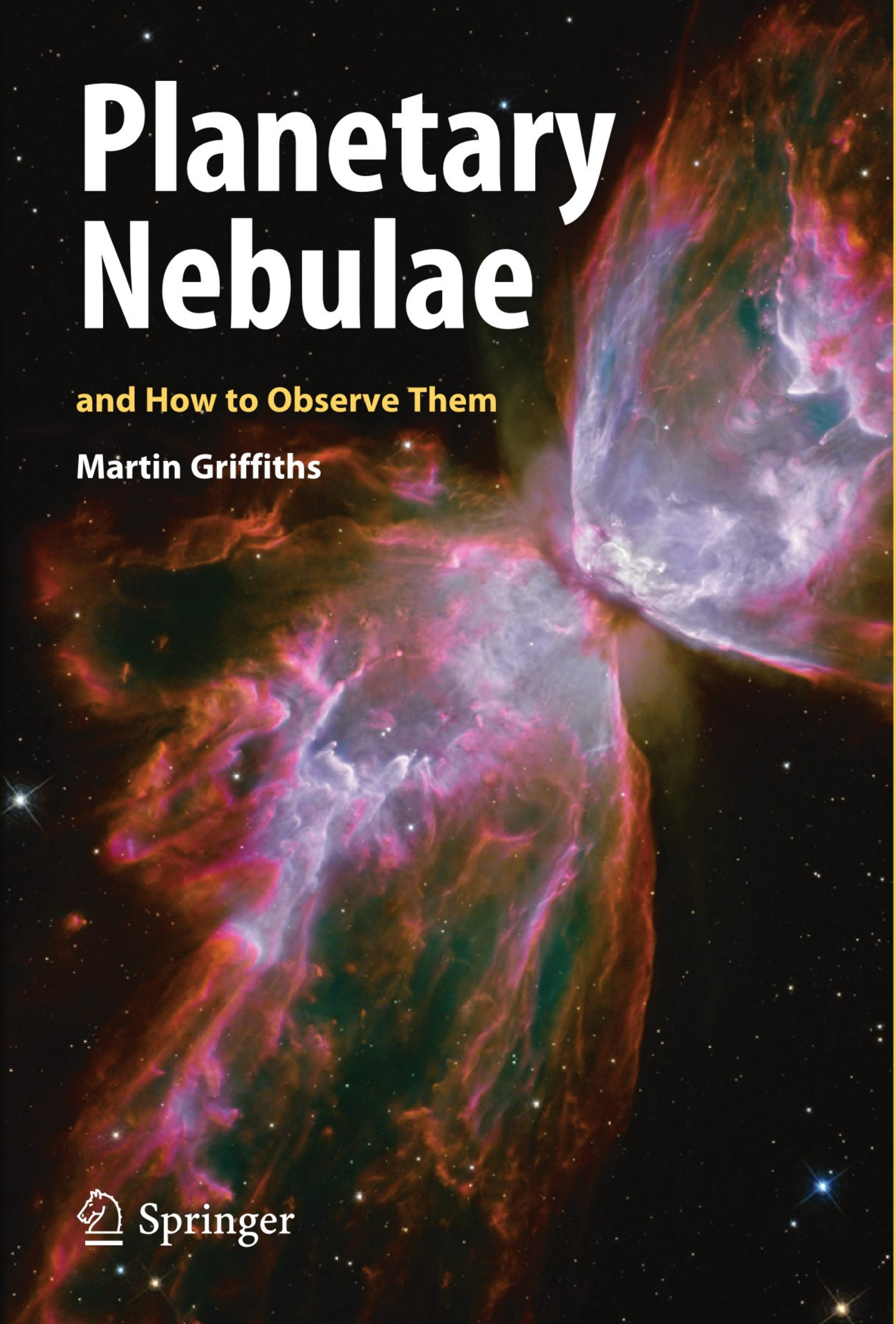
Planetary Nebulae

and How to Observe Them

Martin Griffiths



Springer

ASTRONOMERS' OBSERVING GUIDES

Astronomers' Observing Guides

Series Editor
Dr. Michael D. Inglis, BSc, MSc, Ph.D.
Fellow of the Royal Astronomical Society
Suffolk County Community College
New York, USA
inglism@sunysuffolk.edu

For further volumes:
http://www.springer.com/series/5338

Martin Griffiths

Planetary Nebulae and How to Observe Them

Springer

Martin Griffiths
University of Glamorgan
Glyntaf, United Kingdom

ISSN 1611-7360
ISBN 978-1-4614-1781-1 e-ISBN 978-1-4614-1782-8
DOI 10.1007/978-1-4614-1782-8
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011946227

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

For Dena

Preface

Planetary nebulae are among the diverse forms of astronomical objects available for amateur study and may be some of the most inspiring sights nature has to offer. Seldom is there a group with such a range of shapes, sizes and colors that have particular idiosyncrasies from object to object. Planetary nebulae are fascinating, beautiful and enchanting; what could be more wonderful than contemplating these small celestial objects, realizing that 1 day our Sun may join this band of heavenly entities? Their ethereal nature, short lifetime and range of forms make observing them a most pleasing study.

I have been entranced by them from a young age and can still remember my first look at the famous 'Dumbbell' Nebula, Messier 27, through a small refractor I had purchased from a friend. It was a puff of gas, blue-gray in color with a definite indentation on both sides nestled in a field of fainter stars, yet overflowing and seeming to envelop a few. I was hooked; since then, all planetaries have filled me with a delight that is not fully shared with other objects. Yes, I enjoy looking at faint galaxies, bright nebulae and majestic star clusters, but planetary nebulae are still my favorite objects and the ones I preferentially seek out while observing, no matter what telescope I am using. I am fortunate in that my life in both amateur and professional astronomy overlaps our increasing understanding of these lovely phenomena – an understanding that complements my frequent views of faint smudgy forms almost lost in the darkness of the midnight sky.

I hope that this volume will provide the tools necessary to start searching for these wonderful entities. It does not matter what the aperture of your telescope is or how frequently you observe, there are enough bright objects included in this book to please and delight most observers, and hopefully the illustrations will satisfy an armchair astronomer. I have attempted to strike a balance between easily visible objects that can be seen in any telescope or binoculars, to nebulae that are a direct challenge to those with large aperture equipment. With over 1,000 objects to choose from, the enclosed observing list represents just 10% of the number that could theoretically be seen or imaged, although it is fair to report that this 10% probably represents the best of the catalogues for amateur study.

I have also included an historical and physical analysis of planetary nebulae in order that the reader has a ready volume covering both observational and astrophysical aspects of the subject, which will give added understanding and impetus to the search. I find that when teaching students, the ability to see a faint or fuzzy blob of light is augmented by the fuller physical understanding of its intrinsic nature, leading to a greater appreciation for the object. How often have we shown someone a celestial delight we consider significant, only to have that observer disparage the eyepiece view? Observing any deep sky object with relatively small telescopes is not going to reveal a professional, observatory quality image, but this lack can be turned to our advantage by imparting some fore knowledge on the inherent nature of the item viewed, enabling an appreciation of cosmic distance, scale and power from our fleeting Earthly platform.

I have also included within the finder maps of some objects several additional planetary nebulae as they were shown in *Sky Map Lite*. These P-K nebulae may become challenge objects for observers wishing to go beyond the range of this book, and any information on them may be gleaned from the P-K catalogue included here or from sky chart programs or the Internet.

In the final analysis, I want observers to enjoy their experiences in hunting down these wonderful nebulae and discovering them for themselves. Our universe is not something that can be fully appreciated by superlatives, by numbers or formulae or by concentrating on specifics; it is something to be sensed, experienced, savored and valued. I especially feel this way when observing planetary nebulae. The great American poet Walt Whitman, conscious of such emotions penned:

> When I heard the learned astronomer,
> When the proofs, the figures, were ranged in columns before me,
> When I was shown the charts and diagrams, to add, divide, and measure them,
> When I sitting heard the astronomer where he lectured with much applause in the lecture-room,
> How soon unaccountable I became tired and sick,
> Till rising and gliding out I wandered off by myself,
> In the mystical moist night-air, and from time to time,
> Looked up in perfect silence at the stars.
>
> (*Leaves of Grass* 1882)

I hope this small book will help one to grow in knowledge and appreciation of one striking facet of the universe around us.

Martin Griffiths BSc MSc FRAS
University of Glamorgan UK

Acknowledgements

This work has been the culmination of many years of research and practical activity in both amateur and professional astronomy. As such, it would be impossible to name all the people whom I have encountered who have provided encouragement and support for this venture.

However, I would like to thank the Faulkes telescope team for their encouragement and access to the Faulkes telescopes to provide the images, especially Dr. Sarah Roberts for supplying the illustrations of the EM Spectrum, the H-R diagram and the frontispiece photograph of Abell 39; the editorial staff at Springer for their helpful comments and suggestions and Ted Forte of the Astronomical League for his communication and encouragement.

Unless otherwise acknowledged in the text, all photographs have been taken by the author and are copyrighted.

About the Author

Martin Griffiths is an enthusiastic science communicator, writer and professional astronomer. Over his career he has utilized history, astronomy and science fiction as tools to encourage greater public understanding of science. He is a recipient of the Astrobiology Society of Britain's Public Outreach Award (2008) and the Astronomical League's Outreach Master Award (2010). He also holds the League's Master Observer certificate and has written or contributed to over 100 published science articles for many journals.

He was one of the founder members of NASA's Astrobiology Institute Science Communication Group, which was active between 2003 and 2006; he also managed a multi-million-pound ESF programme in Astrobiology for adult learners across Wales between 2003 and 2008. Since then he has been involved in promoting adult education, assisting in the development of a new observational astronomy award at the University of Glamorgan and various other projects, including initial consultation on the setup of an observatory in Andalucia, Spain. He is a consultant to the Welsh government through his involvement with the Dark Sky Discovery initiative, enabling public access to dark sky sites in association with Dark Sky Wales, Dark Sky Scotland and Natural England.

Martin is a Fellow of the Royal Astronomical Society and a member of the Astrobiology Society of Britain, the European Society for the History of Science, the British Astronomical Association, the British Science Association, the Webb Deep-Sky Society, the Society for Popular Astronomy, and the Astronomical League. He is also a local representative for the BAA Campaign for Dark Skies and is a member of the Honourable Society of Cymmrodorion, dedicated to promoting the literature, science and arts of Wales.

Contents

Preface vii

Acknowledgements ix

About the Author xi

Chapter 1 A Short History of Planetary Nebulae 1
Further Discoveries 1
The Nature of the Nebulae and Modern Catalogues 3

Chapter 2 The Evolution of Planetary Nebulae 7
The Lives of the Stars 7
Stages in the Life Cycle of a Sun-like Star 9
The Asymptotic Giant Branch 10
Proto-Planetary Nebulae and Dust 12
Interactive Winds 13
Emissions from Planetary Nebulae 14
Central Stars 16
Planetary Envelopes 17
Binary Stars and Magnetic Fields 19
Lifetimes of Planetary Nebulae 21
Conclusion 21

Chapter 3 Observing Planetary Nebulae 23
Telescopes and Mountings 23
Telescope Mounts 26
Eyepieces 27
Limiting Magnitudes and Angular Resolution 29
Transparency and Seeing 31
Dark Adaptation and Averted Vision 32
Morphology of Planetary Nebulae 33
Nebular Filters 35
Star Charts, Observing and Computer Programs 38
Observing Procedures 42

Chapter 4 Photographing Planetary Nebulae 45
Camera Equipment 45
Software 48
Filters for Astrophotography 49
Shooting 50
Conclusion 53

Chapter 5 Planetary Nebulae Catalogues 55
Main Planetary Nebulae 56
Additional Planetary Nebulae 58

Chapter 6 Planetary Nebulae by Constellation 81
Andromeda 83
Apus 85
Aquarius 87
Aquila 90
Ara 103
Auriga 106
Camelopardalis 108
Canis Major 111
Carina 113
Cassiopeia 119
Centaurus 123
Cepheus 126
Cetus 129
Chameleon 131
Corona Australis 133
Corvus 135
Cygnus 137
Delphinus 154
Draco 157
Eridanus 160
Fornax 162
Gemini 164
Hercules 170
Hydra 174
Lacerta 178
Leo 180
Lepus 182
Lupus 184
Lynx 190
Lyra 192
Monoceros 195
Musca 198
Norma 203
Ophiuchus 205
Orion 211
Pegasus 214
Perseus 219
Puppis 225
Pyxis 229
Sagitta 232

Sagittarius . . . 236
Scorpius . . . 253
Scutum . . . 258
Taurus . . . 260
Triangulum Australe . . . 262
Ursa Major . . . 266
Vela . . . 268
Virgo . . . 272
Vulpecula . . . 274

Chapter 7 A Planetary Nebulae Marathon . . . 277
Why Introduce Another List? . . . 277
Overlaps with Other Object Lists . . . 278
Outstanding Planetaries . . . 279

References and For Further Reading . . . 281

Index . . . 285

Chapter 1

A Short History of Planetary Nebulae

The beautiful objects we now recognize as planetary nebulae led invisible lives until the middle of the eighteenth century. On the evening of July 12, 1764, the French comet hunter Charles Messier observed a barely resolved blob of light in the constellation of Vulpecula. His note of the discovery shows that he dismissed it immediately after recording its position. After all, it was not the kind of object he was interested in:

> Nebula without star, discovered in Vulpecula, between the two forepaws, & very near the star 14 of that constellation, of 5th magnitude according to Flamsteed; one can see it well with an ordinary telescope of 3.5-ft [FL]; it appears of oval shape, & it contains no star.

It seems strange to us now that Messier turned to other objects without really examining this seminal discovery. His record shows that he noted what we now call Messier 27 in his catalogue of "objects to avoid while hunting for comets" as something that was relatively easy to see, but he spent little time examining it or he would have seen stars all across the surface of this singular nebula. Unfortunately, many of his contemporaries also paid as much attention to planetary nebulae as he. One cannot really hold them to account. They had no idea what such objects were, no idea of their size or distance or even the fundamental materials of which they were made. The only thing they could describe was their visual appearance and leave the rest to posterity.

Further Discoveries

Such nebulae may have aroused curiosity, but any further work on such types had to wait until there were further discoveries to enable comparison. However, they were not long in coming. Astronomer Antoine Darquier discovered an interesting round patch of light almost midway between γ and β Lyra in January 1779, and Messier independently discovered it later that month. Darquier described it as a "nebula between gamma and beta Lyrae; it is very dull, but perfectly outlined; it is as large as Jupiter and resembles a planet which is fading." This interesting description may have been quite suggestive, as we shall go on to see. Within a short time, Pierre Mechain discovered Messier 76 in September 1780 and Messier 97 was discovered by him a year later.

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides,
DOI 10.1007/978-1-4614-1782-8_1,

Some of the best types of this intriguing astronomical class had now been discovered, yet they were merely catalogued. No one knew what kind of body they represented or what their true physical properties were.

In the summer of 1782, William Herschel, the German-born astronomer and discoverer of the planet Uranus began a systematic survey of the heavens in order to uncover and catalogue as many nebulae as possible with a view to determining their positions, distribution and possible make-up. One of the first objects in his new catalogue was found by him on September 7 of that year, a small extended object that he described as "very bright, nearly round *planetary* disk, not well defined." Clearly the term we now use for such objects was already in the minds of a few observers.

Herschel went on to classify 79 objects in his catalogue as planetary nebulae and gave then the appellation H IV. He arrived at the name we now use for such objects sometime in 1784 simply because they reminded him of the disk of the planet Uranus, which he remembered as a round greenish entity – very akin to planetary nebula. Most observers of the day expected such objects to become resolved into stars with greater magnification or with larger aperture telescopes. Even Herschel himself was initially convinced of their star-like qualities, and he was not inclined to consider them as true nebulae for some time.

NGC 1514 – Herschel's first planetary nebula.

However, the first hint of their true nature came to Herschel when he observed one of his own discoveries, the nebula we now call NGC 1514, on November 13, 1790. He described his observation succinctly as a "star of about 8th magnitude with a faint luminous atmosphere, of circular form and about 3 min in diameter. The star is perfectly in the centre and the atmosphere so delicate, faint and equal throughout that there can be no surmise of it consisting of stars, nor can there be any doubt about the connection between the atmosphere and the star," he wrote a paper for the Royal Society in 1791, which was published as "Nebulous Stars, properly so called," where he speculated that "[W]e therefore have a central body which is not a star, or have a star which is involved in a shining fluid of a nature totally unknown to us." The first evidence of the evolution between stars and nebula had been found. In 1800 the astronomer Friedrich von Hahn found the central star of M57 from Mecklenburg observatory and confirmed the relationship between stars and the strange vaporous atmospheres now being recognized as planetary nebulae.

Due to the lack of further analytical tools, the story of planetary nebulae did not advance much further than this. There were more discoveries of this type of object in the next century when Karl Ludwig Harding discovered the Helix nebula (NGC 7293) whilst compiling his great work *Atlas Novus Celestis* at Gottingen in 1820. William's son, John Herschel, discovered 16 planetaries in the southern hemisphere while cataloguing the southern sky at Feldhausen between 1834 and 1837. Both Frederick Struve and James Dunlop added further examples to the growing astronomical catalogues of the time until much of their work was amalgamated by J. L. E. Dreyer at the end of the nineteenth century into the *New General Catalogue of Nebulae and Star Clusters* (NGC). The total of known planetary nebulae had then risen to 95 entries, and a further 35 nebulae were listed in the supplement to the NGC, the Index Catalogue (IC).

The Nature of the Nebulae and Modern Catalogues

The real breakthrough in determining the nature of planetary nebulae arrived with the invention of spectroscopy by Kirchoff and Bunsen in the mid-nineteenth century. Their experiments with elements burned in a pure flame led to the formulation of three major laws of this discipline. The first law states that an "incandescent solid liquid or gas under high pressure (or temperature) emits a continuous spectrum"; the second is: "a hot gas under low pressure emits a bright line or emission spectra," and the third law states that "a continuous spectrum viewed through a cool low density [or temperature] gas produces an absorption spectra [dark lines]." The most important here is the second law, which states that a hot, low density gas produces an emission line spectrum. All it now required was an astronomer with a powerful enough telescope to be able to resolve such lines in the nebula.

The first person to do this was Sir William Huggins at Tulse Hill, London. On August 29, 1864, he trained his telescope and new spectroscope on the planetary nebula NGC 6543 in the constellation of Draco. Any argument over the true character of these heavenly objects faded away immediately. Huggins discovered a single emission line in the spectrum, which characterized the nebula as a hot gas.

A year later he used an improved spectroscope on the same nebula and discovered three emission lines in the spectrum, one of which he recognized as hydrogen, but he could not account for the other two. Thinking that he had discovered a new element, he christened the lines "nebulium" and wrote a paper entitled: "On the Spectra of Some Nebula" for the *Philosophical Transactions of the Royal Society*. The intensity of his research and the applications of the new scientific methods of photography and spectroscopy are brilliantly brought together by Huggins to explain the nature of planetary nebulae. He states:

> As expected for gaseous emission nebulae, the spectra of planetaries consist of emission lines, but 90 to 95 % of the visible light is emitted in one single emission line only! This *'Chief Nebular Line'* occurs at 5007 Angstroms, (now 500.7 nm) in the green part of the spectrum. It is in this circumstance that planetary nebula brightness differ significantly if determined with various methods: These objects are often considerably brighter (up to 2 magnitudes) visually than photographically, because the 5007 Angstrom line lies close to the highest sensitivity of the human eye. Also, as films are often less sensitive in the green part of the spectrum, it is difficult to get a good "true color" image of planetary nebulae. As this spectral line at 5007 Angstroms could not be assigned to a known element at the time of its discovery, I suspect that it must be emitted from a previously unknown substance.

Huggins was assisted in his discoveries by his wife Margaret, an avid astronomer in her own right who used the spectroscope to discover that gases of the Orion Nebula consisted of oxygen. Together they wrote an *Atlas of Representative Stellar Spectra* and speculated on the evolution of stars. So much had been achieved by Huggins that echoes down the years to anyone observing planetary nebulae today. He drew attention to the problems of colour definition, the difference between visual and photographic observations and left a legacy of further research on these wonderful objects that begged explanation of the chemical make-up and physical properties of planetaries. He had discovered that they were a form of emission nebula; now it became the province of others to uncover exactly what sort of astronomical object they were and the course of their evolution.

The twentieth century saw many advances in this field. Among the first was the Harvard Observatory survey of 1910 under the direction of Edward Pickering, where planetary nebulae were initially identified by placing a prism in front of the telescope, enabling the discrete spectral lines to be recognized. Margaret Mayall and Annie Jump Canon later discovered several others on photographic plates from the Harvard Observatory's southern telescope in Arequipa, Peru.

In 1918, a photographic study by Heber Curtis at Lick Observatory in California determined the position of many planetaries to be within the Milky Way Galaxy. His plates showed for the first time the enigmatic structure of planetary nebulae with double lobed structures, rays, ansae, blobs and other irregularities. Following on from the work of James Keeler at Allegheny Observatory and W. H. Wright at Mount Wilson, his spectroscope allowed him not only to obtain excellent spectra of planetary nebulae but also determine possible distances from the shift of the spectral lines of each object. However, due to their relative rarity, he put forward the suggestion that planetary nebulae were probably a very unusual stellar evolutionary path – a suggestion that we now know to be incorrect.

In 1922, Edwin Hubble, using data obtained with the 60- and 100 inch. telescopes at Mount Wilson, discovered a correlation between the magnitudes of the central stars of planetary nebula and their size. He then suggested that their enigmatic emission line spectrum was due to the nebula absorbing the continuous UV radiation from the central star. That same year, W. W. Campbell and J. H. Moore made high resolution spectroscopic studies of 43 planetary nebulae and discovered internal motions in 23 of them. They also noted that the spectral lines were split, which indicated nebular expansion.

A few years later in 1928 the astronomer Ira Bowen, working at the Mount Wilson observatories determined that the lines discovered by Huggins and named nebulium were, in fact, lines of the common element oxygen, but doubly ionized (known as OIII). Bowen also showed that the gaseous component of planetary nebulae were extremely rarefied; the OIII lines could only be produced as a result of what are now called forbidden line transitions, which result from interactions within extremely low density gases. Other lines in the emission spectra of planetaries were found to be those of nitrogen and neon that were also undergoing a forbidden line transition.

Around the same time, the American-born Argentinean astronomer Charles Dillon Perrine discovered that the observed splitting of the spectroscopic lines of planetary nebulae were due to two different velocities within the nebula – a blue shift indicating material moving toward the observer and a red shift indicating material moving away from the observer. He correctly interpreted this as a "bubble" of gases that were expanding away from a central source – or a central star. In 1927 the physicist Herman Zanstra at the California Institute of Technology determined a method of measuring the temperature of the central star of planetary nebulae and tied its ionizing effect to the atmosphere of expanding gases, the so called Zanstra method. His paper entitled "An Application of the Quantum Theory to the Luminosity of Diffuse Nebulae" was a seminal landmark in astronomer's attempts to understand how physical interactions at atomic scales played a large role in determining what type of astronomical object is observed.

Planetary nebulae as a group were becoming one of the most intriguing types of astronomical object and one of the most challenging to interpret. Studies before World War II by John C. Duncan working at Mount Wilson enabled astronomers to see that planetary nebulae underwent several stages of expansion. Duncan's photographs of extended filaments outside of the main envelope of M57, the "Ring Nebula," indicated previously unknown behavior of stars undergoing evolution to the planetary nebula stage. His studies led the way for further discoveries of planetary nebulae envelopes in the work of You-Hua Chu and George Jacoby at Kitt Peak Observatory in 1985 and the studies undertaken with the Hubble Space Telescope in the last two decades.

With the advent of the Palomar Observatory and its 48 inch Schmidt camera after World War II, the pioneering astronomer George Abell discovered many large planetary nebulae from the Palomar Observatory Sky Survey photographic plates in the 1950s. A decade later, Rudolph Minkowski used the 10 inch. telescope at Mount Wilson and discovered many small, distant planetary nebulae. Additionally, the astronomer and future astronaut Karl Henize, working at the Lamont-Hussey Observatory in South Africa, discovered a large number of previously unsuspected planetary nebulae in the early 1950s.

Contributions to our understanding of planetary nebulae were truly international. The Russian astrophysicist Ioseph Shklovsky noted the similarities between white dwarfs and the central stars of planetary nebulae in 1956, leading to further progress in our understanding of the evolution of stars and their relationship to planetary nebulae. What was needed was a catalogue that brought all these discoveries together and concentrated on this one type of object.

This defining catalogue of planetary nebula is the comprehensive 1967 work of Czech astronomers Lubos Perek and Lubos Kohoutek resulting in the *Catalogue of Galactic Planetary Nebulae,* affectionately known as the Perek-Kohoutek (P-K) catalogue, containing over 1,000 entries. Both astronomers broke with tradition and delineated planetary nebulae according to their galactic coordinates of latitude and longitude rather than right ascension and declination. The P-K catalogue coordinates seem a little strange at first, but the catalogue does contain the RA and Dec of each object also.

Many astronomers have added their names to the long roll of planetary nebula discovery over the course of the last 120 years, and it is not possible to go into every individual discovery in detail. The P-K catalogue and the more recent *Strasbourg-European Southern Observatory Catalogue of Galactic Planetary Nebulae* by Agnes Acker and colleagues remain the standard work on such objects, and over 1,500 planetaries are now known. Currently, David Frew and colleagues in Australia, working with the Macquarie/AAO/Strasbourg Hα Planetary Nebula Catalogue (MASH), are discovering nebulae in the proto-planetary stage and will add at least 1,000 more objects to modern catalogues.

After almost 250 years of observation, planetary nebulae remain one of the most surprising and beautiful of all celestial objects, and more and more of them are becoming visible as our understanding grows. One is forced to ask; what kinds of stars become planetary nebulae, and what are the physical parameters that create them?

Chapter 2

The Evolution of Planetary Nebulae

The connection between stars and the gaseous envelopes we now call planetary nebulae was not evident to observers of the past. William Herschel's 1784 insight was the first step on the road to a fuller understanding. Today, astronomers are concerned with modeling the minutiae of planetaries, and although we have a far greater understanding than our historical counterparts, there are still many problems to be overcome in our quest for a final agreement between observation and theory.

The Lives of the Stars

Planetary nebulae are the end product of particular stars. That is, they are the end result of stars with a particular range of masses, as it is mass that determines what sort of life and what sort of endpoint such stars become.

Stars are born out of huge clouds of gas and dust that exist in the spaces between the stars within a galaxy such as the Milky Way. This interstellar medium (ISM), as it is known, consists of primordial hydrogen and helium with an enrichment of heavier elements from the deaths of previous generations of stars. The ISM contains small amounts of almost every element on the periodic table, but the elements of smaller atomic mass predominate; elements up to iron are common in space even though their abundances are very small in comparison with that of hydrogen and helium.

Stars are born from the ISM when gravity begins to pull the material together after an initial overpressure from a density wave or supernova, compresses this otherwise inert material. Once there is a local density within the ISM, gravity begins to bring the material together in greater amounts until the dense cloud begins to fragment into individual units – proto-stars within proto-clusters. The initial mass of each proto-star to some degree determines the future evolutionary pathway of the star, although mass loss can still take place at this and later stages in the life of a star.

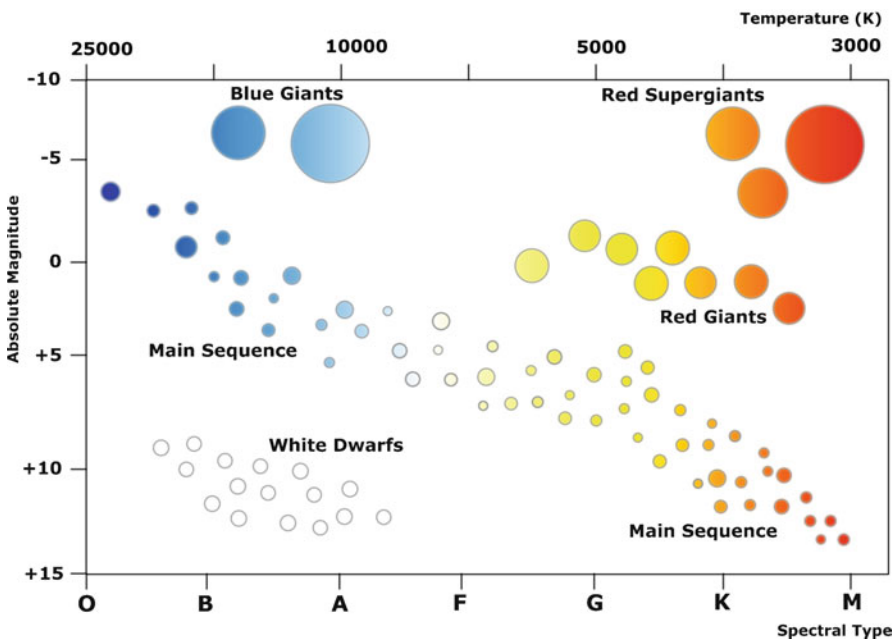
Once the temperature at the core of a proto-star becomes sufficient to fuse hydrogen into helium in the interior, the resultant flood of radiation away from the core and surface stop further aggregation of material, and within a few million

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides,
DOI 10.1007/978-1-4614-1782-8_2, © Springer Science+Business Media, LLC 2012

years a star will settle into a regular and steady luminosity. This luminosity will be dependent on its mass; for stars between one and eight times the mass of our Sun, the radiation trickling out of them will sustain such luminosities for a few billion years.

In this rather simplified scenario, stars will convert hydrogen into helium for a significant fraction of their lives. Stars that accomplish this are known as main sequence stars and can be found situated on the S-shaped curve of the accompanying diagram. Their position is dependent on their mass. A star of one solar mass will release the bulk of its energy in the visible part of the spectrum and is predominantly yellow in color. A more massive star will convert hydrogen to helium at an increased rate as the internal pressures squeeze more materials together in the core, which results in a larger rate of nuclear reactions. Such stars will be yellow-white or white while larger ones will be blue in color and exhibit themselves at the top left of the diagram. Those stars that are dim and red will occupy the opposite part of the diagram at the bottom right. The diagram gives us a quick view of the stellar temperatures, colors, luminosity and an indication of mass while the star remains on the main sequence.

Louise Mayall and Annie Jump Canon first classified the spectral sequence within the H-R diagram in the early twentieth century at Harvard college observatory. Canon took over the early work by Mayall and turned a vague classification into a powerful detecting device by tying the colors, temperatures and chemical signatures of the stellar spectra into a tool that went from high to low on the temperature scale, which then matched the color of the star and its luminosity on the main sequence. Her classifications are shown here in the following table.



Hertzsprung Russell diagram.

Harvard spectral sequence

Spectral type	Temperature (K)	Colour	Characteristics
O	40,000	Blue	Ionized helium and few metals, weak hydrogen lines
B	25,000	Blue-white	Neutral helium stronger hydrogen lines
A	12,000	White	Hydrogen lines dominant, ionized metals appearing
F	8,000	Yellow-white	Hydrogen weakening, neutral and ionized metals
G	6,000	Yellow	Ionized calcium prominent, neutral and ionized metals
K	4,000	Orange	Neutral metals prominent molecular lines appearing
M	3,000	Orange-red	Titanium oxide prevalent, molecules dominant and neutral metals
R	2,500	Red	CH and CN dominant and neutral metal lines
N	2,500	Red	CH and CN dominant and neutral metal lines
S	2,500	Red	Zirconium oxide prevalent, neutral metal lines common

This sequencing enabled astronomers to discover the life cycles of stars and account for their various positions on the H-R diagram. As their knowledge increased, they were able to explain the changes stars undergo during their latter stages to become planetary nebula. The sequence and the H-R diagram together are wonderful implements that give the trained mind give a quick representation of expectations over the lifetime of a star.

Stages in the Life Cycle of a Sun-like Star

It is the relatively small- to medium-sized stars that will undergo evolution to the planetary nebula stage. The diagram below reveals the basics of the changes the star will suffer and the predicted track across the diagram to an end point. If one starts with a Sun-like star with a temperature of 6,000 K and a yellow color, such a star will convert hydrogen into helium in its interior for about 8–10 billion years. Known as the proton-proton chain, wherein four hydrogen nuclei are converted into a helium nucleus, this process is dependent on core temperature. Above a temperature of 17.5 million K the CNO process, or carbon, nitrogen, oxygen process, dominates, where these elements become the catalysts to convert four hydrogen nuclei into a helium nucleus. The end product is the same, though the energies in the process are subtly different. This conversion from hydrogen to helium is a very stable process despite its very high temperatures, and the energy flow maintains the star's radiative output for a very long time.

Once there is sufficient helium build up in the core to significantly interfere with the hydrogen reactions, the core shuts down and begins to contract. However, there is a lot of latent energy in the overlying layers from radiation attempting to escape the outer envelope. As a consequence of this radiation pressure, the star will begin to expand as gravity works primarily upon the greater mass of the core and only has a relatively weak effect on the outer layers. At this point the core contracts and the outer layers expand. To an external observer the star now star begins to cool as it expands and moves toward the right of the diagram, off the main sequence.

As it does this, the spectral signature of the star changes as it cools to an orange K type sub-giant. The star then utilizes the energy of hydrogen–helium conversion, which now takes place in a shell around the inert hydrogen core rather than throughout the core, as in its previous incarnation. Over time the star will continue to expand and cool until it becomes a red giant. It is now large, luminous and has an extensive solar wind, which is driving the material of the outermost layers off the star. This expulsion of material is important in the development of a planetary nebula. Under such forces, a star can lose as much as 1/100,000th of a solar mass per year. One can imagine that this is not a stage that can last too long.

Eventually, gravity compresses the helium core until sufficient pressures and temperatures build up inside to fuse helium to carbon in a process where three helium nuclei make one nuclei of carbon – the triple alpha process. Once a new source of energy has been established, the star attempts to move back toward the main sequence, as can be seen in the above diagram. However, there is insufficient helium fuel to power the star, and as this fuel becomes exhausted, the outer layers expand again with latent energy from the radiation release and are eventually lost to space with an increase in the power of the stellar wind at this stage. Once the luminous outer envelope of the star is lost, the naked core is all that is left, a small, hot remnant with a fraction of the luminosity of the whole star, and the object dims appreciably and makes its way rapidly down to the bottom left on the diagram to end its days as a white dwarf.

This simplistic view is the broad facet of what astronomers have gathered over the last century. The detail of what happens during the planetary nebulae stage is all-important to our understanding of the stellar life cycle.

The Asymptotic Giant Branch

The most important phase in a star's life that leads to the expulsion of material forming part of a planetary nebula is that of its course as an asymptotic giant. In the H-R diagram above, this course is represented by a horizontal line between the giants and super-giants leading to the left of the diagram. The kinds of pulsations the star will undergo, the chemical enrichment and core burning stages at this phase are dependent on the initial mass of the star.

It is difficult to accurately define exactly what a low, medium and high mass star is. Astronomers use generalized terms that cover a variety of options in mass to determine which category a particular star will fit into. Generally speaking, a low mass star ranges from 45% of the mass of the Sun to two times this mass; a medium mass star will be measured as one between two and five solar masses, while a high mass star can be anything above this level, culminating in masses that can be measured between 5 and 40 times the mass of the Sun. Planetary nebulae are known to derive from relatively low mass stars, so some confusion may result among the usage of such terms, especially when one considers that recent developments in planetary nebula research have discovered nebulae with a total mass (gas and central star) of around eight times the mass of our Sun.

From our perspective, the mass of the progenitor star on the AGB is important in that this initial mass will define the chemical makeup of the central stars and indicate the constituents of the surrounding gaseous shrouds. Low mass stars

(1 solar mass) on the AGB will produce carbon-rich end products, including the central star. Intermediate mass stars (2–3 solar masses) will produce cores rich in carbon and oxygen, while higher mass stars (3–6 solar masses) will have nitrogen- and neon-rich cores. This mass function also has implications for the evolution of the outer envelopes of the stars and their variability, stellar wind and thermal pulsations.

To the external observer, the star still follows the Harvard classification system, as our observations cannot penetrate the opaque core where all this interesting nuclear physics is occurring. Therefore, most AGB stars are classified as M, R, N or S, designations that have mostly been replaced by a collective term C, or "carbon stars." Such stars have an abundance of carbon or oxygen in their photospheres, as there is an exchange of material between the core and the photospheres in such stars due to the nature of their convective cores. Some AGB stars have photospheres that are heavily obscured by carbon dust, which indicates the nature of their cores. Others have high incidences of oxygen and the spectral signatures of silicates. Due to the obscuring nature of such dust, much current research is done in the infrared, and there is excellent correlation between infrared and optical spectroscopy on AGB stars. Any one of these spectral signatures is of interest to astronomers researching the production and evolution of planetary nebulae.

Stars that are only 45% of the Sun's mass do not become AGB stars; rather they cross the horizontal branch of the H-R diagram and become C-O white dwarfs, which then gradually fade away after their hydrogen envelopes have been lost during the planetary nebula phase. The upper limit for low mass stars is somewhere in the region of 2.2 solar masses, according to recent research. Low and intermediate mass stars become AGB stars once they have exhausted helium burning and develop an electron degenerate C-O core. During this phase, the star burns both residual hydrogen and residual helium in two thin shells surrounding the degenerate core. During the early phases of the AGB the hydrogen shell is extinguished as a result of expansion of the star, and helium burning provides the luminosity, but hydrogen in the outer parts of the core re-ignites at later stages and contributes to the thermal pulsations of the star, thus accelerating the mass loss. As helium also becomes dense enough to undergo further nuclear reactions in the core, pulsations are set up that cause the star almost literally to oscillate and lead to greater mass loss during this stage, which is known as the Thermal Pulsing Asymptotic Giant branch, or TP-AGB.

