents. But we received responses up to more than six weeks later.

For the purposes of some of our analyses, countries were grouped into developed and developing regions: USA, Canada, West Europe, Australia, New Zealand on the one hand (55 responses), and Mexico, South America, East Europe, Asia, Russia (14 responses) on the other. These categories are in some respects arbitrary and provide only a gross indication of the differences.

In any case, the survey was not based on proper sampling techniques. The results should be seen as indicating trends, not absolute states-of affairs.

3. Communicating among astronomy librarians

Astronomy librarians are a well-connected group, and colleagues from other disciplines often are surprised at how close our cooperation is. The main reason is that the number of astronomy librarians worldwide is rather small, and many colleagues know each other personally. This helps immensely to start and maintain good working relationships, and to coordinate actions. In this limited group, a few active players are sufficient to develop a strong network for the exchange of information, to set up joint efforts in order to provide better service to our users, and to launch innovative projects.

The most obvious method of interaction is direct communication between two or a few colleagues; 31% of the survey respondents stated that they communicate daily or several times per week with other astronomy librarians, 40% a few times per month, 23% a few times per year, 6% never. In addition, astronomy librarians are also in contact with non-astronomy librarians: 33.5% contact them daily or several times per week, 26% a few times per month, 33.5% a few times per year, 7% never.

Electronic mail has brought upon us a communication revolution, and it has quickly grown to become the most frequent method of communication. The ease and speed of writing e-mail messages points towards even increased use in future. Never before was it so convenient to contact colleagues instantly, allowing them to reply whenever they find the time and opportunity to do so. Even though the internet "netiquette" defines guidelines for e-mail, everybody is rather free to compose messages according to personal preferences in language, grammar, style, and content. This seems to be an irresistible advantage of electronic communication as opposed to letters on paper, telephone conversations and even personal contacts. A clear majority of 62.5% of the survey respondents listed e-mail as their most frequent method of corresponding with colleagues. The second most common method, namely meeting face to face in their libraries (including other staff in their own library), falls far below that at 19.5%. But e-mail as the first choice of communicating with colleagues varies, quite predictably, between developed and developing countries: while 63% of the respondents from the former group noted e-mail as the most frequently used medium, only 53% of the respondents from the latter group did so.

4. Networking

As access to the internet is becoming easier worldwide, e-mail is used increasingly for all kinds of enquiries, comments, and exchange of information among librarians. A wide audience can easily be reached through mailing lists which are ideal forums to quickly and inexpensively disseminate information among peers, to put forward information requests to a large group, and to participate in discussions among colleagues from all parts of the world. In astronomy, most librarians are subscribed to at least one of the mailing lists Astrolib, PAMnet (Special Libraries Association (SLA) / Physics, Astronomy, Mathematics (PAM) division mailing list) or PAM-APF (SLA-PAM - Asia/Pacific Rim Forum (APF)). While some messages are cross-posted to more than one list, each list focuses on slightly different audiences. Astrolib, founded in 1988 following the first LISA (Library and Information Services in Astronomy) conference, targets well topics that are relevant to astronomy librarians worldwide; in addition to librarians, several astronomers have joined this list because of their interest in information and documentation issues in general as well as database and technology-oriented topics in particular.

PAMnet covers also physics, mathematics and computer science library matters; here are subscribed many editors and other publishing staff who share their insight into publishing procedures with the library community. PAMnet traditionally has been an active mailing list where not only new products and services are announced, as often is the case on subject-specific lists, but extensive discussions take place (Duda, Meszaron & Markham 1997). The third, PAM-APF, focuses on issues of special interest to the Asian and Pacific Rim area, in particular to developing countries in this region.

Typically, a few subscribers of mailing lists are very active participants, while the majority only "listens". However, the importance of passive participation in listservs is immense, especially on mailing lists with an international audience where librarians from all parts of the world share their points of view and thus increase awareness of problems in countries other than our own.

E-mail communication works best with those colleagues who have previously met. As electronic mail lacks some important features of personal communication (body language, tone of the voice, etc.), knowing each other personally helps to avoid misunderstandings, in particular if senders and recipients don't share the same communication mentality, cultural background, command of language, etc. Additionally, it encourages electronic contacts that might not otherwise be made. As observatories are often geographically isolated, it is difficult for our professional group to meet in person, and these rare events are therefore highly valued. For astronomy librarians, LISA conferences are important opportunities to get to know colleagues.

Two questions in our survey focused on the LISA conferences and their respective benefits. Of the respondents, 49% had attended at least one of the three conferences; more specifically, 17% attended LISA I in 1988, 30% LISA II in 1995, and 36% LISA III in 1998. Almost 67% ranked enhanced future communications after meeting colleagues as the number one positive outcome. This confirmed the conclusion of the "Open Forum on Optimizing Communication Amongst Astronomy Librarians" held at the end of LISA III; the audience felt that the mixture of conference participants, consisting of librarians, astronomers, computer scientists and publishers, was very helpful in understanding concerns and positions of the other professional groups (Regan 1998).

Other benefits of LISA conferences as noted in comments on our survey responses are learning about new astronomy products and services sooner and more effectively than otherwise possible (22%) and learning about new and better library management techniques (11%). One colleague stated that LISA conferences made her realize that effective communication among librarians can make more resources more accessible for astronomers all over the world. Without exception, the respondents felt that the conferences were useful to them. Other comments confirmed the strong sense of cooperation and solidarity among astronomy librarians and even pride in belonging to this professional group. This may have the positive effect that the more active librarians become, the higher their self-esteem will get, which in turn makes them even more active – a divine (as opposed to vicious) circle.

Since LISA II, it has become a tradition that a small group of librarians, "Friends of LISA (FoL)", mount a fundraising effort for each conference and are successful in partially or wholly funding dozens of librarians from developing countries who could not otherwise attend. All preparatory and organization work of the FoL committee is done by e-mail as the group members are located in different parts of the world.

Another important venue for astronomy librarians is the SLA Annual Conference which is held each year in early June. The conference program comprises numerous presentations and discussions on virtually all topics of interest to information specialists. In addition, a wide range of Continuing Education courses is offered; these are half or full day professional development courses that allow librarians to gain an insight into topics with which they are not yet familiar.

The problems associated with conference attendance are obvious – expenses are high (registration fee, travel costs, etc.), and attendance approval requires a lot of support from the authorities in our institutes who decide on funds allocation. Fortunately, LISA conferences seem to be increasingly recognized by astronomers and observatory directors which may improve chances for even increased future attendance.

In 1999, the PAM International Relations Committee under the leadership of Jeanette Regan, librarian at the Mount Stromlo Observatory, established the PAM International Membership Award (PAM-IMA) which, together with the PAM International Travel Award (PAM-ITA), is awarded each year to a librarian from the developing world; the award allows him/her to attend the SLA Annual Conference and become an SLA member for two years in order to interact more with colleagues in the association. In addition to recognizing the achievements of the recipient, the award has also other communication benefits as it bonds the librarians' community and publicizes the network and conferences.

Astronomy librarians traditionally have been good at resource sharing. In addition to interlibrary loan, many collaborative projects have been initiated over the years, including databases of preprints and observatory publications, union lists of journals, meeting lists, compilations of book reviews and the Astronomy Thesaurus (Shobbrook & Shobbrook 1993). Many of these projects would previously have been very time consuming and difficult to compile because librarians in several far flung locations are involved in the production; they are now much more easily and effectively completed, almost entirely by e-mail, and made available to the astronomy community on the world wide web.

The need for more formal cooperation among astronomy librarians is reflected by increased membership in the professional organizations that enable us to join forces. A well-structured approach, in particular regarding publishers, often leads to far better results than attempts from individual librarians. Many astronomy librarians have already joined the Special Libraries Association, in particular its Physics-Astronomy-Math division;

currently, SLA comprises members from approx. 60 countries. Special attention should also be given to regional groups, for instance the Asia/Pacific Rim Forum (PAM-APF) that concentrates their efforts on developing countries and the problems libraries and scientists are facing in these areas, the ALOHA librarians on Hawaii and the network of astronomy libraries in India (Vagiswari & Louis 1998).

5. Communicating with library users

Communicating with library users is an essential part of the librarian's work. The main purposes are communicating library services and products to our users, providing requested information and assessing users' needs. In times of increasing numbers of information resources and decreasing funds, it is more important than ever to know library users' needs; actually, this is the prerequisite to providing good service.

When scientists approach librarians with requests, usually a short interview follows in order to understand exactly what our users are looking for. While this sort of communication often is carried out face-to-face in the library, personal interaction is increasingly being replaced by communication through electronic means. E-mail is an excellent medium for this purpose as it is quick, cheap, and available in most parts of the world; several messages can be sent back and forth within a short time if necessary, regardless of the geographical distance between the scientist and the librarian. Accordingly, 48% of the survey respondents stated that e-mail is most frequently used to communicate with library users, although closely followed by face-to-face communication (42%). With regard to e-mail interaction with users, a remarkable difference can be seen between groups of countries – while 57% of librarians from developed countries communicate most frequently by e-mail with their users, this is only the case for 40% of librarians from developing countries.

Quite interestingly however, only 29% of the respondents of our survey regard e-mail conversation with library users also as the most effective method of communicating, while the surprisingly large number of 60% consider personal face-to-face interactions most effective.

Many libraries provide web pages that contain those information resources (or links to them) which are sought frequently by astronomers. From personal communications, it has become obvious that scientists indeed appreciate these ready-for-use resources. Strangely, when asked about the most frequent method of communicating, librarians often are not aware how important this service is for their users. Apparently, "communicating" still is associated with exchanging questions and answers. In our survey, only under 5% of the respondents considered their web pages to be the most frequent or most effective way to communicate with the astronomers. On the other hand, a large portion of librarians stated that they visited another library's or the PAM web page daily or several times per week (28%) or a few times per month (44%); nobody chose the option "never". Even if we use web pages to fulfill our own information needs, we obviously do not conclude that scientists do the same.

The usefulness of web pages becomes more obvious with sophisticated web-based reference services designed for "live" communications back and forth, for instance the Collaborative Digital Reference Service [1] and the Virtual Reference Desk [2]. Increasingly, these services are provided by groups of libraries, covering various geographical areas (at least within one country) as well as different time zones. Thus, service can be provided to users on a 24 hours per day / 7 days per week ("24/7") basis. However, librarians are no longer the only group that answers questions over the internet. Numerous "Ask-A" services, some of them commercial rather than non-profit, have become available. It is important to make sure that information obtained from these services is "usable, relevant, authoritative and verifiable" (Kresh 2000). Astronomy is covered by all large university reference services; there are also some specialized "Ask an Astronomer" sites.

In addition to individual personal communication with users, there are also other means to assess user needs and provide service (see Cummins 1998). Within an organization, a library liaison can be asked to convey scientists' needs to the library. This approach has its limitations of course, as an individual may not be able to represent all groups of users. It can also be difficult to find volunteers to take on this additional workload, especially in smaller institutions. Depending on the size of the organization, a focus group, consisting of representatives from the various user groups may be a fairer and more balanced solution. Questionnaires and surveys can be distributed to get feedback from library users, but it is a tedious and time-consuming process which needs to be well-planned and can only be used occasionally. Answers to questionnaires also can sometimes be ambiguous and misleading so that their interpretation and evaluation must be done extremely carefully.

Whatever method is applied to assess user needs, it will lead to initiating or adjusting services which shall meet these needs. After some time, it is essential to evaluate the success (or failure) of the changes.

A more structured way to communicate with astronomers is the Working Group on Libraries of the International Astronomical Union (IAU), Commission 5 (Documentation and Astronomical Data). Through reports and presentations during the IAU General Assembly, librarians can inform

---

[1] `http://www.loc.gov/rr/digiref/`

[2] `http://www.vrd.org/`

scientists about ongoing projects and activities in astronomy libraries, as well as get feedback on existing services.

6. Communicating with publishers

Astronomy librarians have enjoyed more frequent, more formalized and more intense communications with publishers in the last few years. Some relationships or exchanges have been acrimonious, but more have been productive. An early example of the latter was the official appointment of a librarian to the Publications Board of the American Astronomical Society (AAS). One result of this formal and enthusiastic exchange of ideas with the AAS was the development of a license for electronic journals that is easily understood and carries through to their electronic versions the rights that users had for the print publications; it is therefore widely admired, even beyond astronomy. Since then, many other publishers have appointed librarians as liaisons, both formally and informally.

Astrolib and PAMnet have publishers on them who both contribute and listen; astronomy librarians often speak of senior editors in publishing houses familiarly by name.

All is not rosy though. Many publishers are less than ideally responsive.

The survey inquired into how often, by what means, and for what purposes astronomy librarians communicate with publishers. Twenty percent contact a publisher a few times per month, 68% make contact a few times per year, 12% never. These numbers are almost the same for developed and developing countries, the biggest difference being that there were 11% of the former who responded never, compared to 14% of the latter. It must be noted that many people have subscription agents so that direct communication with publishers is not necessary for most purposes.

As with other sections of the survey, e-mail was by far the preferred method of communication at 62%. Telephone (13%) and visiting exhibits at conferences (12%) followed far behind.

Not surprisingly, 50% of the communications had to do with errors in products, problems with subscriptions etc.; 23% of the contacts related to new products or new features of products and 21% of the discussions related to prices.

Methods of communicating with publishers do vary as between developed countries and poorer countries. For developing countries communication by e-mail was much more predominant (77% compared to 56%) but that was only because their options were more limited; they did not visit exhibits at conferences, did not check in at publishers websites, did not telephone publishers. Nor did they have the advantage of having publishers visit their campuses or institutions for demonstration purposes.

7. Barriers to effective communication

Some traditional barriers, most importantly geography, i.e., the distance between librarians or between them and their users, have become significantly less important. In spite of these advances many barriers to easy, effective communications remain. Two sections of our survey focused on barriers to communication with other librarians and with users.

E-mail and all electronic communications require infrastructure that is often very expensive, inadequate or missing altogether. Computer literacy is often underdeveloped and hard to improve because of inconvenient access to computers and to the internet. This is a problem not just in underdeveloped countries; there are still university libraries in North America where not every librarian has a computer on her desk. Given the variety of levels of infrastructure and funding available to librarians, it is remarkable that e-mail is so overwhelmingly favoured in all countries as a method of communication with other librarians.

Other effects of the new technologies can be seen in the regretful comments on our survey responses, such as "Astronomers just don't use the library much". In the question about barriers to communications with their users, the most frequently cited barrier (almost 28% of the responses) is that astronomers know a lot about electronic journals, searching etc., or think they do, and don't consult the librarian or come into the library as often as they used to. Those in developing countries elected this barrier 35% of the time while those in developed countries chose it 27% of the time. This is not a significant difference given the presumably wide variation in access to electronic journals etc. Outreach and focus are more important than ever in these times of end-user searching and desktop access to the literature.

There are other barriers which are not directly related to technology.

Scientists are used to communicating their research in English but librarians do not have that custom. Language therefore can be a significant barrier, not so much to communicating at all, but to the kind of fluent, comfortable, frequent communications that enable fruitful personal networking.

The size, type and culture of one's organization, its atmosphere, its wealth or lack thereof, the physical arrangement of the offices, can all facilitate or prevent effective communications, especially, but not exclusively, with library users. A librarian in a small observatory might have more contact with individual researchers than one in a larger library in a physically vast institute. A librarian who works in a university library which serves multiple disciplines and thousands of faculty and students is going to be more removed from the needs of individual astronomers than one who works in a specialized astronomy library in a similar university, especially if the former librarian works in a department such as collection development and has no direct contact with library users. The generalist librarian may have less contact with specialist librarians too. These things cannot be changed by individuals, but compensation, through special efforts to talk to researchers directly, can and must be made.

The stereotype of librarians is something to be eschewed but certainly there are some tendencies in the personalities of librarians who enjoy working in small, isolated observatory libraries. These self-reliant, introspective types may have a difficult time reaching out to astronomers and other librarians. Shyness, reticence and timidity are characteristics which may apply to many women and to some ethnic cultures. In our survey several people mentioned as a barrier their "reserve" or other similar aspects of their personality. The low status of women and/or librarians in some cultures may inhibit the free interchange of ideas. Although only 7.6% of the responses to the question of barriers indicated that "low status" was a problem, 23%, or the second most frequent response (along with their own workload), was the time and workload constraints of their users. It may be true that astronomers are too busy, but it may also be true that librarians simply assume that astronomers don't consider communicating with librarians important or of high priority.

Some countries discourage or censor foreign communications; there is not much fellow librarians can do to counteract this policy, except communicate with colleagues from these countries in the way that is most appropriate to them.

The advent of new electronic media comes at a time when staffing and financial constraints are even tighter than before. The workload of the average librarian has increased as she/he takes on the navigation of these new electronic waters in addition to the traditional media. Time to communicate with others is therefore squeezed. "My workload" was the second most frequent response to the question of barriers (along with the workload of their users).

The same financial and time constraints can prevent attendance at meetings, especially remote ones. Further, the inability to purchase some expensive new tools decreases the interest that some librarians have in communicating with others who do have them; interests-in-common are diminished.

There is also the issue of awareness of barriers. Some librarians responded that there were "no barriers" yet they had not attended any LISA conferences. Why not – surely those librarians had something to learn or gain by attending! Perhaps time and money constraints are so much a part of a librarian's environment that they are taken for granted. Not knowing what you are missing is surely an insidious barrier.

If only we could talk to all the librarians who did *not* respond to the survey we would have a much better grasp on the real barriers.

8. Useful resources

- **Professional Organizations**
  - Special Libraries Association (SLA) [3]
  - PAM (SLA Physics-Astronomy-Math division) [4]
  - PAM International Relations Committee (incl. access to the PAM International Travel Award) [5]
  - International Astronomical Union (IAU), Commission 5: Documentation and Astronomical Data, Working Group on Libraries [6]
- **Mailing Lists**
  - Astrolib. Moderated mailing list for astronomy librarians. Contact person: Ellen Bouton, NRAO Library [7]
  - PAMnet. Unmoderated mailing list of SLA-PAM. Contact person: David Stern, Yale University [8]
  - PAM-APF. Unmoderated mailing list of the SLA-PAM Asia Pacific Forum. Contact person: Jeanette Regan, Australian National University, Astronomy Branch Library [9]
- **Contact Persons and Conferences**
  - PAM publisher liaisons [10]
  - Directory of astronomy librarians [11]
  - LISA conferences [12]
  - SLA annual conferences [13]

---

[3] `http://www.sla.org`
[4] `http://pantheon.yale.edu/~dstern/pamtop.html`
[5] `http://msowww.anu.edu.au/library/pam/intro.htm`
[6] `http://ulda.inasan.rssi.ru/IAU/wgl.html`
[7] `library@nrao.edu`
[8] `david.e.stern@yale.edu`
[9] `jeanette.regan@anu.edu.au`
[10] `http://www.sla.org/division/dpam/manual/staff.liaisons.html`
[11] `http://www.eso.org/libraries/astro-addresses.html`
[12] `http://www.eso.org/libraries/lisa.html`
[13] `http://www.sla.org/content/Events/conference/index.cfm`

Acknowledgements

We are very thankful to Ellen Bouton, NRAO librarian and Astrolib moderator, who generously shared with us her knowledge on mailing lists and e-mail access in developing countries. Special thanks go to all colleagues who responded to our questionnaire on communicating and networking; the answers were essential to compile this chapter.

References

1. Cummins, M. (1998) The symbiotic relationship: assessing user needs, in: *Library and Information Services in Astronomy III*, ed.: U. Grothkopf *et al.*, Astronomical Society of the Pacific, San Francisco, CA, ASP Conference Series; 153, pp. 19–25, `http://www.eso.org/libraries/lisa3/cumminsm.html`
2. Duda, A.L., Meszaros, R.L. and Markham, J.W. (1997) A month in the life of a mailing list: communication among science and technology librarians, *Issues in Science and Technology Librarianship*, **Summer 1997**, `http://www.library.ucsb.edu/istl/97-summer/article1.html`
3. Kresh, D.N. (2000) Offering high quality reference service on the web, *D-Lib Magazine*, **Vol. 6 no. 6**, `http://www.dlib.org/dlib/june00/kresh/06kresh.html`
4. Regan, J. (1998) Open Forum on optimizing communication amongst astronomy librarians in the digital age, in: *Library and Information Services in Astronomy III*, ed.: U. Grothkopf *et al.*, Astronomical Society of the Pacific, San Francisco, CA, ASP Conference Series; 153, pp. 253–256, `http://www.eso.org/libraries/lisa3/reganj.html`
5. Shobbrook, R.M. and Shobbrook, R.R. (1993) The Astronomy Thesaurus. Anglo-Australian Observatory, Epping, Australia, `http://msowww.anu.edu.au/library/thesaurus/`
6. Vagiswari, A. and Louis, C. (1998) Networking of astronomy libraries and resource sharing in India, in: *Library and Information Services in Astronomy III*, ed.: U. Grothkopf *et al.*, Astronomical Society of the Pacific, San Francisco, CA, ASP Conference Series; 153, pp. 237–243, `http://www.eso.org/libraries/lisa3/louisc.html`

EDITING THE ENCYCLOPEDIA OF ASTRONOMY AND ASTROPHYSICS

PAUL MURDIN
Particle Physics and Astronomy Research Council
British National Space Centre
151 Buckingham Palace Road
London SW1W 9SS, UK
`paul.murdin@pparc.ac.uk`

Abstract. The *Encyclopedia of Astronomy and Astrophysics* is perhaps the largest single astronomical encyclopedia published, with 2500 articles by 600 authors. The book was rooted in the global astronomical community. A World-Wide Web edition is planned, with revisions some four times per year to maintain its currency.

1. Conception

The initiative for the *Encyclopedia of Astronomy and Astrophysics (EAA)* came from Robin Rees of the Institute of Physics Publishing (IoPP). IoPP envisaged that it would construct *EAA* as an ambitious astronomical encyclopedia by professional astronomers. It aimed to be the largest and most complete astronomical encyclopedia of the present day.

IoPP used its established teams of editors who were used to the normal academic standards of publishing in Physics and Astronomy. The book is published by IoPP and by Macmillan, later renamed the Nature Publishing Group under a company re-organisation. The Macmillan editor was Andrew Diggle. With their extensive list of reference works, Nature Publishing Group has experience in constructing such an encyclopedia and making it commercially successful. Robin consulted me at an early stage as an adviser for the book, and I became its Editor-in-Chief.

The main parameters defining editorial choice were set by the market place – the book's maximum size and its wide scope. In order to recover costs the book had to sell widely and be suitable for a general readership, as well as of professional standard. Fortunately, astronomy lends itself to a

A. Heck (ed.), Organizations and Strategies in Astronomy II, 221–228.

general treatment – its science is widely accessible, although, of course, like all sciences as practised at a professional level, it has its specialised aspects.

2. Readership

We identified the target readership. The most readily identifiable and primary readership group was the community of professional astronomers reading articles not primarily in their special fields. Given the likely cost of the book, we anticipated that institutes and university departments and their libraries would be the likely purchasers.

At the wide level that we envisaged, we intended that university teachers of undergraduates could assign articles, as supplementary reading material, so general university libraries would also purchase the book. If the book was organised to contain general reference material it might be possible for librarians in general city or large school libraries to use the book to look up facts to answer questions by members of the public or by students.

Private purchase was also a factor – a larger number of private individuals than I thought purchase reference material in astronomy at the likely price of the book. I cannot give figures for the readership because that is a matter of commercial confidence, but the book has already recovered its editorial costs through advance orders.

The overall vision was that *EAA* could be the first call for an astronomical query by anybody, that it might well satisfy that query or, if not, show where to go for further material.

3. Web version

It was envisaged from the outset that *EAA* would be available eventually on the World-Wide Web, indeed that it would become the primary edition, with its currency maintained. Electronic publishing makes regular updating possible, and we plan to update every few months, with an average refresh time of five years. In some ways I regard the electronic *EAA* as a self-organising version of the articles published year by year in *Annual Reviews of Astronomy and Astrophysics.*

EAA is the first full publication of Macmillan/Nature's science reference programme and the print edition was prepared ahead of the Web version. Building on *EAA*'s experience, the publisher is preparing an *Encyclopedia of Life Sciences* primarily as an on-line work. To exploit some of the capabilities of the WWW, the publisher is moving towards hypertext linkages internally within the book and externally to the WWW. This will make more illustrations economically feasible. One idea is to create 'folders' of associated articles that can be set by a teacher as reading assignments, or by a researcher as favourite articles. We regard all these ideas as experiments. The main advantage, it seems to me, of the Web edition of *EAA* is that it is always up to date.

4. Organisation of the material

When we were planning the subject matter of the book, I identified subject areas in astronomy such as solar-terrestrial physics, the solar system, galactic structure and cosmology. I drew the subject areas as wide as possible. I listed some material about the way that astronomy is carried out at its edges, such as geophysics, and astronomy's contact with the arts. Some articles feature the way that astronomy is carried out as a profession. I estimated the relative size of each group of articles. This estimate was based on the proportions in each subject classification of the published literature in *Astronomy and Astrophysics Abstracts.*

The estimates became a target quota for the commissioning editors in each subject area. The recent burgeoning of solar-terrestrial physics as a result of the SOHO mission and other space missions of the International Solar-Terrestrial Physics programme prompted the editor primarily responsible for the solar physics areas, Prof. Eric Priest, to organise a definitive overall statement of where solar physics is today.

It was a given by the publisher that the book would be alphabetically organised. I wanted to try to keep related articles together, so this produced groups of articles headed with a 'Title: subtitle' structure, for example:

Venus
Venus: atmosphere
Venus: interaction with solar wind
Venus: surface.

This formula did not always work very well. For example 'Solar flares' and 'Solar photosphere' ought to be near 'Sunspots.' But the formula suggested a structure that looked repetitive and cumbersome.

Sun: solar flares
Sun: solar photosphere
Sun: sunspots.

I am not completely happy with the outcome of our compromises. But in a book, there is only one order to a batch of articles. The alphabetical arrangement is a limitation. In hypertext, the construction can be ordered as a Web. This makes sense and the WWW version of *EAA* will exploit this, with a 'home page' type article that will act as a logical index.

I identified reference material additional to the main articles. These included biographies of astronomers, notes on observatories and space missions, small entries of the nature of definitions of astrophysical concepts and the like. To give an overview of astronomy in the world today I identified the astronomically active countries and foresaw an account of their activities from a prominent astronomer who has an organisational role in each of them.

In a spread-sheet I adjusted the numbers of articles of various kinds and their length so as to satisfy the overall length requirement, including an estimate of the numbers of illustrations. As the book turned out, there are 700 main signed articles by 600 authors. There are 800 small articles on astronomical definitions, including individual astronomical objects, 250 short articles on observatories, 100 on space missions, and 650 biographies.

At first we ruled out colour illustrations for cost reasons. During the writing stage, some authors represented that it was necessary to publish some colour material to show particular scientific material. The science case was clear and we agreed to do this, but only in the most economical way, by using central groups of illustrations. I was glad because colour illustrations in astronomy can be very beautiful. To maintain scientific sense, we put a black and white version of the colour plate near its reference in the text.

I drafted schemes of how the articles would be constructed. For the articles, the format started with a title, and then a paragraph explaining the title and defining its scope. The article would then lay out the background to the topic, including a brief historical sketch before starting a modern description of the state of the topic, ending with a look into the future. The idea was that the article would get progressively more 'difficult' so that a reader could exit the article at the point where it satisfied the level of interest and ability. This idea has had mixed success. It might be better to identify separate articles on the same subject at different levels.

The smaller articles were commissioned from professional authors. The biographies would give the dates of the life of the individual, his or her birth-place, as many details of his or her life as were necessary, and then principally the astronomical and other scientific advances to their credit, with a summing up. I have seen it suggested that 95% of all the astronomers that there have ever been are still alive, but I did not want to be the one who chose who, amongst the living, would be included and who left out. At first I wanted to include only astronomers who were dead. But it was clear that, if the book was to be a fundamental reference work, we had to include some still living astronomers such as Nobel Prize winners and Astronomers Royal, and some others, whom libraries would expect to be included. It proved impossible to produce consistent objective criteria, and I anticipate argument about the biographies – it is probably significant that the four complaints that I have had so far refer to some of them.

Observatories and spacecraft were included if they had achieved significant astronomical results. The guideline was to emphasise the science, with enough technical detail to make sense. Some spacecraft have been particularly significant and we commissioned main articles for those.

We chose our list of current observatories and astronomical institutes from the directory *StarGuides* (the new name of the directory *Astronomy, Space Sciences and Related Organizations of the World (ASpScROW)*), edited by André Heck and published by Kluwer [1]. To maintain diversity, we chose on a combination of the importance of the organisation (associated with a large volume of important work) and geographical spread. I could not think of a scheme to identify consistently, to commission or to write entries on universities containing large, productive departments of astronomers.

In the art world these would be identified as a 'school of astronomy' — for example those centred on the California Institute of Technology, or the University of Leicester. The focus on astronomical institutes and observatories is in the historical tradition of astronomy, but under-represents one of the major forces in modern astronomy (more in some countries like the USA, the UK and the Netherlands than in others, especially in continental Europe) – the university community. Until historians of astronomy lay the academic groundwork, this remains a limitation of my approach.

On this basis, the publishers accepted the scheme for the book and the commissioning work began. As one of the 'organisational astronomers' whom I mentioned above, I have been too far from the coal face of research to be able to plan the articles in detail. We set up an editorial board to do so.

5. Authors

We decided that the main articles would be authored by practising astronomers, and signed, guaranteeing their integrity. This was consistent with our vision that *EAA* would represent astronomy as currently practised.

As a corollary, we decided that we would not impose arbitrary rules such as an editorially 'correct' set of physical units. I have received one message taking me to task for letting authors use units outside the SI system. I replied that I did not think it was an editor's business to impose on practising scientists of international reputation. Just as particle physicists use units scaled to aid an intuitive feeling (such as MeV) so astronomers use solar masses, parsecs, years and AU/day; and some use ergs/s. I have

---

[1] See for instance `http://www.wkap.nl/book.htm/0-7923-6509-7` for the paper copy and `http://vizier.u-strasbg.fr/starworlds.html` for the corresponding on-line database *StarWorlds* at CDS. (Ed.)

been warned that I may have to fight this battle again with the publishers over the updating of the Web version.

The authors were asked to provide bibliographic information to enable further study of the topic, via review articles and conference proceedings. Some authors added complete references to the scientific literature. Again, rather than force a consistency we allowed each author to offer the bibliography that suited the current state of the scientific topic. The bibliographies are one of the areas that we plan to link to the outside world in the Web version.

Astronomy is an international subject and I wanted an internationally representative work. The editorial board was chosen, of course, to be representative of the diversity of astronomical topics, but also to be from a range of the astronomically active countries of the world.

Since astronomy is one of the most international sciences, with more than half carried out in anglophone countries, and actively communicated across the English-dominated World-Wide Web, we accepted that *EAA* would be in English. As a native English speaker I worried about this, whether I was presuming too much. What decided me was not only the commercial reality but also the example of *Astronomy & Astrophysics*, the European journal published in English from continental Europe. The dialect of English used is known as 'mid-Atlantic,' the sort of American English used by British editors armed with an American English spell-checker.

We met for a day and planned the articles that would be commissioned, including their potential authors. Editors in charge of particular sections of the book listed topics and cross-checked against adjacent areas so that there was no (or little) overlap. The commissioning editors sent invitations to authors to write their articles. The acceptance level was remarkably high (higher than average in the experience of the publishers) and most authors delivered on time against their accepted commission. I think this is an indicator of the high morale and community cohesiveness of astronomers. In a very few cases, where an article on an important topic was not delivered, we commissioned some of the many widely talented general astronomical authors to fill the hole.

There was no attempt to control the geographical distribution of authors apart from the composition of the editorial board. In the event, the encyclopedia has 600 authors of the 700 signed articles, 53% of whom come from North America and 40% from Europe.

I have compared the authors' addresses in the *EAA* and the *Astronomy and Astrophysics Encyclopedia (AAE)* (published in 1992 by Van Nostrand Reinhold and by Cambridge UP, edited by S. Maran), with the relative proportions of locations of the home institutes of publishing astronomical authors, as listed by ISI's National Science Indicators (1999 release).

TABLE 1. Locations of author institutes – Percentage of total

	AAE	ISI	*EAA*	ISI
Literature published in (year)	1992	1992	2001	1998
North America (%)	78	46	53	36
Europe (%)	16	40	40	47
Rest of World (%)	6	14	7	15

In both encyclopedias, North American authors are over-represented and both badly under-represent authors from outside Europe and North America. The explanations presumably lie in the cultural practices of astronomy in the various countries, including language considerations, in the cultural limitations of the respective editors and in the respective sizes of the commercial markets for the books.

6. Production process

All the major articles were sent for a referee's opinion and were accepted if the report was positive, or revised or recommissioned if not. There were few disputes, and mostly we retained confidence in the refereeing process.