This pulsation is of central importance in the production of planetary nebulae. Many photographs from ground and space observatories reveal materials external to the main body of the planetary nebula, which derive from former mass loss due to pulsation. Pulsating AGB stars become long-period variables like o Ceti or Mira and recent studies of Mira reveal a long tail of lost materials released by its pulsations as it moves across the heavens. Studies of M57, the Ring Nebula in Lyra, also show much material outside that of the main shell released in the distant past when the progenitor was an AGB star. It seems this pulsation on the AGB phase is a common feature of mass loss, and such losses have been noted to be as much as 10^{-5} of a solar mass per year, indicating that AGB stars can lose substantial mass during this phase. Indeed, considering the timescale for the nuclear power production rates in the core, such mass loss can exceed the core lifetime by two or three orders of magnitude, which determines the lifetime of the AGB phase as that controlled by the mass loss rather than from core nuclear burning. It is easy to see therefore that even high mass stars may lose substantial amounts of material and slim down to produce cores that are below the Chandrasekhar limit (1.4 solar masses), thus ensuring that such stars can also produce planetary nebulae.

The mechanisms of such mass loss have been debated for some time. It seems reasonable to conclude that there are probably three main models with one or more of the mechanisms working together. The main mass loss at the AGB phase comes from thermal pulsation, stellar winds and radiation pressure. The radiation pressure drives both gas and silicate or carbonate dust away from the star, but measured speeds of around 50 km/s indicate that this process also carries gas away with the grains as the expected speeds should be much higher than this. Stellar winds will carry away materials from the photosphere at an increasing rate, and the thermal pulsations due to the energizing of the hydrogen and helium burning shells will add to the mass loss as large portions of the photosphere expand and contract, resulting in ejection speeds that exceed the local escape velocity.

The AGB phase is possibly the most important aspect of the production of planetary nebulae. This phase typically lasts about a million years and, due to mass loss, can ensure that even some high mass stars will produce cores that will become white dwarfs, the central stars of planetary nebulae. Typically the termination of the AGB phase occurs when the hydrogen envelope is depleted by mass loss and the star then begins to evolve toward the blue side of the H-R diagram. At this stage the star is on its way to produce a planetary nebula. The ejection of materials and the buildup of dust in the circumstellar envelopes of AGB stars ensure that these materials will become important parts of the gaseous shrouds we recognize.

Before we discuss the production of the nebula, let us examine the early phases of this phenomenon in the light of recent research.

Proto-Planetary Nebulae and Dust

Once the loss of the majority of the hydrogen envelope has occurred, the star will move to the left- or blue-ward side of the H-R diagram, and its temperature will increase. Eventually the stellar remainder will become hot enough, until at about 25,000–30,000 K the ultraviolet output from the star will ionize the surrounding hydrogen shed during the AGB phase. At this point, the body becomes a planetary nebula, but this scenario omits a crucial stage in the story.

Once the star has shed the majority of its hydrogen shell, the remnant will continue to get hotter. As it does so, the previously shed materials begin to radiate in the infrared and a peak output in its spectra will be that of carbon monoxide (CO) emission from the circumstellar shell. In the visible spectrum, the Harvard class becomes F or G and its luminosity indicates it to be a very luminous giant. At this point most of the envelope is neutral, with no line emission to indicate what is happening to the underlying star; indeed the star may be obscured by carbon and silicate dust that is condensing out or has condensed out during the AGB phase.

The composition of this dust component is also partly dependent on core nuclear burning and thus initial stellar mass, as the resultant elemental abundance from core burning in relatively low mass AGB stars is carbon, while the products from core burning in intermediate to high mass stars will contribute oxygen, nitrogen and silicates to the circumstellar shell. These carbon and silicate grains are the major dust component of proto-planetary nebulae (PPN).

In some sources, spectroscopy reveals CH, OH, H_2O, CN, HCN, SiO, C_2H_2 (acetylene) and Fe_3O_4 (magnetite) in addition to nano-diamonds and fullerenes (C_{60}) to be present in large measure, while polycyclic aromatic hydrocarbons (PAHs) also provide a large spectral spike, all of which are exciting molecules for those interested in the chemistry of life. Even in death, stars becoming planetary nebulae contribute pre-biotic materials to the interstellar medium and the next generation of stars.

Naturally, as this phase is very short in the star's lifetime, such PPN are going to be very rare as optical objects but may be numerous as infrared objects. Studies in the infrared using IRAS (Infrared Astronomy Satellite) and ISO (Infrared Space Observatory) coupled to radio studies of thermal CO emission have shown about 100 candidates; NGC 7027 in Cygnus is one of the most studied candidates, as it is bright and relatively close enough to reveal detail (and indeed is visible as an object of study within this book). Other examples are the 'frosty Leo' nebula IRAS 09371 + 1212 (also visible to amateurs and included in this book) and the fabulous 'red rectangle' HD 44179 in Monoceros, which is visible as a starry point to most observers as it has an integrated magnitude of 9.2 (and is also included here).

Due to the combination of circumstellar dust and peak radiative output in the infrared, most PPN are relatively faint. It is possible, though, that the orientation of the nebulae may play a part in its visibility, as a 'pole on' nebulae will appear brighter as the circumstellar dust shells will primarily be lost in an equatorial disk initially and the central star may peep through the thinner polar clouds, resulting in the PPN looking more star-like than those visible as mere infrared objects. The dispersal of these dust shells and the emerging central stars with their high temperatures and ionization potential indicate the PPN is becoming a full-fledged planetary nebula. The dispersal of such shells indicate the presence of strong stellar winds, and it is to these winds and their dynamics to which we now turn.

Interactive Winds

During the AGB stage, the star is losing up to 10^{-5} solar masses per year in the form of a vast stellar wind. This high rate of mass loss explains why the AGB phase is terminated by the loss of the hydrogen shell rather than helium depletion in the core; the great mass loss leads to less gravitational pressure, and thus the core is not able to sustain high pressures and temperatures. This loss, exacerbated by thermal pulsing, contributes to the production of an expanding circumstellar shell in the PPN phase. However, a planetary nebula is formed when the hot and fast-moving winds from the uncovered core begin to compress and overtake these lost shells.

It was thought for many years that the thermal pulsations themselves were responsible for planetary nebula formation. However, initial investigations in the 1970s soon showed that the wind velocities in the expansion of stellar winds in AGB stars and those of the winds from hot central stars were significantly different, resulting in the astronomer Sun Kwok proposing the version now favored by most working in the field – the interacting winds model.

The expansion velocities of the stellar wind and thermal pulsation mass loss may be between 50 and 100 km/s; this gives the impression of a gently moving outwardly expanding mass of diffuse gas. However, the velocities of the hot winds that are given off by the central star are in the region of 1,000–1,500 km/s, much faster than the gentle winds described formerly. This fast, expanding super-wind then hits the slowly expanding outer gases and creates a snow plough effect in that it collects this material and compresses it into the intricate structures we see in the shells of many planetary nebulae today. At the same time, the naked core of the central star is giving off vast amounts of UV radiation, which cause the gases to become ionized and then fluoresce, giving out the emission lines in the optical that are noticed by astronomers. Typical lines are Ha, OIII, NII and SII, which are visible as bright lines against a dark backdrop in an optical spectrometer.

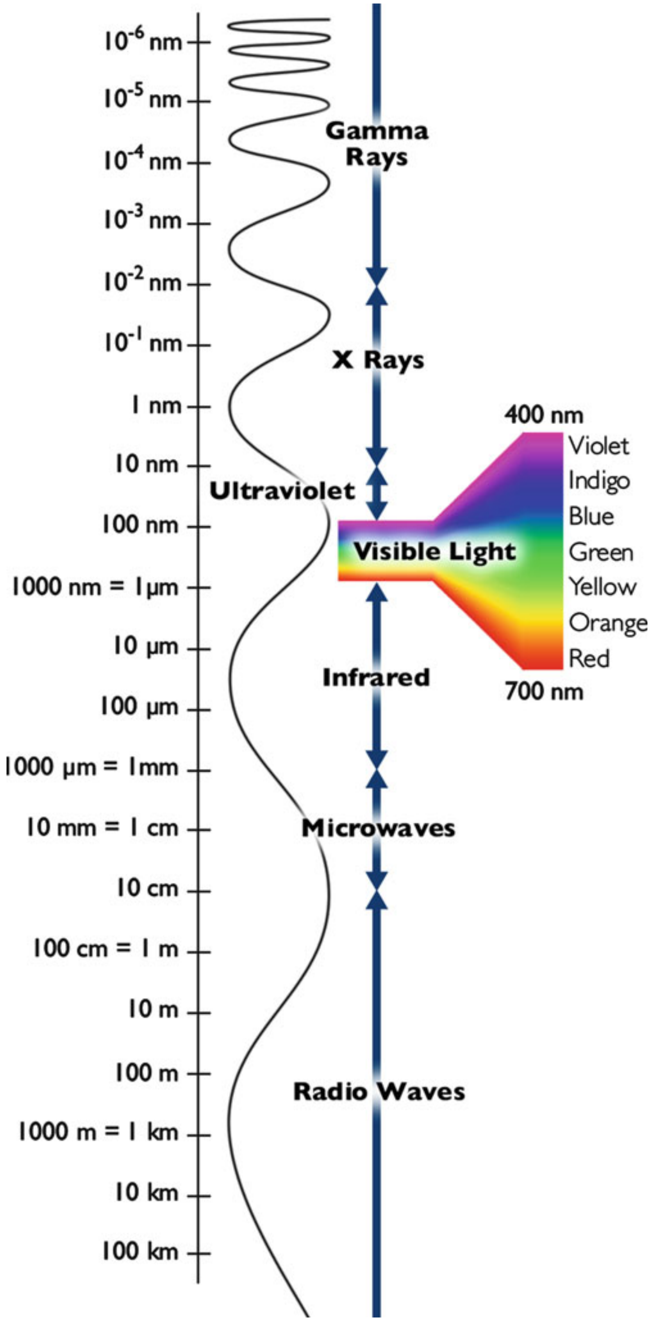
As the hot wind catches up with the materials released during the slow stellar winds and thermal expansion gases of the AGB stage, it causes the material to bunch up into a dense shell. Evidence of such interactions should come through deep sky observations of planetary nebulae in which a halo of material at great distance from the star would be visible as a slowly expanding shell, whereas within the interior of the planetary and at the densest parts of the nebulae, a high velocity wind should be measured. This is precisely what was found in surveys after this proposal; planetary nebulae are surrounded by large, amorphous, slowly expanding envelopes of material from the AGB phase while their densest parts and those closest to the central stars are dominated by fast-moving winds and ultraviolet light from the core. The various shell structures are explained by the interaction of the slowly moving AGB wind and the fast wind from the central star.

One of the predictions of this model was the presence of X-ray emission in planetary nebulae. When an object is moving faster than sound in a medium, a shock wave is generated, which in the case of planetary nebulae would be a shock wave occurring when the fast wind hits the slowly moving material. In the late 1990s this prediction was confirmed by both ROSAT and CHANDRA X-ray observatories, which found X-ray emission from the shocked region where the slow and fast winds collided.

The interaction of these winds and the inhomogeneous densities among the materials in the expanded layers are therefore responsible for the plethora of different shapes, densities and interior structures of planetary nebulae that render them such beautiful objects of study for amateur and professional alike. The nebulous shells that we so admire are an ever-changing spectacle, albeit on large timescales, that illustrate the intricate interface of winds from the star.

Emissions from Planetary Nebulae

The beautiful shells that thrill observers are responsible for the main emission spectra from the object. As planetary nebulae are primarily hot gas, their spectral characteristics are epitomized by bright lines against a dark background with no continuum, with the lines of OIII, Ha, NII, NeIV and SII strongly represented in typical examples. In early surveys it was difficult to differentiate between emission nebulae and planetary nebulae, leading to confusion and misclassification of small but ordinary HII regions as planetary nebulae. A study of the Perek-Kohoutek catalogue by Aker et al. in 1987 re-classified 262 objects, almost a quarter of the catalogue as non planetary nebulae! This emphasizes the difficulties of classifying planetaries, although modern techniques have considerably refined the process. The Strasbourg ESO Macquarie study has added over 1,000 more planetary nebulae to the existing numbers of known objects of this type.



The electromagnetic spectrum courtesy of Faulkes telescope.

These errors in identification are due to the fact that emission nebulae and planetary nebulae have many lines in common. The main differentiating characteristic in planetary nebulae is the very low density of the gases involved. This low density leads to electron transitions within the atoms of the rarefied gas known as “forbidden lines,” of which the OIII, NII and SII lines are typical examples. Hydrogen lines present are due to electron recombination as the high temperatures in the gases do not allow neutral hydrogen to remain that way for very long, and the protons marry up with free electrons in what are termed “free-bound” transitions. There are also collisionally excited lines where a free electron may pass close by to an element that has retained most of its electrons but may cause an excitation by transferring energy to the element, resulting in the excited element giving off a photon.

Within planetary nebulae, forbidden lines, free-bound transitions and collisional excitation all work side by side to present a nebula that is visible across the electromagnetic spectrum from X-rays to radio. Untangling the atomic origins of this web of light has been one of the great success stories of twentieth-century science.

It is these narrow emissions that give planetary nebulae their distinct colors visible to the observer. OIII is strongly centered on the green part of the spectrum at 500 nm (the ‘nebulium’ of William Huggins), while OII is centered in the blue part of the spectrum at 372 nm. Observers often refer to the observable color as green or blue, though other distinct colors are seen, such as red, in bright planetary nebulae such as M57. These narrowband lines can be used to determine the existence of faint, diffuse or almost invisible planetary nebulae by the observer, by means of using specialist filters at the eyepiece. We shall refer to this technique later.

The gases of the planetary nebulae are at temperatures of 10,000 K or more and are mostly in an excited or ionized state. Where does the energy to heat the nebula come from?

Central Stars

Inside all planetary nebulae is the remnant core of the original star. This core, now shining blue-white and relatively dim in comparison to the expanding envelope, is responsible for the energy heating the gas. Once the AGB phase is ended, there may be a small remnant of hydrogen gas still surrounding the core. This gas is further depleted by a steady stellar wind, but not to the same extent as the initial huge mass loss during the AGB. Many central stars of planetary nebulae have been studied and have been shown to have the spectral characteristics of hydrogen present, indicating that our general understanding of this stage in a star’s life is fairly well understood. In some nebulae the central stars are burning helium, indicating that there may be a number of final thermal pulses that eject the hydrogen envelope. This late burning gives rise to the radiation responsible for the heating of the planetary shell.

Once this hydrogen or helium is exhausted, all that is left is a degenerate C-O core. At this stage, the core has settled down to a life where it no longer shines by nuclear fusion; rather it is now feebly radiating away by conduction and is now located astrophysically in the bottom left side of the H-R diagram. It loses luminosity and temperature and is now a white dwarf. This remnant continues to radiate UV light that comes from the thermal energy released during gravitational contraction, adding to the ionization and excitation of the nebula, before the dwarf rapidly (astronomically speaking) cools.

White dwarfs are fantastic creatures. They are the compressed remnants of the cores of AGB stars and are primarily composed of carbon, the end result of helium nucleosynthesis. However, as most of the mass of a star is to be found at the core, the white dwarf becomes extremely dense as gravity crushes it, and the radiation pressure from nuclear burning no longer holds the star up. Eventually the atoms are squeezed together until they have very little room. The electrons within the atom take up positions in or close to their ground states, and as an atom is mostly empty space, the starry remnant can therefore become very small, just a few 1000 km in comparison to the millions of kilometers of the former giant. A star the size of the Sun, one million km in diameter, will have a diameter as small as Earth's, at 10,000 km.

The squeezed atoms are then subject to electron pressure, where they continue to be confined to the ground state of the atom, and they consequently begin to move at very high speeds in these orbits, holding off further collapse. This state is known as electron degeneracy, a condition that was first theoretically explored by the physicist Wolfgang Pauli in 1925. Under these circumstances, the star is extremely dense; a cubic centimeter of such material – the same size as a cube of sugar – can weigh many tons. The materials within the star eventually take up station where they are equidistant from each other to produce a crystalline lattice. In such a condition, a white dwarf consisting of carbon will become a very large and pure diamond!

Astronomers classify white dwarfs by the elemental abundances revealed through the spectroscope. All white dwarfs have the appellation (D), indicating a degenerate star with the letters DA indicating the presence of hydrogen, DB indicating helium, DZ for metallic lines such as manganese or iron and DQ for stars with carbon or molecular carbon in their spectral lines. In this classification, one can have a mixture of letters such a DAZ, which acknowledges secondary features of importance in the spectra. However, considering that the great majority of white dwarfs arise from AGB stars, the remnants of their hydrogen envelopes are discernable and almost 80% of white dwarfs stars are DA types.

Slowly the white dwarf cools until it no longer shines, becoming a black, cold, dense remnant of its former glory. However, such end products are not our concern here, and we should revisit what happens during the planetary nebulae stage and especially attempt to account for the plethora of wonderful shapes created by these processes.

Planetary Envelopes

Planetary nebulae have a very wide range of shapes that belie the usual perception of nice, round, ring-like objects. We shall later examine the morphological classifications recognized by visual observers; here we want to understand how such disparate forms are fashioned.

Heber Curtis first described the various morphological types in his 1918 study of planetary nebulae. His classifications of helical, annular, disk, amorphous and stellar have stood the test of time and have been the base subjects of re-classifications since, with one of the latest by B. Balick emerging as a simplified designation system of three types, namely round, elliptical and butterfly. Although such terms may not sound hyper-scientific, they more than adequately describe what is being observed. Most astronomers now use the system designated by Letizia Stanghellini of the Space Telescope Science Institute and her colleagues R. Corradi and H. E. Schwartz, which defined planetary nebulae by the following shapes:

1. Stellar
2. Elliptical
3. Bipolar
4. Point symmetric
5. Irregular

The advent of CCD imaging and the superb pictures from the Hubble Space Telescope have given astronomers new insights into how these different shapes are created by the same processes. Essentially the winds during the AGB phase create a circumstellar shell as we have seen, but the densest parts of the shell are found around the equatorial regions as the centrifugal forces there are a little higher than the rest of the star's envelope, allowing more material to be lost. When the hydrogen shell is puffed off in thermal pulsations, the expanding gases encounter this denser central "ring," or torus, around the star's equator and slow down at that point, while the rest of the escaping gases continue at their regular velocities. This then creates two expanding hemispheres of material and a 'waist' of slowly moving material, giving rise to the classic bipolar or helical shapes noticed in many planetary nebulae.

It is postulated, not without evidence, that all planetary nebulae are formed in this manner. The gases from the star are ejected as an expanding ellipsoid, which then becomes distorted due to interaction with circumstellar material. Classic examples such as the Ring Nebula, M57, and the Helix Nebulae, NGC 7293, are merely seen from the point where we are looking down directly onto their poles – the two hemispheres merging to make a 'ring' shape. If seen side on or from the equator, we would see the typical hourglass shape of a bipolar nebula.

Conversely, the outflow of gas may be collimated by magnetic fields or collected into a collimated jet of materials flowing from the poles that spreads and distorts as it hits the circumstellar shells ejected by the AGB star. Many proto-planetary nebulae have been observed to have such collimated outflows such as the Cygnus Egg and Minkowski 2–9. In all probability both mechanisms are in effect; it is merely a question of what point in the formation of a planetary nebulae does each mechanism becomes the most dominant feature at work.

There is some evidence that the type of nebula that results is tied to the mass and spectral type of the central star. A study of 160 planetary nebulae in the 1970s by W. E. Grieg found that bipolar nebulae have WC dwarfs at their centers and have a higher incidence of NII, OII and OI in relation to hydrogen lines in their spectra than other types. Corradi and Schwartz found a similar result in their 1995 study of bipolar nebulae, suggesting that such planetaries have a more massive, or intermediate mass, star as their progenitor. They also concluded that given the angular dimensions of the planetaries they studied, the bipolar planetaries were also more advanced in age; younger planetaries just emerging from the proto-planetary nebula stage were more symmetrical and smoother in appearance, indicating an evolutionary path between young and old objects. Whether much of the foregoing is due to selection effects is yet to be seen. Needless to say, this is a fresh and exciting field of study.

There are some fantastic examples of bipolar nebulae available for amateur study, with M27, the Dumbbell Nebula, being the brightest of this class. Others include M76, the Little Dumbbell in Perseus; NGC 6302, the Bug Nebula in Scorpius; NGC 2440 in Puppis; and NGC 7008 in Cygnus. All are included in this book.

Other features that are also observable in some objects are the so-called microstructures, or clumps of denser materials in some planetary nebulae. These are characterized by "ansae," or rays, to use the old definition usually found in observational literature. These structures are known as FLIERs, or 'fast, low ionization emission regions,' usually seen as knotty inclusions in the shells of planetary nebulae, of which the structures forming the 'rings' in NGC 7009, the Saturn Nebulae, are among the best observed structures on a professional or amateur level. Occasionally a nebula can reveal some point symmetric structure, similar to an S-shape, which have the appellation BRET, or 'bipolar rotating episodic jets,' which are probably the result of magnetically collimated outflows, though FLIERs also may come under this description. The 'furry hood' of the Eskimo Nebula, NGC 2392, is due to inclusions termed 'cometary knots' and is evidence of interaction with the fast winds and the dust/gas ejected by the AGB star.

Such features can be difficult to see under direct viewing but may reveal themselves to a photograph or CCD image. Amateurs using such equipment may pick up such aspects in planetaries such as NGC 2371/2, NGC 7009 and NGC 4361 in Corvus.

How much of the planetary shell and its morphology is contributed by binary partner stars is as yet unknown. Considering the high percentage of stars of intermediate mass in binary partnerships (possibly 60%), it is important to account for the interaction between gas and binary partner in such emerging systems.

Binary Stars and Magnetic Fields

Stars in binary systems must go through the planetary nebulae stage at some point in their lives. It has always been assumed that single stars will inevitably go through the planetary nebulae process if their masses were sufficient enough, but over the last two decades doubts have been raised about the mechanisms of planetary nebulae formation from single objects. Conversely, astronomers did not know enough about the dynamics of binary systems to agree upon a model that could produce such nebulae.

Until recently, it was unclear how such interactions between a main sequence partner and an engorged giant star could lead to development of a planetary envelope as the mass transfer within the system was presumed to be via the Roche lobe interface between the stars, a gravitational point between the two stars where the extending envelope of the giant star would spill over into the gravitational domain of the other. This would then lead to mass sharing and the demise of any envelope that could develop to the planetary nebulae stage.

However, what if the separation of the stars was sufficient so that there would be little mass transfer due to distance, or if the interaction between the binary partner and the AGB stars slowed the orbital speed of the partner, but it did not spiral into the gravitational domain where Roche lobe transfer would be dominant? What if both stars were of small mass? It was important to model such systems there is evidence from several sources where planetary nebulae had binary stars at the center. How did the interaction between the stars contribute to the nebula?

Initial studies by Noam Soker in the late 1990s suggested that the binary separation of low mass red giant branch (RGB) stars and their partners would lead to mixing and possible coalescence of the two bodies as ejected materials from the RGB star caused orbital drag, resulting in the partner star spiraling inwards and sharing a common envelope.

Occasionally the cores would coalesce, too, depending on how long the RGB stage was and when the two stars began their interaction. Soker's calculations found that the stars would share a common envelope but remain as separate cores with distances between them of five or more solar radii. He further found that low mass stars would coalesce to form a single star if they had sufficient mass to spin up the envelope of the primary and thus ensure further gravitational interaction with the gas of the system. A star might even become an AGB star at this stage, but due to this coalescence, the resulting planetary nebulae may become an ellipsoid. This suggests that low mass stars could not form bipolar nebulae at all.

Stoker's work began to focus on the partners of intermediate mass stars where the two bodies remained separate. Although a partner could also be subject to tidal drag and spiral inwards in its orbit, if it remained separated by the end of the AGB phase then the orbital momentum of the system would contribute to the ejection of a bipolar nebula. His conclusions were that stars lower than 1.5 solar masses would not become bipolar planetary nebulae. Therefore, the wonderful bipolar nebulae we see in many instances come from the interaction of AGB stars and binary partners where the system collectively is made of intermediate or high mass stars.

These stars may still share a common envelope and thus the combined gases of the system will contribute to a large amount of material being lost in the equatorial plane of the system. This then forms a large torus of gas and dust that is slowly expanding. Once the ejection of material in a fast wind occurs, this wind is funneled through the torus to create the classic bipolar shape described earlier.

The mechanics of these systems are still ill defined, and work is ongoing in this fascinating field. It is essential to our understanding of planetary nebulae that we can tease out the contribution made by binary systems, comprehend their dynamics and explain how such interactions contribute to planetary nebula morphology. To date, many astronomers accept that bipolar nebulae are created by binary star partnerships, and observations, coupled to astrophysical modeling, provides vital clues. Recent studies by Soker (2004–2010) and others argue that single stars almost never become planetary nebulae, that binary systems are the key to their development rather than the single-star models used in former years. This has implications for our Solar System – perhaps the Sun will not end its life as a planetary nebula after all despite many years of belief that this was to be its end.

Increasingly astronomers are uncovering evidence that many planetary nebulae are a consequence of binary star partnerships. It is ironic that most of the modeling done on such systems has always involved single stars. Now that ideology is being overturned and a new era in planetary nebula research is dawning.

It is also unclear how large a part magnetic fields play in the production of planetary nebulae. Several examples such as NGC 6881, Minkowski's footprint and NGC 6537 appear to have outflows that resemble large magnetic sheaths or collimated patterns that resemble the electrical and magnetic phenomena known as Birkeland currents. Magnetic activity could certainly account for the appearance of BRETs and some FLIERs too; it is known that several isolated white dwarfs have very large magnetic fields. Recent studies by J. Nordhaus et al. have demonstrated that when two stars share a common envelope, then strong patterns are set up that result in an accretion disk forming around the heavier star. This disk then acts as a giant dynamo and increases the magnetic field strength of the system. Once the gaseous shroud of the nebula is lost, all that is left is a highly magnetized white dwarf.

Considering the ionization potential of the hot central stars of planetary nebulae, magnetic and electrical fields will play a part in the creation of gaseous outflows and streaming. Binary partnerships and magnetic fields, working together, probably account for the bipolar appearance of such nebulae.

Lifetimes of Planetary Nebulae

The expanding shells of luminous material that astronomers commonly image are very ephemeral on an astronomical scale. Most planetary nebulae will have faded into invisibility between 15,000 and 20,000 years after their production, and the materials composing them will become an inextricable part of the interstellar medium within a million years of their formation.

These materials are important in that they not only recycle hydrogen but also in that they enrich the ISM with carbon, oxygen, nitrogen and a host of other elements. These elements are also joined by exotic molecules such as polycyclic aromatic hydrocarbons (PAH), naphthalene, benzine, acetylene, hydrogenated amorphous carbon (HAC), methane and many more, which raise important issues as to the contribution of planetary nebulae to the materials necessary for life. Astronomers have found amino acids in the ISM such as glucose; the production of all these molecules from planetary nebulae beg the question of how such materials form chemical bonds under such rarefied conditions and whether they can be delivered to planetary surfaces. This is an interesting field of study that sadly is beyond the scope of this book.

Conclusion

As observers, we can revel in the beauty of such objects and consider the means of their construction. The astrophysical processes here described may form the basis of further studies for the reader should they so wish. Most, though, will probably be looking forward to discovering how such wonderful objects can be observed. This is the subject of our next chapter.

Chapter 3

Observing Planetary Nebulae

Planetary nebulae are one of the most varied groups of objects to observe. Many can be seen in relatively small telescopes, while others of their class require larger apertures and specific observing techniques involving filters. They range in magnitude from 7.5 for the Dumbbell Nebula to 14th or 18th magnitude for some of the fainter Abell or P-K catalogue members. Although several astronomical objects also have wide ranges of magnitudes, planetaries have something special about them in their variation in morphology, brightness, size and observability under different conditions.

Although binoculars will suffice to show the observer some of the brightest examples of their class, their details will be limited, and as such, a telescope brings out the best in these beautiful objects.

Telescopes and Mountings

Many amateurs will own a small telescope. It is impossible to recommend a specific type to observe planetary nebulae, as both refractors and reflectors have their uses. A small refractor will generally give good clear views if the optics are of good quality and for their size and portability they are very hard to beat. Others will rely on reflector telescopes, which may have larger apertures than the 70–100 mm of small refractors. Planetary nebulae can be seen in either instrument, but obviously the aperture and optical quality of such telescopes range widely.

Refractors

A good quality refractor in the 100–120 mm range is a very versatile instrument and will provide a good platform for observing most deep sky objects, including, of course, planetary nebulae. Refractors of this size give much better images than reflectors and even some Maksutov-Cassegrains or catadioptrics, as the light path is unrestricted and provides a ready platform for an SLR camera or CCD device.

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides,
DOI 10.1007/978-1-4614-1782-8_3,

A point to note with refractors is that their focal ratio (f) can vary between types. Some of the short focus refractors such as the Skywatcher Equinox ED-Pro are superb instruments made with the best quality optics, but some of their 80 mm scopes are a fast f5 ratio, which means that the field of view through the instrument is quite large, spanning more than 2° with a low power eyepiece. Although this is not necessarily a consideration for most observers, should you wish to image or visually observe planetary nebula then this large field of view may lead to some confusion in identifying objects that are only a few arc seconds in size. A refractor with a longer focal length (f10, for example) may be a better requisite for such observations or imaging. Having said that, the Equinox ED-Pro series now come in a range of focal ratios and are superb instruments priced at the high end of the market due to their exceptional quality.

The drawback of such an instrument is its limited size. A good refractor is a versatile instrument, but the difficulty of making quality objective lenses in sizes larger than 150 mm for commercial sale has always provided the amateur with a problem of aperture. To see really faint and indistinct objects, reflectors are the instruments of choice, as they are very durable, portable despite their larger size and the sheer aperture and light grasp plays into the hands of those looking for fainter objects or more detail in the brighter ones. Personally this author use both types of instrument when observing, but not everyone can have such a choice.

Types of telescopes.

Reflectors

Reflectors therefore become the main telescope of most observers, as large apertures can be purchased for a fraction of the cost of a top-quality refractor. Most reflectors are built according to the Newtonian design, where a parabolic mirror at the base of the telescope reflects light back up the tube to a mirror angled at 45° (a flat) and then out through the side of the tube at a comfortable height for viewing. For the price of a good quality refractor you can buy a 250 mm or 300 mm reflector on a Dobsonian mount. Despite this size the instrument is still portable and can be transported easily, though it is incumbent on the observer to check that the optics remain collimated when you set up.

A difference between refractors and reflectors in practice is also that a refractor is "ready to go" virtually after set up, whereas a reflector may take some time cooling down to the external temperature before it obtains fine images. Tube currents play a pervasive role in visual astronomy, and it is best to let a reflector settle before attempting to view any fainter objects on a target list. In addition, many of the Newtonian reflectors found for commercial sale are not built for photography but just visual observing. Although this is not a concern for most observers, this is something to be taken into account if one uses a large reflector. A Dobsonian mount negates the ability to track the sky effectively and so makes astrophotography a moot issue. A reflector on an equatorial mount overcomes such problems, but then the size and the weight of the complete system begin to work against them as easily portable objects.

Catadioptrics

These are almost a compromise optical system between reflectors and refractors in that they use both mirrors and lenses to achieve focus. Most amateurs will be conversant with the typical setup of such a telescope, known as the Schmidt Cassegrain, wherein a corrector lens at the front of the 'scope adjusts the light path to fall on a spherical mirror', which then bounces light onto the silvered spot on the lens and back down the tube and out through a hole in the primary mirror to a focus outside the rear of the mirror cell. Maksutov-Cassegrains use much the same light path, the principal difference being in the curvature of the front lens or meniscus of the system. In such a manner, the light path is quite long in a relatively small instrument as the light path makes three trips around the system, resulting in a long path and a larger focal ratio, generally between f10 and f13 or more.

The advantage of such a telescope is its portability, small size and stability coupled to a ready platform for an SLR or a CCD device. The small field of view ensures that any extended object fills the field, which is typically about 0.5° and makes looking for small planetary nebulae easier due to the small field size.

Catadioptrics come in a range of apertures from small 90 mm scopes to 40 cm giant telescopes, which are not really portable objects at all. Several well known manufacturers make catadioptric telescopes, and they are available at reasonable prices in outlets worldwide. They are easy to set up and maintain, though use of a dew shield is a must, as the primary lens of the system is right at the front of the 'scope and will suffer from dewing if it is not properly shielded. Dew shields, dew zappers and associated equipment can be obtained from all good astronomical suppliers, or can be home-made quite easily and cheaply.

The above represent a typical selection of telescopes available for amateurs. There is no "right" telescope to use specifically for planetary nebulae; it will all depend on the observer's choice, affordability and variety of use. The one thing that any observer will need, however, is a good, stable mount.

Telescope Mounts

Telescopes come with a variety of platforms enabling the observer to mount the telescope in a stable manner to observe the sky. Mounts vary in type and use, but the most common are the simple alt-azimuth and the equatorial mount.

The alt-azimuth is a basic design that grips the telescope and allows it to be turned along a horizontal axis paralleling the horizon (azimuth) and then raised upwards along its second axis so that it climbs higher (altitude), describing a 90° arc that goes from the horizon to the zenith (point directly overhead in the sky). Most small refractors are fitted with this design and most reflectors are, too, the best example being the Dobsonian mount. These designs are fine for basic observing and are very useful but have their limitations when it comes to photography. Even some of the computer-controlled alt-azimuth systems that can be purchased today have limiting factors such as field rotation, which can spoil an image if the exposure is too long. Poncet, or equatorial adjustments for Dobsonian telescopes, are in use among some observers, and these are very effective in retaining an image in the eyepiece, but again have limits due to field rotation after 60 s of photographic exposure.

The best mount for all-purpose observing and photography is the equatorial mount, which comes in several styles – fork-mounted as in the Meade and Celestron range of telescopes or the more common German equatorial for refractors and some reflectors. There are many manufacturers of such mounts, and it is not the purpose of this book to make any recommendations as to which is the best. However, the main issue that any observer will have to take into account is portability and stability, as without these functions the telescope will not perform to its best standard.

The equatorial mount is a must for any long-exposure astrophotography as it sweeps the sky in right ascension order and can maintain its lock on an image, once properly aligned, for hours if necessary. Coupled to a quality telescope, this mount enables the observer to make observations uninterrupted by the constant need to move and adjust an alt-azimuth mounting. Many on the market can be motor driven in both axes and come with GOTO systems that can find any object of preference once properly aligned. Although many amateurs can find objects using star-hopping techniques, the GOTO ability of these mounts is extremely useful if one is going to image an object as this then negates identifying the field and object with an eyepiece and then switching to a camera or CCD with the resulting nightmare of re-focusing.

A driven, equatorial mount is an essential pre-requisite if you wish to photograph all of the objects within this book. Although all were observed using nothing but a Dobsonian mounted reflector, the ability to enjoy the visual appearance of

Equatorial mount.

the object and define faint detail is only available if the object can be kept in the field of view and therefore, such a mount is necessary to perform this operation.

Eyepieces

There is no point in having a quality telescope and then spoiling the ability to see detail by using inferior quality eyepieces. It is often the case that a good telescope and mount can be purchased as a complete item along with eyepieces only to find that the eyepieces are not the kind of quality that matches the telescope. Over the years, many amateurs have learned this lesson; the supplied eyepieces with any system are not as good as they could otherwise be, and they have invested in a range of eyepieces for use with the range of 'scopes they may possess'.

If the observer has built up a good standard set of eyepieces, then obviously all perform slightly differently on each telescope that the observer will use. The main denominator will be the difference in field of view (FoV) and magnification of the eyepiece on each telescope. Magnification is obtained by dividing the focal length of the eyepiece into the focal length of the telescope. For example, a refractor of 100 mm aperture may have a focal length of 1,000 m, making an f10 system (1,000/100). If the eyepiece of choice is a 20 mm then the magnification of such in use with this refractor will be ×50 (1,000/20).

If the 20 mm eyepiece is used with a system having a longer or shorter focal length then adjustments have to be made accordingly. I.E. a 700 mm focal length will now have a magnification of ×35 (700/20), while a 1,400 mm focal length will now have a magnification of ×70 (1,400/20). This magnification will also impact upon the field of view of each instrument using that eyepiece.

Most standard eyepieces have FoVs that vary from 30° to 50°. Of course, when in use this field is not 30–50° at all. One now has to divide the magnification the eyepiece gives on a particular instrument into the field of view quoted. So, for an eyepiece with a FoV of 50° and a magnification of ×50, the apparent field of view through the eyepiece will be 1° (50/50), whereas one with a magnification of ×50 and a FoV of 30° will give a FoV through the telescope of 0.6° (30/50). The observer will have to make all these calculations across the range of his or her 'scopes and eyepieces' so that he or she will then understand the FoV through each instrument and will be able to use this information in observing the field for faint objects and making a mental determination of how large an astronomical object would appear in such a combination. This is extremely useful for hunting down faint extended nebulae or small compact star-like planetaries, as the FoV will enable the observer to gauge the size of the target more effectively.