The material was typeset via LaTeX, either as supplied by the authors themselves or by the editorial staff. For the Web version we converted from Latex to HTML by a programme. This was not trivial for the particular form of LaTeX that we used. We had to do a fair bit of adjustment by hand. In future we would give more thought to this.

The editors proof-read the articles and so did the authors. I set myself the task to read all the articles. This was not mainly to check if they were correct (although I spotted and queried some items that seemed strange to me). I checked if the articles conformed to the guidelines for readability and to see if they made sense to me, for example if the illustrations manifestly showed what the captions or the text said they ought. Fortunately I travel a lot, so I read proofs on journeys. The lack of reference material on the plane or train was an advantage – the articles had to make self-contained sense, and, if they did not, it was obvious.

7. Birth

The publishers prepared and distributed impressive leaflets about the *EAA*. We launched it at a noisy reception at the IAU General Assembly in Manchester in August 2000, where a beta Web version was available for test. The feedback was detailed and positive; we have incorporated some of the suggestions for improvements. The *EAA* was published in January 2001. I was gratified to see it when I had my first copy. It is baby sized but the gestation time (4 years) was similar to a baby elephant rather than a baby human. The publisher is happy with the number of prepublication orders, and, as I write, I am waiting apprehensively for the reviews.

References

1. Murdin, P. (Ed.) 2001, The Encyclopedia of Astronomy and Astrophysics (paper version) NY and London: Nature Publishing Group and Institute of Physics Publishing Co, Four volumes, xx + 3670 pp., ISBN: 0-333-75088-8 and ISBN: 1-56159-268-4 (US)
2. Murdin, P. (Ed.) 2001, The Encyclopedia of Astronomy and Astrophysics (Web version) NY and London: Nature Publishing Group and Institute of Physics Publishing Co., (`http://www.ency-astro.com/eaa/eaa/index.html`)

EDITING A MULTILINGUAL ASTRONOMY MAGAZINE

NOËL CRAMER
Observatoire de Genève
Chemin des Maillettes 51
CH-1290 Sauverny, Switzerland
`noel.cramer@obs.unige.ch`

Abstract. The readership of a national astronomy magazine addressing the amateur community is necessarily restricted to a small percentage of the general population. When the latter is significantly less numerous than that of a large world city, uses four national languages and is accordingly multicultural, the task of the editors becomes akin to tightrope-walking. Here we discuss the case of *Orion*, the journal of the Swiss Astronomical Society, that has survived for 59 years in such conditions, and so far in good health.

1. The background

Switzerland is a small but unusually multi-cultural and multilingual country. It has grown out of an alliance of three Germanic rural communities willing to militarily defend their independence in the face of exploitation by the Habsburg branch of the Austro-Hungarian Empire in the late 13th century. The scheme was eventually successful enough to persuade neighbouring city-states and their dependencies to gradually join the coalition.

The present Confederation may be regarded as an alliance of opportunity consisting of 26 Cantons totalling some 7 million inhabitants, each of the former enjoying a large degree of autonomy, occupying regions physically separated by mountains and where German (74%), French (20%) and Italian (5%) are official languages. A small community of about 20,000 persons in the Eastern part of the country speaks Rhaeto-Romanic, the fourth national language, a dialect traceable to the occupation by the Roman Empire.

This, at first sight, seemingly unnatural cultural as well as geographical disparity is cemented to a great extent by the understanding that national

A. Heck (ed.), Organizations and Strategies in Astronomy II, 229–238.

independence is difficult to maintain below a certain critical size, and by the practice of democracy at its most basic level for decision-making on the local as well as Federal echelons. Such is the rather complex and fragmented background that a journal aiming to address a community sharing common interests on a national scale has to contend with – all the more so in the context of astronomy. The initially small potential readership has to comply to a variety of concessions which the editors, in their turn, have to render acceptable in the best possible manner to the whole community.

Astronomy is presently represented in Switzerland by less than 150 professional or student astronomers based essentially at the German-speaking universities of Basel, Bern and Zürich and the French-speaking ones of Genève and Lausanne. To that number we may add about 3400 "declared" amateurs – *i.e.* members of the Swiss Astronomical Society (SAS) which is made up of 40 local sections. Apart from the latter, a few times that number most certainly form a "silent majority" of smaller local associations and astronomically interested individuals distributed among the general population but who do not desire to belong to a larger association.

Astronomy, as in all communities enjoying widespread literacy, benefits from a great deal of public good-will. The issues tackled by contemporary observational and theoretical astronomical work address fundamental existential questions that concern most individuals. Among these are the question of our origins, our place in the cosmos, the prospects for extraterrestrial life, the evolution of our universe and, not least, the pure beauty of the images and poetic content of cosmic objects revealed by large modern instruments. For the more scientifically minded, the huge variety of challenges narrowly related to most of the exact sciences and put into perspective by the "outward look" at Nature is most forceful.

Quite generally, an ideal amateur journal must strive to appeal to readers of all social conditions and levels of education who share a common interest. It must consistently avoid appearing as "silly" to too large a fraction of the readership, or to be accused of being too "highbrow" or academic by another. Its basic mission is to find a language that is as attractive as possible to the broad diversity of its readers, while strictly maintaining scientific integrity. Those heavy constraints become much more severe in the case of a multicultural *and* multilingual journal addressing a small readership, such as *Orion*, produced by the Swiss Astronomical Society (SAS).

2. Orion

The SAS was founded in Bern in November 1938 and has been led by 13 presidents up to the present day. The first issue of its official journal, *Orion*, appeared in October 1943. It was a 16-page A5 format booklet edited by Max Schürer, Privat Dozent at the University of Bern and later Professor of Astronomy and director of the Astronomical Institute of the same University; by the serious amateur and producer of the almanac *Der Sternenhimmel* Robert A. Naef of Zürich; by the dental surgeon and reputed observer of Mars Maurice Du Martheray of Genève; and by Émile Antonini, also of Genève.

It is interesting to mention that a copy of that first issue was carried aloft by the astronaut Claude Nicollier in the space shuttle Endeavour in December 1993 during the first Hubble Space Telescope servicing mission – celebrating thus in a highly symbolic manner the fiftieth anniversary of *Orion* as, maybe, the first amateur astronomy journal to fly in space and orbit the Earth 163 times in the company of one of the most powerful modern telescopes!

Starting as a slim pamphlet with four yearly issues and a predominantly "academic" style, the journal rapidly evolved into a platform where amateurs throughout the country presented their work, most often concerning telescope-making and instrumentation (the purchase of a serious astronomical telescope was relatively much more costly than it is now). In 1964 and 1965 the frequency of publication rose to five issues and, from 1966 onwards to six yearly issues. In the latter year, the format was expanded to $200 \times 265\text{mm}^2$ and it was only in 1997 that the present A4 format was adopted.

The journal is still produced on a non-commercial basis, the authors as well as the members of the editorial board are not remunerated. The only running costs are those resulting from printing and postal distribution, and are barely covered by the subscription dues and revenue from advertisers. A concise history of the journal and of the SAS up to 1994 has been related by F. Egger[1].

Throughout its existence, except during the first years and after 1990, the editorial board of the journal was led mainly by active and serious amateurs, professionals, often in public education, but not astronomers.

In 1990, following a number of financial problems owing to the increasing costs of printing that caused the SAS to mandate another company for that work, and a decrease of confidence of the readership due to the unreliability of the end product followed by a second change of printer, the President of the society at that time, Dr. Heinz Strübin, persuaded the author to provisionally take over the responsibility of editing the journal.

That responsibility subsequently proved to be so difficult to relinquish, for lack of willing and competent candidates, that in 1997 Dr. Andreas Verdun from the German-speaking Astronomical Institute of Bern agreed

---

[1] See *Orion* **260**, February 1994.

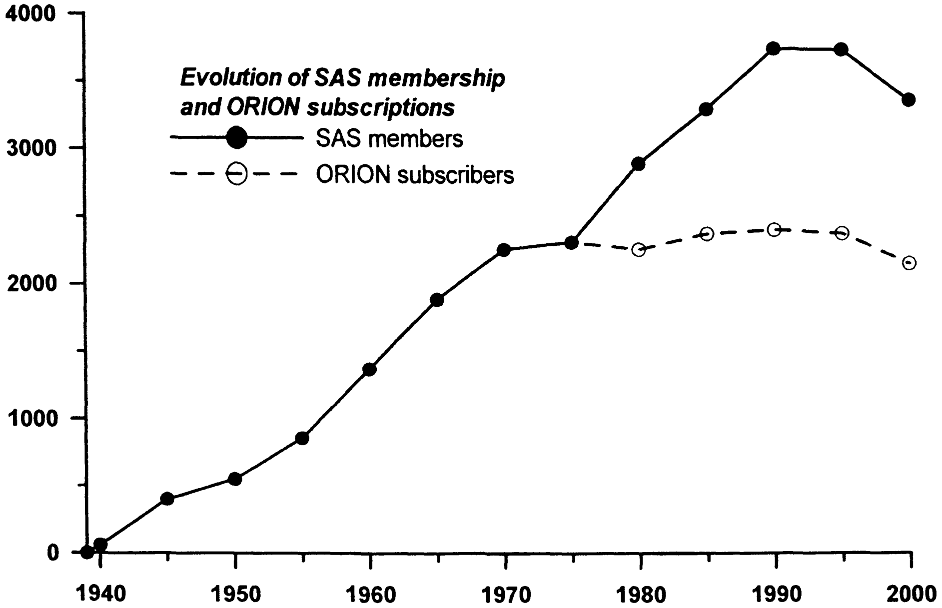


Figure 1. Evolution of the membership of the Swiss Astronomical Society (SAS) and of the subscriptions to its magazine *Orion.*

to share the editorial leadership on an equal basis. So, the editorial board is presently headed by two professional astronomers seconded by some ten devoted collaborators including the secretary of the SAS, Mrs. Sue Kernen, who bears with much fortitude the thankless task of administering the membership of the Society as well as the subscriptions to the journal. All that work is done on a voluntary, unpaid basis.

3. Statistics and reflections

To proceed further with the discussion, let us examine some data regarding the readership and production of *Orion* throughout its existence.

Fig. 1 shows the evolution with time of the membership of the SAS and the subscriptions to *Orion.* The regular ascent following the foundation of the society does not significantly change after the war but gathers momentum shortly before 1960, presumably owing to the increasing public awareness of astronomy due to the advent of the space age. In that context, the levelling-off in 1970 could at first glance be attributed to what we may jestingly call the "post-Apollo syndrome", but its true reason lies elsewhere.

Up to 1975, the journal *Orion* was an integral part of membership of the SAS and explains the confluence of both lines. In 1975, the obligation for members of the local sections of the SAS to subscribe was abolished and that explains the divergence of both trends: a flattening-out of the number of subscriptions and a renewed ascent of SAS membership.

The post-1975 curve of subscribers thus better represents the true aptitude of the journal to captivate its readership, and it was that "saturation" which was retarding the progression of SAS membership in the early seventies by putting off less motivated potential affiliates.

The evolution during the last decade is more complex, with a number of distinct factors. Paradoxically, the recent decline of both curves is most likely related to the increase of interest of the general public world-wide in regard to astronomy. Commercial or partially commercial editors of the neighbouring countries (France, Germany, Italy) have gauged the potential readership of their (much larger) country and are producing journals of increasingly good standing in their national language. A multilingual journal like *Orion* offers its full potential only to those who are articulate in the national languages (essentially French and German). Others will be frustrated and tempted to turn toward the "sirens" across the borders ...

Others still are "allergic" to the presence of another language. That type of intolerance has long been present in the French speaking-minority but is new to the German-speaking national majority. It is best illustrated by the popular media (radio and television) increasingly resorting to Swiss-German dialect during these last 10 years at the expense of High German. It is interesting to note that that trend seems to follow in the wake of the identity crisis unleashed by the debate regarding joining the European Union.

Another more recent factor is the increasingly easy access to electronic publishing. The Web enables global access to the latest news in astronomy and astronautics at all levels of interest. Local astronomy clubs and individuals manage Web pages where they present their work and write articles. The need to join an association becomes less interesting. It is easier and much faster to publish on one's own Web page where, moreover, no critical or potentially unfriendly editor stands in the way. Many of the younger amateurs have turned to the Web community and, on examining SAS files, it appears that part of the most recent downward trend is due to membership and readership quite literally "dying off" and not being replenished fast enough by fresh enrolments. The maybe not-yet-fully realised inconvenience of Web publishing is, however, its volatility.

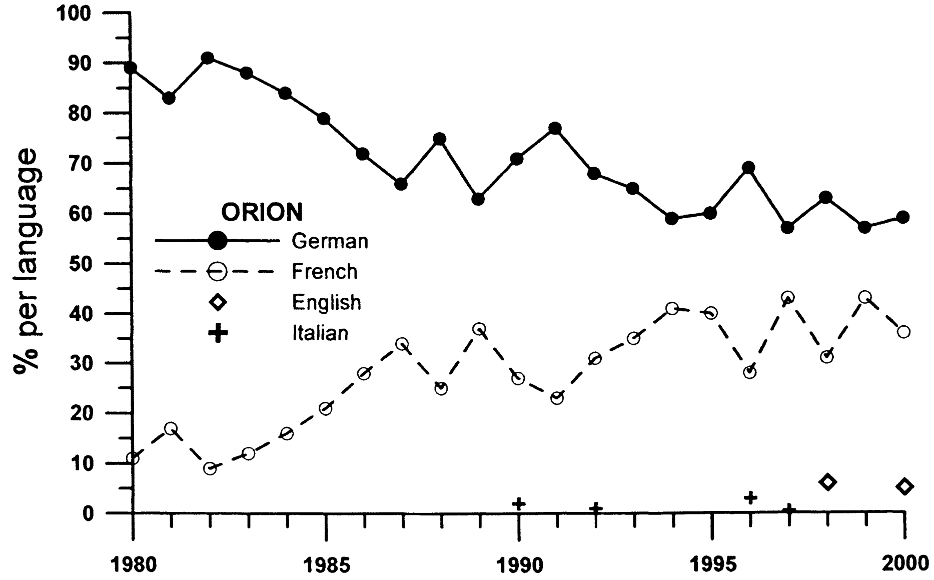


Figure 2. Percentile text volume over the last 20 years of the magazine *Orion.*

A further factor is related to the constantly decreasing price of telescopes and ancillary equipment during the last decade. If one examines earlier issues of the journal, one notices that many contributions were from amateurs describing the grinding and polishing of their own optics and the construction of their telescopes. The journal was a convenient forum where information could be swapped. That subset of the readership has now practically disappeared because it is no longer worth the effort of spending a great deal of time on exacting work, when one can purchase a good enough instrument with all the refinements of computer technology for a reasonable price.

Another important aspect regarding the evolution of the readership is visible in the variation of the relative presence of the various languages in the journal. Fig. 2 displays the percentile text volume over the last 20 years.

The most striking trend is the strong decrease of text in the German language to the advantage of French within the period 1980-1990. That is not due to any kind of censorship by the editor, Karl Städeli, who was resident in Zürich, though he did encourage the French-speaking community to contribute more, and strove to translate some texts into French. He was following the wish of the SAS Central Committee to alleviate resentment in the French-speaking minority who were complaining that "there was only German" in the journal.

The general trend continued after the author took over the editorship and is now stabilising at a ratio of $F/G \approx 2/3$. It is most interesting to note that, within the last year, the first complaints from German-speakers saying "there is no more German" have started to be heard, whereas one continues to hear "there is no French"! Cynically, one could retort that the "Golden Rule" has at last been attained. But the truth is more complex and reflects some basic changes regarding the authors who submit their work.

The last 15 years or so have seen the publication in *Orion* of many articles in French written by professional and student astronomers, informative and well popularised. However, it has been, and still is, more difficult to get the same response from the German-speaking Universities in spite of the efforts undertaken by A. Verdun from Bern.

One of the reasons invoked is lack of time, which most certainly is true. But underlying that is the fact that publication in an amateur journal is still regarded as "improper", to a certain extent, in those academic circles. Young astronomers and students tend to apprehend the disapproval of their mentor if they publish in a popular journal. The situation is very different in French-speaking astronomical circles, and that most certainly reflects the persistence of the deep-seated change of attitude regarding information of the public initiated by the first director of the "new" Geneva Observatory, M. Golay, some 30 years ago[2].

It also appears that the somewhat higher level of these recent contributions has had the perverse effect of discouraging "amateur" contributors, most of whom write in German. The apparition of foreign contributions of excellent quality in English since 1998 are expected to enhance that trend, but it is still too early to evaluate the consequences. It has now become our priority to encourage the amateur contributors of all levels to write "shamelessly" of their experiences, reassure them that there has been no "censorship" as some have suggested, while maintaining the high standard of the leading articles.