An additional tool for determining the FoV is to put a bright star such as Altair (α Aquilae) or δ Orionis on the edge of your eyepiece field and allow the star to drift through the field until it reaches the other side. Time this event and multiply the time by 15 to obtain the FoV in minutes and seconds. As 60 min make 1°, it will be easy to determine FoV with this method and adjust accordingly.

When choosing different focal length eyepieces it is important to remember two things, the size of the exit pupil and the necessary eye relief of each one. The exit pupil is defined by dividing the diameter of the primary lens or mirror of your telescope by the magnification of the eyepiece; this is always quite a small number. The exit pupil of a 100 mm f10 refractor telescope using a 20 mm eyepiece is therefore 2 mm (100/50) and provides an adequate exit pupil for most observers. The smaller the focal length of the eyepiece, the smaller the exit pupil and therefore the more difficult in practice the eyepiece becomes to use. This can be alleviated choosing eyepieces that have an ultra-wide flat field, making it a little easier to find the image.

Another consideration when choosing an eyepiece is the eye relief given to the observer, especially for those who may wear eyeglasses, but as a general rule, the higher the magnification of the eyepiece, the smaller the eye relief.

Most observers use multi-element eyepieces that have weird and wonderful names such as Plossl, Erfle and Orthoscopic; these eyepieces are now the standard for observers and provide exceptional views through most instrumentation, giving flat fields with no astigmatism or blooming of images at the edge of the field. They also vary in price, and the super high quality types may cost as much as a small telescope themselves! Nevertheless, a selection of good eyepieces giving a range of magnification is a must for all astronomers and provide a bonus for seeing those small, faint or difficult objects due to variations in FoV, contrast and color rendition.

One accessory that will aid with magnification is the Barlow lens. This negative focus lens effectively doubles or triples the magnification of each eyepiece, and the quality versions have a demountable lens that will fit into the adapter sleeve of an SLR camera, thus increasing the focal ratio of the optical system and enabling a smaller FoV around the object one wishes to image. These lenses are available from all good suppliers, but the quality can vary.

Limiting Magnitudes and Angular Resolution

No matter what the instrumentation in use they are all limited in particular senses. These limitations are the resolving power of the telescope and the faintest objects that can be seen with the equipment in use. The standard scale of brightness of objects or magnitude in astronomy is a logarithmic measurement of the differences in brightness between celestial bodies as seen by observers here on Earth. It is properly called apparent magnitude and has an historical precedent, as this scale was first used by Hipparchus of Rhodes to define the brightest to faintest naked-eye stars. His scale went from the brightest objects (first magnitude) to the faintest magnitude visible with the eye (sixth magnitude).

The scale has now been updated mathematically so that each magnitude represents a difference in brightness of 2.5 between each magnitude class. Therefore, stars of first magnitude are 100 times brighter than stars of sixth magnitude (2.5^5). This scale is highly important, as the differences between the apparent magnitudes of an object and its absolute magnitude (its brightness if mathematically calculated to be 32.6 light years away) enable astronomers to define the distance of whatever object they care to observe.

For the amateur observer, these differences are not so crucial until one comes to observing any object. The fainter the object, the higher its magnitude number and the less chance it has of being seen, depending on the aperture of the observer's telescope. Obviously, the larger the telescope aperture, the more light it can collect and therefore the fainter the objects that can be seen with it. Small telescopes can appreciably increase the resolving and collecting power of the eye, and larger instruments can resolve much more.

The limiting magnitudes for any sized telescope can be seen from the table below:

Telescope size (mm)	50	70	100	150	200	250	300	400
Limiting magnitude	11	12	12.7	13.6	14.2	14.5	15.2	16.7

The larger the instrument, the greater the number of objects that can be seen. In the case of planetary nebulae a small telescope of 100 mm aperture will probably result in the observer seeing about 50% of the objects described in this book, whereas an observer equipped with a 300 mm telescope will see the majority if not all of them. Of course they will differ markedly in appearance due to atmospheric conditions, seeing and transparency in addition to their altitude above the horizon.

In these days of increasing light pollution the limiting magnitude of stars at the observer's zenith is an important consideration. For those that live in light-polluted areas a calculation can be made that will give greater accuracy to the above table. In a typical city environment, the light pollution limits the observer to seeing stars with a magnitude of 4. Anything fainter than this is lost in the haze of light, and the limiting magnitude of the telescope optics is also affected by stray light and skyglow. The equation here is:

$$\text{Limit} = 5 \log (d_1/d_0) + 6$$

where D_1 is the diameter of the primary mirror or lens in millimeters and D_0 is the diameter of the eye pupil (typically 6 mm). Thus a 250 mm telescope would give a gain of 8 magnitudes to 14th magnitude or so beyond the range of the limiting naked-eye magnitude and render objects of 12th to 13th magnitude visible.

There is also the consideration of surface brightness as an indication of visibility for any extended object, a class that planetary nebulae obviously belong to. In general the surface brightness is the total energy emitted per cm^2 from the surface of an extended object. As planetary nebulae receive their emissive power from the central star and such power for observational purposes remains a constant, it follows that the more extended the nebulae, the greater the surface area, and thus the same power has to now cover a larger area, leading to the inevitability that the largest planetary nebulae will have the more diminished surface brightness and will be fainter to the visual observer.

As an example of this, consider the wonderful Helix Nebula, NGC 7293, which has an integrated magnitude of 6.5, just under naked-eye visibility, yet a surface area of 900 × 700 arc seconds. One would imaging that the Helix can be seen easily in binoculars, but this decrease in surface brightness across its large disk ensures that the object fades into the background sky, making a sizeable telescope necessary to view it. Conversely, small, almost stellar sized planetary nebulae will have a relatively high surface brightness and will be visible in relatively modest telescopes.

This leads us on to considerations of resolution regarding the instrument in use. When one reflects on the fact that the angular size of planetary nebulae differ markedly from object to object, the observer also has to calculate if the resolving power of their telescope is sufficient to see the nebulae as something other than a point of light. The ability to resolve an object with a given aperture is known as angular resolution and can be calculated by using the following formulae:

$$\alpha = 0.25(\lambda/D)$$

Where α is the resolution in arc seconds (″), λ is the wavelength of light in microns and D is the diameter of the telescope in meters. Using such a formula we can obtain the resolution of any telescope we wish with a simple calculation. If l is the middle of the optical spectrum at 500 nm, in microns it will be 0.5 and the diameter D of a telescope is 100 mm or 01.M then dividing λ by D we arrive at 5, which now must be multiplied by 0.25, which gives us an angular resolution of 1.25″.

As an additional calculation, there is the method of determining angular resolution from the Dawes limit, named after its discoverer the Rev. William R. Dawes in the nineteenth century. Simply put the sum is:

$$116/D$$

where the aperture of the telescope in millimeters is simply divided into 116 and the product is represented in arc seconds. For example, a 100 mm aperture will therefore have a resolving power of 1.16″ (116/100). Note that this sum deviates slightly from the angular resolution noted above and denotes the smallest size of the Airy discs observed around a star of a given magnitude. As planetary nebulae generally do not have such disks, one can see that the resolving power of even a modest telescope is quite good indeed.

Very few planetary nebulae smaller than this are visible to amateur telescopes and therefore the entire catalogue of objects contained in this book are theoretically resolvable with a 100 mm telescope. However, as we have seen from the limiting magnitude above, resolution does not equal observability due to the limitations of light grasp in smaller apertures.

Transparency and Seeing

These terms are a little subjective and are usually judged by the observer to be dependent on several factors such as location and local meteorological effects. However, in the middle of the twentieth century the astronomer Eugene Antoniadi invented a "seeing" scale that has become the most dominant model in use. There are additional scales usually based on observer judgment that range from 1 to 10, with 1 being the worst conditions with a quivering atmosphere and high humidity and 10 being perfect, steady seeing with low humidity, but they do not have the descriptiveness of the Antoniadi scale and are going to vary from observer to observer in their manner of sampling. The important thing to note is that seeing is usually defined as the steadiness of the air.

The Antoniadi scale is:

I. Perfect seeing without a quiver
II. Slight quivering of the image with perfect moments of calm for several seconds
III. Moderate seeing with larger air tremors that blur the image
IV. Poor seeing. Constant troublesome undulations that spoil the image
V. Very bad seeing, hardly enabling a sketch to be made

This scale enables the observer to make an observation of how calm the sky is to enable one to take an image or to physically observe – or not observe at all!

Transparency on the other hand is a term used to describe the clarity of the sky and is affected by two things, darkness and extinction. Darkness is obviously a measure of how dark the night sky is and is affected by such things as twilight, moonlight and light pollution and is tied to the scattering of light particles in the atmosphere by the air itself or by droplets of water vapor, smoke or dust. Where the atmosphere is unaffected by haze or humidity, the transparency will be excellent, whereas the opposite will be true for bad transparency. The brighter the sky or the hazier it is, the worse the extinction factor that will limit the magnitude of objects available to view.

A transparency scale numbering 1–5 can be utilized here using whole numbers rather than Roman numerals to distinguish it from the Antoniadi scale. A typical example will be:

1. Dark blue sky – excellent transparency
2. Medium blue sky – above average transparency
3. Light blue sky – average transparency
4. Pale blue sky – poor transparency
5. Gray sky – very poor transparency

Both scales when used together can be excellent indicators of the prospects for good observing, where even some of the fainter objects can stand out with good clarity under excellent skies – or not as the case may be! Sometimes, a beautiful sunny day can be the worst nightmare for an observer, as the conditions at night are going to be filled with wavy air currents, high humidity and dew points in contrast to the balmy day just enjoyed! Paradoxically, some of the best observing conditions with perfect transparency and seeing are enjoyed during the cold winter months when the air is steady and clear after a frosty day with little humidity and no rising warm air.

Most observers will recognize that getting perfect clarity and steady seeing is a relative rarity, so compromise is essential. Timing your observing run can alleviate some of these problems, with many observers learning that observing is best after midnight or in the small hours when the heat of the day has dissipated and the atmosphere has cooled and gone beyond the dew point. The grass may be wet as you set up, but the sky conditions are at their optimum.

Dark Adaptation and Averted Vision

The ability to see objects in the dark is not a usual function of the human eye; we have adapted to living in the daylight, and our eyes have only a modest response to the darkness. However this response can be maximized by staying at a dark sky site, or as far away from artificial lights as possible, and allowing your eye to gradually adapt to the darkness. The iris of the eye does this automatically; by allowing the pupil to dilate to its largest size, which is about 6–7 mm or more, varying slightly between individuals. Once the pupil is at its largest extent, the observer is now dark-adapted. This complete process may take up to 30 min, but it is well worth the wait as your eye is now maximized as an observing tool. In such conditions, any white light will destroy the adaptation by narrowing the pupil, and therefore any necessary light should come from a torch fitted with a red filter or adapted for the purpose.

A trick that is used by most astronomers to help discern more detail in an object is that of averted vision, or looking at an object "with the corner of the eye," using one's peripheral vision. This is a rather strange practice but is nevertheless very useful due to the physiology of the human eye.

Just at the center of the retina, at the back of the eye, the area directly behind the pupil (the fovea) is populated by cells known as "cones." The cones are densely packed and enable the observer to discern color and detail. However, they do not work so well in low light conditions, as these cells have evolved to maximize our sight during the day when humans are generally awake. This inherited ability in the darkness is known as scotopic vision.

Away from these cones, the rest of the retina is comprised of cells called "rods." One sees less detail and no color with the rods, yet they are far more light sensitive than the cones; therefore, if one lets the light from the eyepiece fall onto the rods about 16–20° away from the cones, one can discern fainter detail, yet see no particular increase in the color rendition of an object. In astronomy, light grasp is everything, so this trick of averted vision, or allowing light from the object to fall outside of the center of the retina, is helpful in gauging fainter detail, or even in seeing a faint object in the first place. With such a technique, observers report an increase in light grasp corresponding to one or two magnitudes, though this experience will vary from observer to observer depending on their acuity.

Under dark conditions the eye also experiences a phenomena known as the "Purkinje effect," named after the Czech anatomist Jan Evangelista Purkinje, who noticed that under low light conditions, the sensitivity of the eye shifts toward the blue end of the spectrum, thus rendering any color at the red end of the spectrum a gray or black color. It's an important effect if one is doing variable star observations and estimates of magnitudes, especially if one of the stars is red.

Physically, it is based on the nature of rhodopsin, one of the light-sensitive pigments of the retina, which is sensitive to light with a wavelength of 500 nm. The cone cells utilize opsins, which are sensitive to wavelengths of about 420 nm in the blue, 534 nm in the blue-green and 564 nm in the yellow-green. In the case of planetary nebulae that have a peak output of between 495 and 500 nm (the light of OIII), the Purkinje effect actually works in the favor of the observer, though larger nebulae such as M57 or NGC 7293 will be lacking some of the red colors that give them such beauty on photographs.

Finally, to assist in maximizing your dark adaption and averted vision techniques, astronomers also use something called scope-rocking or tube-tapping to bring out fainter objects. The human eye is quite sensitive to movement, and this practice where the telescope is tapped lightly with the fingers or moved slightly so that the field of view shimmers or vibrates, can bring the desired object into view on the rods while holding your head still at the eyepiece. Although such procedures require a little practice, they are easy enough to implement until it becomes almost second nature.

In addition to the above methods, the observer must not neglect the physiology of their bodies. Observer's night vision can often be improved by taking a brief rest and by having something to eat and drink. High blood sugar levels often have a positive effect on visual acuity while low blood sugars have the opposite function. Ensure that nothing alcoholic is drunk, too! A tot of brandy may seem the ideal way to warm up, but it has been shown that for each unit of alcohol consumed, the ability to see faint objects may drop by up to half a magnitude.

Now that you are ready to observe, what is the most evident feature visible?

Morphology of Planetary Nebulae

The general shape and appearance of planetary nebulae is one of the most obvious features that observers will note. Planetary nebulae have some beautiful shapes that are almost unique to them and with many in the listings within this book, the morphologies are quite stunning, defining the nebula well and resulting in some of the common names for these objects.

The first morphological classifications were suggested by Heber Curtis of Lick Observatory after his photographic sampling of 78 planetary nebulae. He stressed division into five main groups: helical, annular, disk, amorphous and stellar, which led the way for most catalogues. Perek and Kohoutek ranged across similar five divisions – namely stellar, disk, irregular, ring and anomalous – while W. Grieg, Bengt, Westerlund and Karl Henize utilized elliptical, rings, interlocking, peculiar and doubtful! This visual mish-mash was augmented by Bruce Balick in 1987 to include round, elliptical and butterfly. The study by Westerlund and Henize in 1967 revealed that small, bright planetary nebulae were probably young objects and showed a greater structural regularity than older more diffuse nebulae, hinting at an evolutionary effect.

From a professional point of view Grieg's studies of 160 planetary nebulae correlated their appearance and shape to nebular excitation and the type of central star exhibited. He concluded that planetaries fall into two main groups, which he designated B and C; B-type nebulae are characterized by large ansae, or rays, emanating from the object, tubular structures or filaments, with most of the class being bipolar in form. Spectroscopically speaking, the B class have strong NII and OIII emission lines and have carbon-rich central stars.

Class C planetaries have a central brightness and are generally smoother in appearance than Class B and have weaker emission line intensities in their spectrum. Grieg also made the observation that Class C planetaries also seem to inhabit higher galactic latitudes, whereas Class B were more confined to the disk of the Milky Way Galaxy, and the difference between each group could be accounted for by underlying chemical characteristics of the progenitor stars. However, few observers are going to be interested in these astrophysical characteristics, and they would rather concentrate on visual appearance. Therefore, in one of the latest morphological studies by Stanghellini, the five main divisions of morphology are now:

1. Stellar
2. Elliptical
3. Bipolar
4. Point symmetric
5. Irregular

It is important to note that these morphological types are based on the apparent structure of the nebulae and describe the two-dimensional appearance as photographed or viewed. There is some ambiguity over whether these classifications represent an evolutionary sequence between planetary nebulae types or if they represent stand alone morphologies that are intrinsic to each star and its interactions, magnetospheres or binary pairing. Ongoing work is attempting to determine if there is a genuine evolutionary sequence between each type and early indications are that this is indeed the case.

Due to the rise of amateur skill in CCD and SLR imaging, a few planetary nebulae show remarkable structure and require some additions to the morphological types described here. Most of these additions are due to the underlying physics within the object and can be described here as haloes, FLIERS, microstructures and cometary knots.

Haloes are the faint outer "atmospheres" of some nebulae such as M57, the Ring Nebula, and are indicators of past outflows from the star while FLIERS are fast low ionization emission regions and are characterized as ansae or filaments in some photographs and can even be seen visually in such planetary nebulae as NGC 7009, the Saturn Nebula. Microstructures are clumps of denser materials found in the outer parts of some nebulae, while cometary knots are also dense and dark inclusions in the outer edges of planetary nebulae and can be seen to great effect in Hubble Space Telescope images of the Helix Nebula, NGC 7393. Whether amateurs will in fact notice these distinctions is unclear as it depends on the size of telescope or type of imaging instrumentation in use.

For most amateurs, the major classification group for observing planetaries is that of Boris Vorontsov-Velyaminov, first detailed in 1934. This Russian astronomer invented a morphological system that sums up quite accurately the different types of nebulae, incorporating photographic and visual evidence to enable any observer to classify their description along a common theme. The categories are:

1. Stellar image
2. Smooth disk
   (a) Smooth disk, brighter toward center
   (b) Smooth disk with uniform brightness
   (c) Smooth disk with traces of ring structure
3. Irregular disk
   (a) Irregular disk with an irregular brightness distribution
   (b) Irregular disk with traces of ring structure
4. Ring structure
5. Irregular form similar to a diffuse nebula
6. Anomalous form

These morphological types may be used as a guide to one's observations, though it is important to remember the limitations of your telescope and magnification in use in comparison with these classifications, which are based on observatory images via photography, CCD and spectroscopic analysis.

Nebular Filters

The use of bandpass filters in observational astronomy is increasing all the time. Specialist filters for Ha, Hb and OIII in addition to light-pollution reduction and ultra high contrast filters are widely available and are sold by most good astronomical suppliers. These filters work by allowing only a narrow selection of wavelengths through and can be geared to make the most of particular objects. Several are useful if the observer is going to concentrate on planetary nebulae, though prices and quality will vary depending on location and local manufacturers. As a general rule, they can be broken down into broadband, narrowband and line filters. The more specific the filter to a particular bandwidth of the spectrum, the more useful it will prove in searching for planetary nebulae.

The Oxygen (OIII) Filter

The most useful filter for planetary nebulae observation is the OIII filter. This line filter allows an 11 nm band of light centered on 500 nm (495–506 nm), which corresponds to the chief nebular lines in planetary nebula and are of great assistance in spotting such objects if faint or observing conditions are not optimal. The OIII filter suppresses the light from stars within the field while prioritizing the emission lines from the nebula and appreciably enhances the contrast between object and background, making it spring into view. The OIII filter is easily the most useful tool in the planetary nebula hunter's armory.

Filters for planetary nebula.

The Hydrogen (Hβ) Filter

This is another specialized line filter, which is useful in many instances when hunting down faint objects and particularly the envelopes of planetaries, as Hβ is one of the prominent lines emitted from diffuse nebulae. It has a 9 nm bandpass and is good at illuminating some low ionization features in planetaries such as Campbell's star and NGC 7293, but it is not as versatile as the OIII filter due to the low emission of Hb from such objects.

The Hydrogen (Hα) Filter

A much more useful line filter for planetary nebulae observations than the Hβ; the Hα filter improves contrast between the object and background and can illuminate some of the delicate outer shells a little more effectively. Its bandpass at 656 nm is good, but obviously limited to extended, bright objects in the planetary catalogue, as the emission lines are chiefly dominated by OIII. Such filters are versatile, as they can be used on extended nebula such as HII regions quite well, and with the correct equipment can also be fitted to a small telescope for solar viewing, depending on the manufacturer's recommendations.

Light Pollution Reduction Filters (LPR)

This is the least specialized filter and, given the predominance of light pollution across our towns and cities, probably the filter used by most amateurs. The LPR as a broadband filter is designed to eliminate light from a variety of sources such as low pressure sodium and mercury vapor lights in addition to airglow, and as such is not a narrow bandpass, as it covers an appreciable part of the spectrum. In some instances LPRs are useful for tracking down planetary nebulae and can provide a little more contrast if one is looking for a faint object from a less than ideal site. As they are a general purpose filter, their results will vary from object to object, with some observers reporting good definition on some nebulae while others report no difference at all.

Ultra High Contrast (UHC) Filters

This narrowband filter is quite a useful tool for planetary nebulae observers, as its 24 nm bandpass of between 486 and 510 nm covers the main OIII emission lines from planetaries and is good at enhancing the contrast of diffuse nebula. Although not as useful as the OIII filter, UHC filters from various manufacturers differ slightly in their bandwidth and can be a good tool to use in the absence of an OIII filter.

As one can appreciate, the abundance of commercially available filters by Lumicon, Orion and Meade makes any particular recommendation on which manufacturer is best difficult. Talk to someone with experience using particular filters from these manufacturers for their viewpoints. The best filter for any planetary nebula work is probably the ubiquitous OIII, which covers the correct emission line bandwidth for seeing such objects in greater detail.

Using a Filter

A technique that is very useful when using filters is that of "blinking" the field, which involves not screwing the filter to the eyepiece barrel but holding it between the eye and eyepiece and moving it in and out of the field. Working like a blink comparator, the use of the filter then turns the nebula "on and off" as it crosses the field of view and makes the body stand out in sharper relief as the stars diminish or virtually disappear. This exercise is easy enough to do and makes a massive difference in the hunt for faint nebulae.

A common misperception is that filters are unnecessary if you have truly dark skies. However, a narrowband filter, by its very nature, enhances the visibility of objects with emission at specific wavelengths and is therefore even more effective at a dark sky location, as city lights, dust and smog are now taken out of the equation, leaving the filter to concentrate on those faint details that sky clarity would otherwise obscure. Such filters also offer additional detail under moonlit conditions and so extend the amount of observing time throughout the waxing or waning of the Moon.

So far what has been discussed here pertains to visual observation. These filters are also useful for photography via DSLR or CCD cameras, too, and some are specifically made for CCD imaging; most observers who record planetary nebulae prefer to stack images taken with red, blue and green filters (RGB) to gain the most natural image. Other filters that can be used alongside photography are the Sulphur SII filter, which in combination with a Hα and an OIII filter on a CCD camera can obtain good tri-color shots of planetary nebulae. I will have a little more to say on the use of filters in the chapter on photography.

Star Charts, Observing and Computer Programs

The kinds of star charts or computer programs that one would use to locate planetary nebulae are going to depend on the observer's experience and expertise, the size of the telescope in use and its limiting magnitudes. Given these constraints, we can examine a range of star charts and computer programs that would be useful to plan any search activity.

Star Charts in Book or Paper Formats

One of the commonest star charts and reference handbooks in use is *Norton's Star Atlas*; this versatile book gives coverage of both the northern and southern hemispheres and covers stars down to sixth magnitude while covering deep sky objects down to 11th magnitude. It is an ideal source for observers who are equipped with telescopes in the 70–150 mm range. The charts are fairly clear and distinct, though they are not large format, and unless one knows exactly where some planetaries are, they can be a little hard to pick out of the background of the charts. Additionally, although there are lists of interesting objects accompanying the charts, not all the deep sky objects are represented in such lists, and several interesting nebulae are overlooked. Nevertheless, *Norton's* is a very good source of materials on basic observing, photography and telescopes and is a must for many observers.

In a similar vein is Wil Tirion's *Cambridge Star Atlas*, which has a format like its bigger brother, the *Sky Atlas 2000*. The key, use of colors to illustrate particular objects and its detail are very appealing, although its single page charts cram a lot of information into a small space, and the descriptions of deep sky objects alongside the charts do not include all the planetary nebulae visible on the page. However, in contrast to *Norton's*, the *Cambridge Star Atlas* does list many planetaries that would be beyond the grasp of a 150 mm telescope and thus renders it a good tool for the observer looking for something more challenging. This atlas contains stars down to sixth magnitude, and as a helpful aside, also lists planetaries in ascending order of size in arc minutes, which is a useful indicator of its visibility if the observer has some experience with estimating surface brightness. The *Cambridge Star Atlas* covers both northern and southern hemisphere, and its rich color makes it a nice book to scan through during the day in order to pick one's targets. It also has a series of charts that indicate the visibility of particular constellation groups at specific times of the year and month, thus aiding the observer's planning.

The workhorse of star charts and one that is very familiar to most observers is Wil Tirion's and Roger Sinott's *Sky Atlas 2000*, a larger, colored edition of the *Cambridge* atlas, which comes in a black and white laminated field edition, a colored deluxe edition and a colored desk edition with loose leaved charts that are boxed rather than the usual spiral bound – so the observer has plenty of choice! Within its 26 large, foldout, detailed charts, the stellar magnitudes displayed go down to 8.5 magnitude, revealing 81,312 stars and 2,700 deep sky objects, including many planetaries. The key is similar to the *Cambridge* atlas, with planetaries marked out according to arc minute size. For observers who prefer to star hop to objects, the number of stars represented on these charts give a good indication of what would be visible in a finderscope, and the larger format enables better indicators for hopping techniques. Again, this atlas covers both hemispheres in great detail and is very easy to use when at the telescope. It truly is an excellent tool and for more experienced observers it is a must. *Sky Atlas 2000* contains planetary nebulae down to 13th magnitude, enabling observers with telescopes in the range of 70–250 mm to see many, if not all of them, depending on the aperture in use.

A useful adjunct to the *Sky Atlas 2000* is the *Sky Catalogue 2000* by Alan Hirschfield, which, in its two volumes, covers 50,000 stars down to magnitude 8 (volume 1) and data on binary stars, variables and over 500 deep sky objects.

For those who want to go a little deeper, the *Millennium Star Atlas* in three volumes contain over one million stars down to magnitude 11 and exhibit 10,000 deep sky objects of all kinds. This atlas has 1,548 sky charts and is based on the European Space Agency's *Hipparchos* spacecraft studies, which contain the first Tycho guide star catalogue. It is extremely detailed and contains labeled information on stellar distances and is quite an exquisite atlas for the serious observer.

The final star chart that lies within many an observer's armory and is the acknowledged epitome of star charts in book format is *Uranometria 2000*. This atlas, also by Wil Tirion in conjunction with Barry Rappaport and George Lovi, is a huge work, an observatory standard, and comes in three volumes. Volumes one and two cover the northern and southern sky, respectively, while the third volume is a deep sky field guide that details the objects held within the other volumes. Its 473 charts contain 3,000,000 stars down to magnitude 9.5 and includes over 10,000 deep sky objects. The maps are very detailed and contain a wealth of information, which the deep sky guide complements nicely. From the perspective of the observer, the deep sky field guide contains information on 1,144 planetary nebulae, making it one of the most useful tools one can have for this type of work. It is also an excellent all around set of volumes that will enable planning and execution in deep sky work for many years to come. As an atlas, it is difficult to see how it can be surpassed.

Observing Programs

Most astronomers prefer to make their own observing programs, tailoring them to the reach of their apertures and deep sky experience. However, it can be useful to follow a program set up by an astronomical society or by the larger groups such as the Astronomical League or the American Association of Amateur Astronomers, the British Astronomical Association, the Federation of Astronomical Societies (FAS) or similar national representative bodies.

The league and the FAS promote a particularly rewarding program to assist the deep observers gain the maximum from themselves and their equipment. This program is called the Herschel 400, a compendium of the best 400 objects of the New General Catalogue created by the great astronomer William Herschel. Brenda Branchett and other members of the Ancient City astronomy club in Florida compiled the original list in 1980. All 400 objects can be seen from northern climes, but this does not rule out southern observers totally, though some of the objects will be very low on their horizons. The Herschel 400 contains 24 planetary nebulae, only 6% of the total catalogue, yet these are among the best for amateur observation.

Another observation program is the Caldwell catalogue, compiled by Sir Patrick Moore in the UK and containing 13 planetary nebulae, though seven of these are also objects contained in the Herschel 400 program, the other six being planetary nebulae in the southern sky inaccessible to northern observers. It is a handy list of generally bright objects, and some of the Caldwell planetaries are the best in the sky.

The preeminent amateur observing program dedicated to these lovely objects is that of the Astronomical League's planetary nebula award club. The league publishes a very helpful observing guide that is detailed, illustrated and full of advice for the deep sky observer. This program contains 110 objects, but is still focused on objects available mainly to northern observers. Its coordinator, Ted Forte, is considering enlarging the scope of the guide to include many of the southern planetary nebulae that are included in this book. The updated guide will be a globally accessible program for observers wherever their location. The league presents two observing certificates for completing this course; the first level is for visual observation and the other is for photographic imaging of planetary nebulae. See the group's website at http://www.astroleague.org/ for further details.

Computer Programs for Deep Sky Astronomy

There are many specialized computer programs for mapping the night sky, but within the context of hunting down planetary nebulae, it is preferable to have something that can create detailed charts of small areas of sky within which would be the targeted object.

One of the most common pieces of software that can be obtained free of charge is *Stellarium,* which is a very nice piece of software obtainable at: http://www.stellarium.org/. It can be tailored to Mac, Windows or Linux and is an excellent program for those with computer skills, as one can add deep sky and solar system objects, products and services and even your own landscapes if desired. It can be constantly updated and is very user friendly, giving a very real "feel" to the sky. Given that CCD photography necessitates use of a laptop in the dark, *Stellarium* can also be adapted to drive the telescope and find the objects, too. With its catalogue of 600,000 stars (which is upgradable to 210 million if they are required!) it is a very powerful tool that is adaptable and useful although it does not show objects such as planetary nebulae in sufficient detail unless they are part of the Messier catalogue or the most obvious ones from the NGC.

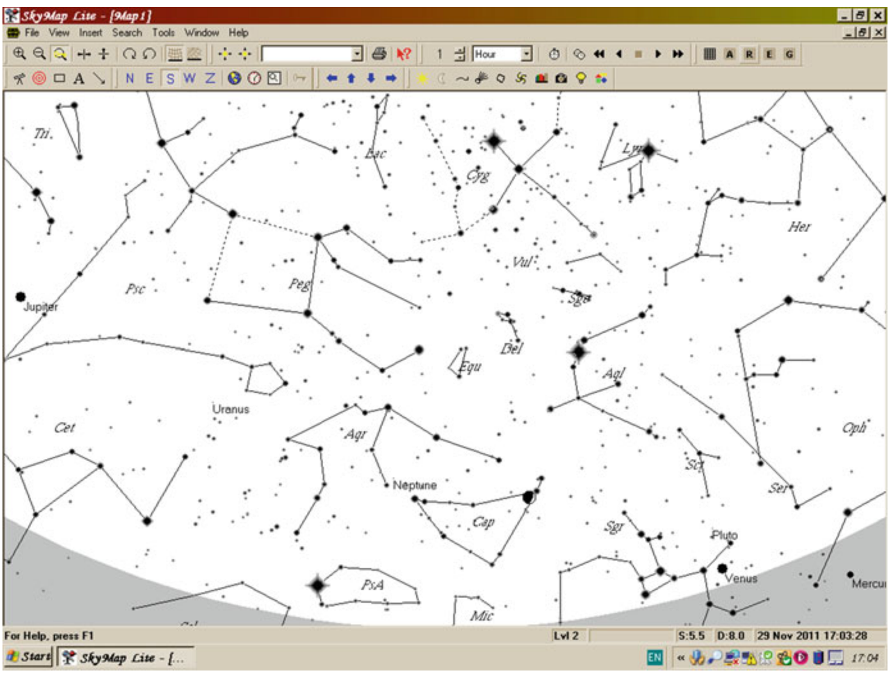
A very useful piece of freeware are the sky charts that can be produced using *Cartes du Ciel* (Sky Charts), obtainable from http://www.ap-i.net/skychart/start; this also operates on Mac, Windows and Linux. The star maps are quite detailed and one can upgrade the software to include the entire Tycho guide star catalogue of almost 19 million objects if desired. It contains several nebulae catalogues, including the *Catalogue of Galactic Planetary Nebulae,* and the quality of the printouts is very good, as is the interface. In addition, *Cartes* can also drive the observers telescope and is especially good for those who wish to star hop, as stars down to 15th magnitude can be displayed, thus making *Cartes* a very versatile system that will appeal to users of small or large telescopes.

A standard piece of software that is in general use is Software Bisque's *TheSky*, which in its current format is one of the best available planetarium software tools. It is not free, however. It can be purchased from various outlets or direct from Software Bisque, and the current format (version X) has the digital sky survey and many other deep sky catalogues included in its database. It is truly an excellent piece of software and one that prints good quality charts if needed and can project stars down to 30th magnitude. Users of large aperture scopes may use

TheSky already, and the versions 5 to X all contain software to train and focus a telescope on whatever object one wishes to look at. It is usually available in windows format only, but Mac versions are obtainable. Linux users will have to pass on this one currently. *TheSky* has a large database of movie files and photographs of particular objects that some observers will find useful.

A large percentage of avid deep sky observers use a program that has been in existence for over 20 years and has been constantly updated since. *Megastar* is one of the most versatile software packages; it has excellent displays and a database of 78,000 deep sky objects, including over 1,000 planetary nebulae. It also comes with a supplemental CD-ROM containing 129,000 deep sky images so that the observer can gain a visual impression of what to expect in the eyepiece (or not, as the case may be – depending on the aperture of the telescope in use). As a charting program it is probably second to none with its 15 million star database and over 200,000 deep sky objects, and the quality of its displays or charts is excellent. *Megastar* has become almost an industry standard and is one of the best planetarium and deep sky observing tools on the market.

Another excellent piece of software is *SkyMap Lite* (or *SkyMap Pro*), which is available from Skymap software on http://www.skymap.com/smlite_main.htm This is a wonderful tool for printing charts as it can be rendered in a full chart quality black and white image on the screen, and the user can toggle any object for general information and tailor the chart down to the quality of the observer's instruments. It has a massive database of over 2.5 million stars and every one of the P-K catalogue's planetary nebulae in addition to over 100,000 other deep sky objects. It is extremely versatile.



SkyMap Lite screen shot.

There are also professional tools such as SIMBAD and ALADIN readily available online that enables the observer to gain the most observational and visual information before going to find and observe a particular object. Both these tools realize a large database of background stars and other essential information that is a useful accompaniment to other atlases or software.

Finally, for a complete database of planetary nebulae, there is the excellent Strasborg ESO catalogue of Galactic Planetary Nebulae containing 1,143 objects and is available at http://www.blackskies.org/SEC_data00.htm, where the list is in right ascension order and tabulated in 23 charts in an accessible and easy to read format. This catalogue is ideal for some research as to morphology, distance, magnitude and a host of other factors which make it a useful tool to plan your own observing list.

It is not the intention here to recommend any one of the above atlases or software packages; these are the basic accessories that many observers have to complement their knowledge of the skies and are utilized as the observer gains experience or familiarity with specific objects. To present an exhaustive list is beyond the scope of this book and observers will all have their particular favorites with which they will feel comfortable.

Observing Procedures

Now that the observer is prepared, it is important to make the best quality observations possible. Such practices vary between observers and each has his routine in the way that objects are recorded. Some prefer to describe the object in writing; others will make a sketch, while others would rather photograph the object. Observing techniques are up to the individual, though there are a few common factors that are usually taken into account.

It is useful to put down several factors if one is going to take note of the object, no matter if one is photographing, drawing the object or just looking at it. Such obvious items as telescope aperture and focal length should be included, as should the magnifications of any eyepiece in use. Once this is accomplished, one can move on to the more subjective matters of seeing and transparency; location, date, time in Universal time, or local time as one prefers, and anything else pertinent to the record before then beginning your description.

A useful set of descriptive principles to follow during any observing run are:

1. *Size of the object.* You may have such a measurement in minutes or arc seconds in the back of your mind from earlier familiarity or reading, but with the magnification and scope in use, does the size match your expectations? Can you measure it effectively in minutes or seconds in comparison to the eyepiece FoV?
2. *Brightness*. Is the object living up its described magnitude? Is it fainter or brighter than quoted? Does it appear bright in the middle and then tail off at the edges or is the situation reversed, with a bright edge and fainter center?
3. *Morphology.* What is the shape of the nebula? Does it match your research or expectations? Is it round, extended, stellar, small, irregular or amorphous? If there is any elongation, what is the position angle of the main axis?

4. *Color*. Is the nebula exhibiting any color at all? If so, what color predominates if there are several colors visible? In some objects there is a marked green or blue color, while in others the nebula may even have a reddish hue. Color is an important indicator of peak emission of the gases within the nebula, telling us much about the underlying astrophysical characteristics.
5. *Central stars*. Is the central star visible, or is the nebula opaque or dark at its center? Are there any stars involved in the nebula, and if so, how many?
6. *Filters*. If a filter is in use, record which one was necessary to gain the best view of the object. Was it an OIII, an Hα or an LPR filter? Record all such details.

A general rule of thumb in any observation is to include as much detail in your observing notes or log as possible. In doing so, one forms a mental image of the object that can last and ease familiarity the next time one observes that particular nebula. In such cases, it is also quite common to take a good look at the relationship of the object to the background stars, a technique that is essential in recognizing the object at a later date if star hopping to it. The patterns, magnitudes and arrangements of stars in the nebula background are a subconscious benefit to observers who have been using star hopping techniques for many years. The field of view when searching again for a planetary not seen for some time stands out as either "right" or "wrong" almost immediately, though such abilities come with many years of training. Observers equipped with GOTO telescopes will not have this problem, though a fuller appreciation of the night sky is sometimes lost if the observer has not "hopped" to the object before. Each observer will have a preference.

It is hoped the above insights will assist the observer to get the best out of his or her equipment and to carefully plan any session to look for planetary nebulae. These intriguing objects are very rewarding to study yet are elusive and faint, requiring all the skills and tools at one's disposal.

Chapter 4

Photographing Planetary Nebulae

On the face of things, photographing planetary nebulae seems to be a daunting task. Most of the objects are faint or small and the average astronomers list of photographic equipment could be limited. While this may have been true in the past, today's amateur observers have access to fantastic equipment at reasonable prices, equipment that can grab faint details and reveal small nebulae in just a few seconds of exposure. In the last 20 years, the digital revolution has changed astronomical imaging forever. Digital SLR cameras, CCD cameras and webcams now provide the user with opportunities that previous generations could only dream of.

It is not possible to recommend specific cameras or to deal with the subject of astrophotography in any great detail here. There are many books available that cover this ground very well, and the observer would be better placed in reading one of these such as Michael Covington's *Astrophotography for the Amateur* or *Digital SLR Astrophotography;* Jerry Lodriguss' *A Guide to Astrophotography with Digital SLR Cameras;* Steve Howell's *Handbook of CCD Astronomy* or Greg Parker's *Making Beautiful Images: Astrophotography with Affordable Equipment and Software,* just to name some examples. The British Astronomical Association sells a small booklet for novice astrophotographers entitled *Introduction to DSLR Astrophotography,* and other national societies worldwide may do the same.

Suffice to say that a photograph provides the observer with a permanent record of the observation that can be perused again and again and also a visual hint to other observers who wish to track down planetary nebulae.

Camera Equipment

The advent of digital SLR cameras and CCD imaging systems means that good quality photographs are within easy reach of most amateurs. However, adding such equipment to your personal store entails a bit of spending! Good quality DSLR's can be purchased for just a few hundred dollars, and CCD cameras can also be purchased in a similar price range, though items do obviously become more expensive dependent on quality and reliability.

This is not to say that 35 mm film has now been relegated to history. It is still a very versatile medium to work with and in expert hands provides images of exquisite

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides, DOI 10.1007/978-1-4614-1782-8_4,

quality. However, film has an ethos all of its own and is a vehicle that requires some knowledge of its capabilities and drawbacks. It is hard to imagine that just a few years ago, 35 mm film was all that was available, and its storage, processing and hypering were arts in themselves, without having to cope with coupling a camera to a telescope or getting a sharp image at the point where the observer was at the scope rather than home in the darkroom. It is best to leave the vagaries of film to one side, even though this author grew up with the method and holds a qualification in such photography. As the DSLR is in the ascendant it is becoming increasingly difficult to find good quality high ISO 35 mm film in shops and recourse to a good photographic supplier is increasingly necessary to continue this art.

For our purposes within this book, it is better to concentrate on what the market currently holds, and as the majority of cameras are now in digital format, it is these types that astronomers routinely use.

Ideally the observer should be equipped with either a CCD camera or DSLR. Choosing such equipment can be a long process of comparison and getting advice from experts in the field, but such advice is well given and worth considering so as to avoid common mistakes. A DSLR is a versatile piece of equipment and of course is very useful for photography outside that of astrophotography, whereas a CCD camera is not. There are many manufacturers, but the general consensus is to purchase either a Nikon, Canon or Olympus camera, as these manufacturers have a wide range of auxiliary equipment available such as lenses, T mounts, adapters, focusing screens and filters. Although digital, these cameras follow a similar format as 35 mm film cameras in that their sizes, weights and controls are flexible, and they are easy to set and control once one has some experience with them.

It is not the intention here to recommend any particular brand; this is merely a choice of preference and cost. In addition to the camera, the observer will require a cable release inimical to their camera system, which will cost additional money, to prevent shaking. If the observer intends to connect the camera to a telescope, then a T-Mount and an adapter sleeve are also essential.

Telescope with T-mount attachment to the camera.

The next problem is how to bond the camera to the telescope, or what sort of lens one is to use if the observer is mounting the camera in piggyback mode or using a driven camera mount such as an Astrotrac.

If the observer is going to use a driven camera mount, then the choice of lens will be crucial. Occasionally a DSLR can be purchased with a choice of lenses, typically a 28–80 mm focal length or a larger one with a 75–300 mm focal length. These lenses are not built for astrophotography, though they do serve to provide wide-field shots of the sky. Naturally, any image gained will be very small and require a lot of enlargement and enhancement with this basic method. Larger examples of planetary nebulae such as M27 or NGC 7293 (the Helix Nebula) may be resolved with such methods, but smaller planetaries will be invisible or just splotches in the background.

The best approach to photographing these objects is to connect the camera to a telescope at its focus point. This procedure then gives one the advantage of having a large telephoto lens with an f ratio exactly the same as the telescope. With this arrangement the observer doesn't have to do any complicated mathematics in working out f-ratios or thinking about exposure times. With DSLR's several photographs may be taken of one object and then stacked in the appropriate software to produce a single, higher resolution image.

Alternately, the observer can purchase a piece of equipment commonly called a Steadypix. This functions as a connector between the camera lens of your DSLR and an eyepiece of choice and fixes to any eyepiece on the eyepiece holder. Such photography is called eyepiece projection or afocal astrophotography.

If one is using this arrangement, remember to put the camera lens at its lowest f stop (f2.8 or 5.6) and focus it on infinity (by placing it on manual focus rather than automatic!). Then the focal ratio must be worked out, which can be done with the following equation:

$$Fr = [(C/E) - 1]T$$

where Fr is the focal ratio, C is the focal length of the camera lens, E is the focal length of the eyepiece and T is the focal ratio of the telescope. To find the focal ratio of your telescope, divide the instrument aperture into the focal length. If you have a 1,000 mm focal length telescope with an aperture of 200 mm, then the focal ratio will be 1,000/200 = f5.

In the above configuration a telescope of focal ratio f10 using a 50 mm camera lens and a 25 mm eyepiece will have the sum 50 mm/25 mm − 1 = 1. This single unit can then be multiplied by the telescope's focal length (f10) to get the focal ratio of the entire system. With an eyepiece of 15 mm focal length, the resultant focal ratio with this telescope will be f23 (50 mm/15 mm − 1 × T) and so on as one uses different eyepieces. Although occasionally afocal astrophotography enables a relatively large initial image to be obtained, it has drawbacks in that the system must be accurately driven; the contrast of the system will decrease with increasing magnification, and some large focal ratios of f40 and above are just giving diminishing returns. Additionally, focusing the system accurately can become very problematic. It is best to attach the camera directly to the telescope with a T-mount and play with the image software later, though many amateurs have gained good results from using Steadypix systems. Again, it is a question of preference.

Alternatively, many astronomers have CCD cameras such as the various Atik cameras, models by the Santa Barbara Instruments Group (SBIG) or Starlight Express. Many of the models are full color CCD's, and others are black and white and require colored filters such as RGB or BVR to produce a full color image. Once again, choice is down to observer preference and costs. The advantage of the CCD camera over the DSLR is the smaller field of view and the rapidity of capture and quality of the images, which can be manipulated in various programs such as *Maxim DL, Artemis* and others.

Webcams specifically made for astronomy may also be employed in a similar way to CCD's, although the resolution depends on the chip. One of the most popular of such items is the DMK camera, which requires a program entitled *RegiStax* (or similar) to complete the image processing. If the observer wishes to use this form of photography, see Massey's and Quirk's *Deep Sky Video Astronomy* (Springer 2008), which covers in depth the video and *RegiStax* techniques needed to take great pictures.

There are so many variants of CCD camera available that it is not possible to cover them all in great detail, and it is recommended that the observer read the reviews of them online to make the best choice.

Once observers have this equipment, most will just get on with imaging planetary nebulae and other astronomical delights without a care in the world. Experienced observers using such equipment perform the usual controls of taking dark and flat fields to maximize the image on the CCD along with windowing, bias framing, binning and maximizing the gain. CCD imaging is an art in itself, and readers are advised to ask advice of practiced astrophotographers or read through any of the books on the subject to gain expertise and skill.

Software

If one is using a digital camera of any type, it is necessary to use support software that either comes with the camera or is compatible with the camera format. Canon and Nikon both produce their own reduction software that is fairly basic, and observers will move away from these as quickly as possible, as they have very limited capabilities. Most astrophotographers use *Photoshop* and its variants, such as *Lightroom*, or *Paintshop Pro*, *Maxim DL, GIMP* and others to manipulate their images. Some of these programs are industry standard, and it is likely that the observer has come across them in everyday life and is relatively familiar with their use. If not, then learning image manipulation is another skill that has uses beyond the field of astronomy; in today's job market, the ability to use many software packages is a bonus that many employers acknowledge.

The essential detail that the software should have is the ability to correct the colors, background, shadowing and light levels of the image. The ability to stack several images together or to stitch a mosaic is also necessary, and these skills can be learned quickly merely by playing with the images. Don't be afraid of making mistakes – in the world of software they can always be undone! In *Photoshop* most of the features stated here can be found under the single menu heading 'enhance,' and other programs have similar transferable menu headings that enable the user to substitute quickly between programs. *Photoshop* is probably one of the best programs available, and it or its derivatives such as *Photoshop Elements* can be purchased for a nominal sum.

With a CCD or webcam, however, *Photoshop* manipulation probably comes last, as programs such as *Maxim DL* or *GIMP* provide their own reduction techniques by taking the images as Flexible Image Transport System (FITS) files that can be altered in these programs initially or by *FITS Liberator* (available as a free download) before being transferred to *Photoshop* or equivalent if necessary. The raw files from a DSLR camera can be processed in a program such as *Deep Sky Stacker*, which is available as a free download and is useful in that it adds your dark frames, bias and flat frames to your images and stacks the selected frames automatically so you can get on with other things (like sleep!) or transfer the finished files across (in TIF format) to *Photoshop* if necessary. Most experienced astrophotographers use such software as a general photo editor before moving the files across to the software equivalents of their big brothers.

Just as in the purchase of a camera, the use and application of software to reduce and alter images is a question of choice in most cases. Nevertheless such software is an essential part of getting the best from your shots. The amount of information that a CCD or DSLR chip records is amazing; manipulating shots brings out the maximum from the hidden data and can turn a seemingly mediocre picture into a work of art. Ultimately, it is up to the individual to make the most of the picture with the best quality software available.

Filters for Astrophotography

Just as in visual astronomy, there are a series of filters that will enable the astronomer to gain the most from their imaging. However, as a caveat, remember that the inclusion of a filter in any astrophotography may have an effect on exposure times, and it is wise to take this into account, as it may increase the exposure by two or three times. The filters increase the signal to noise ratio of light passing into the camera or telescope and enable good results in a relatively short time.

Filters come in two types, as with visual astronomy – narrow bandpass and wide bandpass. The most common ones used by astrophotographers are wide bandpass light-pollution suppressing filters (LPS or LPR 'light pollution reduction'), as many astronomers live in proximity to towns and cities. The creeping nuisance of light pollution affects much of what we do as observers, but these filters give a little relief from some of these problems. They are a form of bandpass filter that takes out common streetlight wavelengths between 538 and 630 nm, in addition to suppressing upper atmosphere glow at 538 nm. This leaves the Hα and OIII components of the light untouched and available for capture.

Another general purpose filter is the minus violet filter, which may be a useful accessory if one is using a refractor or a camera lens, as it reduces some of the blue transmission beyond 420 nm, though a skylight filter on a camera lens will achieve the same results. Some observers report no difference between using a minus violet filter or not, so it may depend upon the quality and transparency of the optics of the system. As this is a general filter it is not strictly necessary anyway.

In addition to the LPS/LPR filter, one can obtain narrow bandpass filters such as Hα, SII or OIII that are more specific to photographing planetary nebulae. It must be remembered that these filters will have to be used in conjunction with RGB-colored filters to obtain a color photograph, but with most CCD imaging, this is not a problem. DSLR users will have their own problems when it comes to swapping filters. It is also worth remembering that the inclusion of a filter may change the focus of the system slightly, so check the focus once the filter is in place; this is especially true for users of non-apochromatic systems or Cassegrain telescopes.

There are many filter manufacturers on the market, but the best available for astrophotographers are made by Orion, Lumicon and Hutech. They are not a cheap item, but if you are a suburban astronomer, they will make a world of difference to your pictures and are worth considering. Hutech filters fit the front of DSLR camera lenses and come in a variety of sizes to fit the lens optic whilst both Orion and Lumicon's Deep Sky range are a little more affordable and come in sizes between 1.25 and 2 in., thus fitting most telescopes or CCD camera. It obviously then depends on the kind of photography one is doing as to which filter is best suited.

If one is using a webcam or CCD, another filter for the arsenal is an I-R blocker. Most camera chips are very sensitive to infrared depending upon exactly what objects one captures, the time of night and atmospheric conditions. Although most CCD's today incorporate I-R blocking filters, and additional external I-R blocking filter may improve the quality of the images. Most DSLR manufacturers include an I-R filter as an internal part of the camera, enabling correct white balance and color correction at all times. It is not possible to cover all eventualities on this subject in a book of this nature, and the author recommends referring to the books named in the beginning of this section for further details.

Shooting

Compiling a list of the best planetary nebulae to image will be up to the individual observer and the capabilities of his or her telescope and camera. It is vital that no matter what astronomical object one wishes to image, the DSLR user must put the camera in high resolution raw data mode to achieve the best results and have a high ISO number selected such as 1,600 or more; though this is subjective, many astronomers use ISO's of 800 or so for deep sky work, moving to higher ISO's for piggybacked shots.

One of the factors essential to any photography is the focus; it must be sharp and free of any obvious defects such as smearing at the edges. It may take time and practice for any astronomer to achieve a good focus, but it is well worth the effort, as anything that is out of focus is disappointing when one looks at the pictures. Focusing is a slightly frustrating task when out in the field yet is the most essential component of any photography and getting the focus right deserves time and attention. Many DSLR's have a 'live-view' facility, a consideration to be taken into account when purchasing one, while a CCD has the ability to download a picture there and then to judge for focus and quality.

The first item to consider when photographing planetary nebulae is their size; the majority of these objects are quite small, and even on the enlarged field of a CCD image, they still look like round smudges or star-like spots. It is therefore best to pick objects carefully for maximum photographic effect.

To do this, the astronomer needs to find the field of view of the DSLR or CCD and then make a determination of which objects within this book to shoot. To achieve this one needs to be aware of a number of factors. It is important to know what is the resolution of the chip before we advance to discovering the field coverage of the camera. Chip and pixel size for CCD and DSLR cameras can be found online or with the camera specifications produced by the manufacturer. To calculate the pixel resolution of the chip we need to multiply the size of each pixel (in microns μ) by 206 in the following way:

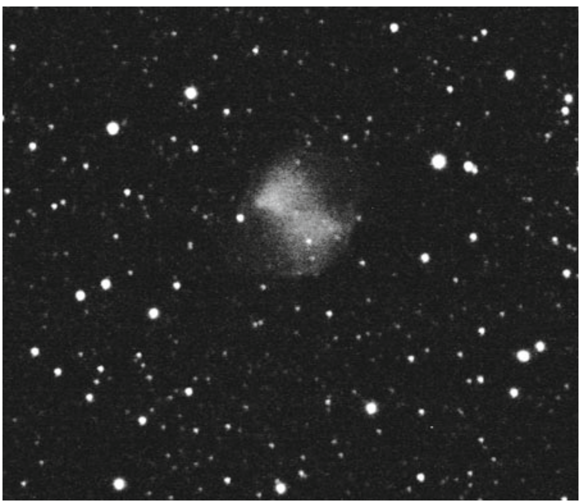
$$R'' = Ps(\mu)206 / a(mm) / f(mm)$$

where R″ is the angular resolution in arc seconds, Ps(μ) is the pixel size, a(mm) is the telescope aperture and f(mm) is the focal ratio of the telescope. If the camera has pixels of 10 μ size then the above sum is $10 \times 206 = 2{,}060$. This can then be divided by the aperture of a telescope – say 200 mm to produce $2{,}060/200 = 10.3$; this can then be divided by the focal ratio of the telescope – say f5: $10.3/5 = 2.06$. Therefore a 200 mm f5 telescope coupled to a chip with 10 μ pixels will produce an angular resolution of 2.06 arc sec. To derive the coverage of the entire frame seen through this instrument we then need to do the following calculation:

$$S^\circ = Pr \times Pn/3{,}600$$

where S° is the size of the frame in degrees, Pr is the pixel resolution, Pn is the number of pixels along the axis of the chip divided by 3,600. If we consider the past example and take it that the axis of the chip is 1,500 pixels, then $2.06 \times 1{,}500 = 3{,}090$; divide this by 3,600 to produce $3{,}090/3{,}600 = 0.85^\circ$ – resulting in a field slightly larger than three quarters of a degree.

From this one can see that an observer can capture most planetary nebulae except objects of just a few arc seconds in diameter, where their small size will make them almost indistinguishable from the stars. All but the very largest planetary nebulae in this book may be captured using a CCD and a modest aperture telescope.



M27. One-second image through an Atik CCD camera RAW.

The same mathematics will apply to users of DSLR cameras where the large chip sizes will naturally lead to larger field sizes. Equipped with the above, each observer can produce his own specifications of camera and telescope for their notes. The images above and below show the differences between each type of camera.

Once this has been achieved, the exposure times for each object or each frame will have to be deduced. This is generally dependent on a number of conditions such as sky conditions, field drift, guiding, saturation, ISO, filters, change of focus, etc. Many astronomers find it advantageous to take many images with 10, 20 or 30 s exposures and then stack them later to produce one image. Stacking can be done

M27. Thirty-second image through a Canon 1000D and 100 mm telescope.

manually in *Photoshop* or by using stacking software such as *Deep Sky Stacker* mentioned above. Others will take exposures of many minutes before performing this task, or with well-aligned telescopes, take a single long exposure shot. It is not possible to cover every contingency in a book of this type; experience will assist the observer in determining the factors to take into account when shooting planetary nebulae.

M97, the 'Owl Nebula.' 5 × 30 s exposures stacked in *Photoshop*. (Canon 1000D and 100 mm telescope).

Conclusion

Photography is a very useful art, and it has a valid place in any astronomer's set of skills. However, this book is primarily about observing planetary nebulae, and the descriptions found here are not based on photographs but upon visual observations, and it is to these accounts and deep sky catalogues that we now turn.

Chapter 5

Planetary Nebulae Catalogues

The first list details the main features and positions of 135 planetary nebulae contained within this book. The list following that is based on the P-K catalogue as a supplement to this main catalogue and is included to allow astronomers with larger apertures or CCD cameras to observe and capture many further objects should they wish. It assumes that the reader is familiar with sky coordinate systems, and all are marked in RA order and their magnitudes and sizes given.

Neither list gives a complete account of the numbers and natures of planetary nebulae, though they do contain the best examples of such and are generally concerned with detailing the kinds that would be available for study by amateur astronomers. The additional list is a more extensive collection, and the majority will be outside of the viewing experience of most observers, being faint, small and distant in many cases. Readers are invited to trawl through both lists and challenge their telescope aperture and visual acuity in preparing an alternative list to the first one presented here.

To make the most of the observer's experience, this author recommends the use of the NGC catalogue online or SIMBAD databases in order to get a rounded observational and astrophysical feel to the object. For those just interested in tracking the objects down as a visual exercise, please refer to both the initial list here and Chap. 3 of this volume to gain the most from your observing sessions.

It is hoped that the lists provide enough for the observer to construct a lengthy astronomical observation program or provide alternative objects to view throughout the year. Whichever the reader picks, we hope that you enjoy these objects as much as this author.

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides,
DOI 10.1007/978-1-4614-1782-8_5, © Springer Science+Business Media, LLC 2012

Main Planetary Nebulae

Name	Constellation	RA	Dec	Size (")	Magnitude
NGC 40	Cepheus	00 h 13 m 01 s	+72.31.3	38	12.3
NGC 246	Cetus	00 h 47 m 03 s	−11.52.3	250	10.8
NGC 650/1	Perseus	01 h 42 m 20 s	+51.34.5	135	10.1
IC 1747	Cassiopeia	01 h 57 m 36 s	+63.19.3	13	12.1
Abell 4	Perseus	02 h 45 m 24 s	+42.33.3	25	14.1
IC 289	Cassiopeia	03 h 10 m 19 s	+61.19.0	40	13.3
NGC 1360	Fornax	03 h 33 m 15 s	−25.52.3	400	9.4
IC 351	Perseus	03 h 47 m 35 s	+35.02.8	8	12.3
IC 2003	Perseus	03 h 56 m 22 s	+33.52.5	7	11.5
NGC 1501	Camelopardalis	04 h 06 m 56 s	+60.55.2	56	11.4
NGC 1514	Taurus	04 h 09 m 17 s	+30.46.6	130	10.9
NGC 1535	Eridanus	04 h 14 m 16 s	−12.44.4	50	9.6
Sh 2-216	Perseus	04 h 45 m 35 s	+46.48.5	100	13.0
J320	Orion	05 h 05 m 34 s	+10.42.0	7	11.9
IC 418	Lepus	05 h 27 m 28 s	−12.41.8	14	9.3
NGC 2022	Orion	05 h 42 m 06 s	+09.05.2	28	11.9
IC 2149	Auriga	05 h 56 m 24 s	+46.06.3	15	10.7
HD 44179	Monoceros	06 h 19 m 58 s	−10.38.2	1	9.2
IC 2165	Canis major	06 h 21 m 43 s	−12.59.2	9	10.6
J900	Gemini	06 h 25 m 57 s	+17.47.2	12	11.8
M 1-7	Gemini	06 h 37 m 21 s	+24.00.4	29	13.0
NGC 2346	Monoceros	07 h 09 m 23 s	−00.48.4	60	11.8
NGC 2371/2	Gemini	07 h 25 m 35 s	+29.29.4	115	11.4
Abell 21	Gemini	07 h 29 m 04 s	+13.15.2	300+	11.3
NGC 2392	Gemini	07 h 29 m 11 s	+20.54.7	50	9.2
NGC 2438	Puppis	07 h 41 m 51a	−14.44.1	75	11.1
NGC 2440	Puppis	07 h 41 m 55 s	−18.12.5	75	9.4
NGC 2452	Puppis	07 h 46 m 26 s	−27.20.1	31	12.2
Jn-Emb 1	Lynx	07 h 57 m 50 s	+53.25.0	400	12.5
NGC 2610	Hydra	08 h 33 m 23 s	−16.09.0	50	12.8
M 3-6	Pyxis	08 h 40 m 39 s	−32.22.1	8	10.7
NGC 2792	Vela	09 h 12 m 20 s	−42.25.1	12	12.7
NGC 2818	Pyxis	09 h 16 m 02 s	−36.37.6	35	11.9
NGC 2867	Carina	09 h 21 m 25 s	−58.18.4	14	9.7
IRAS 09371	Leo	09 h 39 m 53 s	+11.58.8	25	11.2
IC 2501	Carina	09 h 38 m 08 s	−60.05.0	20	11.1
NGC 3132	Vela	10 h 07 m 0 s	−40.26.0	60	9.7
NGC 3195	Chameleon	10 h 09 m 12 s	−80.55.11	35	10.1
IC 2553	Carina	10 h 09 m 35 s	−62.40.1	12	13.0
NGC 3211	Carina	10 h 18 m 06 s	−62.43.2	12	12.1
NGC 3242	Hydra	10 h 26 m 46 s	−18.38.5	45	7.8
IC 2621	Carina	11 h 00 m 40 s	−65.18.3	5	13.2
NGC 3587	Ursa major	11 h 14 m 48 s	+55.01.1	200	9.8
NGC 3918	Centaurus	11 h 50 m 48 s	−57.14.4	12	8.2
NGC 4071	Musca	12 h 04 m 18 s	−67.18.3	75	12.7
NGC 4361	Corvus	12 h 24 m 31 s	−18.47.1	70	10.9
IC 3568	Camelopardalis	12 h 33 m 07 s	+82.33.8	18	11.1
Abell 35	Hydra	12 h 53 m 24 s	−22.52.3	700	12.7
IC 4191	Musca	13 h 08 m 47 s	−67.38.3	5	10.6
NGC 5189	Musca	13 h 33 m 32 s	−65.58.2	90	10.1
Abell 36	Virgo	13 h 40 m 41 s	−19.52.9	300	13.1

(continued)

(continued)

Name	Constellation	RA	Dec	Size (")	Magnitude
NGC 5307	Centaurus	13 h 51 m 47 s	−51.15.4	15	11.9
IC 4406	Lupus	15 h 12 m 15 s	−38.07.5	3	11.2
NGC 5873	Lupus	15 h 12 m 50 s	−38.07.5	13	11.2
NGC 5882	Lupus	15 h 16 m 50 s	−45.38.9	21	10.4
He 2-131	Apus	15 h 37 m 17 s	−71.54.1	6	11.1
NGC 5979	Tri. Australe	15 h 48 m 37 s	−61.14.2	15	12.3
He 2-138	Tri. Australe	15 h 56 m 00 s	−66.09.0	3	11.0
He 2-141	Norma	15 h 59 m 14 s	−53.23.1	4	12.2
NGC 6026	Lupus	16 h 01 m 21 s	−34.32.6	55	12.1
NGC 6058	Hercules	16 h 04 m 27 s	+40.41.0	25	13.1
IC 4593	Hercules	16 h 11 m 45 s	+12.03.3	12	9.8
NGC 6072	Scorpius	16 h 12 m 58 s	−38.13.8	70	11.6
NGC 6153	Scorpius	16 h 31 m 30 s	−40.15.0	30	10.6
He 2-172	Ara	16 h 37 m 07 s	−55.42.4	6	12.6
NGC 6210	Hercules	16 h 44 m 30 s	+23.48.0	50	8.8
IC 4634	Ophiuchus	17 h 01 m 34 s	−21.49.6	10	10.9
M 2-9	Ophiuchus	17 h 05 m 38 s	+10.08.0	20	14.6
NGC 6302	Scorpius	17 h 13 m 44 s	−37.06.2	83	9.6
NGC 6309	Ophiuchus	17 h 14 m 04 s	−12.54.6	52	11.3
NGC 6326	Ara	17 h 21 m 40 s	−51.45.7	12	12.1
NGC 6337	Scorpius	17 h 22 m 16 s	−38.29.0	50	12.3
NGC 6369	Ophiuchus	17 h 29 m 21 s	−23.45.6	60	11.4
NGC 6445	Sagittarius	17 h 49 m 15 s	−20.00.6	55	11.2
IC 4670	Sagittarius	17 h 55 m 07 s	−21.44.7	7	13.2
NGC 6543	Draco	17 h 58 m 33 s	+66.38.0	23	8.1
NGC 6537	Sagittarius	18 h 05m13 s	−19.50.6	11	11.6
NGC 6565	Sagittarius	18 h 11 m 53 s	−28.10.7	10	11.6
NGC 6563	Sagittarius	18 h 12 m 03 s	−33.52.1	54	11.0
NGC 6572	Ophiuchus	18 h 12 m 06 s	−06.51.2	16	8.1
NGC 6567	Sagittarius	18 h 34 m 45 s	−19.04.1	11	11.0
NGC 6578	Sagittarius	18 h 16 m 17 s	−20.27.0	9	13.4
NGC 6620	Sagittarius	18 h 22 m 54 s	−26.49.3	5	12.7
NGC 6629	Sagittarius	18 h 25 m 43 s	−23.12.2	16	11.3
NGC 6644	Sagittarius	18 h 32 m 35 s	−25.07.7	3	10.6
IC 4732	Sagittarius	18 h 33 m 55 s	−22.38.7	3	12.1
IC 4776	Sagittarius	18 h 45 m 51 s	−33.20.6	8	10.4
NGC 6720	Lyra	18 h 53 m 35	+33.01.7	86	8.8
IC 1295	Scutum	18 h 54 m 37 s	−08.49.6	90	11.7
NGC 6742	Draco	18 h 59 m 18 s	+48.28.0	31	13.4
Sh 2-71	Aquila	19 h 02 m 01 s	+02.09.4	107	13.2
NGC 6741	Aquila	19 h 02 m 37 s	−00.27.0	9	11.4
NGC 6751	Aquila	19 h 05 m 56 s	−05.59.5	21	11.9
NGC 6765	Lyra	19 h 11 m 01 s	−30.33.0	38	13.1
NGC 6772	Aquila	19 h 14 m 36 s	−02.42.4	60	12.8
IC 4846	Aquila	19 h 16 m 28 s	−09.02.6	5	11.9
IC 1297	Cor. Australis	19 h 17 m 23 s	−39.36.8	12	10.7
NGC 6778	Aquila	19 h 18 m 25 s	−01.35.8	25	12.3
NGC 6781	Aquila	19 h 18 m 28 s	−06.32.2	120	11.4
NGC 6790	Aquila	19 h 22 m 57 s	+01.30.8	10	10.5
Vy 2-2	Aquila	19 h 24 m 23 s	+09.53.9	14	12.7
NGC 6803	Aquila	19 h 31 m 16 s	+10.03.4	6	11.4
NGC 6804	Aquila	19 h 31 m 35 s	+09.13.5	60	12.0
NGC 6807	Aquila	19 h 34 m 34 s	+05.41.0	3	12.2
BD +30 3639	Cygnus	19 h 34 m 45 s	+30.31.0	13	9.9

(continued)

(continued)

Name	Constellation	RA	Dec	Size (")	Magnitude
M 1-92	Cygnus	19 h 36 m 18 s	+29.32.8	3	11.0
NGC 6818	Sagittarius	19 h 43 m 58 s	−14.09.2	22	9.3
NGC 6826	Cygnus	19 h 44 m 48 s	+50.31.5	30	8.8
NGC 6833	Cygnus	19 h 49 m 47 s	+48.57.7	3	11.1
NGC 6853	Vulpecula	19 h 59 m 36 s	+22.43.3	400	7.3
NGC 6884	Cygnus	20 h 10 m 24 s	+46.27.7	6	11.0
NGC 6879	Sagitta	20 h 10 m 27 s	+16.55.4	8	12.5
NGC 6881	Cygnus	20 h 10 m 09 s	+37.25.0	3	13.6
NGC 6886	Sagitta	20 h 12 m 43 s	+19.59.4	9	11.4
NGC 6891	Delphinus	20 h 15 m 09 s	+12.42.3	74	10.5
NGC 6894	Cygnus	20 h 16 m 24 s	+30.33.9	45	12.3
IC 4997	Sagitta	20 h 20 m 09 s	+16.43.9	2	10.4
NGC 6905	Delphinus	20 h 22 m 23 s	+20.06.3	42	11.1
NGC 7008	Cygnus	21 h 00 m 33 s	+54.32.6	100	10.7
CRL 2688	Cygnus	21 h 02 m 19 s	+36.41.6	16	13.5
NGC 7009	Aquarius	21 h 04 m 11 s	−11.21.8	44	7.8
NGC 7026	Cygnus	21 h 06 m 19 s	+47.51.1	27	10.9
NGC 7027	Cygnus	21 h 07 m 01 s	+42.14.2	18	8.5
Sh 1-89	Cygnus	21 h 14 m 09 s	+47.46.4	44	14.5
NGC 7048	Cygnus	21 h 14 m 15 s	+46.17.3	60	12.1
Pease 1	Pegasus	21 h 30 m 0 s	+12.10.0	1	15.1
IC 5117	Cygnus	21 h 32 m 31 s	+44.35.8	3	11.5
HU 1-2	Cygnus	21 h 33 m 7 s	+39.38.2	5	12.1
NGC 7094	Pegasus	21 h 36 m 53 s	+12.47.3	100	13.4
IC 5217	Lacerta	22 h 23 m 56 s	+50.58.0	7	11.3
NGC 7293	Aquarius	22 h 29 m 39 s	−20.50.2	700	7.3
NGC 7354	Cepheus	22 h 40 m 20 s	+61.17.1	22	12.2
NGC 7662	Andromeda	23 h 25 m 54 s	+42.32.1	32	8.3
Jones 1	Pegasus	23 h 35 m 09 s	+30.28.0	315	12.1
Abell 82	Cassiopeia	23 h 45 m 42 s	57.04.0	94	12.7

Additional Planetary Nebulae

Name	P-K	PNG	RA	Dec	Size	Mag	Con
Abell 86	118 + 8.2	118.7 + 08.2	00:01.6	70.43	70	16.7p	Cep
Abell 1	119 + 6.1	119.4 + 06.5	00:12.6	69.11	46 × 42	18.7	Cep
NGC 40	120 + 9.1	120.0 + 09.8	00:13.0	72.31	38 × 35	10.6	Cep
Vy 1-1	118 − 8.1	118.0 − 08.6	00:18.7	53.53	5	12.6	Cas
BV 5-1	119 + 0.1	119.3 + 00.3	00:20.0	62.59	15	15.7	Cas
Hu 1-1	119 − 6.1	119.6 − 06.7	00:28.3	55.58	5	12.4	Cas
Sh 2-176	120 − 5.1	120.2 − 05.3	00:31.9	57.23	720	?	Cas
BoBn 1	108 − 76.1	108.4 − 76.1	00:37.3	−13.42	3	16.4	Cet
We 1-1	121 + 3.1	121.6 + 03.5	00:38.9	66.24	19	22.0	Cas
BV 5-2	121 + 0.1	121.6 − 00.0	00:40.4	62.51	40	?	Cas
Abell 2	122 − 4.1	122.1 − 04.9	00:45.6	57.57	33 × 29	14.5	Cas
NGC 246	118 − 74.1	118.8 − 74.7	00:47.1	−11.52	240 × 210	10.4	Cet
PHL 932	125 − 47.1	125.9 − 47.0	00:59.9	15.44	275	?	Psc

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
WeSb 1	124 − 7.1	124.3 − 07.7	01:00.9	55.04	150	?	Cas
EGB 1	124 + 10.1	124.0 + 10.7	01:07.1	73.33	270	?	Cas
K 3-90	126 + 3.1	126.3 + 02.9	01:25.0	65.39	9	16.1	Cas
Sim22	128 − 4.1	128.0 − 04.1	01:30.7	58.22	340	?	Cas
M 1-1	130 − 11.1	130.3 − 11.7	01:37.3	50.28	6	14.2	And
NGC 650	130 − 10.1	130.9 − 10.5	01:42.3	51.35	163 × 107	10.1	Per
We 2-5	129 − 2.1	129.2 − 02.0	01:42.6	60.1	195	?	Cas
BV 5-3	131 − 5.1	131.4 − 05.4	01:53.0	56.24	30	15.0	Per
IC 1747	130 + 1.1	130.2 + 01.3	01:57.6	63.19	13	12.0	Cas
K 3-91	129 + 4.1	129.5 + 04.5	01:58.6	66.34	10	21.0	Cas
M 1-2	133 − 8.1	133.1 − 08.6	01:58.8	52.54	stellar	14.9	Per
K 3-92	130 + 3.1	130.4 + 03.1	02:03.7	64.58	12	16.7	Cas
Abell 3	131 + 2.1	131.5 + 02.6	02:12.2	64.09	60	16.0	Cas
K 3-93	132 + 4.1	132.4 + 04.7	02:26.5	65.48	10	17.7	Cas
Abell 4	144 − 15.1	144.3 − 15.5	02:45.4	42.33	22	14.8	Per
Abell 5	141 − 7.1	141.7 − 07.8	02:52.2	50.36	134 × 121	16.0p	Per
Lo 1	255 − 59.1	255.3 − 59.6	02:57.0	−44.1	373	?	Eri
Abell 6	136 + 4.1	136.1 + 04.9	02:58.9	64.3	188 × 174	15.0	Cas
HFG 1	136 + 5.1	136.3 + 05.5	03:03.8	64.54	500	?	Cas
IC 289	138 + 2.1	138.8 + 02.8	03:10.3	61.19	42 × 28	13.5	Cas
HDW 2	138 + 4.1	138.1 + 04.1	03:11.0	62.48	340	?	Cas
HDW 3	149 − 9.1	149.4 − 09.2	03:27.3	45.24	540	?	Per
NGC 1360	220 − 53.1	220.3 − 53.9	03:33.2	−25.52	460 × 320	9.6	For
K 3-94	142 + 3.1	142.1 + 03.4	03:36.1	60.04	7	16.1	Cam
M 1-4	147 − 2.1	147.4 − 02.3	03:41.7	52.17	5	13.6	Per
HaWe 5		156.9 − 13.3	03:45.4	37.49	34	?	Per
IC 351	159 − 5.1	159.0 − 15.1	03:47.5	35.03	8 × 6	11.9	Per
IsWe 1		149.7 − 03.3	03:49.1	50	780	?	Per
Baade 1	171 − 25.1	171.3 − 25.8	03:53.5	19.28	43	15.8	Tau
IC 2003	161 − 14.1	161.2 − 14.8	03:56.4	33.53	7 × 6	11.6	Per
NGC 1501	144 + 6.1	144.5 + 06.5	04:07.0	60.55	56 × 48	11.9	Cam
NGC 1514	165 − 15.1	165.5 − 15.2	04:09.3	30.47	136 × 121	10.9	Tau
M 2-2	147 + 4.1	147.8 + 04.1	04:13.3	56.57	12 × 11	14.0	Cam
K 3-64	151 + 0.1	151.4 + 00.5	04:13.5	51.51	8	16.9	Per
NGC 1535	206 − 40.1	206.4 − 40.5	04:14.3	−12.44	48 × 42	9.4	Eri
K 3-65	153 − 1.1	153.7 − 01.4	04:15.9	48.5	2	18.9	Per
K 4-47	149 + 4.1	149.0 + 04.4	04:20.8	56.18	stellar	?	Cam
M 4-18	146 + 7.1	146.7 + 07.6	04:25.8	60.07	stellar	15.8	Cam
K 3-66	167 − 9.1	167.4 − 09.1	04:36.6	33.4	stellar	15.4	Per
H 3-29	174 − 14.1	174.2 − 14.6	04:37.3	25.03	20	15.3	Tau
K 3-67	165 − 6.1	165.5 − 06.5	04:39.8	36.46	stellar	13.7	Per
CRL 618	166 − 6.1	166.4 − 06.5	04:42.9	36.07	12	18.0	Aur
We 1-2	160 − 0.1	160.5 − 00.5	04:46.7	44.28	92	?	Per
We 1-3	163 − 0.1	163.1 − 00.8	04:54.5	42.17	115	?	Aur
PRTM 1		243.8 − 37.1	05:03.0	−39.46	23	?	Cae
Abell 7	215 − 30.1	215.5 − 30.8	05:03.1	−15.36	871 × 670	13.2p	Lep
MaC 2-1	205 − 26.1	205.8 − 26.7	05:03.7	−6.1	stellar	14.9	Eri
J 320	190 − 17.1	190.3 − 17.7	05:05.6	10.42	11 × 8	11.8	Ori
Abell 8	167 − 0.1	167.0 − 00.9	05:06.6	39.08	62	17.6	Aur
K 2-1	173 − 5.1	173.7 − 05.8	05:07.1	30.5	132	12.0	Aur
IC 418	215 − 24.1	215.2 − 24.2	05:27.5	−12.42	12	9.3	Lep
K 3-68	178 − 2.1	178.3 − 02.5	05:31.6	28.59	10	16.1	Aur
K 1-7	197 − 14.1	197.2 − 14.2	05:31.8	6.56	35 × 32	14.0	Ori