Last, but not least, we may mention the increasing incidence of "consumerism", or "spectatorship", in the amateur community. That phenomenon seems to reflect a general trend in society and merits a deeper analysis, elsewhere.

---

[2] See the chapter by M. Golay in this volume.

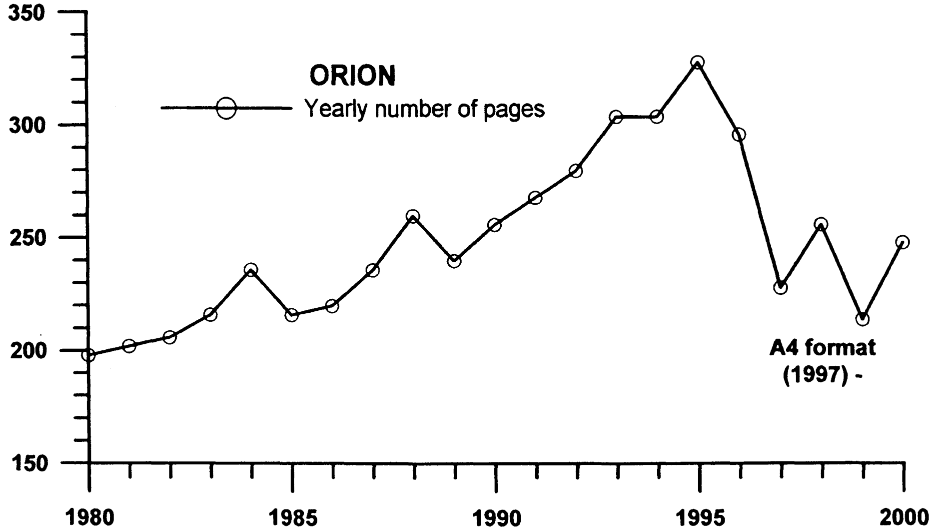


Figure 3. Variation of the number of pages per year for the magazine *Orion.*

The two last figures illustrate two other trends apparent over the last 20 years. Fig. 3 shows the variation of the number of pages per year and shows a regular increase of volume, by more than 50% and levelling out before 1997, when the larger A4 page format was adopted. The change was motivated by several factors such as compatibility with current usage, packing, printing-binding machines, the possibility of using three columns per page and thus acquiring greater flexibility for inserting illustrations.

The new concept was instigated by the young team who manage the Zürich-based "Astroinfo" Web site, and who were of great help during that operation. The opportunity was also seized to change the paper quality and to reduce costs. It is interesting to note the reactions of the readership to the event. About 90% of comments were positive, except for a few complaints from some older readers who mourned the high-quality paper formerly used, and disliked the new size that forced them to re-dimension the levels of their bookshelves!

The final illustration, Fig. 4, shows the evolution of relative printing costs over the same period of time in Swiss Francs (CHF). When weighted by the consumer price index (CPI), one notices that the costs have generally remained stable in real terms since 1985.

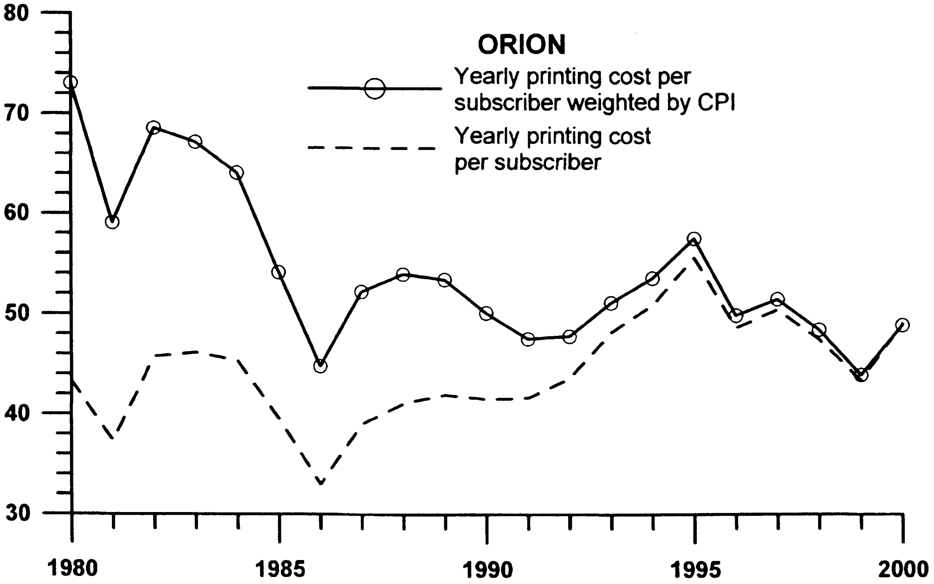


Figure 4. Evolution of relative printing costs over the last 20 years for the magazine *Orion* (see text).

There are, however, some large fluctuations. The dip in the costs around 1985 corresponds to the first change of printing company as mentioned above. In 1990, following the second change of printer they continued to rise, but this time in concurrence with the increasing volume of publication. The measures taken in 1997 then bring about a reduction of cost. The new rise seen at the very end of the decade reflects the increasing use of colour.

4. Conclusions

We have shown that a multilingual popular astronomy journal produced for the readership of a small country such as Switzerland is still viable after having existed for 59 years.

That is only possible if the editorial team is satisfied to work on an unpaid basis, and is capable of ensuring a varied and scientifically accurate content of the journal by finding authors who agree to contribute original articles without fee. The latter are to be found, nowadays, more readily among the academic community where it is still considered as a privilege to be published. Such articles have proven to inhibit some of the potential amateur authors who wrongly assume that their contributions are not up to the required standards. Many of the younger amateurs now also expect to be paid for their contribution.

The potential of the national market is, however, insufficient to support a commercial journal, even less so a multi-lingual one. Commercial astronomy journals with professional editorial staffs already dominate the markets of the much larger monolingual neighbouring countries and would make such an enterprise even more difficult to launch and maintain.

Electronic publishing on the Web also influences readership, but that is non-specific and affects all paper-based journals. Though, it may prove in the future to be less menacing than it seems and play an important complementary role as a carrier of information.

Whatever the future may hold, the editorial staff of our humble journal will have to strive to maintain a high level of quality and adapt quickly to changing circumstances without "falling off the tightrope" that links the diverse cultures and educational backgrounds of its readership.

WORKING WITH THE MEDIA: THE ROYAL ASTRONOMICAL SOCIETY EXPERIENCE

JACQUELINE MITTON
Royal Astronomical Society
Burlington House
Piccadilly
London W1J 0BQ, UK
`aco01@dial.pipex.com`

Abstract. One of the *Royal Astronomical Society*'s objectives is to promote astronomy and geophysics. To achieve this more effectively through the media, the Society appointed its first public relations officer in 1989. The RAS's work with the media has focused on encouraging interest in astronomy and assisting the whole UK research community. The main activities are issuing and circulating press notices and providing a telephone/e-mail enquiry service. Keys to success have included: press officers who are knowledgeable about the subject and able to act with authority as spokesmen rather than being intermediaries; a flexible approach and availability outside normal office hours; the compilation and maintenance of an up-to-date list of media contacts; co-operation with other organisations; strong links with both the international research community and the media.

1. Introduction

Few areas of science fascinate the general public as much as astronomy and space. Only medicine and health are significantly more popular in the media. At first sight it may seem surprising that a subject with little direct relevance to modern every-day life has such a following. Yet why should curiosity about the universe be restricted to those who make it their professional occupation? Of course, it is not. The drive to explore the universe and make some kind of sense of our experience of the cosmos is a deep-seated part of human nature. Astronomical research is publicly funded not because society anticipates immediate economic payback but because people want their curiosity satisfied. They entrust the task to a paid corps of

A. Heck (ed.), Organizations and Strategies in Astronomy II, 239–256.

professional astronomers whose main responsibility is to carry out research as best they can. But that is not all astronomers are expected to do for their part of the bargain. The knowledge they gain does not belong to an academic elite and, as the saying goes, 'He who pays the piper calls the tune'. Democratic societies that fund astronomers through their governments may delegate the choice of 'tune' to the professionals, but they certainly expect to be able to hear it. In other words, the social contract is not complete until the results are communicated, not just to the cognoscenti who read the learned journals but to the public at large.

Adults who have left school or college acquire almost all their new knowledge about science (and indeed many other things) from what we call 'the media'. Television, radio, magazines and newspapers are the most familiar media. Popular books can arguably be included too. And there is a newcomer to the list: the world-wide web, now a fully-fledged and influential medium in its own right. These are the means by which the public expects to hear the results of the research commissioned on its behalf.

As price-tags on state-of-the-art telescopes and the pursuit of space science escalated to keep pace with the technological developments in the latter part of the 20th century, so astronomers increasingly realised that they needed to win and keep public support for their activities. Over the same period, the power of the media to influence public opinion and the actions of decision makers also reached new heights. Scientists began to recognise that it was in their own interests to engage constructively with the media. Against this background, the *Royal Astronomical Society* decided in the late 1980s that it should invest modest resources in building bridges between academics working in astronomy and the media.

2. A learned society ventures into PR

2.1. THE ROYAL ASTRONOMICAL SOCIETY

Founded in London in 1820, the *Royal Astronomical Society (RAS)* is the organisation that represents professional astronomy in the United Kingdom. Its membership of just under 3000 is small compared with many learned societies and professional bodies, but the RAS is well-known internationally particularly because of its successful journals.

Substantial issues of the *Monthly Notices of the Royal Astronomical Society* appear every 10 days and in the year 2000 it published a total of 907 papers. As well as astronomers the RAS includes geophysicists among its members and sponsors the publication of the journal GJI (*Geophysical Journal International*). The RAS has the status of an educational charity – in other words it is a 'not for profit' organisation, though this does not preclude it from business activities directly in support of its aims of advancing astronomy and geophysics.

2.2. PUBLIC RELATIONS FOR ASTRONOMY

In 1988, the governing Council of the RAS was persuaded that it should appoint a Public Relations Officer (PRO). The plan was largely the brainchild of the late Michael Penston but was well supported by other Council members of the time. The person recruited would be expected to devote an average of 7 hours a week to the job, and was to be paid the going rate for the type of work and level of expertise required. Typically, a PRO is charged with ensuring that his or her organisation has a prominent and favourable public profile. The RAS's priority was different, however. Raising the public profile of astronomy and geophysics for their own sakes was to be the principal objective. Promoting the Society was to be of lower priority. Geophysics has always been within the brief but in what follows here I shall refer only to astronomy since that is the subject of this volume.

There was a formal selection procedure and several candidates were interviewed. I was appointed as the RAS PRO in December 1989. I had PhD in astronomy and some relevant experience as a writer, editor and information officer. The first task was to draw up an action plan aimed at achieving the main objectives, which were (and still are) in order of importance:

1. more media coverage world-wide for all aspects of British astronomy
2. more media coverage of astronomy in the UK
3. promoting membership of the RAS and attendance at its meetings
4. bringing the RAS's activities and achievements to public notice.

I identified several target 'publics':

1. members of the general public at large
2. school children and students
3. politicians and decision makers
4. amateur astronomers
5. potential members of the RAS

and drew up a concise summary of the core 'message' the RAS wanted to convey:

1. astronomy is an interesting and important scientific and cultural activity
2. British astronomy is making an important contribution internationally
3. The RAS is an active, lively organisation, promoting astronomy in a variety of ways.

Providing information for the media is not an end in itself but a means of putting over a more fundamental 'message' to target sectors of society (the different 'publics'), so these were essential steps before the real action plan could be put in place. The initial list of activities for conveying the RAS's message included:

1. the establishment of a press notices service
2. the development of contacts with journalists
3. helping astronomers be aware of the 'newsworthiness' of their work
4. training astronomers in how to work with the media
5. developing ways of identifying astronomical subjects suitable for news and features
6. making images available to the media.

All of them involve relations with the media and in the sections that follow I shall elaborate on how each of these has been tackled. It was a deliberate policy to concentrate my efforts on working with and through the media to reach large numbers of people, leaving the RAS's Education Committee to initiate activities aimed at individuals and local groups.

2.3. THE RAS AND THE EVOLVING MEDIA SCENE

Since the RAS took its first steps in PR for astronomy in 1989 there have been changes and developments, both in the media themselves and in the RAS's media-related activities. The internet and better communications generally, including mobile (cell) phones, have had a profound effect on the media's approach to acquiring news and information and on the capacity of organisations to distribute information for both the media and the public. The appetite of the media for science-related material remains generally strong, but the competition for coverage has become tougher as more and more scientific establishments and organizations court the media.

The RAS soon accepted that an average of 7 hours per week was insufficient to carry through a programme of action that would have the desired impact. After the first year, my hours (and fee) were increased by 50 per cent. One or two people would have no difficulty working full-time to further the objectives set out in 1989 but, as a small society, the RAS is in no position to contemplate extending its operation on that scale. However, in 1995, the RAS was offered funding through the British National Space Centre and the Particle Physics and Astronomy Research Council, to take on a second person working one day a week with special responsibility for promoting space science. After a formal selection process, Peter Bond, a space science writer, was appointed. The fact that the RAS was externally funded to almost double its media related activity was a sign that the formula evolved over the previous 5 years was regarded as successful and value for money.

Peter Bond was given the job title 'Space Science Advisor', which, it was realised in retrospect, did not exactly make his role clear. My title of 'Public Relations Officer' became increasingly associated with the practice of putting 'spin' on information presented to the media – in other words, manipulating the facts and presenting news stories in a manner to suit the ends of the issuing organisation. Outsiders often assumed my role was solely to promote the RAS and handle enquiries about its affairs. In 1999, we changed the official titles of our positions with the RAS to Press Officer and Press Officer (Space Science) [1]. It seems that the media regard press officers as people who deal with every kind of enquiry and normally supply straightforward information without the derogatory associations of 'PR', where 'spin' is assumed to take priority over substance.

3. Astronomers and the media

Much of what the RAS press officers do in practice centres around building bridges between astronomers, who mainly operate in an academic setting, and the people who work in the media. Personal experience of both has been of considerable value when it comes to mediating between them.

3.1. WORLDS APART

Scientists presumably watch the television about as much as other sections of society. No doubt they view programmes on topics outside their own speciality, such as the arts, history, cookery and gardening. They expect the programmes to hold their interest – that is, be entertaining – and to be accessible rather than excessively technical. Yet when it comes to their own research areas they often see the television as a way of lecturing to huge numbers of people whose interest can be taken for granted, and they berate programme makers for lack of rigour and substance or for trivialising the subject matter. Meanwhile, the media often see scientists as having unrealistic expectations and a lack of understanding of how the media work. Academia and the media can sometimes seem worlds apart.

TV audiences today have a vast range of channels to choose from. Viewers can switch from one to another with the mere touch of a finger on a remote controller, and will do so as soon as they lose interest in what is on the screen. Science programmes, like any others, have to be entertaining. In that respect, TV is the most demanding but all media are essentially part

---

[1] 'The Press' in this context is understood to encompass all the media, not just the print-on-paper kinds.

of the entertainment industry. They need to make money and they vie for readers, viewers and listeners. In this competitive environment, professional journalists and programme makers have a fairly clear idea what succeeds and what doesn't. Scientists cannot presume to teach them their job but we can give them the factual information and insight into scientific methods to help make their output a more accurate reflection of reality.

3.2. A SYMBIOTIC RELATIONSHIP

One of the most important things we try to do as press officers is help astronomers and the media understand each other's point of view. Each needs the other for their own different purposes so there is a symbiotic relationship between them. Since astronomy is popular with the public, the media want information and participation by its practitioners. For their part, astronomers need coverage in the media to maintain public support for what they do. Both parties have something to gain when the relationship works well with a high degree of mutual understanding.

When working with astronomers on media coverage of their research we endeavour to anticipate what the media will want and offer advice: consider what questions might the media ask; can they easily contact the researchers? We point out how important it is to have patience and to be prepared to put oneself out, perhaps taking out an hour to visit a radio studio for a 2-minute contribution.

Some researchers fear that inviting media attention will be very disruptive. Occasionally it is, when there is a very big news story. However, if the story is of great interest it will in any case be very difficult to fend off the media. Our advice is to co-operate constructively, which gives the greatest chance of accurate coverage.

3.3. MEDIA SKILLS

The RAS itself does not have the resources to offer its members individual formal training in media skills, but we encourage astronomers to take advantage of schemes on offer from other organisations. However, there are regular opportunities to talk about the media to groups and at meetings. Several university departments have asked for a seminar on the media to include in their regular programmes which are normally on research. For a number of years, students beginning graduate studies in astronomy in the UK have attended an introductory workshop lasting a week or so. A session on the media has been a regular feature for them, alongside introductions to topics in research. The RAS has held meetings on the media, bringing in journalists and programme makers as speakers.

The reactions to these events are typically very positive. Our experience is that British astronomers as a whole have seriously accepted the importance of communicating with the public through the media and generally enjoy doing it. This can probably be attributed to a number of developments since 1990, including the lead taken by the RAS and the support and encouragement for activities related to 'the public understanding of science' from the funding Research Councils. Of course, the personalities of some individuals mean that they do not interact easily with the media and no amount of training or persuasion is going to change matters. That has to be accepted and no-one should feel under undue pressure. If I am asked for just one simple piece of advice on dealing with the media it is this: 'Be enthusiastic'. Our experience with all media has shown time and again that scientists who speak of their research with obvious passion for what they do raise a sense of excitement and get over the message that astronomy is worth doing. They find themselves in demand.

4. Press notices

From the start, a press notice service has been central to the RAS's media activities. On average, 30 (plus or minus 10) have been issued each year. Using the short-hand language of the media, an event or result that might be the subject of a media report are described as a 'story'.

4.1. SOURCES OF STORIES

The RAS conducts no research itself but it holds meetings and publishes a research journal, the *Monthly Notices* (MN). Presentations given at its meetings and papers published in MN both provide stories for press notices. One-day discussion meetings are held in London 8 times a year. Media are always welcome as observers and press notices are used to draw attention to selected meetings likely to be of more than specialist interest. The RAS has also overall responsibility for the organisation of the UK National Astronomy Meeting (NAM), normally held annually and at a different location each year.

The NAM was established as part of the same initiative under which the RAS appointed its first PRO. It was not only to be an event to benefit the research community but hopefully a focus for media attention. The RAS had taken note of the way in which other scientific societies and organisations, notably in astronomy the *American Astronomical Society*, were taking advantage of their annual meetings to attract media interest. Some 10 or 15 press notices have normally been issued in connection with the NAM.

The MN is also an important source of stories. Photocopies of the abstracts of every paper accepted for publication are sent to me in regular batches several weeks before publication is due. If any seem suitable as media stories, I contact the author(s). There is no obligation for an author to agree to a press notice. In practice, hardly anyone declines.

RAS press notices are not restricted to stories from its meetings and publications. The service was conceived as being available to the whole astronomical community in the UK (and sometimes farther afield), including amateurs as well as professionals and non-members of the RAS. It has been uncommon to find in British universities press officers or science writers who handle research stories and maintain distribution lists of media interested in receiving them, though the situation is now slowly improving. Research groups and individuals can ask the RAS to help with the preparation of a press release and for it to be distributed under the RAS heading even when the story has no direct RAS connection. The RAS is widely seen as a neutral 'third party' that can appropriately act in this way and indeed may help to lend authority to a release in some circumstances.

We try to ensure that press notice will not mislead the media or bring the RAS into disrepute, though it is implicit that authors of research are ultimately responsible for what they say and write. As press officers we cannot also act as academic referees. We normally expect research described in a press notice to have been accepted for publication in a peer-reviewed journal, to be the subject of a presentation at a respected meeting or from a known and trusted source. Sometimes there are disagreements between research groups or individuals, and researchers occasionally make mistakes that only come to light after publicity. We take the view that this is the nature of science and not something we ought to police. Our overall aim is to be honest with the media and public about how astronomy is being conducted and any debates taking place.

There are no restrictions on what RAS press notices may cover. Celestial events of public interest, significant anniversaries, and British involvement in international projects are often covered for example, though we avoid unnecessary duplication of information widely available to the media from other sources.

4.2. WORKING WITH RESEARCHERS

Typically, we work very closely with an author, speaker or investigator to develop a press notice until all parties are happy with it. This is mostly done by e-mail but telephone conversations can help on occasions. We normally suggest that our academic contact should supply us with about 500 words setting out the story and its context as if explaining it to an intelligent teenager with basic knowledge of science. This first draft does not have to be in the style of a press notice. We have found that it is better to get the story in the person's own words than have them concerned over whether what they write is formatted as a press notice. A few astronomers have become skilled in writing press notices and what they submit requires little or no editing. More often we find that we construct the press notice by writing the all-important first paragraph then, for the rest, reordering and editing paragraphs from the material that has been supplied to us.

The most crucial thing is to identify the real point of the story. It is surprising how often that central point gets lost in a mass of detail and technicalities about the instruments or computations. Identifying the most appropriate 'summary in a sentence' can be the single most important contribution from the press officers. The test is to read the first paragraph of a press notice critically and ask oneself whether a hard-pressed journalist is going to respond, 'Well – so what?' If he is, it needs rethinking. Other things we check for routinely include mentions of full names, titles and affiliations of people involved in the research, explanation of technical terms and acronyms, accuracy of contact details and availability of people named as media contacts when the press notice is to go out.

As an example, consider the following first paragraph of a draft submitted by researchers:

> 'Infrared observations made with CGS4 on the UKIRT reveal the presence of brown dwarf-like mass donor stars in the cataclysmic variables LL And and EF Eri. Cataclysmic variables (CVs) consist of a white dwarf primary and a less massive, cooler secondary star. Theoretical calculations have shown that as a cataclysmic variable becomes very old, the mass losing star will be whittled down to a cold, Jupiter-sized body similar to a brown dwarf.'

In the final version of the press notice, the first paragraph was transformed into this:

> 'Astronomers using the UK Infrared Telescope (UKIRT) in Hawaii have discovered two examples of a kind of star never previously observed. These small, cool stars look superficially like brown dwarfs but are actually the remnants of ordinary stars that have been whittled down to cool Jupiter-sized bodies over billions of years by spilling material over to a white dwarf companion star.

We are told by the media that they prefer a plain, straight-forward, factual style and this is what we aim for. The inclusion of quotations from the scientists involved is also liked, but they should be meaningful rather than vacuous expressions of delight or excitement. Length has to be appropriate to the story, but the usual limits would be 200 to 500 words. If it seems helpful to supply background material, it is best put into supplementary notes after the main press notice.

Where we are dealing with the spokesman for a team, we urge him or her to check with other team members that they are happy about the release going out and to involve them in drafting and approving as appropriate. Only rarely would we issue a press notice without a specific go-ahead on the final version from our chief contact, and then usually by prior agreement because of some problem of deadline or unavailability.

4.3. DISTRIBUTION AND THE IMPACT OF THE INTERNET

A press notice service needs a good system of distribution to likely users in the media. Building a distribution list was one of the first tasks started in 1990 when I was appointed to the RAS. Updating and maintenance is necessary on an almost daily basis.

Prior to 1995 the distribution of RAS press notices was by hard copies in the mail. In 1995, we began to build an e-mail distribution list as significant numbers of journalists began to have access to e-mail and realised its potential for rapid dissemination of news. There was a transition period of about 2 years during which people could choose between e-mail and hard copies or both. In 1997 we finally ceased all hard copy distribution. It is now the case that virtually all media people expect and prefer news releases by e-mail, supported by information on web pages. The internet has had a profound effect on the distribution of information to the media and public. It is now far easier than ever before to reach a huge potential readership. Equally, it means greater care is needed over the distribution of embargoed material. News posted on frequently-visited web sites propagates around the world in minutes.

The RAS primary distribution list has for several years stood at around 200 world-wide. However, several recipients re-distribute press notices to other lists. Most notable is the remarkable service provided by Dr Stephen Maran, Press Officer of the *American Astronomical Society*[2]. His moderated distribution list was over 1000 in 2000. Though the AAS issues no press notices of its own (other than advisory notices about its meetings), astronomy-related press notices sent to Dr Maran from official sources are normally forwarded the same day (allowing for time differences). Given the speed and reliability of this service, many journalists outside the UK have opted not to go on the RAS direct e-mailing list in order to avoid duplication. UK recipients mostly remain on the direct list since press notices

---

[2] See for instance: *Astronomy and the News Media* by S.P. Maran *et al.*, in *Information Handling in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 2000, pp. 13-24. (Ed.)

only of interest in the UK and Europe are not normally sent to the AAS. In general astronomers and space scientists, particularly in the USA and the UK and in European organisations such as ESA and ESO, have been very successful in exploiting the internet to reach the media and the public.

Both the AAS and the RAS distribute e-mail press notices only in the form of plain text in the body of an e-mail message without any attachments and without any images. This is the only format that is universally acceptable to recipients around the world in a wide variety of situations where the hardware, software and means of internet access cover all possibilities.

In addition to direct e-mail distribution, two web-based science news centres have been of significance to astronomy. These are EurekAlert! [3] sponsored by the *American Association for the Advancement of Science (AAAS)* in the USA and *AlphaGalileo* [4] in Europe, sponsored by the *British Association for the Advancement of Science* (the BA). These sites allow press officers, academics and other approved contributors to post press releases on a web site which journalists can visit as a 'one-stop shop' to find the latest science news on any day. This system means that organisations wishing to issue press notices can reach a large readership among journalists without having to maintain specialist distribution lists. The RAS places its own press notices, and those it forwards on behalf of others, on the RAS web site [5] after any embargo has expired as well as on *AlphaGalileo.*

Distributing scientific press notices in the USA or Europe is no longer difficult. As a result, the number of releases in all subjects has steadily risen. In one sense this dissemination of more science is a good thing. However, it means there is more competition for limited space in the media, which has not increased its science coverage in step with this trend. The only exception is the appearance of web-based news services, which have immense capacity. This is an exciting development. Certainly, the attentive public who have internet access and seek out science stories can tap into a wealth of material.

4.4. IMAGES AND VIDEO

A good image can greatly enhance the likelihood of a news story being covered in newspapers and magazines. Moving images may increase the possibility of TV coverage. Our operation at the RAS does not have the resources to allow us to prepare images ourselves or to take on the production and distribution of video. However, where there are images to go with a press release, we encourage the authors of the work to place the images on their own web pages and we give the URL in the press notice. On no ac-

[3] `http://www.eurekalert.org/`

[4] `http://www.alphagalileo.org/`

[5] `http://www.ras.org.uk/`

count do we include images with the body of the press notice or send them as attachments because of the time taken to download even low-resolution files, especially by recipients operating with modems over telephone lines. Though the offices of major media companies are now equipped with powerful and up-to-date IT facilities, many recipients are freelance workers who have basic e-mail and web access but do not have the kind of facilities and skills available to academic researches and large businesses.

We advise that images should have strong aesthetic appeal because they are almost always selected or approved by picture editors rather than science specialists. A graph, a spectrum trace or other technical diagram is only likely to appear in a specialist feature article. It is hardly ever worth offering such an image to go with a general press notice. Equally, patterns of dots, contour diagrams or photographs with lettering and boxes overlaid on them, are restricted to specialist applications.

Resolution can be a problem with digital images on the web. For reproduction of quality images, the requirement is normally 300 dpi and TIFF format preferred. Ideally, high-resolution images should be available for download by the media who require them but they are not appropriate for placing on normal web pages because of their large file sizes.

4.5. EMBARGOES

There are sometimes reasons why an organisation does not want its news story to be made public before a certain date and/or time, but recognising the media's need for time to prepare or wishing to entice the media to cover the story, it issues a press notice under embargo. It is a system of trust. It works only because journalists who break embargoes are likely to be struck off press notice distribution lists and find they are excluded from sources of information.

Embargoes can have advantages for both the issuer of the news and the news media. If orchestrated successfully, an embargo means that the media can all cover a story at about the same time without of one 'scooping' the others. This should lead to the broadest possible coverage. However, embargoes are not always respected and whatever day/time is chosen, some media will be at favoured, others put at a disadvantage. Embargoes can lead to complaints and squabbles. For that reason, we have taken the view that they should be imposed only when there are compelling logical reasons. For example, it is common practice to embargo press notices on presentations at meetings until the days on which the talks take place.

We do not embargo stories stemming from papers in the *Monthly Notices* until the date of publication because of the relatively long period between acceptance and publication, which may be 6 months. In that time, other researchers may pre-empt the results with a publication elsewhere. We favour issuing any press notice as soon as is practicable after a paper's acceptance. In contrast, the weekly magazines *Nature* and *Science* exercise very rigid embargo policies on their contents.

4.6. THE RESULTS OF GOING PUBLIC

Once a press notice has been released, neither the issuing organisation, nor the authors of the work, nor anyone else, has any control on how it will be used in the media and what kind of stories will appear. In our experience, most science journalists (with a very few exceptions) are dedicated to honest and accurate reporting. Nevertheless, authors can sometimes be deterred because they cannot be sure what will appear in the media and they may become upset if they feel their work has not been fully or correctly represented. An article may be accurate and well-written, but placed under a sensational and inappropriate headline. The main concern is often about how professional colleagues will react.

In working with researchers, we try to prepare the ground for these possibilities. We try to convince them that a certain level of acceptance and an understanding of the pressures and constraints on the media are essential if the symbiotic relationship is to operate at all. Though the media are influential, the details of individual stories are mostly transitory. We strive for higher standards and better understanding on both sides but everyone has to recognise that perfection is probably out of reach.

4.7. FORWARDING OF PRESS NOTICES

Sometimes we are requested to forward press notices from other organisations to our distribution list, following the pattern established by the *American Astronomical Society*. This we are happy to do where the source is known to us and we have no reason to question the authenticity. We always clearly distinguish between forwarded press notices and those issued by the RAS.

5. What makes a story?

5.1. ASTRONOMY WITH MEDIA APPEAL

As with great art, the qualities of a good potential media story are hard to define but, with a little experience, one soon begins to recognise such stories when one sees them. However, it is possible to identify a number of factors that often are a feature of science story that make news:

1. Superlative (e.g. nearest, farthest, brightest, biggest...)

2. Image with good visual impact
3. Public may be able to see it (e.g. meteor shower, comet, eclipse)
4. Involves well-known object (e.g. naked-eye planet, bright star)
5. Could affect Earth (e.g. solar activity, possible impact by near-Earth object)
6. Relates to objects/concepts popular with public (e.g. black holes, dark matter)
7. Has a unique intriguing angle
8. Human interest (e.g. student has great achievement)
9. 'News peg' to make something topical (e.g. meeting, publication, anniversary)

I have often added 'tongue-in-cheek' to the this 'serious' list: any connection, however tenuous, with the popular themes of sex, religion, UFOs or astrology. After the UK's National Astronomy Meeting held in Cambridge in April 2001, I could add alchemy to the list. One of the UK's tabloid newspapers (the *Daily Mail*) ran a quite technical piece based on an RAS press notice on how precious metals such as gold and platinum might be created during the merger of two neutron stars under the headline 'Secret of Making Gold'. The piece also featured a box on the history of alchemy headed 'Quest that was outlawed as the Devil's work'. An image of a stack of gold ingots and a period engraving of an alchemist completed the effect. This newspaper article was a classic example of how serious science can be dressed up to have popular appeal by an intriguing link to a human preoccupation.

5.2. NEWS PEGS

Events and occasions present opportunities to publicise astronomy stories that might otherwise be passed over. Journalists and broadcasters are under considerable pressure to be topical. They often need to be able to explain why they are covering something or interviewing a person at a particular time. They are looking for what is called a 'news peg'. This is why meetings are important in the media effort. The publication of a paper or article, an anniversary, or an event such as the launch of a space mission are all news pegs.

It is also possible to 'create' topicality by making an announcement in a high profile manner. Sometimes the publication of a statement is sufficient, if backed up by the authority of a respected organisation or senior figure. A press briefing can be another alternative in the right circumstances, particularly if held under the auspices of a prestigious organisation.

5.3. PRESS BRIEFINGS

The RAS has occasionally arranged press briefings (alternatively called press conferences) for exceptional situations. Examples include the announcement of the discovery of the Sagittarius Dwarf galaxy colliding with the Milky Way, and the impact of Comet Shoemaker-Levy 9 on Jupiter. Our experience with the media, and with press events organised by others, causes us to exercise extreme caution over calling press briefings outside scientific meetings.

A press conference sends a signal to the media that an announcement or event is perceived as highly significant. Calling press conferences inappropriately can either damage relationships with the media or prove embarrassing if poorly attended. Increasingly we find that, apart from major meetings, science journalists tend to remain in their offices, relying on press notices, telephone interviews, and material from the internet.