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
H 3-75	193 − 9.1	193.6 − 09.5	05:40.7	12.21	30	13.9	Ori
PP 40	173 + 2.1	173.7 + 02.7	05:40.9	35.43	30	?	Aur
K 3-69	170 + 4.1	170.7 + 04.6	05:41.4	39.15	stellar	16.5	Aur
NGC 2022	196 − 10.1	196.6 − 10.9	05:42.1	9.05	29 × 28	11.7	Ori
Pu 2		173.5 + 03.2	05:42.6	36.09	20	18.1	Aur
M 1-5	184 − 2.1	184.0 − 02.1	05:46.8	24.22	5	14.6	Tau
Pu 1	181 + 1.1	181.5 + 00.9	05:52.8	28.06	65	15.9	Tau
DeHt 1	228 − 22.1	228.2 − 22.1	05:55.1	−22.54	132	?	Lep
IC 2149	166 + 10.1	166.1 + 10.4	05:56.4	46.06	15 × 10	10.6	Aur
K 1-27	286 − 29.1	286.8 − 29.5	05:57.0	−75.4	46	16.5	Men
K 3-70	184 + 0.1	184.6 + 00.6	05:58.8	25.19	2	17.3	Tau
WeDe 1	197 − 6.1	197.4 − 06.4	05:59.4	10.42	925	?	Ori
Abell 12	198 − 6.1	198.6 − 06.3	06:02.4	9.39	37	12.4	Ori
Abell 13	204 − 8.1	204.0 − 08.5	06:04.8	3.56	174 × 134	15.3	Ori
Abell 14	197 − 3.1	197.8 − 03.3	06:11.1	11.47	40 × 27	17.5p	Ori
K 3-71	184 + 4.1	184.8 + 04.4	06:13.9	26.53	3	18.1	Gem
We 1-4	201 − 4.1	201.9 − 04.6	06:14.6	7.35	40	?	Ori
WeSb 2	183 + 5.1	183.8 + 05.5	06:16.2	28.22	135	?	Aur
PuWe 1	158 + 17.1	158.9 + 17.8	06:19.6	55.37	1200	11.2p	Lyn
IC 2165	221 − 12.1	221.3 − 12.3	06:21.7	−12.59	9 × 7	10.6	CMa
HDW 5	218 − 10.0	218.9 − 10.7	06:23.6	−10.13	94	15.4	Mon
K 3-72	204 − 3.1	204.8 − 03.5	06:23.9	5.3	11	?	Mon
J 900	194 + 2.1	194.2 + 02.5	06:26.0	17.47	12 × 10	11.8	Gem
Abell 15	233 − 16.1	233.5 − 16.3	06:27.0	−25.23	34	15.8	CMa
EGB 4		143.6 + 23.8	06:29.6	71.04	111	?	Cam
NGC 2242		170.3 + 15.8	06:34.1	44.47	22	15.2	Aur
M 1-6	211 − 3.1	211.2 − 03.5	06:35.7	−0.06	5	16.2	Mon
M 1-7	189 + 7.1	189.8 + 07.7	06:37.3	24.01	21 × 11	13.5	Gem
K 4-48	201 + 2.1	201.7 + 02.5	06:39.9	11.07	stellar	15.4	Mon
Abell 18	216 − 0.1	216.0 − 00.2	06:56.2	−2.53	71 × 66	17.0	Mon
Vo 1		291.3 − 26.2	06:59.5	−79.39	stellar	?	Men
Abell 19	200 + 8.1	200.7 + 08.4	06:59.9	14.37	80 × 67	16.3	Gem
We 2-34	210 + 3.1	210.0 + 03.9	07:00.4	4.21	230	?	Mon
PB 1	226 − 3.1	226.4 − 03.7	07:02.8	−13.43	6	13.3	CMa
M 3-1	242 − 11.1	242.6 − 11.6	07:02.8	−31.36	14 × 9	12.0	CMa
M 1-9	212 + 4.1	212.0 + 04.3	07:05.3	2.47	2	13.4	Mon
St 3-1	217 + 2.1	217.4 + 02.0	07:06.8	−3.05	12 × 5	14.2	Mon
K 2-3	234 − 6.1	234.3 − 06.6	07:07.0	−22.02	76 × 53	14.8p	CMa
NGC 2346	215 + 3.1	215.6 + 03.6	07:09.4	−0.48	60 × 50	11.9	Mon
M 1-11	232 − 4.1	232.8 − 04.7	07:11.3	−19.51	stellar	15.9	CMa
K 1-10	229 − 2.1	229.6 − 02.7	07:12.6	−16.06	86 × 45	?	CMa
M 3-2	240 − 7.1	240.3 − 07.6	07:14.8	−27.5	12 × 7	15.7	CMa
Wray 17-1	258 − 15.1	258.0 − 15.7	07:14.8	−46.57	82	11.8	Pup
We 1-6	224 + 1.1	224.9 + 01.0	07:17.4	−10.11	62	?	Mon
M 1-12	235 − 3.1	235.3 − 03.9	07:19.4	−21.44	stellar	15.3	CMa
M 1-13	232 − 1.1	232.4 − 01.8	07:21.2	−18.09	10	12.9	CMa
Abell 20	214 + 7.1	214.9 + 07.8	07:23.0	1.46	65	14.0	CMi
NGC 2371	189 + 19.1	189.1 + 19.8	07:25.6	29.29	74 × 54	11.2	Gem
M 3-3	221 + 5.1	221.7 + 05.3	07:26.6	−5.22	15 × 10	14.3	Mon
M 1-14	235 − 1.1	234.9 − 01.4	07:27.9	−20.13	stellar	13.5	Pup
M 4-2	248 − 8.1	248.8 − 08.5	07:28.9	−35.45	8	12.9	Pup
Abell 21	205 + 14.1	205.1 + 14.2	07:29.0	13.15	744 × 509	10.2	Gem
NGC 2392	197 + 17.1	197.8 + 17.3	07:29.2	20.55	47 × 43	9.2	Gem

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
K 1-11	215 + 11.1	215.6 + 11.1	07:36.1	2.42	105 × 68	15.4p	CMi
M 1-16	226 + 5.1	226.7 + 05.6	07:37.3	−9.39	3	13.3	Mon
M 1-17	228 + 5.1	228.8 + 05.3	07:40.4	−11.32	3	13.5	Pup
NGC 2438	231 + 4.2	231.8 + 04.1	07:41.8	−14.44	73 × 68	11.5	Pup
NGC 2440	234 + 2.1	234.8 + 02.4	07:41.9	−18.13	74 × 42	9.3	Pup
M 1-18	231 + 4.1	231.4 + 04.3	07:42.1	−14.21	31 × 30	14.0	Pup
Abell 23	249 − 5.1	249.3 − 05.4	07:43.3	−34.45	54	13.1	Pup
He 2-5	264 − 12.1	264.4 − 12.7	07:47.3	−51.15	3	12.3	Car
NGC 2452	243 − 1.1	243.3 − 01.0	07:47.4	−27.2	31 × 24	11.9	Pup
SaSt 2-3	232 + 5.1	232.0 + 05.7	07:48.1	−14.08	stellar	?	Pup
K 1-12	236 + 3.1	236.7 + 03.5	07:50.2	−19.18	38 × 36	15.9	Pup
Abell 24	217 + 14.1	217.1 + 14.7	07:51.6	3	265 × 180	13.9	CMi
HDW 7	211 + 18.1	211.4 + 18.4	07:55.2	9.33	94	?	CMi
M 3-4	241 + 2.1	241.0 + 02.3	07:55.2	−23.38	14	14.0	Pup
JnEr 1	164 + 31.1	164.8 + 31.1	07:57.9	53.25	405 × 360	12.0	Lyn
M 3-5	245 + 1.1	245.4 + 01.6	08:02.5	−27.42	9	13.9	Pup
K 1-21	251 − 1.1	251.1 − 01.5	08:04.2	−34.16	28	16.0	Pup
ESO 209-15	263 − 8.1	263.3 − 08.8	08:05.2	−48.23	24	15.4	Vel
K 1-13	224 + 15.1	224.3 + 15.3	08:06.8	−2.53	150 × 145	15.4p	Mon
Sa 2-21	238 + 7.2	238.9 + 07.3	08:08.7	−19.14	40	13.7	Pup
Abell 26	250 + 0.1	250.3 + 00.1	08:09.0	−32.4	40	18.1p	Pup
Y-C 2-5	240 + 7.1	240.3 + 07.0	08:10.7	−20.32	8	14.4	Pup
EGB 5	211 + 22.1	211.9 + 22.6	08:11.2	10.57	170	?	Cnc
He 2-7	264 − 8.1	264.1 − 08.1	08:11.5	−48.43	49 × 42	11.8	Vel
Vo 2		257.1 − 02.6	08:16.2	−39.52	8	18.3	Pup
PB 2	263 − 5.1	263.0 − 05.5	08:20.7	−46.22	3	13.2	Vel
Ns 238	254 + 0.1	254.6 + 00.2	08:20.9	−36.14	56	11.5	Pup
Wray 16-20		260.7 − 03.3	08:23.7	−43.13	60	17.0	Pup
VBRC 1	257 + 0.1	257.5 + 00.6	08:31.0	−38.2	61	14.0	Vel
SaSt 1-1	249 + 6.1	249.0 + 06.9	08:31.7	−27.46	stellar	?	Pyx
K 1-1	252 + 4.1	252.6 + 04.4	08:31.9	−32.06	47 × 40	15.6	Pyx
NGC 2610	239 + 13.1	239.6 + 13.9	08:33.4	−16.09	50 × 47	13.0	Hya
ESO 259-10	265 − 4.1	265.1 − 04.2	08:34.1	−47.17	28	14.3	Vel
Wray 17-20		264.4 − 03.6	08:34.5	−46.26	60	?	Vel
Wray 16-22	255 + 3.1	255.7 + 03.3	08:36.3	−35.16	20	?	Pyx
He 2-11	259 + 0.1	259.1 + 00.9	08:37.1	−39.26	60 × 40	13.9	Vel
Abell 29	244 + 12.1	244.5 + 12.5	08:40.2	−20.54	482 × 335	14.3p	Pyx
M 3-6	254 + 5.1	253.9 + 05.7	08:40.7	−32.22	15 × 11	10.8	Pyx
Abell 28	158 + 37.1	158.8 + 37.1	08:41.6	58.14	268	13.5	Uma
Vo 3		260.7 + 00.9	08:42.3	−40.44	36	?	Vel
Ve 26	265 − 2.1	265.1 − 02.2	08:43.4	−46.08	5	17.5	Vel
Abell 30	208 + 33.1	208.5 + 33.2	08:46.9	17.53	127	13.0	Cnc
K 2-15	263 + 0.1	263.2 + 00.4	08:48.6	−42.54	170	13.4	Vel
He 2-15	261 + 2.1	261.6 + 03.0	08:53.5	−40.04	27 × 21	14.1	Vel
MeWe 1-1		272.4 − 05.9	08:53.6	−54.05	110	15.0	Vel
Abell 31	219 + 31.1	219.1 + 31.2	08:54.2	8.54	970 × 930	12.0	Cnc
PB 3	269 − 3.1	269.7 − 03.6	08:54.3	−50.32	7	13.5	Vel
K 1-2	253 + 10.1	253.5 + 10.7	08:57.8	−28.57	63 × 54	15.3	Pyx
IC 2448	258 − 14.1	285.7 − 14.9	09:07.1	−69.57	11 × 9	10.5	Car
He 2-18	273 − 3.1	273.2 − 03.7	09:08.7	−53.19	12 × 10	14.8	Vel
NGC 2792	265 + 4.1	265.7 + 04.1	09:12.4	−42.26	18	11.8	Vel
He 2-21	275 − 4.2	275.3 − 04.7	09:13.9	−55.28	3	13.5	Vel
PB 4	275 − 4.1	275.0 − 04.1	09:15.1	−54.53	14 × 9	12.8	Vel

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
NGC 2818	261 + 8.1	261.9 + 08.5	09:16.0	−36.38	85 × 47	11.5	Pyx
PB 5	268 + 2.1	268.4 + 02.4	09:16.2	−45.29	5	14.2	Vel
He 2-25	275 − 3.1	275.2 − 03.7	09:18.0	−54.39	5	15.7	Vel
He 2-26	278 − 6.1	278.6 − 06.7	09:19.5	−59.12	stellar	12.0	Car
NCC 2867	278 − 5.1	278.1 − 05.9	09:21.4	−58.19	18 × 16	9.7	Car
He 2-28	275 − 2.1	275.2 − 02.9	09:22.1	−54.1	11 × 9	14.8	Vel
He 2-29	275 − 2.2	275.8 − 02.9	09:24.7	−54.36	14	13.3	Vel
NGC 2899	277 − 3.1	277.1 − 03.8	09:27.1	−56.06	120 × 68	12.2	Vel
Pe 2-4	275 − 1.1	275.5 − 01.3	09:30.8	−53.1	7	15.5	Vel
He 2-32	278 − 4.1	278.5 − 04.5	09:30.9	−57.37	45 × 27	16.2	Car
Wray 17-31	277 − 3.2	277.7 − 03.5	09:31.5	−56.18	110	14.7	Vel
IC 2501	281 − 5.1	281.0 − 05.6	09:38.8	−60.06	stellar	10.4	Car
Abell 33	238 + 34.1	238.0 + 34.8	09:39.2	−2.49	275 × 260	12.9	Hya
He 2-34	274 + 2.1	274.1 + 02.5	09:41.2	−49.23	10	17.5	Vel
He 2-35	274 + 2.2	274.6 + 02.1	09:41.6	−49.58	5	13.7	Vel
He 2-36	279 − 3.1	279.6 − 03.1	09:43.4	−57.17	27 × 18	13.4	Car
Abell 34	248 + 29.1	248.7 + 29.5	09:45.6	−13.1	281 × 268	12.9	Hya
He 2-37	274 + 3.1	274.6 + 03.5	09:47.4	−48.58	24 × 22	14.0	Vel
HBDS 1	273 + 6.1	273.6 + 06.1	09:52.7	−46.17	90	?	Vel
EGB 6	221 + 46.1	221.5 + 46.3	09:53.0	13.45	720	10.4	Leo
He 2-39	283 − 4.1	283.8 − 04.2	10:03.8	−60.44	11 × 10	14.2	Car
Lo 4	274 + 9.1	274.3 + 09.1	10:05.8	−44.22	48	16.1	Vel
Wray 17-40		286.2 − 06.9	10:06.9	−64.22	60	15.0	Car
NGC 3132	272 + 12.1	272.1 + 12.3	10:07.0	−40.26	62 × 43	9.7	Vel
He 2-41	286 − 6.1	286.0 − 06.5	10:07.4	−63.55	stellar	13.6	Car
IC 2553	285 − 5.1	285.4 − 05.3	10:09.3	−62.37	11 × 7	10.4	Car
NGC 3195	296 − 20.1	296.6 − 20.0	10:09.4	−80.52	43 × 36	11.5	Cha
Ste 2-1	280 + 2.1*	280.0 + 02.9	10:12.0	−52.38	20	13.5	Vel
PB 6	278 + 5.1	278.8 + 04.9	10:13.3	−50.2	14 × 9	12.8	Vel
Hf 4	283 − 1.1	283.9 − 01.8	10:15.6	−58.51	25 × 18	16.7	Car
NGC 3211	286 − 4.1	286.3 − 04.8	10:17.8	−62.4	17	10.7	Car
He 2-47	285 − 2.1	285.6 − 02.7	10:23.3	−60.33	stellar	14.1	Car
NGC 3242	261 + 32.1	261.0 + 32.0	10:24.8	−18.39	40 × 35	7.3	Hya
Pe 2-5	285 − 1.1	285.4 − 01.1	10:28.7	−59.04	90	16.1	Car
He 2-48	282 + 3.1	282.9 + 03.8	10:31.5	−53.33	15 × 13	15.9	Vel
My 60	283 + 2.1	283.8 + 02.2	10:31.6	−55.21	8	12.7	Vel
He 2-50	283 + 3.1	283.3 + 03.9	10:34.3	−53.41	9	14.2	Vel
K 1-28	270 + 24.1	270.1 + 24.8	10:34.5	−29.11	54	?	Hya
He 2-51	288 − 5.1	288.8 − 05.2	10:35.8	−64.19	12 × 7	14.4	Car
Pe 1-1	285 + 1.1	285.4 + 01.5	10:38.5	−56.47	3	14.0	Vel
Pe 1-2	285 + 1.2	285.7 + 01.2	10:39.5	−57.06	5	15.0	Vel
Pe 2-7	285 + 2.1	285.4 + 02.2	10:41.3	−56.09	stellar	15.5	Vel
Pe 1-3	288 − 2.1	288.4 − 02.4	10:44.5	−61.4	9 × 8	14.1	Car
He 2-55	286 + 2.1	286.3 + 02.8	10:48.7	−56.03	18	15.2	Vel
Hf 39	288 − 0.1	288.9 − 00.8	10:54.0	−60.27	72	10.4	Car
Hf 38	288 + 0.1	288.4 + 00.3	10:54.6	−59.1	29 × 22	13.7	Car
ESO 215-04	283 + 9.1	283.9 + 09.7	10:54.7	−48.47	300	?	Vel
He 2-57	289 − 1.1	289.6 − 01.6	10:56.0	−61.28	20	16.6	Car
IC 2621	291 − 4.1	291.6 − 04.8	11:00.3	−65.15	stellar	11.4	Car
Hf 48	290 − 0.1	290.1 − 00.4	11:03.9	−60.36	36	15.0	Car
Lo 5	286 + 11.1	286.5 + 11.6	11:13.9	−47.57	215	11.7	Cen
NGC 3587	148 + 57.1	148.4 + 57.0	11:14.8	55.01	202 × 196	9.8	UMa
He 2-62	295 − 9.1	295.3 − 09.3	11:17.7	−70.5	stellar	13.8	Car

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
ESO 216-02	288 + 8.1	288.7 + 08.1	11:18.2	−52.1	36	15.5	Cen
He 2-63	289 + 7.1	289.8 + 07.7	11:24.0	−51.51	3	14.7	Cen
K 1-22	283 + 25.1	283.6 + 25.3	11:26.7	−34.22	188 × 174	12.6	Hya
He 2-64	291 + 3.1	291.7 + 03.7	11:27.4	−57.18	9×8	17.5	Cen
NGC 3699	292 + 1.1	292.6 + 01.2	11:28.0	−59.57	71	11.0	Cen
Fg 1	290 + 7.1	290.5 + 07.9	11:28.6	−52.56	45 × 30	11.6	Cen
He 2-67	292 + 1.2	292.8 + 01.1	11:28.8	−60.07	6 × 4	13.2	Cen
Wray 16-93		292.7 + 01.9	11:30.8	−59.17	12	16.1	Cen
He 2-68	294 − 4.1	294.9 − 04.3	11:31.8	−65.58	stellar	14.9	Mus
PB 8	292 + 4.1	292.4 + 04.1	11:33.3	−57.06	5	13.0	Cen
He 2-70	293 + 1.1	293.6 + 01.2	11:35.2	−60.17	45 × 27	13.8	Cen
He 2-71	296 − 6.1	296.4 − 06.9	11:39.2	−68.52	stellar	14.8	Mus
He 2-72	294 − 0.1	294.9 − 00.6	11:41.6	−62.29	68	14.5	Cen
He 2-73	296 − 3.1	296.3 − 03.0	11:48.6	−65.09	4	12.9	Mus
NGC 3918	294 + 4.1	294.6 + 04.7	11:50.3	−57.11	19	8.2	Cen
ESO 320-28	291 + 19.1	291.4 + 19.2	11:52.5	−42.18	32	16.3	Cen
BlDz 1	293 + 10.1	293.6 + 10.9	11:53.1	−50.51	82	12.3	Cen
Lo 6	294 + 14.1	294.1 + 14.4	12:00.7	−47.33	62	15.3	Cen
NGC 4071	298 − 4.1	298.3 − 04.8	12:04.3	−67.19	80 × 51	13.0	Mus
He 2-76	298 − 1.2	298.2 − 01.7	12:08.4	−64.12	16 × 12	14.8	Cru
He 2-77	298 − 0.1	298.1 − 00.7	12:09.0	−63.07	22	17.4	Cru
He 2-78	297 + 3.1	297.4 + 03.7	12:09.2	−58.43	3	17.6	Cru
HaTr 1	299 − 4.1	299.4 − 04.1	12:16.6	−66.46	72	17.5	Mus
He 2-81	299 − 1.1	299.8 − 01.3	12:23.0	−64.02	7 × 6	17.0	Cru
He 2-82	299 + 2.1	299.5 + 02.4	12:23.9	−60.13	24	15.3	Cru
NGC 4361	294 + 43.1	294.1 + 43.6	12:24.5	−18.47	93 × 37	11.0	Crv
He 2-83	300 + 0.1	300.2 + 00.6	12:28.8	−62.06	6 × 5	19.6	Cru
He 2-84	300 − 0.1	300.4 − 00.9	12:28.8	−63.45	34 × 23	14.2	Cru
He 2-85	300 − 1.1	300.5 − 01.1	12:30.1	−63.53	13 × 8	14.4	Cru
ESO 095-12	300 − 3.1	300.8 − 03.4	12:30.4	−66.14	18	15.3	Mus
He 2-86	300 − 2.1	300.7 − 02.0	12:30.5	−64.51	4 × 3	14.2	Mus
K 1-23	299 + 18.1	299.0 + 18.4	12:30.9	−44.14	42	12.6	Cen
IC 3568	123 + 34.1	123.6 + 34.5	12:33.1	82.34	18	10.6	Cam
CTIO 1230	298 + 34.1	298.0 + 34.8	12:33.2	−27.49	7	17.1	Hya
Wray 16-120	302 + 2.1	302.2 + 02.5	12:45.9	−60.2	12	16.3	Cru
DuRe 1		302.3 − 01.3	12:45.9	−64.1	75	?	Cru
Wray 16-121	302 − 0.2	302.6 − 00.9	12:48.5	−63.5	48	15.0	Cru
Abell 35	303 + 40.1	303.6 + 40.0	12:53.7	−22.52	938 × 636	13.3	Hya
LoTr 5	339 + 88.1	339.9 + 88.4	12:55.6	25.53	525	?	Com
H 4-1	049 + 88.1	049.3 + 88.1	12:59.5	27.38	3	14.7	Com
Wray 16-122	304 + 5.2	304.2 + 05.9	13:00.7	−56.53	36	13.5	Cen
He 2-88	304 + 5.1	304.8 + 05.1	13:05.8	−57.39	10	14.3	Cen
IC 4191	304 − 4.1	304.5 − 04.8	13:08.8	−67.39	18 × 11	10.6	Mus
He 2-90	305 + 1.1	305.1 + 01.4	13:09.6	−61.2	10	13.7	Cen
Wray 17-59	305 − 3.1	305.7 − 03.4	13:19.5	−66.09	24	14.5	Mus
Th 2-A	306 − 0.1	306.4 − 00.6	13:22.6	−63.21	23	14.4	Cen
Wray 16-128	307 + 5.1	307.3 + 05.0	13:24.4	−57.31	18	14.3	Cen
Lo 8	310 + 24.1	310.3 + 24.7	13:25.6	−37.36	115	?	Cen
MeWe 1-3		308.2 + 07.7	13:28.1	−54.42	18	16.2	Cen
NGC 5189	307 − 3.1	307.2 − 03.4	13:33.5	−65.58	185 × 130	9.5	Mus
ESO 040-11	305 − 13.1	305.6 − 13.1	13:34.2	−75.46	72	14.7	Cha
MyCn 18	307 − 4.1	307.5 − 04.9	13:39.6	−67.23	16 × 10	12.6	Mus
Abell 36	318 + 41.1	318.4 + 41.4	13:40.7	−19.53	478 × 281	11.8	Vir

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
He 2-96	309 + 0.1	309.0 + 00.8	13:42.6	−61.23	4	14.4	Cen
VBRC 5	309 + 1.1	309.2 + 01.3	13:44.0	−60.5	68	16.7	Cen
He 2-97	307 − 9.1	307.2 − 09.0	13:45.4	−71.29	stellar	12.6	Mus
NGC 5307	312 + 10.1	312.3 + 10.5	13:51.1	−51.12	15 × 10	11.2	Cen
He 2-99	309 − 4.1	309.0 − 04.2	13:52.5	−66.23	17	?	Cir
Vo 4		310.4 + 01.3	13:53.4	−60.34	stellar	19.1	Cen
NGC 5315	309 − 4.2	309.1 − 04.3	13:54.0	−66.31	6	9.9	Cir
MaC 1-2		309.5 − 02.9	13:54.5	−64.59	stellar	16.4	Cir
He 2-101	311 + 3.1	311.1 + 03.4	13:54.9	−58.27	stellar	18.3	Cen
SuWt 2		311.0 + 02.4	13:55.8	−59.23	65	?	Cen
He 2-102	311 + 2.1	311.4 + 02.8	13:58.2	−58.54	9	13.6	Cen
IC 972	326 + 42.1	326.7 + 42.2	14:04.4	−17.14	43 × 40	13.6	Vir
He 2-103	310 − 2.1	310.7 − 02.9	14:05.6	−64.41	22 × 18	13.9	Cir
He 2-104	315 + 9.1	315.4 + 09.4	14:11.9	−51.26	stellar	14.1	Cen
LoTr 7	310 − 5.1	310.8 − 05.9	14:15.4	−67.32	16	14.2	Cir
He 2-105	308 − 12.1	308.6 − 12.2	14:15.4	−74.13	31	13.5	Aps
He 2-108	316 + 8.1	316.1 + 08.4	14:18.2	−52.11	12 × 10	13.8	Cen
He 2-107	312 − 1.1	312.6 − 01.8	14:18.7	−63.07	11 × 9	16.4	Cen
He 2-109	315 + 5.1	315.4 + 05.2	14:20.8	−55.28	9 × 6	15.1	Lup
LoTr 8	315 + 5.2	315.7 + 05.5	14:22.0	−55.02	19	16.9	Lup
IC 4406	319 + 15.1	319.6 + 15.7	14:22.4	−44.09	100 × 37	10.2	Lup
He 2-111	315 − 0.1	315.0 − 00.3	14:33.3	−60.5	18 × 8	13.2	Cen
He 2-112	319 + 6.1	319.2 + 06.8	14:40.5	−52.35	8 × 6	13.3	Lup
LoTr 9	315 − 1.1	315.7 − 01.2	14:41.3	−61.2	28	?	Cen
VBRC 6	317 + 3.1	317.8 + 03.3	14:41.6	−56.15	45	16.9	Cir
LoTr 10	316 − 1.1	316.3 − 01.3	14:46.4	−61.14	54	?	Cir
MeWe 1-5		321.0 + 08.3	14:46.6	−50.23	27	17.3	Lup
He 2-113	321 + 3.1	321.0 + 03.9	14:59.9	−54.18	stellar	15.8	Lup
ESO 223-10	324 + 9.1	324.1 + 09.0	15:01.7	−48.21	18	16.0	Lup
He 2-114	318 − 2.1	318.3 − 02.0	15:04.1	−60.53	34 × 22	14.5	Cir
He 2-115	321 + 2.1	321.3 + 02.8	15:05.3	−55.11	4 × 2	14.9	Lup
He 2-117	321 + 2.2	320.9 + 02.2	15:06.0	−55.59	6 × 4	14.9	Cir
He 2-116	318 − 2.2	318.3 − 02.5	15:06.0	−61.21	51 × 44	15.1	Cir
He 2-118	327 + 13.1	327.5 + 13.3	15:06.2	−43	stellar	12.7	Lup
ESO 135-04	318 − 3.1	318.4 − 03.0	15:08.7	−61.44	20	17.4	Cir
NGC 5844	317 − 5.1	317.1 − 05.7	15:10.7	−64.4	68 × 41	13.3	TrA
He 2-120	321 + 1.1	321.8 + 01.9	15:11.9	−55.4	29 × 25	14.5	Cir
NGC 5873	331 + 16.1	331.3 + 16.8	15:12.8	−38.08	8 × 6	11.2	Lup
NGC 5882	327 + 10.1	327.8 + 10.0	15:16.8	−45.39	16 × 15	9.5	Lup
PM 1-89		324.0 + 03.5	15:19.1	−53.1	27	?	Lup
LoTr 11	313 − 12.1	313.8 − 12.6	15:21.2	−72.14	112	?	Aps
Me 2-1	342 + 27.1	342.1 + 27.5	15:22.3	−23.38	6	11.6	Lib
He 2-123	323 + 2.1	323.9 + 02.4	15:22.3	−54.08	8 × 6	15.1	Lup
He 2-125	324 + 2.1	324.2 + 02.5	15:23.6	−53.51	4 × 3	17.9	Lup
Pe 2-8	322 − 0.1	322.4 − 00.1	15:23.7	−57.09	2 × 1	17.9	Cir
He 2-128	325 + 4.1	325.8 + 04.5	15:25.1	−51.2	stellar	14.4	Lup
He 2-129	325 + 3.1	325.0 + 03.2	15:25.5	−52.51	2 × 1	14.9	Lup
HaTr 2	321 − 3.1	321.0 − 03.8	15:30.3	−61.02	12	18.1	TrA
Mz 1	322 − 2.1	322.4 − 02.6	15:34.3	−59.09	29 × 23	12.0	Nor
He 2-131	315 − 13.1	315.1 − 13.0	15:37.2	−71.55	6	11.8	Aps
He 2-132	323 − 2.1	323.1 − 02.5	15:38.0	−58.45	20 × 16	14.8	Nor
He 2-133	314 − 1.1	324.8 − 01.1	15:42.0	−56.37	4	16.6	Nor
Lo 9	330 + 51	330.2 + 05.9	15:42.2	−47.41	107	?	Lup

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
DS 2	335 + 12.1	335.5 + 12.4	15:43.0	−39.2	180	?	Lup
NGC 5979	322 − 5.1	322.5 − 05.2	15:47.7	−61.13	8	11.8	TrA
Lo 10	328 + 1.1	328.2 + 01.3	15:49.5	−52.31	12	?	Nor
Wray 16-189	330 + 4.2	330.9 + 04.3	15:51.3	−48.26	15	14.9	Nor
Cn 1-1	330 + 4.1	330.7 + 04.1	15:51.3	−48.45	1	12.9	Nor
Sp 1	329 + 2.1	329.0 + 01.9	15:51.7	−51.31	80	12.6	Nor
He 2-136	322 − 6.1	322.1 − 06.6	15:52.2	−62.31	10	12.5	TrA
VBe 3	326 − 1.2	326.1 − 01.9	15:53.0	−56.24	12	16.9	Nor
ESO 330-02	335 + 9.1	335.4 + 09.2	15:53.2	−41.5	29	17.2	Lup
VBRC 7	329 + 1.1	329.5 + 01.7	15:55.1	−51.24	100	?	Nor
He 2-138	320 − 9.1	320.1 − 09.6	15:56.0	−66.09	7	13.3	TrA
He 2-140	327 − 1.2	327.1 − 01.8	15:58.1	−55.42	3	17.1	Nor
He 2-141	325 − 4.1	325.4 − 04.0	15:59.2	−58.24	16 × 12	12.3	Nor
He 2-142	327 − 2.1	327.1 − 02.2	16:00.0	−55.55	4 × 3	16.0	Nor
Wray 16-199	332 + 3.1	332.2 + 03.5	16:00.4	−48.16	8	?	Nor
He 2-143	327 − 1.1	327.8 − 01.6	16:01.0	−55.06	7 × 4	15.2	Nor
NGC 6026	341 + 13.1	341.6 + 13.7	16:01.3	−34.33	54 × 36	13.2	Lup
StWr 4-10	336 + 8.1	336.9 + 08.3	16:02.2	−41.34	stellar	15.2	Lup
Lo 11	340 + 12.1	340.8 + 12.3	16:03.4	−36.01	60	?	Lup
NGC 6058	064 + 48.1	064.6 + 48.2	16:04.4	40.41	24 × 21	12.9	Her
Lo 12	340 + 10.1	340.8 + 10.8	16:08.4	−37.09	79	?	Sco
He 2-145	331 + 0.1	331.4 + 00.5	16:09.0	−51.02	13 × 8	14.9	Nor
Lo 13	345 + 15.1	345.5 + 15.1	16:09.7	−30.54	71	?	Sco
He 2-146	328 − 2.1	328.9 − 02.4	16:10.7	−54.58	24 × 20	14.2	Nor
IC 4593	025 + 40.1	025.3 + 40.8	16:11.7	12.04	13 × 10	10.8	Her
Wray 17-75		329.5 − 02.2	16:12.6	−54.24	24	16.7	Nor
NGC 6072	342 + 10.1	342.1 + 10.8	16:13.0	−36.14	70	11.3	Sco
H 1-1	343 + 11.1	343.4 + 11.9	16:13.5	−34.36	3	14.1	Sco
He 2-147	327 − 4.1	327.9 − 04.3	16:14.0	−56.59	stellar	16.9	Nor
He 2-149	329 − 2.1	329.4 − 02.7	16:14.4	−54.48	3	15.1	Nor
Mz 2	329 − 2.2	329.3 − 02.8	16:14.5	−54.57	25 × 21	12.0	Nor
He 2-152	333 + 1.1	333.4 + 01.1	16:15.3	−49.13	13 × 10	13.6	Nor
He 2-151	326 − 6.1	326.0 − 06.5	16:15.7	−59.54	stellar	16.3	Nor
Mz 3	331 − 1.1	331.7 − 01.0	16:17.2	−51.59	35 × 16	13.8	Nor
He 2-153	330 − 2.1	330.6 − 02.1	16:17.2	−53.32	14 × 12	14.4	Nor
KoRe 1		327.7 − 05.4	16:19.3	−57.58	14	?	Nor
IC 4599	338 + 5.1	338.8 + 05.6	16:19.4	−42.16	16 × 13	12.4	Sco
Sn 1	013 + 32.1	013.3 + 32.7	16:21.1	−0.16	6	12.9	Ser
He 2-157	331 − 2.1	331.0 − 02.7	16:22.2	−53.41	stellar	16.2	Nor
K 1-3	346 + 12.1	346.9 + 12.4	16:23.3	−31.45	154 × 94	15.5	Sco
He 2-158	327 − 6.1	327.8 − 06.1	16:23.5	−58.19	2	14.6	Nor
Pe 1-6	336 + 1.1	336.2 + 01.9	16:23.9	−46.42	14 × 11	16.3	Nor
He 2-159	330 − 3.1	330.6 − 03.6	16:24.4	−54.36	16 × 8	13.9	Nor
He 2-161	331 − 2.2	331.5 − 02.7	16:24.6	−53.23	17×10	14.8	Nor
Abell 39	047 + 42.1	047.0 + 42.4	16:27.6	27.55	170	12.9	Her
He 2-162	331 − 3.1	331.4 − 03.5	16:27.9	−54.01	stellar	16.6	Nor
He 2-163	327 − 7.1	327.8 − 07.2	16:29.5	−59.09	22 × 18	13.5	Nor
He 2-164	332 − 3.1	332.0 − 03.3	16:29.9	−53.23	16	13.9	Nor
He 2-165	331 − 3.2	331.5 − 03.9	16:30.0	−54.1	54 × 45	13.9	Nor
Pe 1-7	337 + 1.1	337.4 + 01.6	16:30.4	−46.03	5	17.7	Nor
MeWe 1-6		334.3 − 01.4	16:31.1	−50.27	17	?	Nor
NGC 6153	341 + 5.1	341.8 + 05.4	16:31.5	−40.15	28 × 21	10.6	Sco
He 2-171	346 + 8.1	346.0 + 08.5	16:34.1	−35.05	10	15.0	Sco