6. An information service for the media

Apart from press notices, the other major strand of media activity for the *Royal Astronomical Society* has been the provision of a telephone help and information service. Enquiries occasionally arrive by e-mail but remain mostly by telephone. After the RAS service was first established at the end of 1989, the numbers of enquiries rose steadily for several years to about 500 annually. Since late 1999, there have been fewer direct enquiries. We attribute this to two factors: the availability of information from the world-wide web, aided by more sophisticated search engines, and the establishment of a public and media enquiry service at the Royal Observatory, Greenwich. Nevertheless, it is still a very important aspect of the work of the *Royal Astronomical Society* press officers.

6.1. WHAT THE MEDIA WANT TO KNOW

The subjects of media enquiries have encompassed virtually everything connected with astronomy and space. Certain topics arise with predictable regularity. These tend to be the things that cause dismay in the professional community, such as the naming of stars and the identification of mysterious lights in the sky (UFOs). However, we regard all enquiries as opportunities to correct misapprehensions and to put a positive case for real astronomy. One of the most bizarre was a request from a women's magazine for a suggestion for an attractive 'eligible bachelor' who was an astronomer to take part in a featured competition in which readers would vote for the men they liked best! The magazine regarded being an astronomer as a glamorous profession. We did our best to oblige but never heard the final outcome ...

Many enquiries relate to press notices received, not only from the RAS, but from other organisations such as NASA and ESA. Some enquirers are looking for clarification of information, others for people to speak on the media or to give attributable comments.

6.2. PRESS OFFICER SERVICE

Our approach is to answer as many enquiries as possible from personal knowledge and from our own resources. We refer enquirers to other experts only if the question is so specialised that we cannot find the answer or if the enquirer specifically asks to be put in contact with an academic expert. Having a broad knowledge of the astronomy and space science scene and of what is topical is essential for being able to do this. It is often the case that press officers are enablers, who can make appropriate connections between enquirers and experts, but are not themselves empowered as spokesmen. The RAS model of having press officers who do act on their own authority as spokesmen has proved successful and popular with the media. As a result of media enquiries, I and my colleague Peter Bond have contributed to numerous TV and radio programmes.

Media usually want immediate replies to their enquiries. The two RAS press officers, being part-time and having other commitments, are not always available to answer enquiries in person in standard office hours as might be the case with a formally established press office but, set against that, the RAS system has certain advantages. With two press officers, it is likely that one will be available at any given time. Though part-time, we have no fixed hours so always respond to calls if possible whenever they come. Working from home, we are prepared to take calls outside normal office hours, for example in the evenings and at weekends.

That availability has on occasion been much appreciated by the media when it is impossible to contact academics through their departments or press offices that are only active during standard office hours. Though our home phone numbers are known to large numbers of media people and easily found on the web by anyone, we have been inconvenienced by callers only on one or two occasions. Once I was woken by a call during the early hours of the morning. I had just retired having stayed up to see the beginning of the total phase of an eclipse of the Moon. The journalist who roused me genuinely believed that all members of the RAS were bound to be up all night observing the eclipse!

6.3. LIBRARY SERVICE

In addition to the service provided by the press officers, the RAS Library in the Society's premises in London handles a significant number of requests from the media and the public. These are often for information or pictures in books held by the Library. The Librarian has also prepared a number of information sheets to help with common enquiries, such as sources of images and information on careers.

7. Evaluating the RAS media service

7.1. EVALUATING THE RESPONSE OF THE MEDIA

We have never attempted to carry out regular or formal evaluation of the success of the RAS service through a newspaper cuttings service or broadcast monitoring. The expense in terms of both finance and human resources has been prohibitive. It is also very difficult to identify all the positive outcomes of media relations in such a simplistic way. Instead we have largely relied on general awareness, keeping in touch with our contacts and anecdotal feedback. We regard the maintenance of personal contacts with the media as being our most important means of judging our performance. On two or three occasions we have carried out surveys of the media who receive our press notices directly. These resulted in a high level of response and a very positive reaction to the quality and nature of service being provided.

7.2. STRENGTHS AND WEAKNESSES

As is true in many situations, we are aware that more could be done if more human and financial resources were available. We operate at minimal cost with a commitment (in 2001) of 145 person-days annually (or its equivalent on average), split between two press officers. We are not able to develop web sites, print literature, arrange expensive media events. However, we believe we have demonstrated that a considerable impact can be made by the 'cottage industry' approach, without a formal press office staffed by employees.

I suggest that our strengths have derived from a small number of features of how Peter Bond and I operate under the auspices of the RAS:

1. Authority to speak about astronomy and space matters in the name of the RAS (not 'political' or policy matters without consultation)
2. Flexibility of hours: being available to answer enquiries whenever we can
3. Freedom to determine our own agendas
4. Practice of keeping up-to-date with developments in our subject areas by devoting part of our time to reading press notices from other astronomy-related organisations, reading magazines and being aware of the contents of journals, attending professional meetings, visits to research groups, etc.

5. Developing and using our own writing and media skills
6. Sharing the experience of our media 'clients' and understanding their needs through our own writing and broadcasting experiences, many of which are not part of our contract with the RAS

I and my fellow press officer have been fortunate in our relationship with the *Royal Astronomical Society*, whose Council has continued to support our flexible approach to working with the media and has allowed us complete freedom to operate as we think best in the interests of promoting astronomy and space science. I have no doubt that this trust and support has been one of the most significant factors underlying the successes we have achieved.

CREATIVITY IN ARTS AND SCIENCES: A SURVEY

ANDRÉ HECK
Observatoire Astronomique
11, rue de l'Université
F-67000 Strasbourg, France
`aheck@cluster.u-strasbg.fr`

Abstract. The motivation for this chapter lies in a survey on creativity among a significant number of artists and scientists (largely but not only astronomers) worldwide. It mainly illustrates there is no unique creativity process, although similarities abound between artistic and scientific creativity. No major difference appears between the groups of artists, nor between the subsamples of male and female surveyees. Comparisons are offered on the basis of well-documented creativity processes as well as a few additional comments.

1. Introduction

The unfortunate lady next to me lost a number of her illusions that evening. At least, she lost a few of her romantic and idealistic views on the way paintings were conceived and materialized.

The noted local artist in front of us, also a guest for dinner of a mutual friend, had just gently explained her that, every time he was standing in front of a blank canvas, the challenge was simply to produce something he could sell and make a living out of it – a quite materialistically-minded creativity indeed. He would of course give as much as he could of himself in the work, but he would also totally integrate external constraints for his own subsistence and career. In fact, his creativity was basically market-driven.

Is it different for science and astronomy in particular?

We, in science, have certainly a much more comfortable situation as the financial aspect is generally ensured on a monthly basis ... once a grant or a position has been secured. But could we say our creativity is not *market*-driven either? Getting a position is not all in science. Career has to be pursued, essentially based on *recognition*. And this recognition relies

A. Heck (ed.), Organizations and Strategies in Astronomy II, 257–268.

largely on the capacity to include refereed publications in a curriculum vitae. Recognition is also critical for obtaining acceptance of proposals (*e.g.* leading to data collection), and for achieving funding of projects (allowing materialization of ideas).

Beyond intrinsic merits, this cannot be done without consideration of external elements. Research must be identified as excellent, certainly trendy and worth being invested in financially and humanly by the funding agencies and by the decision makers and takers.

2. Creativity?

This is not the place here for a treatise on creativity. The concept has become fashionable nowadays and several web sites are already offering extensive compilations of creativity-related books and quotations[1].

The list of these could be extended almost *ad infinitum*, from the late French President François Mitterand (1916-1996) declaring that "had [he] had creative talents, [he] would have never entered politics" (Martí 2001) to the London-based Spanish shoe designer Manolo Blahnik (1943-) saying his creativity surges from his obsessive and neurotic phases (Fernández-Santos 2001) – just to take a couple of examples from recent news reports.

How could a scientist not be curious about his/her own creativity? My own interest in creativity processes dates a long time back and can probably be traced to (or has been reinforced by) two influences.

The first one was with British writer Arthur Koestler[2] whose book *The Act of Creation* (1964) has been hailed as a richly documented study on creativity[3]. Briefly said, Koestler argues in that book that the mind's capacity for inspiration and thought is enhanced when rationality is suspended (as, for example, in dreams and trancelike states) and when automatic routines of behavior are suppressed. Kellner (1965) calls it "the most ambitious attempt yet made to integrate the findings of a range of disciplines into a single theory of creativity".

Koestler is well known for many other books, such as *The Sleepwalkers* (1959) where he shares his – again well-documented – sympathies and antipathies for great astronomers of the past. In the tragi-comedy *The Call-*

---

[1] See for instance `http://members.ozemail.com.au/~caveman/Creative/Books/` and `http://members.ozemail.com.au/~caveman/Creative/Resources/crquote2.htm/` .

[2] Budapest, 1905 – London, 1983.

[3] Interestingly the two volumes of the original English-US edition have been reduced to one by Koestler himself for the French edition entitled *Le cri d'Archimède* (1965). The author explains that critics reproached him to put together two parts addressed to two different audiences, the second one being directed to specialists (embryology, etc.). In the same foreword, Koestler also modestly expects progress in psychology and neurology will show his theory of creation is unsatisfactory, but hopes it will nevertheless be a step towards a better understanding of human thoughts and emotions.

Girls (1972, 1974), he stigmatises certain superficial scientific attitudes on the background of an imminent world conflict.

The Belgian writer Georges Simenon[4] has been very outspoken on his creativity processes, especially in interviews. As however his biographer Assouline reminds us in his voluminous and masterly written work (1996), one must always be careful with what individuals under study have written or declared on themselves – the usual differing perspectives between memoirs and biographies[5].

A rich personality, this prolific writer (under his own name and a number of pseudonyms) with an international career (Belgium, France, USA, Switzerland) originates from a city and a region quite familiar since I grew up and lived there for about thirty years. Characters like Simenon (his way of expressing himself, his exuberant sexual life, his stylish personality, his extensive travelling, the daily pragmatism of his books and his deep understanding of the human nature shown in his characters, ...) are not uncommon in the area. Simenon actually will be, not our reference in the following, but a kind of comparison for the survey.

3. A survey on creativity among artists and scientists

3.1. GENERALITIES

A few basic questions were put together and sent to a number of people worldwide. The purpose of this initial approach was essentially to collect reactions from a wide range of disciplines and sensitivities. So diversity was more important than a large number of answers.

The surveyees were also promised confidentiality and anonymity. So no names will be given hereafter, nor personal elements nor indications allowing some identifications (or they would be vague enough). Except where gender identification will be interesting for a couple of comments (essentially Question 4), the surveyees will be identified in a neutral way, as 'persons'.

3.2. THE SURVEY QUESTIONS

Here were the questions of that survey:

1. What is your category of recognized creation?

---

[4] Liège, 1903 – Lausanne, 1989.

[5] This must be obvious, so is it necessary to recall that people with public profile tend naturally to improve their image and would rarely confess anything that might be damaging to it? Autobiographies evidently always emphasize the 'nice' sides and are rather discrete on the other ones – unless they are well known, in which case they would be explained, excused or minimized.

[painting, writing, music, science, ...]
2. What are your motivations for creating?
   [none (spontaneous process), making a living, conveying messages, knowledge advancement, career progress, ...]
   If several motivations, please rank them by decreasing order of importance.
3. Is the result of your creativity expected (you know in advance what you will achieve) or (even partially) unexpected?
4. Would you say that creating is giving birth to something?
   [feel free to elaborate]
5. Would you say that your creativity is produced by another 'person' inside you?
   [feel free to elaborate]
6. What is the time of the day/week/month/year when the creative process is working best?
7. Is weather influencing your creativity?
8. Is any stimulant helping or indispensable to your creativity?
9. Please describe your creative process in a few words.
   Are there several phases?
   [preparation, concentration, depression, ...]
10. Did you notice an evolution/changes with age?
11. Would you say your creativity is a family gift?
    [other creative people in your family?]
12. What do you think of the claimed parallel between artistic and scientific creativity?
13. Additional comments?

3.3. SYNTHESIS OF THE ANSWERS TO THE SURVEY

About 50% of the questionnaires were returned, which can be considered as a good score, but, more important for our purpose, the answers were received in about equal numbers from artists and scientists, as well as from male and female surveyees. This last aspect is also interesting as one could expect differing sensitivities from men and women. Question 4 was especially interesting to peruse in this respect.

The answers were not only coming from a large range of creative areas (see hereafter Question 1), but also from quite different parts of the world: Europe, both Americas and Australasia.

There was one wholly negative reaction: a scientist simply declared having no time anymore for creativity. There might have been a misunderstanding on the term creativity, unless that person understood the survey was aiming at non-professional creativity. It is true also that this person now has important managerial responsibilities.

In a couple of instances, surveyees did not answer some questions directly for themselves, but were telling their general philosophy on the point (complementary definition). We either disregarded the answers or adopted what was somehow defined *in absentia*.

As mentioned earlier, we shall give, whenever we found the information (Assouline 1992; Simenon 1959 & 1963), what would Simenon have answered to each question.

3.3.1. *Question 1: category of recognized creation?*

Here is the large range of disciplines covered by the returned survey questionnaires (alphabetical order, with of course some overlapping, but also frequently several answers per category): architecture, astronomy, biology, chemistry, computing, dance, design, digital media, drawing, geology, history, lecturing, literature, movies, multimedia, music, painting, photography, physics, printing, presenting, scientific research, sculpture, software, sound arts, teaching, virtual reality, visual arts, writing.

Our comparison Simenon was of course a writer.

3.3.2. *Question 2: motivations for creating?*

The wording of that question (see 3.2.2) suggested some options. About half of the surveyees repeated them, often saying they were identifying a mixture of the possible reasons listed, but that it would be difficult to rank them by importance as the actual situation was depending of various factors and/or evolving over time.

The most frequently reasons listed, about equally, were an inner necessity (mainly, but not exclusively, by artists) and the advancement of knowledge (by scientists). Communicating with a larger audience (both categories) followed, as well as conveying information and career progress. Making a living was also mentioned a few times, as well as the spontaneous process, probably of the same family as the inner necessity. A couple of surveyees beautifully answered the "quest for immortality" which is to be linked with the need for recognition answered by others. Fun, meaning in life, sharing experiences were also among the motivations quoted.

For Simenon, this was an imperious inner necessity.

3.3.3. *Question 3: result unexpected?*

The overwhelming answer here was partially unexpected, sometimes with additional comments in the spirit "of course, otherwise there would be no creativity".

Some surveyees answered the result was always unexpected, totally unexpected, unexpected at beginning, not always expected, "it depends", and a couple of answers were simply 'expected'.

For Simenon, the result was partially unexpected (the failure of the novels was not always known to him beforehand).

3.3.4. *Question 4: giving birth to something?*

This 'psychic' question has been the source of interesting strong reactions and it is appropriate to make here a distinction between answers from male surveyees (ms) and female surveyees (fs).

The majority of surveyees found they were somehow giving birth to something. Here are a few of the comments, starting with clearly negative ones and ending with positive ones:

- No, I think that is a male cliché by people who will never actually give birth. (fs)
- No, I'm too macho. (ms)
- No, I think of it more in terms of inventing, more closely related to finding then giving birth, more like being an explorer. (fs)
- It is the process of creating that I cherish, not so much the product. (fs)
- Yes, but it would be pretentious to believe I give birth to something entirely new. I am happy if I am able to inspire a few other people. (fs)
- Yes and no. There is an internal period of gestation during which the form begins. But the realization of the form only happens through the process of [creating]; that is, the thing is not fully formed within, then ejected from the body. The process is a halting one. The [work] may emerge misformed and one has a chance, many chances, to refine and reshape until the integrity is there. (fs)
- Yes, there is a spark (a thrill) of idea + image. A gestation period, then as the work comes into being. I am, quite literally, dismembered (in the persona, psyche + though physically) and my life/soul energy is taken to bring the work across 'the river'. (fs)
- Birth involves intense pain and pleasure, and involves something new that is more than the sum of its parts, so yes! (ms)
- Yes, of course. It can also be said to release something that is present without form. Ideas are like this. (ms)
- Yes very much so; my [work was] my third baby (mother of two).

Simenon was definitely giving birth to something.

3.3.5. *Question 5: created by another person inside?*

This other 'psychic' question has sometimes been answered by describing the creative process itself (cf. Question 9) than by simply 'yes' or 'no'. But in those terms, the general answer was negative.

Simenon repeatedly explained he was in the skin of someone else when he was writing.

3.3.6. *Question 6: best time for creativity?*

That question was initially drafted with simple times of the day or the year in mind. Another aspect was however frequently mentioned instead in the answers: the best time is when there are no disturbance, distractions, inescapable solicitations and duties, burdens of all kinds, financial difficulties, health problems, etc., or even, as said a (male) surveyee, "when not in love"! All these situations can of course happen at different times of the day and year.