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
He 2-169	335 − 1.1	335.4 − 01.1	16:34.2	−49.21	24 × 20	17.4	Nor
He 2-170	332 − 4.1	332.3 − 04.2	16:35.4	−53.5	stellar	13.6	Ara
PC 11	331 − 5.1	331.1 − 05.7	16:37.7	−55.42	5	12.0	Ara
He 2-175	345 + 6.1	345.6 + 06.7	16:39.5	−36.34	11 × 4	15.0	Sco
HaTr 3	333 − 4.1	333.4 − 04.0	16:39.6	−52.49	42	16.2	Ara
DdDm 1	061 + 41.1	061.9 + 41.3	16:40.3	38.42	stellar	13.4	Her
Vd 1-1	344 + 4.1	344.2 + 04.7	16:42.6	−38.54	10	14.9	Sco
PC 12	000 + 17.1	000.1 + 17.2	16:43.8	−18.57	5 × 4	14.5	Oph
SuWt 3	343 + 3.1	343.6 + 03.7	16:44.4	−40.03	20	18.4	Sco
NGC 6210	043 + 37.1	043.1 + 37.7	16:44.5	23.48	20×13	8.8	Her
K 2-16	352 + 11.2	352.9 + 11.4	16:44.8	−28.04	23	?	Sco
HaTr 4	335 − 3.1	335.2 − 03.6	16:45.0	−51.12	23	16.7	Ara
Vd 1-2	345 + 4.1	345.0 + 04.3	16:46.8	−38.37	stellar	?	Sco
MeWe 1-7		335.9 − 03.6	16:48.0	−50.43	9	18.4	Ara
Abell 40	359 + 15.1	359.1 + 15.1	16:48.6	−21.01	30 × 27	17.8	Oph
MeWe 1-8		335.6 − 04.0	16:48.7	−51.09	24	?	Ara
MGP 1		348.0 + 06.3	16:48.8	−35.01	3	?	Sco
H 1-2	347 + 5.1	347.4 + 05.8	16:48.9	−35.47	5	13.1	Sco
Vd 1-3	344 + 3.1	344.8 + 03.4	16:49.5	−39.21	stellar	19.1	Sco
PC 13	351 + 9.1	351.9 + 09.0	16:50.3	−30.2	5	14.1	Sco
Vd 1-4	345 + 3.1	345.0 + 03.4	16:50.4	−39.08	5	15.7	Sco
Vd 1-5	344 + 2.1	344.4 + 02.8	16:50.6	−40.03	stellar	16.9	Sco
H 1-3	342 + 0.1	342.7 + 00.7	16:53.5	−42.39	18 × 14	16.2	Sco
H 1-4	351 + 7.1	351.3 + 07.6	16:53.6	−31.41	stellar	14.7	Sco
Vd 1-6	345 + 3.2	345.9 + 03.0	16:54.5	−38.44	20	15.4	Sco
He 2-182	325 − 12.1	325.8 − 12.8	16:54.6	−64.15	5	12.1	TrA
H 1-5	344 + 0.1	343.9 + 00.8	16:57.4	−41.38	6 × 5	17.9	Sco
MeWe 1-9		337.6 − 04.2	16:57.5	−49.47	17	16.6	Ara
He 2-186	336 − 5.1	336.3 − 05.6	16:59.6	−51.42	3	13.5	Ara
M 2-4	349 + 4.1	349.8 + 04.4	17:01.1	−34.5	5	13.5	Sco
He 2-185	321 − 16.1	321.3 − 16.7	17:01.3	−70.06	5	12.3	TrA
HaTr 5	343 − 0.1	343.3 − 00.6	17:01.5	−43.06	120	?	Sco
IC 4634	000 + 12.1	000.3 + 12.2	17:01.6	−21.5	11 × 9	10.9	Oph
He 2-187	337 − 5.1	337.5 − 05.1	17:01.6	−50.23	6	15.4	Ara
M 2-5	351 + 5.1	351.2 + 05.2	17:02.3	−33.1	5	16.4	Sco
SaSt 2-12	334 − 7.1	334.8 − 07.4	17:03.0	−53.56	stellar	14.1	Ara
M 1-19	351 + 4.1	351.1 + 04.8	17:03.8	−33.3	8	14.2	Sco
M 2-6	353 + 6.2	353.3 + 06.3	17:04.3	−30.53	8	13.7	Sco
H 2-1	350 + 4.1	350.9 + 04.4	17:04.6	−33.59	6	14.4	Sco
Vd 1-8	347 + 1.1	347.7 + 02.0	17:04.6	−37.53	stellar	17.2	Sco
M 2-7	353 + 6.1	353.7 + 06.3	17:05.2	−30.32	8	16.6	Sco
IC 4637	345 + 0.1	345.4 + 00.1	17:05.2	−40.53	21 × 17	11.7	Sco
M 2-8	352 + 5.1	352.1 + 05.1	17:05.5	−32.32	5 × 4	14.9	Sco
M 2-9	010 + 18.2	010.8 + 18.0	17:05.6	−10.09	39 × 15	14.6	Oph
Vd 1-9	343 − 1.1	343.0 − 01.7	17:05.7	−43.57	stellar	18.5	Sco
Th 3-1	358 + 9.1	358.0 + 09.3	17:05.8	−25.24	6	14.9	Oph
PC 14	336 − 6.1	336.2 − 06.9	17:06.2	−52.3	8 × 6	12.8	Ara
Pe 1-8	342 − 2.1	342.9 − 02.0	17:06.4	−44.13	18	14.0	Sco
H 1-6	344 − 1.1	344.2 − 01.2	17:07.0	−42.41	14 × 10	16.8	Sco
He 3-1333		332.9 − 09.9	17:09.0	−56.55	stellar	?	Ara
K 2-17	336 − 7.1	336.8 − 07.2	17:09.6	−52.13	38	?	Ara
H 1-7	345 − 1.1	345.2 − 01.2	17:10.5	−41.53	9	13.4	Sco
M 4-3	357 + 7.1	357.2 + 07.4	17:10.7	−27.09	stellar	14.2	Oph

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
Sa 1-5	340 − 4.1	340.9 − 04.6	17:11.5	−47.25	stellar	16.8	Ara
IC 4642	334 − 9.1	334.3 − 09.3	17:11.8	−55.24	18 × 15	12.4	Ara
TeJu 8		358.0 + 07.5	17:12.5	−26.26	17	?	Oph
M 3-36	358 + 7.1	358.6 + 07.8	17:12.7	−25.44	5 × 4	14.9	Oph
Na 1	018 + 20.1	018.0 + 20.1	17:12.9	−3.16	5	13.1	Oph
NGC 6302	349 + 1.1	349.5 + 01.0	17:13.7	−37.06	83 × 24	9.7	Sco
Sa 4-1	075 + 35.1	075.7 + 35.8	17:13.8	49.16	13	15.2	Her
NGC 6309	009 + 14.1	009.6 + 14.8	17:14.1	−12.55	52	11.5	Oph
M 2-10	354 + 4.1	354.2 + 04.3	17:14.1	−31.2	5 × 3	16.9	Sco
H 1-8	352 + 3.2	352.6 + 03.0	17:14.7	−33.25	3	16.9	Sco
Th 3-3	356 + 5.1	356.5 + 05.1	17:17.3	−29	17	16.4	Oph
Th 3-4	354 + 3.1	354.5 + 03.3	17:18.9	−31.39	stellar	16.4	Sco
M 3-37	359 + 6.1	359.8 + 06.9	17:19.2	−25.17	11 × 10	16.4	Oph
Th 3-6	355 + 3.3	354.9 + 03.5	17:19.3	−31.13	stellar	19.1	Sco
He 2-207	342 − 4.1	342.9 − 04.9	17:19.5	−45.53	40 × 26	12.6	Ara
Trz 41		000.3 + 06.9	17:20.4	−24.52	12	?	Oph
M 2-11	356 + 4.1	356.9 + 04.5	17:20.6	−29.01	15	14.5	Oph
NGC 6326	338 − 8.1	338.1 − 08.3	17:20.8	−51.45	6 × 11	11.1	Ara
M 3-38	356 + 4.2	356.9 + 04.4	17:21.1	−29.03	stellar	16.6	Oph
M 3-39	358 + 5.1	358.5 + 05.4	17:21.2	−27.11	21 × 15	15.3	Oph
H 1-11	002 + 8.1	002.6 + 08.1	17:21.3	−22.19	4	14.5	Oph
H 1-9	355 + 3.2	355.9 + 03.6	17:21.5	−30.21	7	15.6	Sco
TeJu 18		357.1 + 04.4	17:21.6	−28.55	8	18.4	Oph
NGC 6337	349 − 1.1	349.3 − 01.1	17:22.3	−38.29	49 × 45	12.0	Sco
M 3-40	358 + 5.2	358.7 + 05.2	17:22.5	−27.09	stellar	?	Oph
Wray 16-266	337 − 9.1	337.4 − 09.1	17:22.6	−52.47	18	16.4	Ara
H 2-7	357 + 4.1	357.3 + 04.0	17:23.4	−28.59	5	16.9	Oph
M 2-12	359 + 5.1	359.8 + 05.6	17:24.0	−25.59	5	?	Oph
Th 3-11	355 + 2.3	355.1 + 02.3	17:24.4	−31.43	stellar	?	Sco
M 3-7	357 + 3.1	357.1 + 03.6	17:24.6	−29.24	7 × 6	15.0	Oph
Th 3-10	355 + 2.2	355.9 + 02.7	17:24.7	−30.52	stellar	19.5	Sco
H 2-8	003 + 7.1	003.7 + 07.9	17:24.8	−21.34	4 × 3	?	Oph
M 3-8	358 + 4.1	358.2 + 04.2	17:24.9	−28.06	6 × 5	16.8	Oph
Th 3-12	356 + 3.1	356.8 + 03.3	17:25.1	−29.45	stellar	20.3	Oph
TeJu 19		359.8 + 05.2	17:25.3	−26.13	8	?	Oph
Th 3-13	356 + 2.1	356.1 + 02.7	17:25.3	−30.41	stellar	18.3	Sco
M 3-9	359 + 5.2	359.9 + 05.1	17:25.7	−26.12	18 × 16	15.6	Oph
Th 3-14	359 + 4.1	359.2 + 04.7	17:25.7	−26.58	stellar	?	Oph
M 3-41	357 + 3.2	357.3 + 03.3	17:26.0	−29.22	4	?	Oph
Cn 1-3	345 − 4.1	345.0 − 04.9	17:26.2	−44.11	5	11.9	Sco
H 1-12	352 + 0.1	352.6 + 00.1	17:26.4	−35.02	9 × 5	18.5	Sco
MaC 1-4	007 + 10.1	007.9 + 10.1	17:26.6	−16.48	stellar	17.6	Oph
SaWe 2		358.8 + 04.1	17:26.9	−27.41	70	?	Oph
M 3-42	357 + 3.4	357.5 + 03.2	17:27.0	−29.16	8 × 4	17.0	Oph
Th 3-15	358 + 4.2	358.8 + 04.0	17:27.2	−27.44	stellar	?	Oph
M 3-10	358 + 3.1	358.2 + 03.6	17:27.3	−28.28	4 × 3	14.2	Oph
Th 3-16	357 + 3.5	357.5 + 03.1	17:27.4	−29.21	6	?	Oph
H 2-10	358 + 3.2	358.2 + 03.5	17:27.5	−28.31	5	16.0	Oph
Al 2-B	359 + 3.9	358.5 + 03.7	17:27.8	−28.11	stellar	?	Oph
Cn 1-4	342 − 6.1	342.8 − 06.6	17:27.8	−46.56	10	12.9	Ara
PM 1-149		002.9 + 06.5	17:27.9	−22.57	stellar	?	Oph
H 1-14	001 + 5.1	001.7 + 05.7	17:28.1	−24.25	7	16.2	Oph
H 1-13	352 − 0.1	352.8 − 00.2	17:28.5	−35.08	3 × 11	16.2	Sco

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
M 2-13	011 + 11.1	011.1 + 11.5	17:28.6	−13.26	7	14.5	Ser
H 1-15	001 + 5.2	001.4 + 05.3	17:28.6	−24.51	6 × 5	16.3	Oph
Th 3-19	358 + 3.3	358.4 + 03.3	17:28.7	−28.27	stellar	?	Oph
M 4-4	357 + 2.5	357.0 + 02.4	17:28.8	−30.08	7	18.2	Sco
M 1-20	006 + 8.1	006.1 + 08.3	17:29.0	−19.16	7	13.5	Oph
Abell 41	009 + 10.1	009.6 + 10.5	17:29.1	−15.13	16 × 7	15.6	Ser
NGC 6369	002 + 5.1	002.4 + 05.8	17:29.3	−23.46	30	11.5	Oph
H 2-11	000 + 4.1	000.7 + 04.7	17:29.4	−25.49	3	19.1	Oph
H 1-16	000 + 4.2	000.1 + 04.3	17:29.4	−26.26	5	15.5	Oph
H 1-17	358 + 3.7	358.3 + 03.0	17:29.7	−28.41	5	15.4	Oph
H 1-18	357 + 2.4	357.6 + 02.6	17:29.7	−29.33	stellar	16.5	Oph
H 1-19	358 + 3.4	358.9 + 03.4	17:30.0	−27.59	stellar	17.6	Oph
Wray 16-278	344 − 6.1	344.4 − 06.1	17:30.1	−45.23	stellar	17.7	Sco
Al 2-E	359 + 3.4	359.3 + 03.6	17:30.2	−27.3	stellar	19.8	Oph
Th 3-23	358 + 2.2	358.0 + 02.6	17:30.4	−29.1	stellar	?	Oph
Al 2-F	358 + 2.4	358.5 + 02.9	17:30.5	−28.36	stellar	18.5	Oph
H 2-12	004 + 6.1	004.5 + 06.8	17:30.6	−21.29	5	?	Oph
H 1-20	358 + 3.6	358.9 + 03.2	17:30.7	−28.04	5×4	16.0	Oph
Th 3-25	359 + 3.2	359.8 + 03.7	17:30.8	−27.06	7	19.7	Oph
Th 3-24	357 + 2.7	357.1 + 01.9	17:30.9	−30.17	stellar	19.8	Sco
Th 3-55	356 + 1.2	356.5 + 01.5	17:31.0	−31.01	stellar	19.7	Sco
H 2-13	357 + 2.6	357.2 + 02.0	17:31.1	−30.11	stellar	16.6	Sco
Th 3-26	358 + 3.8	358.8 + 03.0	17:31.2	−28.15	6	17.0	Oph
Abell 42	016 + 13.1	016.0 + 13.5	17:31.5	−8.19	60 × 57	16.5p	Oph
HDW 8	358 + 2.5	358.5 + 02.6	17:31.8	−28.42	37	14.9	Oph
H 1-22	350 − 2.1	350.8 − 02.4	17:32.3	−37.58	stellar	16.7	Sco
H 2-14	349 − 3.1	349.2 − 03.5	17:32.3	−39.51	20	15.8	Sco
Al 2-G	359 + 2.5	359.0 + 02.8	17:32.4	−28.15	stellar	?	Oph
H 1-23	357 + 1.1	357.6 + 01.7	17:32.8	−30	3	15.6	Oph
H 1-21	348 − 4.1	348.4 − 04.1	17:32.8	−40.58	stellar	15.2	Sco
Wray 16-286	351 − 1.1	351.9 − 01.9	17:33.0	−36.44	stellar	16.1	Sco
Al 2-H	357 + 1.2	357.2 + 01.4	17:33.3	−30.27	stellar	?	Sco
H 1-24	004 + 6.2	004.6 + 06.0	17:33.6	−21.46	9	16.2	Oph
Al 2-k	359 + 2.7	359.5 + 02.6	17:34.2	−27.56	stellar	?	Oph
H 2-15	003 + 5.1	003.8 + 05.3	17:34.4	−22.53	5 × 4	17.3	Oph
MeWe 1-10		336.9 − 11.5	17:34.5	−54.29	60	?	Ara
He 2-250	000 + 3.1	000.7 + 03.2	17:34.9	−26.36	6	17.1	Oph
M 1-22	007 + 7.1	007.5 + 07.4	17:35.2	−18.34	9	14.7	Oph
M 4-6	358 + 1.1	358.6 + 01.8	17:35.2	−29.03	stellar	18.4	Oph
Th 3-32	359 + 2.4	359.4 + 02.3	17:35.3	−28.07	stellar	?	Oph
M 3-11	005 + 6.1	005.5 + 06.1	17:35.4	−20.57	12	17.7	Oph
Al 2-J	000 + 2.1	000.1 + 02.6	17:35.6	−27.24	9	?	Oph
TrBr 4	357 + 1.3	357.6 + 01.0	17:35.7	−30.21	30	?	Sco
Lo 16	349 − 4.1	349.3 − 04.2	17:35.7	−40.12	83	13.4	Sco
PC 17	343 − 7.1	343.5 − 07.8	17:35.7	−47	6	13.4	Ara
Th 3-33	359 + 2.3	359.8 + 02.4	17:35.8	−27.43	6	?	Oph
Th 3-27	002 + 4.1	002.6 + 04.2	17:36.0	−24.26	10	15.8	Oph
He 2-248	341 − 9.1	341.5 − 09.1	17:36.1	−49.26	stellar	14.0	Ara
Al 2-I	359 + 2.6	359.6 + 02.2	17:36.2	−28.01	stellar	?	Oph
M 3-12	005 + 5.1	005.2 + 05.6	17:36.4	−21.31	7 × 5	14.8	Oph
H 1-26	350 − 3.1	350.1 − 03.9	17:36.5	−39.22	23 × 14	14.5	Sco
Bl B	358 + 1.4	358.3 + 01.2	17:37.0	−29.4	stellar	19.4	Oph
M 1-23	007 + 6.1	007.6 + 06.9	17:37.4	−18.47	8 × 6	14.3	Oph