Otherwise, more to the initial point, a very large majority of the surveyees are more creative in the morning. Among the seasons, Winter and Autumn seem to be best, followed by Spring. Summer has not been mentioned.

Simenon was typing his books from 6:00 to 9:00am (but see also Questions 8 & 9).

3.3.7. *Question 7: weather influence?*

There is no clear majority, except perhaps in the sense that about half the surveyees said they did not notice any influence. Others claim they work better on sunny days, while some prefer rainy days to stay inside and 'work' (create). A couple of more complex answers pointed out that sunny weather and outdoor activities helped getting ideas, but bad weather was ideal to subsequently materialize them.

I have found no evidence of weather influence for Simenon.

3.3.8. *Question 8: stimulants helping or indispensable?*

Do not expect anything spicy here: all the surveyees seem to be quiet and reasonable people. The only substances mentioned recurrently were tea, coffee, chocolates, occasionally red wine and nicotine, otherwise music and stimulating conversations.

Simenon was known as a regularly very heavy drinker, but not as an alcoholic. His exuberant sexuality has also been the source of many commentaries[6]. There is no indication however that this helped or was necessary to his creative process. He often said that, when he was feeling the need to start a new book, he used to go out for a long walk and that it

---

[6] Probably with his cold Belgian humor, he boasted one day when interviewed "10,000 women", most of them prostitutes of course, something immediately echoed by the media. Later on, he 'modestly' claimed that, since he had been active since the age of 13, this corresponded on the average to only one woman every second or third day ...

was the smell or the scent of something that was triggering memories and calling places, faces and characters to his mind.

We shall come back to the stimulants issue in the final comments.

3.3.9. *Question 9: creative process?*

Each case is of course personal and often linked to the specific activities of the surveyees. It would therefore be too long to reproduce all the details here. Additionally some surveyees have obviously been studying their own process more deeply than others.

Summarizing all answers, it seems to me that there are generally at least two main phases.

First, a preparatory phase can take different shapes (quoting representative excerpts from questionnaires):

- meditation in front of a blank piece of paper or canvas;
- reading + thinking + assimilation;
- ideas popping up when travelling, walking in woods or relaxing on couch;
- research, contemplation;
- preparation, concentration;
- gathering data;
- getting rid of all pending things (including domestic ones);
- etc.

The second phase is actually the 'perspiration' one (quoting again):

- it requires effort, determination and tenacity to make things work;
- rush of work in a tunnel of concentration;
- get to doing the work until completed;
- sustained application;
- working, testing, working;
- Etc.

There might be of course several iterations and accessory phases. No surveyee but one reported subsequent phases such as depression, exhaustion, need for rest, and so on. But the painful character of creating, both mentally and physically, is often stressed, as well as the total isolation from the rest of the world during the most intense periods.

Simenon has described his creative process several times with a luxury of details, and this was confirmed by the testimonies of his near relations. When he was feeling that imperious need of writing a book (often a kind of uneasy feeling[7]), a couple of walks would define the places and characters (see Question 8). Then there would be a phase of careful preparation and meticulous gathering of documentation. He would then enter a phase of productivity, being in the skin of someone else (see Question 5), totally

---

[7] The French word he used was 'malaise'.

absorbed (once passing his wife and greeting her without recognizing her), typing frantically in the morning (Question 6) at the rhythm of one chapter per day with absolute prohibition to disturb him, sometimes changing shirts because sweating abundantly.

He was able to hold such a rhythm and withstand the stress for about ten days, which would explain why his novels have less than a dozen chapters. He needed a period of rest afterwards (several days) and was sometimes anxious for his mental integrity (*i.e.* not being sure he would always emerge intact from such periods).

3.3.10. *Question 10: evolution with age?*

Yes, definitely, there are changes with age. So, here is a sample of the most characteristic features listed:

- Younger: bigger need to create, more daring, more spontaneity, more energy, more health, more strength, more enthusiasm, less patience;
- Older: harder to find time, more silence required, loss of innocence, more refinement, slower process, less risk-taking, more down to points, more conscious of impacts, larger experience to build on, rushing before diminution of faculties.

Simenon often said that his understanding of the human nature increased with age as he was going through more experiences. He wanted to write until an old age to be able to go "all the way round the human nature".

3.3.11. *Question 11: family gift?*

Answers are very split on this point, with some (likely statistically unsignificant) predominance of 'no', as probably would have also answered Simenon (no clear statement found on that specific point).

There are of course several examples of creative families (Renoir, etc.) and dynasties of astronomers (Struve, Schwarzschild, etc.), but there are certainly other factors involved here than just genetics.

3.3.12. *Question 12: parallel between artistic and scientific creativity?*

Virtually all surveyees believe this is a true thing. Here are a few additional comments reproduced from the returned questionnaires:

- Some science can be extremely artsy. All is a creative endeavour. In either science or art, creativity is based on work work work. The work is different, but the joy is the same.
- I think (having mixed more with scientists than many in my discipline) that there is more art/beauty/creation in science and scientific theory than many artists realise – *e.g.* the beauty of a formula – or the real meaning of harmony in Pythagoras' theory. I'm sure that creation of scientific ideas

must undergo similar processes to artistic creation.
– Yes, but science does not move the souls as the arts do.
– Being creative is a gift, a fundamental attribute of a person, but it can take several forms: science, art, ...
– Humans are united at a deeper level than the disciplines of their activity. Creation, synthesis, inspiration, all work equally well in art and science.
– Definitely real parallel with scientists having however more boundary conditions (physical laws, etc.) to respect.
– I think research scientists who truly ask/theorize abstractly are great artists.
– Yes of course! An example is the long-term link between music and astronomy since Pythagoras.
– The science provides facts and principles that help our intellect grasp the physical nature and complexity of things, while visual art that deals with these subjects provides interpretation and inspiration leading toward a deeper aesthetic, spiritual, and metaphysical understanding.
– Two different worlds, according to me, but with some obvious links.

Simenon had a rather encyclopaedic view of creativity.

3.3.13. *Question 13: additional comments?*

Most surveyees found the survey interesting and were curious to see the results, in other words to compare their situation with that of others. They were sent a copy of this report.

4. Conclusions and additional comments

The variety of answers to most of the survey questions is an indication, if not a proof, that there is no unique creativity process, although similar features abound. Additionally, no major difference appeared between the group of artists and the group of scientists, nor between the subsamples of male and female surveyees.

The survey undertaken is pointing out a number of directions for further investigation. It should probably be carried out again on a much larger scale, with more questions and a finer stratification of points.

Comparisons could be multiplied, for instance:
– with Leonardo da Vinci whose vision has been extraordinary,
– with Michelangelo who has been one of the greatest and most versatile artists of the *Rinascimento* (Italian Renaissance),
– with Albert Einstein (see *e.g.* Fölsing 1997), hailed as The scientist of the XXth century and who is now the most-quoted philosopher, at least in scientific circles,
– with, why not, the famous Belgian schools of cartoonists (see *e.g.* Dayez

1997) whose members were more than prolific with creativity of all sorts, – and so on.

In OSA Book I, White (2000) presented the INSAP conferences that are opportunities to review the bridges (*cross-overs*) between astronomy and the arts and literature. I attended two of the three conferences organized so far. Following those experiences, it is obvious to me that artists and scientists – the creative ones at least – have a lot in common.

We all know by experience that creativity is not absolutely necessary nowadays to make a career in astronomy (or science in general) as it has become such an intricate business that it offers plenty of slots for competence not involving creativity. This is of course acceptable as long as the career tracks followed are identified as non-creative ones, which is not always the case. Not infrequently, scientists make a career simply by adapting or plagiarizing ideas of others.

This brings us to a general comment on the way universities and most 'grandes écoles' are *not* preparing students to research. Students are too often treated – and rated – rather as good sponges: they are taught a number of things and rated according to their capacity, when pressed and squeezed at exams, to produce the same kind of juice. Some higher education establishments also emphasize too much clanning and good handling of relationships compare to creativity.

Additionally I have seen *many* PhD theses that were largely if not totally devoid of any type of creativity, and this for a number of reasons such as the inappropriate level of the supervisor and/or the student, or because of time constraints on the theses rendering the exercise hopeless.

A final comment regarding the potential usage of stimulants: there is no reason to question the sincerity of the answers to the survey presented in this chapter, but it is obvious that the usage of drugs or of chemical adjuvants is wider-spread than it is accepted generally. Of course, this is a delicate matter and one cannot expect people frankly to tell a surveyor of possible habits in that respect.

It should also be noted that scientists may take drugs for other reasons than just creativity. In the past, winter nights were cold and long at telescopes, and drugs (from chocolate to red wine and perhaps opium) might have been taken to withstand fatigue and keep the brains alert.

To be complete, the existence of a number of medical studies dealing with the influence on creativity of various disorders must be mentioned. This is of course totally outside the scope of this chapter.

Acknowledgments

I am very grateful to individual artists and scientists who returned the survey questionnaires.

References

1. Assouline, P. 1992, Simenon, Julliard, Paris, 1062 pp.
2. Dayez, H. 1997, Le Duel Tintin-Spirou, Ed. Contemporaines, Paris, 256 pp.
3. Fernãndez-Santos, E. 2001, *El País*, 30/05/2001.
4. Fölsing, A. 1997, Albert Einstein, Penguin Books Ltd., Harmondsworth, xiv + 882 pp.
5. Kellner, G. 1965, The Art and Science of Creativity, Holt, Rinehard and Winston, New York.
6. Koestler, A. 1959, The Sleepwalkers, Hutchinson, London, 624 pp.
7. Koestler, A. 1964, The Act of Creation, Arkana, London, 752 pp.
8. Koestler, A. 1965, Le cri d'Archimède, Calmann-Lévy, Paris, 448 pp.
9. Koestler, A. 1973, The Call-Girls, Random House, New York, 167 pp.
10. Koestler, A. 1974, personal communication.
11. Martí, O. 2001, *El País*, 28/04/2001.
12. Simenon, G. 1959, TV interview (J. Modave)
13. Simenon, G. 1963, TV interview (D. Gilles)
14. White, R.E. 2000, The Conferences on 'The Inspiration of Astronomical Phenomena': Excursions into 'Cross-Overs' between Science and the Arts and Literature, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, pp. 203-209.

UPDATED BIBLIOGRAPHY OF SOCIO-ASTRONOMY

Introduction

The following lists gather together papers and books published (from 1980 onwards) in socio-astronomy and on the interactions of the astronomy community with the society at large. A few related contributions have also been included, as well as the decennial reports from the US National Research Council. The first list is chronological and the second one, purely alphabetical on the authors names.

It is of course impossible such a list be complete and we apologize in advance to authors whose related publications could have been omitted. For inclusion in future releases of this compilation and of its web version[1], please send an e-mail (to `heck@astro.u-strasbg.fr`) with the full bibliographical references (including title).

The Editor gratefully acknowledges the assistance of all persons who contributed to the substance of the following list by sending in references and/or reprints of papers.

Chronological list

The following list is alphabetical on the first authors within the successive years. It updates and replaces the list published in the first volume.

1980

1. Abt, H.A. 1980, The Cost-Effectiveness in Terms of Publications and Citations of Various Telescopes at the Kitt Peak National Observatory, *Publ. Astron. Soc. Pacific* **92**, 249
2. Stebbins, R.A. 1980, Avocational Science: The Avocational Routine in Archaeology and Astronomy, *Int. J. Comp. Sociology* **21**, 34-48

---

[1] `http://vizier.u-strasbg.fr/~heck/sda-pap.htm`

A. Heck (ed.), Organizations and Strategies in Astronomy II, 269–280.

1981

3. Abt, H.A. 1981, Long-Term Citation Histories of Astronomical Papers, *Publ. Astron. Soc. Pacific* **93**, 207
4. Abt, H.A. 1981, Some Trends in American Astronomical Publications, *Publ. Astron. Soc. Pacific* **93**, 269
5. Gieryn, T.F. 1981, The Aging of a Science and its Exploitation of Innovation: Lessons from X-ray and Radio Astronomy, *Scientometrics* **3**, 325-334
6. Heck, A. & Manfroid, J. 1981, International Directory of Amateur Astronomical Societies 1981, ed. Heck-Manfroid, iv + 300 pp.
7. Heck, A. & Manfroid, J. 1981, International Directory of Amateur Astronomical Societies 1982, ed. Heck-Manfroid, iv + 304 pp.
8. Stebbins, R.A. 1981, Looking Downwards: Sociological Images of the Vocation and Avocation of Astronomy, *J. Roy. Astron. Soc. Canada* **75**, 2-14
9. Stebbins, R.A. 1981, Science Amators? Rewards and Costs in Amateur Astronomy and Archaeology, *J. Leisure Res.* **13**, 289-304

1982

10. Abt, H.A. 1982, Statistical Publication Histories of American Astronomers, *Publ. Astron. Soc. Pacific* **94**, 213
11. Field, G.B. *et al.* 1982, Astronomy and Astrophysics for the 1980's ['Field Report'], National Acad. Press, xx + 190 pp. (ISBN 0-309-03249-0)
12. Stebbins, R.A. 1982, Amateur and Professional Astronomers, *Urban Life* **10**, 433-454

1983

13. Abt, H.A. 1983, At What Ages did Outstanding American Astronomers Publish their Most-Cited Papers?, *Publ. Astron. Soc. Pacific* **95**, 113
14. Gieryn, T.F. & Hirsh, R.F. 1983, Marginality and Innovation in Science, *Social Studies Sc.* **13**, 87-106

1984

15. Abt, H.A. 1984, Citations to Federally-Funded and Unfunded Research, *Publ. Astron. Soc. Pacific* **96**, 563
16. Abt, H.A. 1984, Citations to Single and Multiauthored Papers, *Publ. Astron. Soc. Pacific* **96**, 746
17. Heck, A. & Manfroid, J. 1984, International Directory of Amateur Astronomical Societies 1984, ed. Heck-Manfroid, iv + 278 pp.

18. Trimble, V. 1984, Postwar Grown in the Length of Astronomical and Other Scientific Papers, *Publ. Astron. Soc. Pacific* **96**, 1007
19. Trimble, V. 1984, How Science Ought to be Done, *New Scientist* (29 Nov 1984) 41

1985

20. Abt, H.A. 1985, An Assessment of Research Done at the National Optical Observatories, *Publ. Astron. Soc. Pacific* **97**, 1050
21. Arunachalam, S. & Hirannaiah, S. 1985, Has Journal of Astrophysics and Astronomy a Future?, *Scientometrics* **8**, 3-11
22. Heck, A. & Manfroid, J. 1985, International Directory of Astronomical Associations and Societies 1986, *Publ. Spéc. CDS* **8**, iv + 266 pp. (ISSN 0764-9614 - ISBN 2-908064-06-5)
23. Trimble, V. 1985, Some Notes on Patterns in Citation of Papers by American Astronomers, *Q. J. Roy. Astron. Soc.* **26**, 40

1986

24. Heck, A. & Manfroid, J. 1986, International Directory of Professional Astronomical Institutions 1987, *Publ. Spéc. CDS* **9**, iv + 276 pp. (ISSN 0764-9614 - ISBN 2-908064-07-3)
25. Herrmann, D.B. 1986, Astronomy in the Twentieth Century, *Scientometrics* **9**, 187-191
26. Trimble, V. 1986, A Note on Self-Citation Rates in Astronomy, *Publ. Astron. Soc. Pacific* **98**, 1347-1348
27. Trimble, V. 1986, Death Comes as the End: Effects of Cessation of Personal Influence on Citation Rates of Astronomical Papers, *Czechosl. J. Phys.* **36B**, 175

1987

28. Abt, H.A. 1987, Are Papers by Well-Known Astronomers Accepted for Publication More Readily than Other Papers?, *Publ. Astron. Soc. Pacific* **99**, 439
29. Abt, H.A. 1987, Reference Frequencies in Astronomy and Related Sciences, *Publ. Astron. Soc. Pacific* **99**, 1329
30. Davoust, E. & Schmadel, L.D. 1987, A Study of the Publishing Activity of Astronomers since 1969, *Publ. Astron. Soc. Pacific* **99**, 700-710
31. Heck, A. & Manfroid, J. 1987, International Directory of Astronomical Associations and Societies 1988, *Publ. Spéc. CDS* **10**, vi + 516 pp. (ISSN 0764-9614 - ISBN 2-908064-08-1)
32. McCrea, W.H. 1987, Clustering of Astronomers, *Ann. Rev. Astron. Astrophys.* **25**, 1-22

33. Peterson, C.J. 1987, The Evaluation of Scientific Research: A Brief Study of Citations to Research Papers from the Dominion Astrophysical Observatory, *J. Roy. Astron. Soc. Canada* **81**, 30-35
34. Stebbins, R.A. 1987, Amateurs and their Place in Professional Science, in *New Generation Small Telescopes*, Eds. D.S. Hayes, D.R. Genet & R.M. Genet, Fairborn Press, Mesa, 217-225

1988

35. Abt, H.A. 1988, What Happens to Rejected Astronomical Papers?, *Publ. Astron. Soc. Pacific* **100**, 506
36. Abt, H.A. 1988, Growth Rates in Various Fields of Astronomy, *Publ. Astron. Soc. Pacific* **100**, 1567
37. Heck, A. 1988, International Directory of Professional Astronomical Institutions 1989, *Publ. Spéc. CDS* **12**, vi + 492 pp. (ISSN 0764-9614 - ISBN 2-908064-10-3)
38. Herrmann, D.B. 1988, How Old were the Authors of Significant Research in 20th Century Astronomy at the Time of their Greatest Achievements?, *Scientometrics* **13**, 135-137
39. Makino, J. 1988, Productivity of Research Groups. Relation between Citation Analysis and Reputation within Research Communities, *Scientometrics* **43**, 87-93
40. Peterson, C.J. 1988, Citation Analysis of Astronomical Literature: Comments on Citation Half-Lives, *Publ. Astron. Soc. Pacific* **100**, 106-115
41. Trimble, V. 1988, Some Characteristics of Young versus Established American Astronomers, *Publ. Astron. Soc. Pacific* **100**, 646-650

1989

42. Abt, H.A. & Liu, J. 1989, Journal Referencing, *Publ. Astron. Soc. Pacific* **101**, 505
43. Heck, A. 1989, International Directory of Astronomical Associations and Societies together with Related Items of Interest – Répertoire International d'Associations et Sociétés Astronomiques ainsi que d'Autres Entrées d'Intérêt Général – IDAAS 1990, *Publ. Spéc. CDS* **13**, vi + 716 pp. (ISSN 0764-9614 – ISBN 2-908064-11-1)
44. Heck, A. 1989, International Directory of Professional Astronomical Institutions together with Related Items of Interest – Répertoire International des Institutions Astronomiques Professionnelles ainsi que d'Autres Entrées d'Intérêt Général – IDPAI 1990, *Publ. Spéc. CDS* **14**, vi + 658 pp. (ISSN 0764-9614 – ISBN 2-908064-12-x)

1990

45. Abt, H.A. 1990, Trends towards Internationalization in Astronomical Literature, *Publ. Astron. Soc. Pacific* **102**, 368-372
46. Abt, H.A. 1990, Publication Characteristics of Members of the American Astronomical Society, *Publ. Astron. Soc. Pacific* **102**, 1161-1166
47. Abt, H.A. 1990, The Use of Publication Studies to Affect Policies and Attitudes in Astronomy, *Curent Contents* **33/39**, 7

1991

48. Abt, H.A. 1991, Science, Citation, and Funding, *Science* **251**, 1408-1409
49. Bahcall, J.N. 1991, Prioritizing Scientific Initiatives, *Science* **251**, 1412-1413
50. Bahcall, J.N. *et al.* 1991, The Decade of Discovery in Astronomy and Astrophysics ['Bahcall Report'], National Acad. Press, xvi + 182 pp. (ISBN 0-309-04381-6)
51. Davoust, E. & Schmadel, L.D. 1991, A Study of the Publishing Activity of Astronomers since 1969, *Scientometrics* **22**, 9-39
52. Heck, A. 1991, Astronomy, Space Sciences and Related Organizations of the World - ASpScROW 1991, *Publ. Spéc. CDS* **16**, x + 1182 pp. (ISSN 0764-9614 - ISBN 2-908064-14-6) (two volumes)
53. Jaschek, C. 1991, The Size of the Astronomical Community, *Scientometrics* **22**, 265-282
54. Thronson Jr., H.A. 1991, The Production of Astronomers: A Model for Future Surpluses, *Publ. Astron. Soc. Pacific* **103**, 90-94
55. Trimble, V. 1991, Long-Term Careers of Astronomers with Doctoral Degrees from Prestigious versus Non-Prestigious Universities, *Scientometrics* **20**, 71-77
56. Trimble, V. & Elson, R. 1991, Astronomy as a National Asset, *Sky & Tel.* **82**, 485

1992

57. Abt, H.A. 1992, What Fraction of Literature References are Incorrect?, *Publ. Astron. Soc. Pacific* **104**, 235-236
58. Abt, H.A. 1992, Publication Practices in Various Sciences, *Scientometrics* **24**, 441
59. Jaschek, C. 1992, The 'Visibility' of West European Astronomical Research, *Scientometrics* **23**, 377-393
60. White II, J.C. 1992, Publication Rates and Trends in International Collaborations for Astronomers in Developing Countries, Eastern European Countries, and the Former Soviet Union, *Publ. Astron. Soc. Pacific* **104**, 472-476

1993

61. Abt, H.A. 1993, The Growth of Multiwavelength Astrophysics, *Publ. Astron. Soc. Pacific* **105**, 437-439
62. Abt, H.A. 1993, Institutional Productivities, *Publ. Astron. Soc. Pacific* **105**, 794
63. Davoust, E. 1993, L'Astronomie, Cartographie d'une Discipline, *Cahiers ADEST*, n-ro spécial, 44-49
64. Davoust, E., Bergecol, H. & Callon, M. 1993, À Quoi Sert la Scientométrie?, *J. Astron. Français* **44**, 13-19
65. Heck, A. 1993, StarGuides 1993 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **20**, x + 1174 pp. (ISSN 0764-9614 – ISBN 2-908064-14-6) (two volumes)
66. Trimble, V. 1993, Patterns in Citations of Papers by American Astronomers, *Q. J. Roy. Astron. Soc.* **34**, 235
67. Trimble, V. 1993, Patterns in Citations of Papers by British Astronomers, *Q. J. Roy. Astron. Soc.* **34**, 301

1994

68. Abt, H.A. 1994, Institutional Productivities, *Publ. Astron. Soc. Pacific* **106**, 107
69. Abt, H.A. 1994, The Current Burst in Astronomical Publications, *Publ. Astron. Soc. Pacific* **106**, 1015
70. Heck, A. 1994, StarGuides 1994 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **23**, viii + 880 pp. (ISSN 0764-9614 – ISBN 2-908064-21-9)
71. Saurer, W. & Weinberger, R. 1994, Planetary Nebulae: Some Statistics on a Continuously Growing Field and its Contributors, *Scientometrics* **31**, 85-95
72. van der Kruit, P.C. 1994, The Astronomical Community in the Netherlands, *Q. J. Roy. Astron. Soc.* **35**, 409-423
73. van der Kruit, P.C. 1994, A Comparison of Astronomy in Fifteen Member Countries of the Organization for Economic Co-operation and Development, *Scientometrics* **31**, 155-172

1995

74. Abt, H.A. 1995, Changing Sources of Published Information, *Publ. Astron. Soc. Pacific* **107**, 401-403
75. Abt, H.A. 1995, Some Statistical Highlights of the Astrophysical Journal, *Astrophys. J.* **455**, 407
76. Heck, A. 1995, StarGuides 1995 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **25**, viii + 814 pp. (ISSN 0764-9614 – ISBN 2-908064-23-5)

77. Liu, J. & Shu, Z. 1995, Statistical Analysis of Astronomical Papers in China during 1986-1990, *Scientometrics* **32**, 237-245
78. Trimble, V. 1995, Papers and Citations Resulting from Data Collected at Large American Optical Telescopes, *Publ. Astron. Soc. Pacific* **107**, 977-980

1996

79. Abt, H.A. 1996, How Long are Astronomical Papers Remembered?, *Publ. Astron. Soc. Pacific* **108**, 1059-1061
80. Abt, H.A. & Zhou, H. 1996, What Fraction of Astronomers Become Relatively Inactive in Research after Receiving Tenure?, *Publ. Astron. Soc. Pacific* **108**, 375-377
81. Heck, A. 1996, StarGuides 1996 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **27**, viii + 916 pp. (ISSN 0764-9614 – ISBN 2-908064-25-1)
82. Trimble, V. 1996, Productivity and Impact of Large Optical Telescopes, *Scientometrics* **36**, 237-246
83. Uzun, A. & Özel, M.E. 1996, Publication Patterns of Turkish Astronomers, *Scientometrics* **37**, 159-169

1997

84. Girard, R. & Davoust, E. 1997, The Role of References in the Astronomical Discourse, *Astron. Astrophys.* **323**, A1-A6
85. Heck, A. 1997, StarGuides 1997 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **29**, viii + 956 pp. (ISSN 0764-9614 – ISBN 2-908064-27-8)
86. Lankford, J. 1997, American Astronomy, Univ. Chicago Press, xxvi + 448 pp. (ISBN 0-226-46886-0)
87. Schulman, E., French, J.C., Powell, A.L., Eichhorn, G., Kurtz, M.J. & Murray, S.S. 1997, Trends in Astronomical Publication between 1975 and 1996, *Astron. J.* **109**, 1278-1284

1998

88. Abt, H.A. 1998, Why Some Papers have Long Citation Lifetimes, *Nature* **395**, 756-757
89. Abt, H.A. 1998, Is the Astronomical Literature Still Expanding Exponentially?, *Publ. Astron. Soc. Pacific* **110**, 210-213
90. Fernández, J.A. 1998, The Transition from an Individual Science to a Collective One, *Scientometrics* **42**, 61
91. Heck, A. 1998, StarGuides 1998 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **30**, viii + 1022 pp. (ISSN 0764-9614 – ISBN 2-908064-28-6)

92. Heck, A. 1998, Geographical Distribution of Observational Activities for Astronomy, *Astron. Astrophys. Suppl.* **130**, 403-406
93. Heck, A. 1998, Astronomy-Related Organizations over the World, *Astron. Astrophys. Suppl.* **132**, 65-81
94. Heck, A. 1998, Electronic Publishing in its Context and in a Professional Perspective, *Rev. Modern Astron.* **11**, 337-347
95. Makino, J. 1998, Productivity of Research Groups – Relation between Citation Analysis and Reputation within Research Communities, *Scientometrics* **43**, 87-93
96. Meadows, A.J. 1998, Communicating Research, Academic Press, London, x + 266 pp. (ISBN 0-12-487415-0)

1999

97. Bahcall, J.N. 1999, Prioritizing Science: A Story of the Decade Survey for the 1990s, in *The American Astronomical Society's First Century*, Ed. D.H. DeVorkin, Amer. Astron. Soc., Washington, pp. 289-300
98. Gibson, B.K., Buxton, M., Vassiliadis, E., Sevenster, M.N., Jones, D.H. & Thornberry, R.K. 1999, On the Importance of the PhD Institute in Establishing a Long-Term Research Career in Astronomy, *Bull. Amer. Astron. Soc.* **31**, 1000
99. Heck, A. 1999, StarGuides 1999 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **31**, viii + 1022 pp. (ISSN 0764-9614 – ISBN 2-908064-29-4)
100. Heck, A. 1999, The Age of Astronomy-Related Organizations, *Astron. Astrophys. Suppl.* **135**, 467-475 + **136**, 615
101. Heck, A. 1999, Characteristics of Astronomy-Related Organizations, *Bull. Amer. Astron. Soc.* **31**, 1002
102. Maran, S.P. 1999, The American Astronomical Society and the News Media, in *The American Astronomical Society's First Century*, Ed. D.H. DeVorkin, Amer. Astron. Soc., Washington, pp. 213-220
103. Pottasch, S.R. 1999, The History of the Creation of Astronomy and Astrophysics, *Astron. Astrophys.* **352**, 349-353
104. Schaefer, B.E., Hurley, K., Nemiroff, R.J., Branch, D., Perlmutter, S., Schaefer, M.W., Consolmagno, McSween, H. & Strom, R. 1999, Accuracy of Press Reports in Astronomy, *Bull. Amer. Astron. Soc.* **31**, 1521

2000

105. Abt, H.A. 2000, Do Important Papers Produce High Citation Counts?, *Scientometrics* **48**, 65
106. Abt, H.A. 2000, Astronomical Publication in the Near Future, *Publ. Astron. Soc. Pacific* **112**, 1417-1420

107. Abt, H.A. 2000, The Reference-Frequency Relation in the Physical Sciences, *Scientometrics* **49**, 443-451
108. Abt, H.A. 2000, The Most Frequently Cited Astronomical Papers Published during the Last Decade, *Bull. Amer. Astron. Soc.* **32**, 937-941
109. Abt, H.A. 2000, What can we Learn from Publication Studies?, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 77-89
110. Andersen, J. 2000, Information in Astronomy: The Role of the IAU, in *Information Handling in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 1-12
111. Bohlin, J.D. 2000, NASA Program Solicitations, Proposal Evaluations, and Selection of Science Investigations, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 123-143
112. Burstein, D. 2000, Astronomy and the Science Citation Index, 1981-1997, *Bull. Amer. Astron. Soc.* **32**, 917-936
113. Esterle, L. & Zitt, M. 2000, Observation of Scientific Publications in Astronomy/Astrophysics, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 91-109
114. Heck, A. 2000, StarGuides 2000 – A Directory of Astronomy, Space Sciences and Related Organizations of the World, *Publ. Spéc. CDS* **32**, viii + 1140 pp. (ISSN 0764-9614 – ISBN 2-908064-30-8)
115. Heck, A. 2000, Where the Astronomers Are: A Stagnant Century, *Sky & Tel.* **99**, 32-35
116. Heck, A. (Ed.) 2000, Information Handling in Astronomy, Kluwer Acad. Publ., Dordrecht, x + 242 pp. (ISBN 0-7923-6494-5)
117. Heck, A. 2000, StarGuides 2001 – A World-Wide Directory of Organizations in Astronomy, Related Space Sciences and Other Related Fields, Kluwer Acad. Publ., Dordrecht, xiv + 1224 pp. (ISBN 0-7923-6509-7)
118. Heck, A. 2000, Characteristics of Astronomy-Related Organizations, *Astrophys. Sp. Sc.* **274**, 733-783
119. Heck, A. (Ed.) 2000, Organizations and Strategies in Astronomy, Kluwer Acad. Publ., Dordrecht, x + 222 pp. (ISBN 0-7923-6671-9)
120. Heck, A. 2000, Communicating in Astronomy, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 165-184
121. Heck, A. 2000, Perceptions of Science, *European Ass. Study Sc. & Technol. Review* **19/4**, 8-9
122. Madsen, C. & West, R.M. 2000, Public Outreach in Astronomy: The ESO Experience, in *Information Handling in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 25-43
123. Mahoney, T.J. 2000, The Problems of English as a Foreign Language in

Professional Astronomy, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 185-192

124. Maran, S.P., Cominsky, L.R. & Marschall, L.A. 2000, Astronomy and the news media, in *Information Handling in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 13-24
125. Meadows, J. 2000, Astronomy and the General Public: A Historical Perspective, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 193-202
126. Pfau, W. 2000, The Astronomische Gesellschaft: Pieces from its History, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 65-75
127. Pottasch, S.R. 2000, The Refereeing System in Astronomy, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 111-121
128. Trimble, V. 2000, Some Characteristics of Young versus Established American Astronomers: Entering the New Century, *Scientometrics* **48**, 403-411
129. Volonte, S. 2000, Planning and Implementation of ESA's Space Science Programme, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 145-164
130. White, R.E. 2000, The Conferences on 'The Inspiration of Astronomical Phenomena': Excursions into 'Cross-Overs' between Sciences and the Arts and Literature, in *Organizations and Strategies in Astronomy*, Ed. A. Heck, Kluwer Acad. Publ., Dordrecht, 203-209

2001

131. Abt, H.A. 2001, The Recent Rise of Arabic Astronomy, *Arab Journal of Astronomy and Space Sciences*, in press
132. Abt, H.A. 2001, Electronic Access to Journals, *Highlights of Astronomy*, in press
133. Benn, C.R. & Sanchez, S.F. 2001, Scientific Impact of Large Telescopes, *Publ. Astron. Soc. Pacific* **113**, 385-396
134. Heck, A. 2001, Survey of Non-Professional Astronomy Magazines in Professional Astronomy Libraries, *Astrolib*, 26 Feb 2001
135. McKee, Ch.F. & Taylor Jr., J.H. 2001, Astronomy and Astrophysics in the New Millenium, Nat. Acad. Press, Washington, in press.

Alphabetical list of authors

The numbers refer to the chronological list.