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
PBOZ 24		002.1 + 03.3	17:37.9	−25.21	stellar	?	Oph
M 1-24	007 + 6.2	007.0 + 06.3	17:38.2	−19.38	6	14.2	Oph
M 1-25	004 + 4.1	004.9 + 04.9	17:38.5	−22.09	5	14.1	Oph
Th 3-35	359 + 1.1	359.3 + 01.4	17:38.7	−28.43	stellar	?	Oph
He 2-260	008 + 6.1	008.2 + 06.8	17:39.0	−18.18	10	?	Oph
19 W32	359 + 1.3	359.2 + 01.2	17:39.0	−28.57	24	?	Oph
Fg 2	346 − 6.1	346.3 − 06.8	17:39.3	−44.1	5	12.6	Sco
H 2-16	005 + 5.2	005.8 + 05.1	17:39.9	−21.14	17	15.4	Oph
H 2-17	003 + 3.1	003.1 + 03.4	17:40.1	−24.26	3	?	Oph
H 1-27	005 + 4.1	005.0 + 04.4	17:40.3	−22.19	7 × 4	15.6	Oph
He 2-262	001 + 2.1	001.2 + 02.1	17:40.3	−26.44	4	?	Oph
K 1-4	001 + 1.1	001.0 + 01.9	17:40.5	−27.01	47 × 33	16.5p	Oph
M 3-13	005 + 4.2	005.2 + 04.2	17:41.6	−22.13	stellar	18.6	Oph
DeHt 2	027 + 16.1	027.6 + 16.9	17:41.7	3.07	94	16.3	Oph
Hb 4	003 + 2.1	003.1 + 02.9	17:41.9	−24.42	7 × 6	13.1	Oph
Sa 2-230	010 + 7.1	010.7 + 07.4	17:42.0	−15.56	10	16.2	Ser
M 2-14	003 + 3.2	003.6 + 03.1	17:42.0	−24.11	stellar	18.0	Oph
Te 5		002.3 + 02.2	17:42.5	−25.45	8	18.4	Oph
K 1-14	045 + 24.1	045.6 + 24.3	17:42.6	21.27	47	15.6	Her
Te 2022		358.8 − 00.0	17:42.7	−29.52	12	?	Oph
H 1-28	350 − 5.1	350.5 − 05.0	17:42.9	−39.36	8	17.3	Sco
H 2-18	006 + 4.1	006.3 + 04.4	17:43.5	−21.1	4	16.1	Sgr
Te 1580		002.6 + 02.1	17:43.7	−25.37	11	17.3	Oph
H 1-29	355 − 2.2	355.2 − 02.5	17:44.2	−34.17	stellar	15.1	Sco
M 3-14	355 − 2.1	355.4 − 02.4	17:44.3	−34.07	10 × 5	14.6	Sco
Sa 2-237	011 + 7.1	011.1 + 07.0	17:44.7	−15.45	stellar	?	Ser
K 1-15	051 + 25.1	051.9 + 25.8	17:45.0	27.2	43	17.2p	Her
H 1-30	352 − 4.1	352.0 − 04.6	17:45.1	−38.09	6 × 5	16.2	Sco
M 3-15	006 + 4.2	006.8 + 04.1	17:45.5	−20.58	4	14.7	Sgr
Te 1567		002.8 + 01.8	17:45.5	−25.38	10	17.9	Sgr
H 1-31	355 − 2.4	355.1 − 02.9	17:45.5	−34.34	5	14.5	Sco
IC 4663	346 − 8.1	346.2 − 08.2	17:45.5	−44.54	14 × 12	12.1	Sco
Pe 1-9	005 + 3.1	005.0 + 03.0	17:45.6	−23.02	15 × 9	17.9	Sgr
IC 1266	345 − 8.1	345.2 − 08.8	17:45.6	−46.05	13	12.2	Ara
H 2-20	002 + 1.1	002.8 + 01.7	17:45.7	−25.4	4	19.8	Sgr
M 1-26	358 − 0.2	358.9 − 00.7	17:46.0	−30.12	5 × 4	13.8	Sco
Bl D	358 − 1.1	358.2 − 01.1	17:46.0	−31.04	14 × 9	16.0	Sco
H 1-32	355 − 2.3	355.6 − 02.7	17:46.1	−34.04	5	14.3	Sco
Th 4-2	008 + 5.1	008.8 + 05.2	17:46.2	−18.4	20 × 18	16.6	Sgr
Th 4-1	007 + 4.1	007.5 + 04.3	17:46.3	−20.14	stellar	17.3	Sgr
M 1-27	356 − 2.2	356.5 − 02.3	17:46.8	−33.09	5	?	Sco
M 2-15	011 + 6.1	011.0 + 06.2	17:46.9	−16.17	6 × 5	14.3	Sgr
H 2-22	006 + 3.1	006.3 + 03.3	17:47.6	−21.47	6	?	Sgr
M 1-28	006 + 3.2	006.0 + 03.1	17:47.6	−22.06	24 × 13	16.8	Sgr
H 1-33	355 − 3.1	355.7 − 03.0	17:47.8	−34.08	stellar	15.4	Sco
Hb 5	359 − 0.1	359.3 − 00.9	17:47.9	−30	19 × 12	11.8	Sgr
H 1-34	005 + 2.1	005.5 + 02.7	17:48.1	−22.47	stellar	18.3	Sgr
NGC 6439	011 + 5.1	011.0 + 05.8	17:48.3	−16.28	6 × 5	12.7	Sgr
Te 2111		003.9 + 01.6	17:48.5	−24.41	8	?	Sgr
Th 4-3	006 + 2.1	006.0 + 02.8	17:48.6	−22.17	stellar	?	Sgr
H 2-24	004 + 1.1	004.3 + 01.8	17:48.6	−24.17	6 × 3	18.4	Sgr
Te 2337		002.2 + 00.5	17:48.8	−26.44	28	?	Sgr
H 2-25	004 + 2.1	004.8 + 02.0	17:49.0	−23.43	5 × 4	19.2	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
H 2-23	355 − 3.2	355.7 − 03.4	17:49.0	−34.22	stellar	15.3	Sco
H 1-35	355 − 3.3	355.7 − 03.5	17:49.2	−34.23	2	12.8	Sco
NGC 6445	008 + 3.1	008.0 + 03.9	17:49.3	−20.01	38 × 29	10.9	Sgr
H 2-26	356 − 3.1	356.1 − 03.3	17:49.8	−34	4 × 5	18.5	Sco
H 1-36	353 − 4.1	353.5 − 04.9	17:49.8	−37.01	stellar	12.1	Sco
M 1-29	359 − 1.1	359.1 − 01.7	17:50.3	−30.35	9 × 7	13.6	Sco
M 3-43	000 − 1.1	000.1 − 01.1	17:50.4	−29.25	4 × 3	16.0	Sgr
Th 4-5	009 + 4.1	009.0 + 04.1	17:50.5	−19.03	8 × 5	16.3	Sgr
H 1-38	353 − 5.1	353.2 − 05.2	17:50.7	−37.24	9 × 5	18.3	Sco
H 1-37	351 − 6.1	351.6 − 06.2	17:50.7	−39.17	10 × 8	13.9	Sco
Th 4-6	009 + 4.2	009.3 + 04.1	17:51.0	−18.47	stellar	15.6	Sgr
Hf 2-1	355 − 4.1	355.4 − 04.0	17:51.2	−34.55	11 × 8	13.8	Sco
M 3-44	359 − 1.2	359.3 − 01.8	17:51.3	−30.24	5	16.0	Sco
M 4-7	358 − 2.1	358.5 − 02.5	17:51.7	−31.36	7	?	Sco
Al 2-O	358 − 2.4	358.3 − 02.5	17:51.8	−32.03	stellar	?	Sco
H 2-27	356 − 3.2	356.5 − 03.6	17:51.8	−33.48	stellar	19.1	Sco
HaTr 6	332 − 16.1	332.8 − 16.4	17:51.9	−60.23	36	16.7	Pav
M 2-17	010 + 4.1	010.4 + 04.5	17:52.1	−17.36	7 × 6	14.9	Sgr
M 3-45	359 − 1.3	359.7 − 01.8	17:52.1	−30.05	5	16.6	Sco
Th 4-7	006 + 2.3	006.8 + 02.3	17:52.4	−21.51	6	15.8	Sgr
Bl 3-15	000 − 1.2	000.6 − 01.3	17:52.6	−29.07	3	?	Sgr
M 2-16	357 − 3.2	357.4 − 03.2	17:52.6	−32.46	6 × 5	14.9	Sco
M 1-31	006 + 2.5	006.4 + 02.0	17:52.7	−22.22	stellar	13.7	Sgr
M 3-16	359 − 2.2	359.1 − 02.3	17:52.8	−30.5	7 × 6	15.1	Sco
MeWe 1-11		345.3 − 10.2	17:52.8	−46.42	55	?	Ara
M 1-30	355 − 4.2	355.9 − 04.2	17:53.0	−34.38	5	14.7	Sco
H 2-29	357 − 3.3	357.6 − 03.3	17:53.3	−32.41	4	20.1	Sco
H 1-39	356 − 3.3	356.5 − 03.9	17:53.3	−33.56	5	17.7	Sco
Al 2-Q	000 − 1.7	000.5 − 01.6	17:53.4	−29.17	stellar	?	Sgr
Abell 43	036 + 17.	036.0 + 17.6	17:53.5	10.37	80 × 74	14.7	Oph
Pe 2-10	006 + 2.4	006.8 + 02.0	17:53.6	−21.59	4	18.3	Sgr
Al 2-R	358 − 2.5	358.7 − 02.7	17:53.6	−31.26	stellar	19.6	Sco
M 2-18	357 − 3.4	357.4 − 03.5	17:53.6	−32.59	5	15.6	Sco
Bl M	001 − 1.1	001.3 − 01.2	17:53.8	−28.27	4	20.1	Sgr
Bl O	000 − 1.3	000.8 − 01.5	17:53.8	−28.59	stellar	?	Sgr
M 2-19	000 − 1.5	000.2 − 01.9	17:53.8	−29.44	7 × 5	16.3	Sgr
PM 1-188		012.2 + 04.9	17:54.3	−15.56	4	?	Ser
Vy 1-2	053 + 24.1	053.3 + 24.0	17:54.4	28	5 × 4	12.3	Her
K 2-5	014 + 6.1	014.9 + 06.4	17:54.4	−12.48	30 × 20	17.7	Ser
M 2-20	000 − 1.6	000.4 − 01.9	17:54.4	−29.36	7	14.8	Sgr
Bl Q	001 − 1.2	001.6 − 01.3	17:54.6	−28.13	5	18.1	Sgr
Cn 2-1	356 − 4.1	356.2 − 04.4	17:54.6	−34.22	3 × 2	12.2	Sco
Sa 3-92	001 − 1.4	001.1 − 01.6	17:54.9	−28.49	6	18.5	Sgr
IC 4670	007 + 1.1	007.2 + 01.8	17:55.1	−21.45	5	13.2	Sgr
M 3-46	359 − 2.4	359.1 − 02.9	17:55.1	−31.12	5 × 4	19.3	Sco
Bl 3-10	000 − 2.2	000.1 − 02.3	17:55.4	−29.58	9	14.9	Sgr
H 1-40	359 − 2.3	359.7 − 02.6	17:55.6	−30.34	4	15.0	Sco
HaTr 8	006 + 1.1	006.2 + 01.0	17:55.9	−22.59	12	?	Sgr
Th 4-9	009 + 2.1	009.3 + 02.8	17:56.0	−19.28	stellar	?	Sgr
H 2-31	001 − 1.3	001.7 − 01.6	17:56.0	−28.14	stellar	?	Sgr
Bl 3-13	000 − 2.1	000.9 − 02.0	17:56.0	−29.11	5	18.0	Sgr
H 2-30	358 − 3.2	357.9 − 03.8	17:56.2	−32.38	11	17.6	Sco
M 1-32	011 + 4.1	011.9 + 04.2	17:56.3	−16.29	8 × 7	14.0	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
H 2-32	000 − 2.3	000.6 − 02.3	17:56.4	−29.38	stellar	15.0	Sgr
M 3-17	359 − 3.1	359.3 − 03.1	17:56.4	−31.04	5	18.2	Sco
He 2-306	348 − 9.1	348.8 − 09.0	17:56.6	−43.03	3	14.0	Sco
Th 4-10	010 + 3.1	010.6 + 03.2	17:57.1	−18.07	stellar	16.8	Sgr
H 1-41	356 − 4.2	356.7 − 04.8	17:57.3	−34.1	13 × 7	13.0	Sco
H 1-42	357 − 4.1	357.2 − 04.5	17:57.4	−33.36	6	12.6	Sco
M 3-47	000 − 2.5	000.3 − 02.8	17:57.7	−30.02	stellar	18.7	Sco
M 2-21	000 − 2.4	000.7 − 02.7	17:58.2	−29.44	3	13.5	Sgr
H 2-33	359 − 3.2	359.4 − 03.4	17:58.2	−31.08	7 × 6	18.3	Sgr
H 1-44	358 − 3.1	358.9 − 03.7	17:58.2	−31.43	4	18.7	Sgr
M 3-19	000 − 2.6	000.4 − 02.9	17:58.3	−30.01	5	16.4	Sgr
H 1-43	357 − 4.3	357.1 − 04.7	17:58.3	−33.48	2	?	Sgr
H 1-45	002 − 2.1	002.0 − 02.0	17:58.4	−28.15	6	15.6	Sgr
Sa 3-104	001 − 2.2	001.0 − 02.6	17:58.4	−29.21	5	17.9	Sgr
Pe 2-11	002 − 1.1	002.5 − 01.7	17:58.5	−27.37	6 × 4	19.6	Sgr
M 2-22	357 − 4.2	357.4 − 04.6	17:58.5	−33.29	6 × 5	15.2	Sgr
NGC 6543	096 + 29.1	096.4 + 29.9	17:58.6	66.38	22 × 19	8.1	Dra
M 1-33	013 + 4.1	013.1 + 04.1	17:59.0	−15.32	5	13.8	Ser
H 1-46	358 − 4.1	358.5 − 04.2	17:59.0	−32.22	stellar	14.3	Sgr
M 3-20	002 − 2.2	002.1 − 02.2	17:59.3	−28.14	4	14.3	Sgr
KFL 1		000.5 − 03.1	17:59.3	−30.03	8	19.0	Sgr
ESO 279-14	345 − 11.1	345.9 − 11.2	17:59.6	−46.39	24	?	Ara
M 3-48	359 − 4.1	359.0 − 04.1	17:59.9	−31.55	7	17.9	Sgr
Th 4-11	011 + 2.1	011.3 + 02.8	18:00.2	−17.4	5	18.3	Sgr
Fg 3	352 − 7.1	352.9 − 07.5	18:00.2	−38.5	2	11.7	CrA
H 2-35	356 − 5.1	356.8 − 05.4	18:00.3	−34.28	11	16.0	Sgr
H 1-47	001 − 3.1	001.2 − 03.0	18:00.6	−29.22	5	?	Sgr
KFL 2		002.2 − 02.5	18:01.0	−28.16	5	19.6	Sgr
Sa 1-6	340 − 14.1	340.4 − 14.1	18:01.0	−52.44	11	15.3	Ara
Sa 3-111	014 + 4.1	014.2 + 04.2	18:01.1	−14.3	6	?	Ser
Pe 2-12	002 − 2.3	002.8 − 02.2	18:01.2	−27.38	7 × 3	?	Sgr
M 1-34	357 − 5.1	357.9 − 05.1	18:01.4	−33.18	13 × 10	15.0	Sgr
M 2-23	002 − 2.4	002.2 − 02.7	18:01.7	−28.26	9	12.5	Sgr
Pe 1-11	358 − 5.1	358.0 − 05.1	18:01.7	−33.15	10 × 8	13.3	Sgr
M 2-24	356 − 5.2	356.9 − 05.8	18:02.0	−34.28	11 × 4	14.7	Sgr
M 3-22	000 − 3.1	000.7 − 03.7	18:02.3	−30.14	7 × 6	15.1	Sgr
ShWi 2-1	358 − 3.4	001.4 − 03.4	18:02.5	−29.25	13	18.3	Sgr
M 3-49	356 − 6.1	356.3 − 06.2	18:02.5	−35.13	11 × 9	16.6	Sgr
M 3-21	355 − 6.1	355.1 − 06.9	18:02.5	−36.39	5	11.7	Sgr
M 2-25	359 − 4.3	359.0 − 04.8	18:02.8	−32.1	13	15.0	Sgr
KFL 4		003.0 − 02.6	18:02.9	−27.41	3	17.7	Sgr
KFL 3		359.7 − 04.4	18:02.9	−31.24	14	16.6	Sgr
M 2-26	003 − 2.2	003.6 − 02.3	18:03.2	−26.59	13 × 9	16.3	Sgr
IC 4673	003 − 2.3	003.5 − 02.4	18:03.3	−27.06	16	13.0	Sgr
M 1-35	003 − 2.1	003.9 − 02.3	18:03.7	−26.43	5	14.6	Sgr
ShWi 2-5	358 − 3.8	001.2 − 03.9	18:03.9	−29.51	4	15.8	Sgr
M 2-27	359 − 4.2	359.9 − 04.5	18:03.9	−31.18	2	14.1	Sgr
H 1-50	358 − 5.3	358.7 − 05.2	18:03.9	−32.42	10	11.1	Sgr
Wray 17-107	002 − 3.7	002.4 − 03.2	18:04.1	−28.28	12	17.3	Sgr
H 2-36	359 − 4.4	359.6 − 04.8	18:04.1	−31.39	10	16.7	Sgr
M 3-50	357 − 6.1	357.1 − 06.1	18:04.1	−34.29	7 × 2	15.9	Sgr
H 2-37	002 − 3.2	002.3 − 03.4	18:04.5	−28.38	6 × 4	15.9	Sgr
H 1-51	356 − 6.2	356.7 − 06.4	18:04.5	−34.58	13	16.8	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
Wray 16-363	000 − 4.3	000.2 − 04.6	18:04.7	−31.03	6	?	Sgr
M 3-51	358 − 5.4	358.6 − 05.5	18:04.9	−32.54	12 × 3	17.2	Sgr
M 2-28	000 − 4.1	000.3 − 04.6	18:05.0	−30.58	8 × 5	18.2	Sgr
H 1-52	354 − 7.1	354.4 − 07.8	18:05.0	−37.38	13 × 11	14.8	Cra
ShWi 2-7	358 − 3.10	001.8 − 03.8	18:05.1	−29.19	12	16.3	Sgr
NGC 6537	010 + 0.1	010.1 + 00.7	18:05.2	−19.51	5	11.9	Sgr
PBOZ 34		005.4 − 01.9	18:05.4	−25.13	stellar	?	Sgr
M 1-37	002 − 3.3	002.6 − 03.4	18:05.4	−28.22	stellar	?	Sgr
WeSb 3	028 + 10.1	028.0 + 10.2	18:06.0	0.23	36	16.8	Oph
H 1-53	004 − 2.1	004.3 − 02.6	18:06.0	−26.3	stellar	15.7	Sgr
M 1-38	002 − 3.5	002.4 − 03.7	18:06.1	−28.41	3	?	Sgr
M 2-29	004 − 3.1	004.0 − 03.0	18:06.7	−26.55	6 × 5	14.7	Sgr
KFL 7		003.9 − 03.1	18:06.8	−27.06	5	18.3	Sgr
CTS 1	019 + 5.1	019.8 + 05.6	18:07.0	−8.56	3	16.4	Ser
H 1-54	002 − 4.1	002.1 − 04.2	18:07.1	−29.13	5	14.1	Sgr
M 3-23	000 − 4.2	000.9 − 04.8	18:07.1	−30.34	10	13.8	Sgr
H 1-55	001 − 4.1	001.7 − 04.4	18:07.2	−29.41	5	17.8	Sgr
KFL 9		359.9 − 05.4	18:07.3	−31.43	12	16.4	Sgr
Sp 3	342 − 14.1	342.5 − 14.3	18:07.3	−51.01	36	13.5	Ara
M 1-39	015 + 3.1	015.9 + 03.3	18:07.5	−13.29	5	18.4	Ser
M 3-24	005 − 2.1	005.5 − 02.5	18:07.9	−25.24	19	14.3	Sgr
H 1-56	001 − 4.2	001.7 − 04.6	18:07.9	−29.45	3	14.4	Sgr
KFL 10		004.2 − 03.2	18:08.0	−26.54	6	16.7	Sgr
H 2-39	002 − 3.6	002.9 − 03.9	18:08.1	−28.24	4	15.5	Sgr
M 1-40	008 − 1.1	008.3 − 01.1	18:08.4	−22.17	11 × 8	14.7	Sgr
H 2-40	000 − 5.1	000.1 − 05.6	18:08.4	−31.37	4	17.4	Sgr
HaTr 9	351 − 10.2	351.0 − 10.4	18:09.0	−41.48	162	?	CrA
MaC 1-10	005 − 2.2	005.9 − 02.6	18:09.2	−25.05	10	?	Sgr
H 1-58	005 − 3.1	005.1 − 03.0	18:09.2	−26.02	6	16.5	Sgr
M 1-41	006 − 2.1	006.7 − 02.2	18:09.5	−24.12	8 × 5	17.0	Sgr
H 1-57	356 − 7.2	356.6 − 07.8	18:09.8	−35.44	13	16.0	Sgr
KFL 11		004.1 − 03.8	18:10.2	−27.17	3	17.5	Sgr
M 3-52	018 + 4.1	018.9 + 04.1	18:10.4	−10.29	11	?	Ser
KFL 12		003.2 − 04.4	18:10.5	−28.19	3	17.3	Sgr
M 1-42	002 − 4.2	002.7 − 04.8	18:11.1	−28.59	14	13.2	Sgr
H 1-59	003 − 4.3	003.8 − 04.3	18:11.5	−27.46	7 × 5	14.8	Sgr
Ap 1-12	003 − 4.7	003.3 − 04.6	18:11.6	−28.23	12	?	Sgr
M 1-43	011 − 0.1	011.7 − 00.0	18:11.8	−18.46	7 × 4	17.5	Sgr
NGC 6565	003 − 4.5	003.5 − 04.6	18:11.9	−28.11	10 × 8	11.4	Sgr
NGC 6563	358 − 7.1	358.5 − 07.3	18:12.0	−33.52	50 × 37	10.8	Sgr
NGC 6572	034 + 11.1	034.6 + 11.8	18:12.1	6.51	16 × 13	8.0	Oph
M 4-8	018 + 3.1	018.9 + 03.6	18:12.2	−10.43	stellar	?	Ser
H 2-42	005 − 3.2	005.0 − 03.9	18:12.4	−26.33	17	17.1	Sgr
H 1-60	004 − 4.1	004.2 − 04.3	18:12.4	−27.29	4	14.8	Sgr
H 2-41	003 − 4.4	003.8 − 04.5	18:12.4	−27.52	9 × 7	16.0	Sgr
H 1-61	006 − 3.1	006.5 − 03.1	18:12.6	−24.5	stellar	18.1	Sgr
M 2-30	003 − 4.8	003.7 − 04.6	18:12.6	−27.58	4	13.1	Sgr
KFL 13		005.7 − 03.6	18:12.7	−25.44	14	16.1	Sgr
H 2-43	003 − 4.9	003.4 − 04.8	18:12.8	−28.2	9	15.5	Sgr
Wray 16-385	351 − 10.1	351.7 − 10.9	18:12.9	−41.3	8	14.9	CrA
KFL 14		002.5 − 05.4	18:13.0	−29.25	17	14.7	Sgr
M 2-31	006 − 3.3	006.0 − 03.6	18:13.3	−25.3	5	13.7	Sgr
H 1-62	359 − 6.1	000.0 − 06.8	18:13.3	−32.2	stellar	?	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
H 2-44	005 − 4.1	005.5 − 04.0	18:13.7	−26.09	8	16.5	Sgr
NGC 6567	011 − 0.2	011.7 − 00.6	18:13.8	−19.05	11 × 7	10.9	Sgr
M 4-9	024 + 5.1	024.2 + 05.9	18:14.3	−4.59	46 × 38	14.1	Ser
KFL 15		006.2 − 03.7	18:14.3	−25.21	8	17.9	Sgr
H 2-45	006 − 3.2	006.8 − 03.4	18:14.5	−24.44	5	15.8	Sgr
MaC 1-11	008 − 2.1	008.6 − 02.6	18:14.8	−22.44	stellar	17.3	Sgr
M 2-32	359 − 7.1	359.8 − 07.2	18:14.8	−32.37	10	12.4	Sgr
M 2-33	002 − 6.1	002.0 − 06.2	18:15.1	−30.16	5 × 4	13.1	Sgr
MA 2	022 + 4.1	022.5 + 04.8	18:15.2	−6.57	10	?	Ser
M 3-25	019 + 3.1	019.7 + 03.2	18:15.3	−10.1	4	15.1	Ser
M 3-26	004 − 5.1	004.8 − 05.0	18:16.2	−27.15	8 × 7	13.8	Sgr
SwSt 1	001 − 6.2	001.5 − 06.7	18:16.2	−30.52	stellar	11.9	Sgr
NGC 6578	010 − 1.1	010.8 − 01.8	18:16.3	−20.27	13 × 10	12.6	Sgr
M 1-44	004 − 4.2	004.9 − 04.9	18:16.3	−27.05	4	16.2	Sgr
H 1-63	002 − 6.2	002.2 − 06.3	18:16.3	−30.08	7	12.9	Sgr
KFL 16		005.6 − 04.7	18:16.9	−26.23	12	16.7	Sgr
M 2-34	007 − 3.1	007.8 − 03.7	18:17.3	−23.59	13 × 6	16.2	Sgr
Cn 3-1	038 + 12.1	038.2 + 12.0	18:17.5	10.09	7 × 6	13.5	Oph
M 2-35	000 − 7.1	000.7 − 07.4	18:17.6	−31.57	5	15.4	Sgr
Pe 1-12	004 − 5.3	004.0 − 05.8	18:17.7	−28.17	12	16.0	Sgr
M 2-36	003 − 6.1	003.2 − 06.2	18:17.7	−29.08	9 × 5	11.8	Sgr
MA 3	023 + 4.1	023.0 + 04.3	18:17.8	−6.48	5	18.0	Ser
Pe 2-13	006 − 4.1	006.4 − 04.6	18:18.2	−25.38	7 × 5	15.0	Sgr
H 1-64	008 − 3.1	008.4 − 03.6	18:18.4	−23.25	8 × 7	18.9	Sgr
IC 4699	348 − 13.1	348.0 − 13.8	18:18.5	−45.59	5	12.6	Tel
M 2-37	004 − 5.5	004.2 − 05.9	18:18.6	−28.08	7	17.9	Sgr
H 2-46	000 − 7.2	000.8 − 07.6	18:18.6	−31.55	4	15.7	Sgr
M 2-38	005 − 5.1	005.7 − 05.3	18:19.4	−26.35	9 × 7	13.5	Sgr
H 1-65	007 − 4.1	007.8 − 04.4	18:20.1	−24.15	8	?	Sgr
M 2-40	024 + 3.1	024.1 + 03.8	18:21.4	−6.02	6 × 5	16.2	Ser
K 1-16	094 + 27.1	094.0 + 27.4	18:21.8	64.22	130 × 100	14.6	Dra
M 2-39	008 − 4.1	008.1 − 04.7	18:22.0	−24.11	3	14.6	Sgr
M 2-42	008 − 4.2	008.2 − 04.8	18:22.5	−24.09	5 × 3	14.0	Sgr
M 2-41	002 − 7.1	002.3 − 07.8	18:22.6	−30.43	13	13.8	Sgr
NGC 6620	005 − 6.1	005.8 − 06.1	18:22.9	−26.49	5	12.7	Sgr
M 1-45	012 − 2.1	012.6 − 02.7	18:23.1	−19.17	stellar	?	Sgr
KFL 19		003.3 − 07.5	18:23.1	−29.43	8	16.7	Sgr
K 3-1	032 + 7.1	032.9 + 07.8	18:23.4	3.36	6	14.3	Oph
M 3-53	019 + 0.1	019.9 + 00.9	18:24.1	−11.07	6 × 4	19.6	Sct
PC 19	032 + 7.2	032.1 + 07.0	18:24.7	2.29	14	12.2	Ser
H 1-66	007 − 6.1	007.0 − 06.0	18:24.9	−25.42	9 × 8	14.4	Sgr
Sh 2-68	030 + 6.1	030.6 + 06.2	18:25.0	0.52	400	?	Ser
K 3-2	028 + 5.1	028.5 + 05.1	18:25.0	−1.31	3	19.6	Ser
H 1-67	009 − 4.1	009.8 − 04.6	18:25.1	−22.35	6 × 5	14.1	Sgr
NGC 6629	009 − 5.1	009.4 − 05.0	18:25.7	−23.12	16 × 14	11.2	Sgr
SaWe 3		013.8 − 02.8	18:26.1	−18.12	110	15.3	Sgr
M 2-43	027 + 4.1	027.6 + 04.2	18:26.7	−2.43	15	16.8	Ser
Wray 16-411		353.7 − 12.8	18:26.7	−40.3	30	15.5	CrA
K 3-3	031 + 5.1	031.2 + 05.9	18:27.2	1.14	10 × 9	18.6p	Ser
M 3-27	043 + 11.1	043.3 + 11.6	18:27.8	14.29	1	14.1	Her
Lo 17	356 − 11.1	356.8 − 11.7	18:27.8	−37.16	104	?	CrA
M 1-46	016 − 1.1	016.4 − 01.9	18:27.9	−15.33	12 × 10	14.6	Sct
Vy 2-1	007 − 6.2	007.0 − 06.8	18:28.0	−26.07	7	12.9	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
MaC 1-13	022 + 1.1	022.5 + 01.0	18:28.6	−8.43	17	18.1	Sct
SaSt 3-166		014.9 − 03.1	18:29.2	−17.27	13	?	Sgr
M 1-47	011 − 5.1	011.0 − 05.1	18:29.2	−21.47	5	13.2	Sgr
Cn 1-5	002 − 9.1	002.2 − 09.4	18:29.2	−31.3	7	11.9	Sgr
Sa 3-134	016 − 2.1	016.9 − 02.0	18:29.3	−15.08	stellar	16.5	Sct
M 1-48	013 − 3.1	013.4 − 03.9	18:29.5	−19.06	5	15.8	Sgr
Pe 2-14	013 − 4.1	013.0 − 04.3	18:30.0	−19.41	6 × 5	16.0	Sgr
Abell 44	015 − 3.1	015.6 − 03.0	18:30.2	−16.45	63 × 39	15.8	Sgr
Abell 45	020 − 0.1	020.2 − 00.6	18:30.3	−11.37	302 × 281	12.8	Sct
MA 13	023 + 1.1	023.9 + 01.2	18:30.5	−7.28	stellar	?	Sct
K 3-4	032 + 5.1	032.7 + 05.6	18:31.0	2.26	13 × 11	15.8	Ser
Abell 46	055 + 16.1	055.4 + 16.0	18:31.3	26.56	63 × 60	13.8	Lyr
K 3-5	034 + 6.1	034.3 + 06.2	18:31.8	4.05	9	17.1	Ser
He 2-406	008 − 7.1	008.6 − 07.0	18:31.9	−24.46	8	16.8	Sgr
Hf 2-2	005 − 8.1	005.1 − 08.9	18:32.5	−28.43	17	15.7	Sgr
NGC 6644	008 − 7.2	008.3 − 07.3	18:32.6	−25.08	3	10.8	Sgr
M 3-28	021 − 0.1	021.8 − 00.4	18:32.7	−10.06	10 × 6	17.2	Sct
M 3-54	018 − 2.1	018.6 − 02.2	18:33.1	−13.44	stellar	16.7	Sct
M 3-55	021 − 0.2	021.7 − 00.6	18:33.2	−10.15	8 × 7	19.9	Sct
K 3-6	030 + 4.1	031.0 + 04.1	18:33.3	0.12	stellar	19.8	Ser
M 1-50	014 − 4.1	014.6 − 04.3	18:33.3	−18.17	6 × 5	13.1	Sgr
M 1-51	021 − 1.1	020.9 − 01.1	18:33.5	−11.07	4 × 3	16.7	Sct
IC 4732	010 − 6.1	010.7 − 06.4	18:33.9	−22.39	3	12.1	Sgr
We 3-1	044 + 10.1	044.3 + 10.4	18:34.0	14.49	135	?	Her
M 1-52	017 − 2.1	017.7 − 02.9	18:34.0	−14.52	7 × 6	15.6	Sct
K 3-7	028 + 2.1	028.7 + 02.7	18:34.2	−2.28	8	15.6	Ser
M 4-10	019 − 2.1	019.2 − 02.2	18:34.2	−13.12	stellar	15.0	Sct
Pe 1-13	010 − 6.2	010.7 − 06.7	18:34.9	−22.34	8 × 7	15.2	Sgr
Al 1	006 − 8.1	006.8 − 08.6	18:34.9	−27.06	13	15.2	Sgr
Abell 47	030 + 3.1	030.8 + 03.4	18:35.4	−0.14	17 × 15	19.5	Ser
M 1-53	015 − 4.1	015.4 − 04.5	18:35.8	−17.36	7 × 6	14.0	Sgr
M 1-54	016 − 4.1	016.0 − 04.3	18:36.1	−17	17 × 10	12.5	Sgr
GJJC 1		009.8 − 07.5	18:36.4	−23.55	9	?	Sgr
V-V 3-5	014 − 5.1	014.0 − 05.5	18:36.5	−19.19	stellar	15.2	Sgr
M 1-55	011 − 6.1	011.7 − 06.6	18:36.6	−21.49	stellar	?	Sgr
V-V 3-6	014 − 5.2	014.3 − 05.5	18:37.2	−19.02	stellar	14.5	Sgr
M 2-44	028 + 1.1	028.5 + 01.6	18:37.6	−3.06	8 × 7	13.5	Ser
M 1-56	016 − 4.2	016.1 − 04.7	18:37.8	−17.06	10	13.4	Sgr
M 2-45	027 + 0.1	027.7 + 00.7	18:39.4	−4.2	7	17.8	Sct
M 3-29	004 − 11.1	004.0 − 11.1	18:39.4	−30.41	8	13.1	Sgr
M 1-57	022 − 2.1	022.1 − 02.4	18:40.3	−10.4	9 × 8	13.5	Sct
K 3-11	023 − 1.2	023.8 − 01.7	18:41.1	−8.56	stellar	?	Sct
M 3-30	017 − 4.1	017.9 − 04.8	18:41.3	−15.34	16	14.6	Sct
Pe 1-14	025 − 0.1	025.9 − 00.9	18:42.1	−6.41	5	19.2	Sct
Abell 48	029 + 0.1	029.0 + 00.4	18:42.8	−3.13	43 × 37	17.2	Aql
M 1-58	022 − 3.1	022.0 − 03.1	18:43.0	−11.07	7 × 6	14.0	Sct
PC 20	031 + 1.1	031.7 + 01.7	18:43.1	−0.17	10	?	Aql
M 1-59	023 − 2.1	023.9 − 02.3	18:43.3	−9.05	4	13.3	Sct
M 1-60	019 − 4.1	019.7 − 04.5	18:43.6	−13.45	10	14.1	Sct
M 3-31	014 − 7.1	014.2 − 07.3	18:44.0	−19.55	7	14.3	Sgr
We 1-7	021 − 3.1	021.2 − 03.9	18:44.1	−12.13	17	?	Sct
He 2-418	004 − 11.2	004.7 − 11.8	18:44.2	−30.18	13	14.0	Sgr
M 3-32	009 − 9.1	009.4 − 09.8	18:44.7	−25.2	7 × 5	13.6	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
TDC 1		029.2 − 00.0	18:44.9	−3.21	6	?	Aql
K 3-13	034 + 2.1	034.0 + 02.2	18:45.4	2.01	stellar	18.4	Aql
Pe 2-15	026 − 1.2	026.0 − 01.8	18:45.5	−6.57	3	17.4	Sct
K 4-5	026 − 1.1	026.6 − 01.5	18:45.6	−6.18	20	14.2	Sct
PC 21	013 − 7.1	013.8 − 07.9	18:45.6	−20.35	15 × 12	14.0	Sgr
IC 4776	002 − 13.1	002.0 − 13.4	18:45.8	−33.21	8	10.9	Sgr
M 1-61	019 − 5.1	019.4 − 05.3	18:45.9	−14.28	stellar	12.3	Sct
Pe 1-15	025 − 2.1	025.9 − 02.1	18:46.4	−7.15	6 × 3	16.1	Sct
M 2-46	024 − 2.1	024.8 − 02.7	18:46.6	−8.28	6 × 3	18.3	Sct
H 2-48	011 − 9.1	011.3 − 09.4	18:46.6	−23.27	2	14.1	Sgr
Pe 1-16	026 − 2.1	026.3 − 02.2	18:47.5	−6.54	8 × 7	14.2	Sct
Pe 1-17	024 − 3.1	024.3 − 03.3	18:47.8	−9.09	8 × 7	14.8	Sct
M 3-33	009 − 10.1	009.6 − 10.6	18:48.2	−25.29	6 × 4	13.5	Sgr
K 3-14	042 + 5.1	042.0 + 05.4	18:48.5	10.36	stellar	?	Aql
Pe 1-18	027 − 2.1	027.3 − 02.1	18:48.8	−5.56	7	16.0	Sct
Hu 2-1	051 + 9.1	051.4 + 09.6	18:49.8	20.51	3	11.4	Her
Pe 1-19	026 − 2.3	026.5 − 03.0	18:49.8	−7.02	6 × 3	14.5	Sct
M 1-64	064 + 15.1	064.9 + 15.5	18:50.0	35.15	17	12.9	Lyr
HaTr 10	031 − 0.2	031.3 − 00.5	18:50.4	−1.4	25	?	Aql
M 1-62	012 − 9.1	012.5 − 09.8	18:50.4	−22.34	4	13.2	Sgr
CTSS 2		044.1 + 05.8	18:50.7	12.37	stellar	18.2	Her
WeSb 4	031 − 0.1	031.9 − 00.3	18:50.7	−1.03	30	?	Aql
Sa 1-8	020 − 5.1	020.7 − 05.9	18:50.7	−13.31	8	14.6	Sct
M 1-63	021 − 5.1	021.1 − 05.9	18:51.5	−13.11	4	14.4	Sct
K 3-15	041 + 4.1	041.8 + 04.4	18:51.7	9.55	stellar	18.0	Aql
K 3-16	044 + 5.1	044.0 + 05.2	18:53.0	12.16	8	17.7	Her
Abell 49	027 − 3.1	027.3 − 03.4	18:53.5	−6.29	35 × 33	16.2	Sct
NGC 6720	063 + 13.1	063.1 + 13.9	18:53.6	33.02	86 × 63	8.8	Lyr
Vy 1-4	027 − 3.2	027.4 − 03.5	18:54.0	−6.26	15	13.6	Sct
K 4-8	025 − 4.1	025.3 − 04.6	18:54.3	−8.48	stellar	14.2	Sct
M 4-11	024 − 5.1	024.2 − 05.2	18:54.3	−10.05	22 × 20	13.8	Sct
IC 1295	025 − 4.2	025.4 − 04.7	18:54.6	−8.5	102 × 87	12.5	Sct
YM 16	038 + 2.1	038.7 + 01.9	18:54.9	6.03	350 × 265	13.0	Ser
Y-C 2-32	013 − 10.1	013.7 − 10.6	18:55.5	−21.5	15	13.3	Sgr
Hb 7	003 − 14.1	003.9 − 14.9	18:55.6	−32.16	4	11.9	Sgr
K 3-17	039 + 2.1	039.8 + 02.1	18:56.3	7.07	5	20.0p	Aql
M 1-65	043 + 3.1	043.1 + 03.8	18:56.6	10.52	4 × 3	16.6	Aql
Pe 1-20	028 − 4.1	028.2 − 04.0	18:57.3	−6	11 × 8	16.3	Sct
Pe 1-21	028 − 3.1	028.7 − 03.9	18:57.8	−5.28	10 × 8	16.9	Sct
Ap 2-1	035 − 0.1	035.1 − 00.7	18:58.1	1.37	33	?	Aql
M 1−66	032 − 2.1	032.7 − 02.0	18:58.4	−1.04	10	13.3	Aql
Sa 3-151	033 − 1.1	033.2 − 01.9	18:58.9	−0.33	stellar	?	Aql
K 4-10	052 + 7.1	052.2 + 07.6	18:59.1	20.37	4	13.6	Sge
NGC 6742	078 + 18.1	078.5 + 18.7	18:59.3	48.28	31 × 30	13.4	Dra
Sp 4-1	068 + 14.1	068.7 + 14.8	19:00.5	38.21	2	13.7	Lyr
K 3-18	032 − 3.1	032.0 − 03.0	19:00.6	−2.12	6 × 3	21.5	Aql
Abell 51	017 − 10.1	017.6 − 10.2	19:01.0	−18.12	64 × 58	14.0	Sgr
MaC 1-16	023 − 7.1	023.3 − 07.6	19:01.4	−11.58	10	15.3	Sgr
K 3-19	032 − 2.2	032.9 − 02.8	19:01.6	−1.19	stellar	16.0	Aql
Sh 2-71	036 − 1.1	035.9 − 01.1	19:02.0	2.09	124 × 75	12.3	Aql
K 3-20	032 − 3.2	032.5 − 03.2	19:02.2	−1.49	stellar	19.1	Aql
PM 1-276		043.3 + 02.2	19:02.3	10.17	14	?	Aql
SaWe 4		014.7 − 11.8	19:02.3	−21.27	85	?	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
NGC 6741	033 − 2.1	033.8 − 02.6	19:02.6	−0.27	9 × 7	11.4	Aql
K 3-21	047 + 4.1	047.1 + 04.1	19:02.7	14.29	7	17.6	Aql
HaTr 11	036 − 1.2	036.9 − 01.1	19:03.0	3.02	12	?	Aql
CTSS 3		046.8 + 03.8	19:03.1	14.07	600	?	Aql
K 1-17	051 + 6.1	051.5 + 06.1	19:03.6	19.21	45	16.7	Sge
Abell 52	050 + 5.1	050.4 + 05.2	19:04.5	17.57	37 × 34	16.5p	Aql
K 4-16	048 + 4.2	048.5 + 04.2	19:04.9	15.48	stellar	16.5	Aql
Hb 8	003 − 17.1	003.8 − 17.1	19:05.6	−33.12	2	12.8	Sgr
NGC 6751	029 − 5.1	029.2 − 05.9	19:05.9	−6	21	11.5	Aql
CTSS 4		046.8 + 02.9	19:06.4	13.45	10	?	Aql
Abell 53	040 − 0.1	040.3 − 00.4	19:06.8	6.24	30 × 27	16.3	Aql
HaTr 13	036 − 2.1	036.9 − 02.6	19:08.0	2.21	21	?	Aql
Abell 54	055 + 6.1	055.3 + 06.6	19:08.7	22.59	67 × 47	16.8	Vul
HaTr 14	041 − 0.1	041.2 − 00.6	19:09.2	7.06	18	19.0	Aql
K 3-22	045 + 1.1	045.6 + 01.5	19:09.4	12.01	stellar	?	Aql
Lo 18	341 − 24.1	341.2 − 24.6	19:09.8	−55.35	43	?	Tel
Abell 55	033 − 5.1	033.0 − 05.3	19:10.5	−2.21	47 × 32	13.2	Aql
NGC 6765	062 + 9.1	062.4 + 09.5	19:11.1	30.33	38	13.1	Lyr
M 1-67	050 + 3.1	050.1 + 03.3	19:11.5	16.52	81	?	Sge
K 3-24	048 + 2.1	048.7 + 02.3	19:12.1	15.09	6	18.7	Aql
He 2-428	049 + 2.1	049.4 + 02.4	19:13.1	15.47	16 × 6	15.5	Aql
Abell 56	037 − 3.2	037.9 − 03.4	19:13.1	2.53	188 × 174	14.1p	Aql
K 4-19	038 − 3.1	038.4 − 03.3	19:13.4	3.25	stellar	?	Aql
He 2-429	048 + 1.1	048.7 + 01.9	19:13.6	14.59	4	16.3	Aql
M 2-47	039 − 2.1	039.5 − 02.7	19:13.6	4.38	6	14.9	Aql
M 1-69	038 − 3.2	038.7 − 03.3	19:13.9	3.38	stellar	14.0	Aql
LSA 1		029.8 − 07.8	19:13.9	−6.19	14	14.5	Aql
He 2-430	051 + 3.1	051.0 + 03.0	19:14.1	17.32	5	15.9	Sge
StWr 2-21	005 − 18.1	005.2 − 18.6	19:14.4	−32.34	5	16.2	Sgr
K 3-27	061 + 8.1	061.0 + 08.0	19:14.5	28.41	16	14.9	Lyr
NGC 6772	033 − 6.1	033.1 − 06.3	19:14.6	−2.42	70 × 56	12.6	Aql
K 3-26	035 − 5.1	035.7 − 05.0	19:14.7	0.14	10	16.0	Aql
WhMe 1	051 + 2.1	051.0 + 02.8	19:15.0	17.23	stellar	17.1	Sge
K 3-29	048 + 1.2	048.1 + 01.1	19:15.5	14.04	stellar	17.4	Aql
K 3-30	040 − 3.1	040.4 − 03.1	19:16.5	5.13	stellar	15.8	Aql
IC 4846	027 − 9.1	027.6 − 09.6	19:16.5	−9.03	2	11.9	Aql
Abell 57	058 + 6.1	058.6 + 06.1	19:17.1	25.37	40 × 34	14.4	Vul
DeHt 3	019 − 13.1	019.4 − 13.6	19:17.1	−18.02	32	14.1	Sgr
IC 1297	358 − 21.1	358.3 − 21.6	19:17.4	−39.37	11 × 9	10.7	CrA
Abell 58	037 − 5.1	037.5 − 05.1	19:18.3	1.47	44 × 37	17.4p	Aql
Na 2	026 − 11.1	025.9 − 10.9	19:18.3	−11.06	5	13.8	Aql
NGC 6778	034 − 6.1	034.5 − 06.7	19:18.4	−1.36	25 × 19	12.1	Aql
NGC 6781	041 − 2.1	041.8 − 02.9	19:18.5	6.32	111 × 109	11.6	Aql
Abell 59	053 + 3.1	053.3 + 03.0	19:18.7	19.34	94 × 80	16.4	Sge
K 3-31	052 + 2.1	052.9 + 02.7	19:19.0	19.02	stellar	17.5	Sge
Abell 61	077 + 14.1	077.6 + 14.7	19:19.2	46.15	201	13.5	Cyg
PM 1-295		051.3 + 01.8	19:19.3	17.12	20	?	Sge
Abell 60	025 − 11.1	025.0 − 11.6	19:19.3	−12.15	88 × 77	16.2	Sgr
M 4-14	043 − 3.1	043.0 − 03.0	19:21.0	7.37	8	14.9	Aql
Wray 16-423	006 − 19.1	006.8 − 19.8	19:22.2	−31.31	stellar	13.4	Sgr
K 3-33	045 − 1.1	045.9 − 01.9	19:22.4	10.41	stellar	20.5	Aql
NGC 6790	037 − 6.1	037.8 − 06.3	19:22.9	1.31	10 × 5	10.7	Aql
He 2-432	055 + 2.1	055.2 + 02.8	19:23.4	21.08	5	16.9	Vul

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
He 1-1	055 + 2.2	055.3 + 02.7	19:23.8	21.07	5	16.3	Vul
K 3-34	059 + 4.1	059.0 + 04.6	19:24.0	25.19	11 × 9	15.9	Vul
Vy 2-2	045 − 2.1	045.4 − 02.7	19:24.4	9.54	14	12.7	Aql
DeHt 4	048 − 1.1	048.7 − 01.5	19:26.4	13.2	40	?	Aql
He 1-2	055 + 2.3	055.6 + 02.1	19:26.6	21.1	5	?	Vul
M 3-34	031 − 10.1	031.0 − 10.8	19:27.0	−6.35	6 × 5	12.6	Aql
K 3-35	056 + 2.1	056.0 + 02.0	19:27.7	21.3	stellar	18.5	Vul
PB 9	046 − 3.1	046.3 − 03.1	19:27.7	10.24	12	14.8	Aql
PB 10	048 − 2.1	048.0 − 02.3	19:28.2	12.2	10	14.8	Aql
K 4-28	050 − 1.1	050.4 − 01.6	19:30.3	14.47	stellar	?	Aql
HDW 11	034 − 10.1	034.1 − 10.5	19:31.1	−3.42	47	?	Aql
NGC 6803	046 − 4.1	046.4 − 04.1	19:31.3	10.03	6	11.5	Aql
NGC 6804	045 − 4.1	045.7 − 04.5	19:31.6	9.14	62 × 49	12.2	Aql
He 2-436	004 − 22.1	004.8 − 22.7	19:32.1	−34.13	10	14.2	Sgr
K 3-36	044 − 5.1	044.3 − 05.6	19:32.6	7.28	12	15.9	Aql
He 2-437	061 + 3.1	061.3 + 03.6	19:33.0	26.53	16 × 3	17.0	Vul
Abell 62	047 − 4.1	047.1 − 04.2	19:33.3	10.37	161 × 151	14.7	Aql
K 3-37	059 + 2.1	059.4 + 02.3	19:33.8	24.32	stellar	16.0	Vul
He 2-434	320 − 28.1	320.3 − 28.8	19:33.8	−74.33	8 × 6	12.1	Pav
NGC 6807	042 − 6.1	042.9 − 06.9	19:34.6	5.41	2	12.2	Aql
BD +30 3639	064 + 5.1	064.7 + 05.0	19:34.8	30.31	13 × 10	11.4	Cyg
K 3-38	053 − 1.1	053.2 − 01.5	19:35.3	17.13	4	?	Sge
K 3-39	059 + 2.2	059.9 + 02.0	19:35.9	24.55	stellar	?	Vul
K 3-40	058 + 1.1	058.9 + 01.3	19:36.4	23.4	stellar	16.5	Vul
M 1-71	055 − 0.1	055.5 − 00.5	19:36.4	19.42	5 × 3	14.0	Vul
He 2-440	060 + 1.1	060.5 + 01.8	19:38.1	25.16	3	16.6	Vul
PM 1-310		060.4 + 01.5	19:38.9	25.06	stellar	?	Vul
Me 1-1	052 − 2.2	052.5 − 02.9	19:39.2	15.57	3	12.1	Aql
K 3-41	052 − 2.1	052.9 − 02.7	19:39.3	16.21	stellar	18.7	Aql
K 3-42	056 − 0.1	056.4 − 00.9	19:39.6	20.19	3	?	Vul
He 2-442	061 + 2.1	061.8 + 02.1	19:39.7	26.31	10	16.2	Vul
K 3-43	055 − 1.1	055.1 − 01.8	19:40.4	18.49	3	18.6	Sge
K 2-7	019 − 19.1	019.4 − 19.6	19:40.5	−20.27	140	?	Sgr
M 1-73	051 − 3.1	051.9 − 03.8	19:41.2	14.57	5	13.9	Aql
M 1-72	054 − 2.1	054.4 − 02.5	19:41.6	17.45	10	16.5	Sge
PC 22	051 − 4.1	051.0 − 04.5	19:42.1	13.51	20	14.4	Aql
Abell 63	053 − 3.1	053.8 − 03.0	19:42.2	17.05	40 × 27	16.9	Sge
M 1-74	052 − 4.1	052.2 − 04.0	19:42.3	15.09	5	12.9	Aql
NGC 6818	025 − 17.1	025.8 − 17.9	19:44.0	−14.09	22 × 15	9.4	Sgr
NGC 6826	083 + 12.1	083.5 + 12.7	19:44.8	50.32	128	8.9	Cyg
He 2-447	057 − 1.1	057.9 − 01.5	19:45.4	21.2	5	17.2	Vul
K 3-45	060 − 0.1	060.5 − 00.3	19:46.3	24.11	7	19.5	Vul
Abell 65	017 − 21.1	017.3 − 21.9	19:46.6	−23.08	134 × 34	13.8	Sgr
He 1-3	059 − 1.1	059.0 − 01.7	19:48.4	22.1	8	16.0	Vul
NGC 6833	082 + 11.1	082.5 + 11.3	19:49.8	48.58	2	12.1	Cyg
K 3-46	069 + 3.1	069.2 + 03.8	19:50.0	33.46	32 × 17	16.4	Cyg
M 2-48	062 − 0.1	062.4 − 00.2	19:50.5	25.54	10 × 6	16.6	Vul
K 4-37	066 + 2.1	066.9 + 02.2	19:51.0	31.03	12	?	Cyg
PC 23	068 + 3.1	068.7 + 03.0	19:51.9	32.59	5	14.7	Cyg
K 3-49	069 + 2.1	069.2 + 02.8	19:54.0	33.22	3	19.0	Cyg
NGC 6842	065 + 0.1	065.9 + 00.5	19:55.0	29.17	57	13.5	Vul
K 4-41	068 + 1.1	068.7 + 01.9	19:56.6	32.22	3	15.9	Cyg
Abell 66	019 − 23.1	019.8 − 23.7	19:57.5	−21.37	295 × 241	14.9p	Sgr

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
HDW 12	014 − 25.1	014.8 − 25.6	19:58.2	−26.28	46	?	Sgr
Abell 67	043 − 13.1	043.5 − 13.4	19:58.5	3.02	69 × 61	13.6	Aql
He 1-4	068 + 1.2	068.6 + 01.1	19:59.3	31.55	24 × 21	14.2	Cyg
NGC 6853	060 − 3.1	060.8 − 03.6	19:59.6	22.43	480 × 340	7.1	Vul
Abell 68	060 − 4.1	060.0 − 04.3	20:00.2	21.43	40 × 37	15.2	Vul
NGC 6852	042 − 14.1	042.5 − 14.5	20:00.7	1.44	28	12.9	Aql
WeSb 5	058 − 5.1	058.6 − 05.5	20:01.7	19.55	150	?	Sge
K 3-51	056 − 6.1	056.8 − 06.9	20:02.6	17.37	15	14.8	Sge
K 3-52	067 − 0.1	067.9 − 00.2	20:03.2	30.33	stellar	18.7	Cyg
K 3-53	064 − 2.1	064.9 − 02.1	20:03.4	27.01	6	16.8	Vul
K 3-73	084 + 9.1	084.0 + 09.5	20:04.0	49.19	16	15.2	Cyg
M 1-75	068 − 0.1	068.8 − 00.0	20:04.7	31.27	16 × 11	16.0	Cyg
K 3-54	063 − 3.1	063.8 − 03.3	20:05.0	25.27	stellar	?	Vul
K 3-56	079 + 6.1	079.9 + 06.4	20:06.9	44.14	4	?	Cyg
K 3-55	069 + 0.1	069.7 − 00.0	20:06.9	32.17	5	?	Cyg
Dd 1	078 + 5.1	078.6 + 05.2	20:08.7	42.3	20	16.2	Cyg
M 4-17	079 + 5.1	079.6 + 05.8	20:09.0	43.44	23 × 21	14.6	Cyg
We 1-9	065 − 3.1	065.1 − 03.5	20:09.1	26.27	24	?	Cyg
NGC 6884	082 + 7.1	082.1 + 07.0	20:10.4	46.28	6 × 5	11.0	Cyg
NGC 6879	057 − 8.1	057.2 − 08.9	20:10.4	16.55	5	12.7	Sge
NGC 6881	074 + 2.1	074.5 + 02.1	20:10.9	37.25	3	13.6	Cyg
He 1-5	060 − 7.1	060.3 − 07.3	20:11.9	20.2	29	16.2	Sge
KjPn 1	077 + 3.1	077.5 + 03.7	20:12.2	40.5	6	15.6	Cyg
NGC 6886	060 − 7.2	060.1 − 07.7	20:12.7	19.59	9	11.4	Sge
K 3-57	072 + 0.1	072.1 + 00.1	20:12.8	34.21	6	15.9	Cyg
He 2-459	068 − 2.1	068.3 − 02.7	20:14.0	29.34	5	?	Cyg
NGC 6891	054 − 12.1	054.1 − 12.1	20:15.1	12.42	15	10.4	Del
KjPn 2	077 + 3.2	077.7 + 03.1	20:15.3	40.4	4	17.1	Cyg
NGC 6894	069 − 2.1	069.4 − 02.6	20:16.4	30.34	44	12.5	Cyg
KjPn 3	076 + 1.2	076.4 + 01.8	20:17.3	38.5	6	19.0	Cyg
He 1-6	065 − 5.1	065.2 − 05.6	20:17.4	25.22	18 × 13	14.9	Vul
CRBB 1		359.2 − 33.5	20:19.5	−41.32	8	?	Sgr
PC 24	066 − 5.1	066.9 − 05.2	20:19.6	27	5	13.5	Vul
Abell 69	076 + 1.1	076.3 + 01.1	20:19.9	38.25	25 × 22	20.2	Cyg
IC 4997	058 − 10.1	058.3 − 10.9	20:20.1	16.44	2	10.8	Sge
M 3-35	071 − 2.1	071.6 − 02.3	20:21.1	32.29	5	14.6	Cyg
K 3-58	069 − 3.1	069.6 − 03.9	20:22.0	29.59	10 × 7	15.5	Cyg
NGC 6905	061 − 9.1	061.4 − 09.5	20:22.4	20.06	47 × 37	10.9	Del
K 3-76	073 − 2.1	073.0 − 02.4	20:25.1	33.34	4	17.2	Cyg
Sd 1	078 + 0.1	078.9 + 00.7	20:29.3	40.15	8	17.2	Cyg
Abell 70	038 − 25.1	038.1 − 25.4	20:31.6	−7.05	45 × 40	14.7	Aql
We 1-10	086 + 5.1	086.1 + 05.4	20:31.9	48.53	190	?	Cyg
Abell 71	085 + 4.1	084.9 + 04.4	20:32.4	47.21	165 × 150	14.5	Cyg
K 4-53	078 − 2.1	078.3 − 02.7	20:42.3	37.41	20	16.1	Cyg
K 4-55	084 + 1.1	084.2 + 01.0	20:45.2	44.39	27	?	Cyg
K 3-78	088 + 4.1	088.7 + 04.6	20:45.4	50.23	3	19.5	Cyg
Abell 72	059 − 18.1	059.7 − 18.7	20:50.0	13.33	134 × 121	12.7	Del
K 3-79	092 + 5.1	092.1 + 05.8	20:53.2	53.46	12	17.9	Cyg
Abell 73	095 + 7.1	095.2 + 07.8	20:56.4	57.26	80 × 66	17.0	Cep
NGC 7008	093 + 5.2	093.4 + 05.4	21:00.5	54.33	98 × 75	11.0	Cyg
NGC 7009	037 − 34.1	037.7 − 34.5	21:04.2	−11.22	30 × 26	7.8	Aqr
PRMG 1		006.0 − 41.9	21:05.9	−37.08	8	16.7	Mic
NGC 7026	089 + 0.1	089.0 + 00.3	21:06.3	47.51	29×13	10.9	Cyg

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
NGC 7027	084 − 3.1	084.9 − 03.4	21:07.0	42.14	18×11	8.5	Cyg
K 3-80	084 − 4.1	084.2 − 04.2	21:07.7	41.11	6	17.1	Cyg
We 1-11	091 + 1.1	091.6 + 01.8	21:10.9	50.47	25	?	Cyg
Sh 1-89	089 − 0.1	089.8 − 00.6	21:14.1	47.44	44 × 29	14.5	Cyg
NGC 7048	088 − 1.1	088.7 − 01.6	21:14.3	46.17	62 × 60	12.1	Cyg
Abell 74	072 − 17.1	072.7 − 17.1	21:16.9	24.09	871 × 791	15.8	Vul
We 2-245	087 − 3.1	087.4 − 03.8	21:18.1	43.49	35	?	Cyg
M 1-77	089 − 2.1	089.3 − 02.2	21:19.1	46.19	7	?	Cyg
M 1-78	093 + 1.1	093.5 + 01.4	21:20.7	51.53	6	17.0	Cyg
K 3-81	083 − 8.1	083.9 − 08.4	21:22.3	38.07	10	15.5	Cyg
NGC 7076	101 + 8.1	101.8 + 08.7	21:26.4	62.53	67 × 47	14.5	Cep
K 3-60	098 + 4.1	098.2 + 04.9	21:27.4	57.39	3	16.1	Cep
K 3-61	096 + 2.1	096.3 + 02.3	21:30.0	54.27	6	16.8	Cyg
Pease 1	065 − 27.1	065.0 − 27.3	21:30.0	12.1	1	15.1	Peg
K 3-82	093 − 0.1	093.3 − 00.9	21:30.9	50	19	16.1	Cyg
K 3-62	095 + 0.1	095.2 + 00.7	21:31.8	52.34	3	16.1	Cyg
Abell 77	097 + 3.1	097.5 + 03.1	21:32.2	55.53	67 × 50	14.0	Cep
IC 5117	089 − 5.1	089.8 − 05.1	21:32.5	44.36	2	11.5	Cyg
Hu 1-2	086 − 8.1	086.5 − 08.8	21:33.1	39.38	5	11.8	Cyg
Abell 78	081 − 14.1	081.2 − 14.9	21:35.5	31.42	113 × 88	13.4	Cyg
K 3-83	094 − 0.1	094.5 − 00.8	21:35.7	50.54	6	19.7	Cyg
NGC 7094	066 − 28.1	066.7 − 28.2	21:36.9	12.47	99 × 91	13.7	Peg
M 1-79	093 − 2.1	093.3 − 02.4	21:37.0	48.56	39 × 27	13.3	Cyg
K 3-84	091 − 4.1	091.6 − 04.8	21:38.8	46	8	14.7	Cyg
K 3-63	098 + 2.1	098.1 + 02.4	21:39.2	55.46	8 × 6	16.0	Cep
M 2-49	095 − 2.1	095.1 − 02.0	21:43.3	50.25	8	14.3	Cyg
NGC 7139	104 + 7.1	104.1 + 07.9	21:46.1	63.48	86 × 70	13.4	Cep
M 2-50	097 − 2.1	097.6 − 02.4	21:57.7	51.42	5 × 3	14.5	Cyg
IC 5148	002 − 52.1	002.7 − 52.4	21:59.6	−39.23	120	11.0	Gru
IsWe 2		107.7 + 07.8	22:13.4	65.54	600	?	Cep
M 2-51	103 + 0.1	103.2 + 00.6	22:16.1	57.29	47 × 38	13.6	Cep
DeHt 5	111 + 11.1	111.0 + 11.6	22:19.6	70.56	530	?	Cep
Bl 2-1	104 + 0.1	104.1 + 01.0	22:20.3	58.14	stellar	17.3	Cep
M 2-52	103 + 0.2	103.7 + 00.4	22:20.5	57.36	13 × 12	14.1	Cep
IC 5217	100 − 5.1	100.6 − 05.4	22:23.9	50.58	8 × 6	11.3	Lac
Abell 79	102 − 2.1	102.9 − 02.3	22:26.3	54.5	59 × 49	15.3	Lac
NGC 7293	036 − 57.1	036.1 − 57.1	22:29.6	−20.5	880 × 720	7.6	Aqr
Me 2-2	100 − 8.1	100.0 − 08.7	22:31.7	47.48	5	11.5	Lac
M 2-53	104 − 1.1	104.4 − 01.6	22:32.3	56.1	14	14.8	Lac
Abell 80	102 − 5.1	102.8 − 05.0	22:34.8	52.26	161 × 114	16.0	Lac
NGC 7354	107 + 2.1	107.8 + 02.3	22:40.3	61.17	28 × 20	12.2	Cep
IC 1454	117 + 18.1	117.5 + 18.9	22:42.6	80.27	34 × 31	14.4	Cep
KjPn 6	111 + 6.1	111.2 + 07.0	22:47.9	67.03	6	18.2	Cep
K 4-57	107 − 0.1	107.4 − 00.6	22:48.6	58.29	stellar	19.6	Cep
M 2-54	104 − 6.1	104.8 − 06.7	22:51.6	51.51	4	15.0	Lac
K 3-87	107 − 2.2	107.4 − 02.6	22:55.1	56.43	4	17.7	Lac
M 1-80	107 − 2.1	107.7 − 02.2	22:56.3	57.09	8	13.4	Cep
PM 1-339		110.1 + 01.9	22:58.9	61.58	6	?	Cep
K 3-88	112 + 3.1	112.5 + 03.7	23:12.3	64.39	5	18.6	Cep
Vy 2-3	107 − 13.1	107.6 − 13.3	23:23.0	46.54	5	13.5	And
KjPn 8	112 − 0.1	112.5 − 00.1	23:24.3	60.56	4	18.2	Cas
NGC 7662	106 − 17.1	106.5 − 17.6	23:25.9	42.32	32 × 28	8.3	And
Hb 12	111 − 2.1	111.8 − 02.8	23:26.2	58.11	1	11.8	Cas

(continued)

(continued)

Name	P-K	PNG	RA	Dec	Size	Mag	Con
M 2-55	116 + 8.1	116.2 + 08.5	23:31.9	70.22	42 × 36	14.4	Cep
Jn 1	104 − 29.1	104.2 − 29.6	23:35.9	30.28	314	12.1	Peg
K 1-20	110 − 12.1	110.6 − 12.9	23:39.1	48.13	37 × 31	16.5	And
Abell 82	114 − 4.1	114.0 − 04.6	23:45.8	57.04	94	12.7	Cas
Abell 83	113 − 6.1	113.6 − 06.9	23:46.8	54.45	42 × 37	15.5	Cas
Abell 84	112 − 10.1	112.9 − 10.2	23:47.7	51.24	147 × 114	13.0	Cas

Chapter 6

Planetary Nebulae by Constellation

The following section details in constellation order rather than right ascension order each planetary nebula found on the primary list. This format makes it easier for those interested in planning an observing session around a particular constellation or seasonal group in order to experience not just the planetaries but also the many additional types of objects to be found there. It also allows the reader to enjoy the objects in a more accessible manner.

Included is a general view of each constellation and more detailed finder charts, enabling the observer to track the planetaries down by reference to constellation stars and other bright objects. Each finder chart is not to the same scale, though efforts have been made to provide similar scaling for all such charts.

Each planetary nebula is described in general terms, though it must be stressed that observers may see these objects differently depending on their visual acuity, telescope aperture or maximum/minimum magnifications. It is indicated if such planetary nebulae are part of other catalogues or observing programs such as the Astronomical League's Herschel 400 program or part of the Caldwell catalogue. NGC or other catalogue numbers recognized by the International Astronomical Union are given a part of the identifier to each object. As a final touch, each planetary nebula has been photographed using the Faulkes telescopes in Hawaii and Australia to aid identification. The field of view of each photograph is $4.5' \times 4.5'$, and the pictures are a combination of red, green and blue (RGB) filters combined and adjusted in *Photoshop*. Any deviation from this pictorial angular size is noted in the description for the object.

The Vorontsov-Velyaminov taxonomy is the basis for each description, and recognized classifications are also quoted in the general information for each planetary nebula. Magnitudes are taken from catalogue sources, as are their angular sizes and positions. Although it is possible to make one's own judgment on angular size based on observations at the eyepiece, these quoted sizes have been obtained photographically and thus the eyepiece view may differ slightly, as faint details at the extremes of the object will not be recorded by the eye.

The abbreviations NP, SP, NF, and SF as they appear in the following pages are shorthand for North Preceding, South Preceding, North Following and South Following. These terms are regularly used in amateur and professional astronomy to describe an object's position in relation to a reference star or position within an object (taking into consideration the altitude and the right ascension of the object close to that star/object). Preceding will be West and Following will be East.

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides,
DOI 10.1007/978-1-4614-1782-8_6, © Springer Science+Business Media, LLC 2012

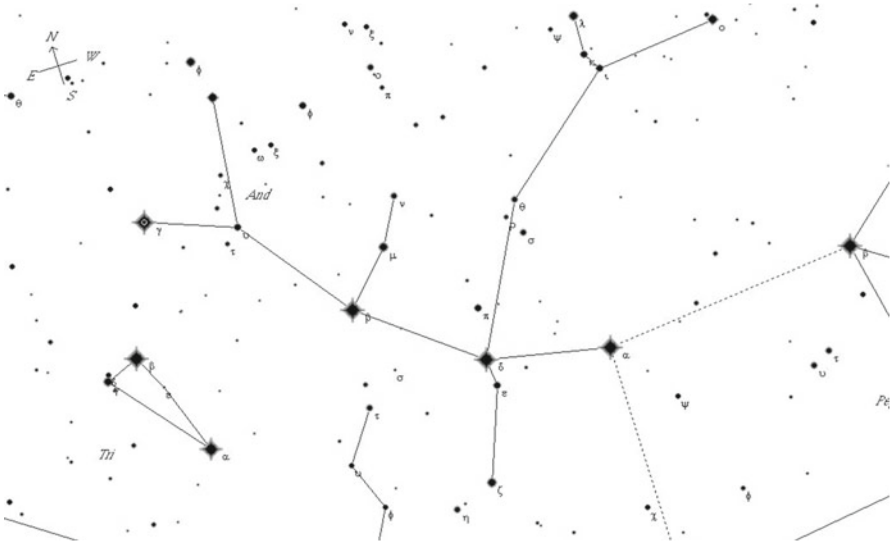
Where possible, the relationship of nebulae to particular guide stars are included for those observers equipped with telescopes that are not driven or have no GOTO systems. Such star-hopping techniques are well known to amateur observers, and sweeping an area for faint objects usually comes with experience, though with today's technology, most observers are content with their GOTO systems, and finding the fields should present few problems – all that is left is locating your planetary nebulae candidate!

Andromeda

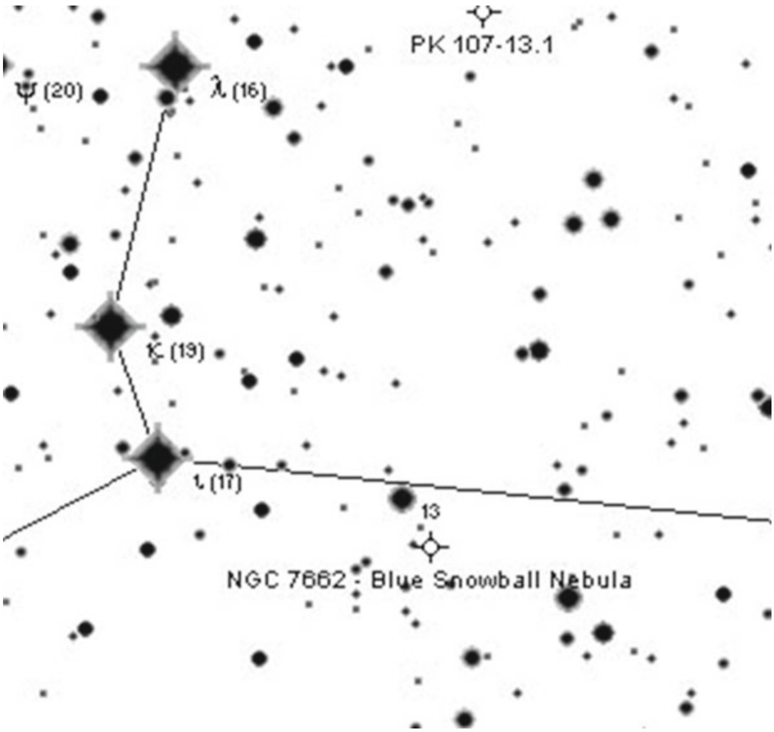
NGC 7662
Andromeda
RA: 23 h 25 m 54 s
Dec: +42.32.1
Size: 32″
Magnitude: 8.3
Class: 4 + 3

The beautiful "Blue Snowball" planetary nebula in northern Andromeda. A wonderful object, as its intense blue color and mottled appearance in low powers renders it precisely as its name implies. It can be found SE of ιAndromedae and is an immediate, arresting sight as a blue ball over 30″ across standing out in the field of view. There is a central condensation visible in moderate powers that occasionally looks star-like. NGC 7662 is visible in any sized telescope, and low to moderate magnifications seem best to use. It is catalogued as a Herschel 400 object and is also known as Caldwell 22.

General view of Andromeda



Finder chart for NGC 7662



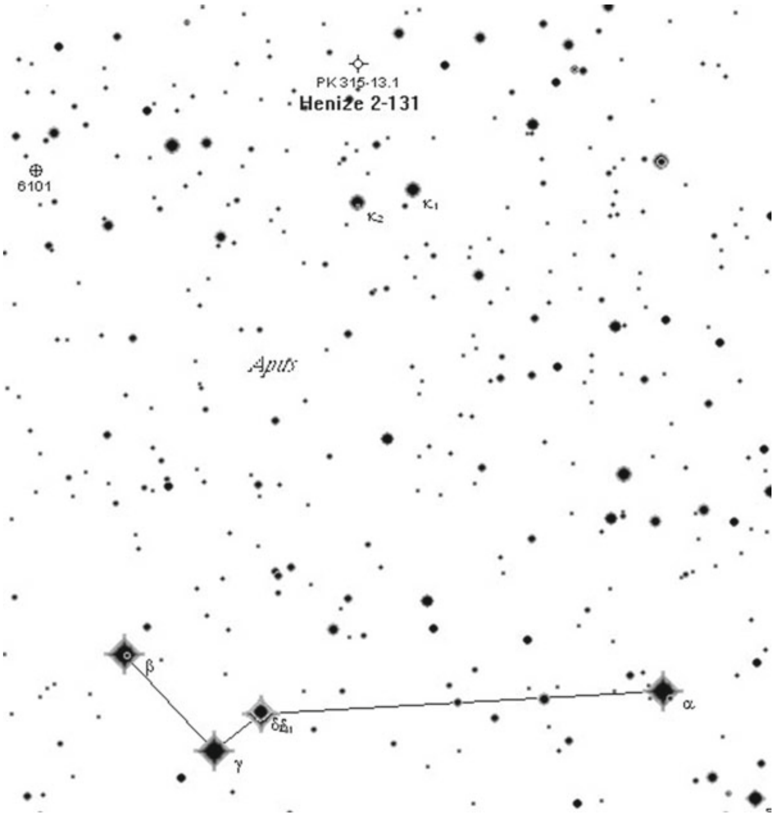
Apus

Henize 2–131
Apus
RA: 15 h 37 m 17 s
Dec: −71.54.09
Size: 6″
Magnitude: 11.1
Class: 2a

A small and relatively faint planetary nebula in Apus that is a challenge for users of ‘scopes below 150 mm aperture, as this object demands a high magnification and good clear field to spot it. There is moderate response to the use of an OIII filter, and the planetary is small and round; it is also slightly blue in high powers and reveals no elongation or extensions at all. It is somewhat of a challenge.

General view of Apus

Finder chart for Henize 2–131



Aquarius

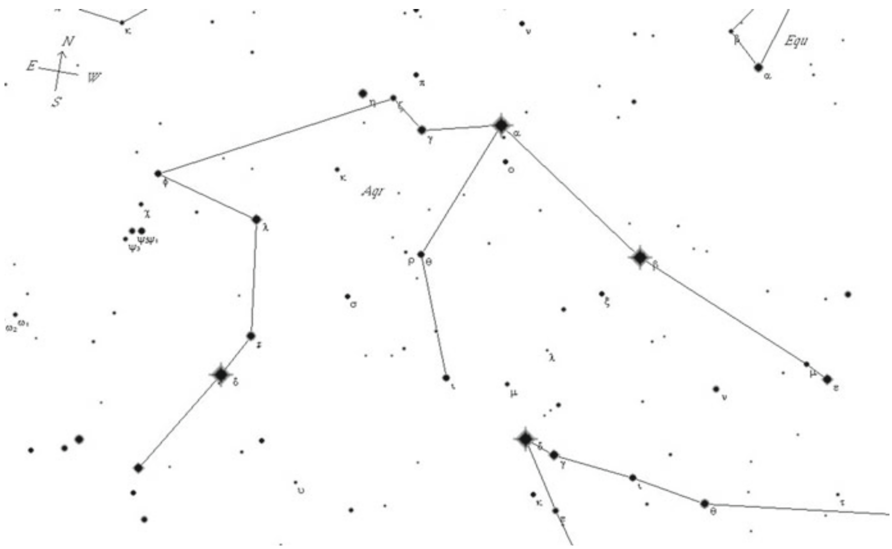
NGC 7009
Aquarius
RA: 21 h 04 m 11 s
Dec: −11.21.8
Size: 44″
Magnitude: 7.8
Class: 4 + 6

The stunning "Saturn" Nebula in Aquarius, which is visible in 'scopes of all apertures and reveals great detail in its elongated body and rays at higher powers. In low power these tiny "ansae," or rays, and FLIERS, plus the lovely green hue of the planetary are instantly visible, although moderate power does show some subtle patterning of the body of the nebula. In averted vision at higher powers, observers equipped with 'scopes of 20 cm + will see small blobs on the end of the ansae. A fantastic object, and it comes as no surprise to learn that it is both Caldwell 55 and a Herschel 400 catalogue object, too.

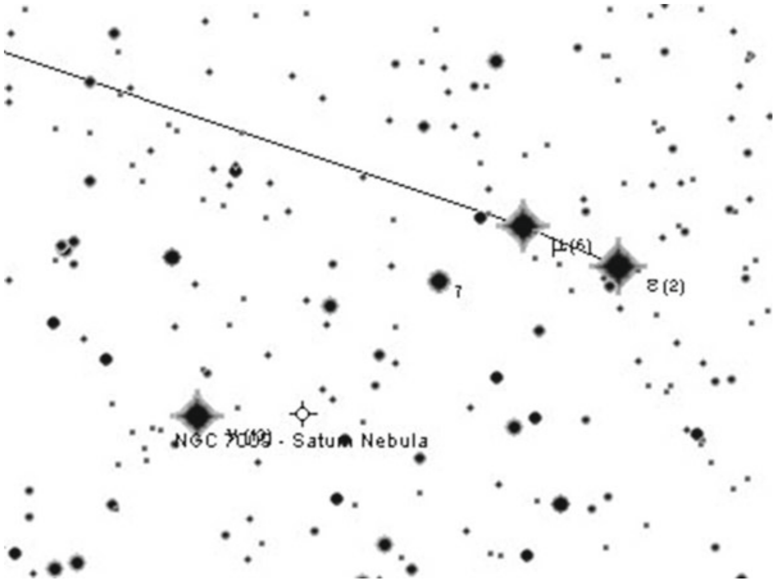
NGC 7293
Aquarius
RA 22 h 29 m 39 s
Dec −20.50.2
Size 12′
Magnitude 7.3
Class 4 + 3

The wonderful "Helix Nebula" in Aquarius, which is a glorious sight in telescopes of large aperture, but despite its magnitude, it remains nearly invisible in smaller telescopes for users in high northern latitudes. It can be seen as a ghostly ring of green-gray light at low powers and is surprisingly large but shows a ring structure and a darker inner core quite easily. NGC 7293 looks best in 20 × 80 binoculars, as the field is larger and the combined light from the object becomes easier to grasp as it is better concentrated – the observer is then looking at it, not through it! NGC 7293 is a beautiful and fairly detailed object, which also has the catalogue number Caldwell 63. This image was captured with a Canon 1000D DSLR and an f10 100 mm refractor.

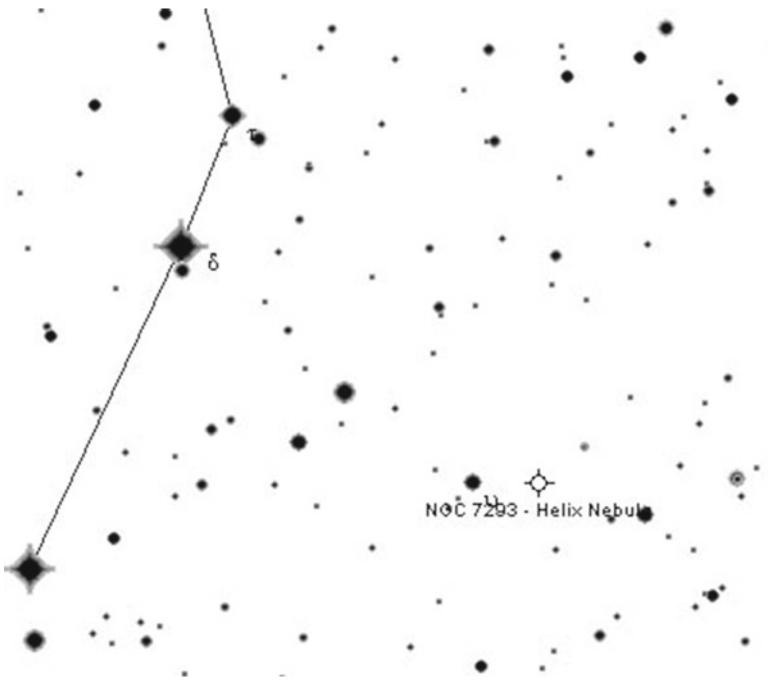
General view of Aquarius



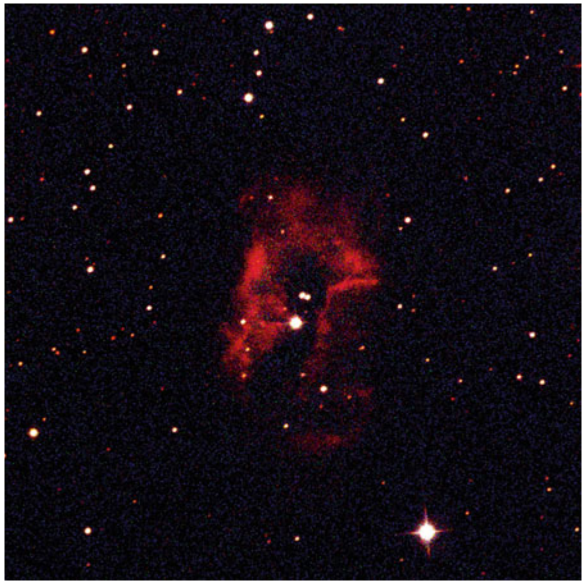
Finder chart for NGC 7009



Finder chart for NGC 7293



Aquila



Sharpless 2–71
Aquila
RA: 19 h 02 m 01 s
Dec: +02.09.24
Size: 107″
Magnitude: 13.2
Class: 3b

Sh 2–71 is a gray smudge of light in a rich Milky Way field in a difficult part of Aquila to get to by star hopping, though GOTO users should have few problems. Once the field is located, most observers with larger telescopes are rewarded with a faint irregular glow that is almost lost against the backdrop sky. Sh 2–71 lies not far from the globular cluster NGC 6749. Low powers initially are a little better than high magnifications, due to the size of this planetary, which is over 1′ across, oval and elongated along a N/S axis with a slightly darker center with averted vision. The nebula responds moderately to use of an OIII filter, but for most observers Sh 2–71 remains a uniformly faint thing, just at the edge of vision.

NGC 6741
Aquila
RA: 19 h 02 m 37 s
Dec: −00.27.0
Size: 9″
Magnitude 11.4
Class 4

Small almost stellar nebula in low powers, which has a distinct greenish hue in averted vision that increases with the contrast of magnification. In moderate powers the nebula is round and well defined, not stellar but just bordering on it, contained in a rich Milky Way field; it responds well to use of an OIII filter. NGC 6741 always seems a bit brighter than it's quoted magnitude of 11.4 and can be seen in most telescopes as a nice greenish ball of light. Higher powers on larger apertures may show the separation of the central mass from the slightly thicker edges.

NGC 6751
Aquila
RA: 19 h 05 m 56 s
Dec: −05.59.5
Size: 21″
Magnitude: 11.9
Class: 3

The "Dandelion Puffball" is a nice little blue planetary south of λ Aquilae that seems much brighter than its quoted 12th magnitude. In low powers it is small, round and mottled with a strong hint of turquoise to it, which moderate and high magnifications seem to bring out a little better, though nothing of the central star is visible as the nebula is evenly filled with pale blue light no matter what instrument is used. NGC 6751 seems brighter than its quoted magnitude and is visible under good conditions in a 110 mm Tal reflector.

NGC 6772
Aquila
RA: 19 h 14 m 36 s
Dec: –02.42.5
Size: 1′
Magnitude: 12.7
Class: 3b

This nebula is a small gray featureless patch of faint light NF the star λ Aquilae, which the OIII filter makes a little more visible in a field replete with faint stars. There is no central star that can be seen with average apertures inside the perimeter, though in larger apertures the outer part of the disk shows a brighter rendering with a faint shimmering within the tiny disk. The planetary is also slightly elongated on a N/S axis, though careful observation with high magnification is required to confirm this.

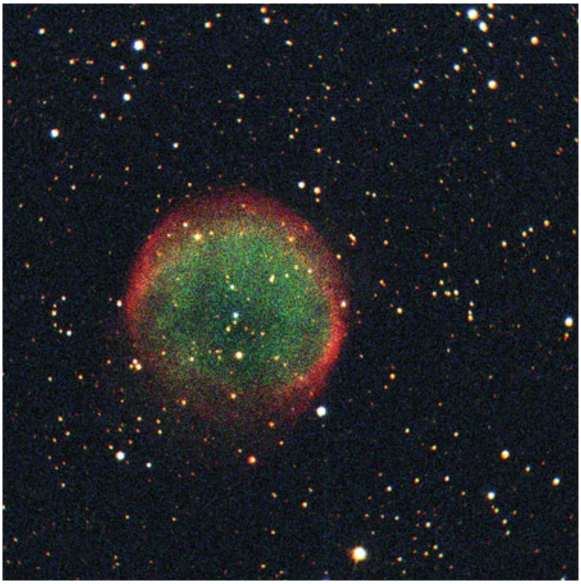
IC 4846
Aquila
RA: 19 h 16 m 28 s
DecV —09.02.6
Size: 5″
Magnitude: 11.9
Class: 2

Discovered on Harvard photographic plates by Williamina Fleming in 1901, IC 4846 is a small faint planetary nebula called SF 20 Aquilae and located in a dense Milky Way field that renders it difficult to spot without use of an OIII filter. It is a subtle, less than stellar spot in moderate powers, with a slight blue hue in averted vision. Higher powers render much the same view and color, and it remains a very star-like dot of light.

NGC 6778 or NGC 6785
Aquila
RA: 19 h 18 m 25 s
Dec: −01.35.8
Size: 25″
Magnitude: 12.3
Class: 3

NGC 6778 is a lovely little planetary with a gray disk-like appearance and a deeper, mottled center hinting at structure. In higher powers the nebula appears to have a thicker outer edge and is oval and slightly elongated with an E-W axis. Use of an OIII filter confirms its presence as it responds well to this aid and it is easy to find just SP, which is a trio of sixth magnitude stars in the center of the constellation SP ν Aquilae. Bright enough to be seen in most 'scopes, and some observers report seeing it in telescopes of 100 mm aperture. It has a dual NGC designation, which is usually shown on charts as NGC 6785.

NGC 6781
Aquila
RA: 19 h 18 m 28 s
Dec: −06.32.2
Size: 120″
Magnitude: 11.4
Class: 3

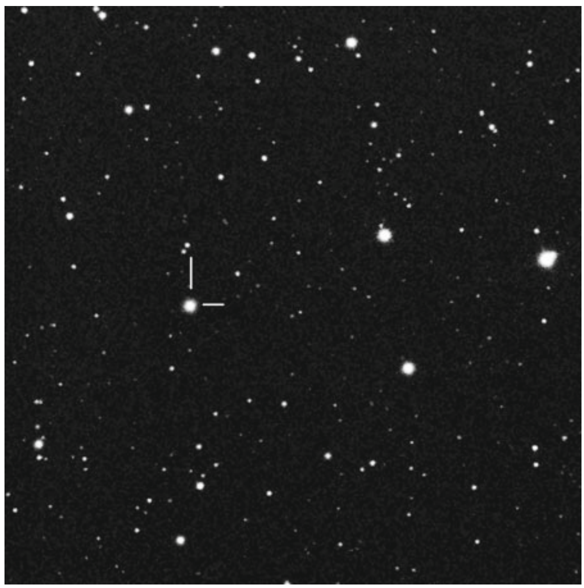


NGC 6781 is a beautiful, ghostly nebula in the heart of Aquila. Best to star hop from δ Aquilae where after locating the field the observer should be rewarded with a large blue-gray patch of light almost 2′ across that is distinctly fainter on the southern portion even at low powers. The nebula is revealed as an 11th magnitude halo with a thicker N edge and a central darkening that is irregular and mottled yet still opaque to the central star. It can be seen in apertures less than 150 mm under good conditions and is also a Herschel 400 catalogue object.

NGC 6790
Aquila
RA: 19 h 22 m 57 s
Dec: +01.30.8
Size: 10″
Magnitude: 10.5
Class: 2

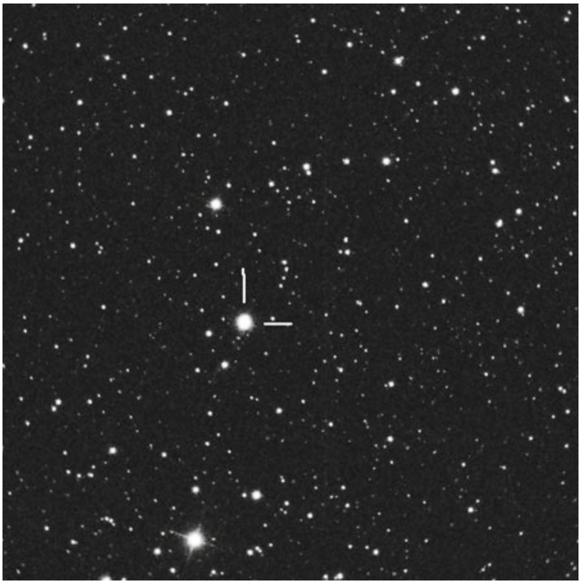
NGC 6790 is a small though fairly bright planetary nebulae forming a triangle with δ and 35 Aquilae in a rich Milky Way field in the central portion of the constellation. The object is blue-white in color and almost stellar in low powers. Moving to higher magnifications gives a better impression, and the planetary seems a little elongated on an E-W axis. NGC 6790 is bright enough to be seen in most telescopes and responds well to use of an OIII filter. Contrast this one with NGC 6781 to make clear the differences between the objects in this class.

Vy 2–2
Aquila
RA: 19 h 24 m 23 s
Dec: +09.53.9
Size: 14″
Magnitude: 12.7
Class: 1



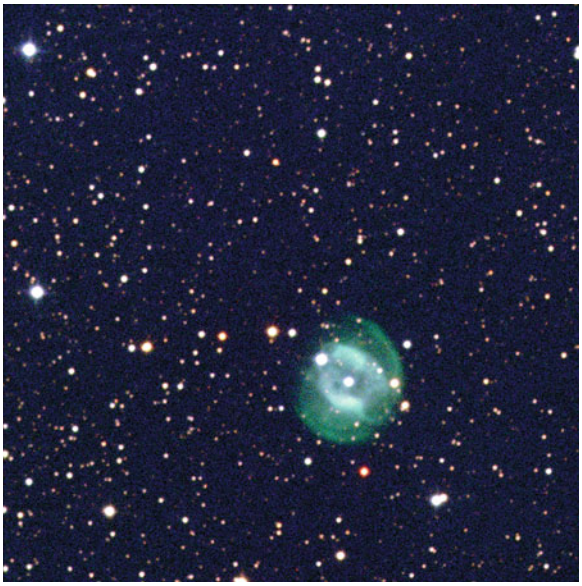
A small and very difficult object in a rich Milky Way field that takes some careful searching and necessitates the use of an OIII filter. Observers may star hop from μ Aquilae 3° NW to a mag 6 star visible in a finder, and the planetary is just a few minutes W of the star. Vy 2–2 is tiny and unimpressive, and one's general impression is that it remains star-like no matter what the power used, although higher magnifications render the object easier to distinguish from the starry backdrop, and a slight enlargement of the object distinguishes it from the stellar points.

NGC 6803
Aquila
RA: 19 h 31 m 16 s
Dec: +10.03.4
Size: 6″
Magnitude: 11.4
Class: 2a



Great little stellar object that shows a hint of green color even at low powers and is easily spotted in a field 3° west of γ Aquilae. NGC 6803 is about 11th magnitude, and although small, it's one of the easiest of the planetary nebulae in Aquila, as it's not a dim blob. In moderate power it separates from the star fields surrounding it, and averted vision makes it look a little blurred – as if it's got a surrounding "shell." It also looks a little elongated due to the proximity to a faint star on its N edge. A lovely planetary that should be visible in most telescopes despite its small size.

NGC 6804
Aquila
RA: 19 h 31 m 35 s
Dec: +09.13.5
Size: 60″
Magnitude: 12.0
Class: 4 + 2



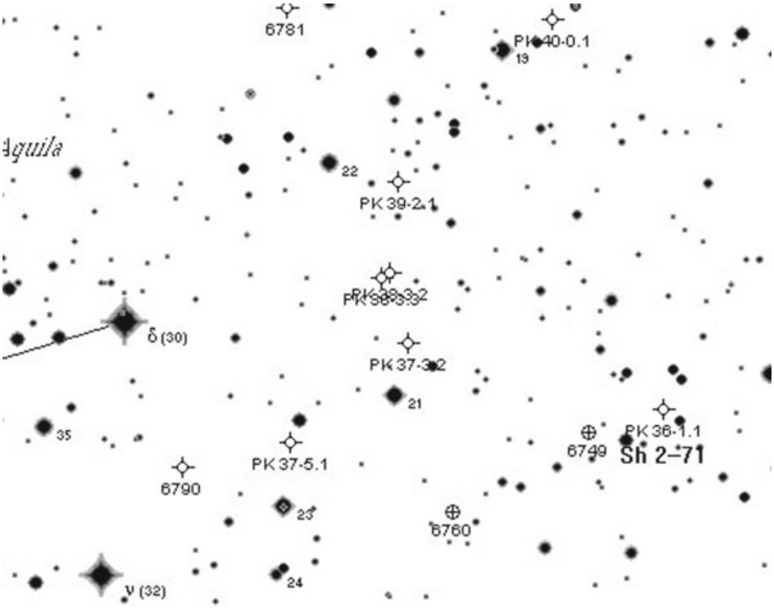
A wonderful, ghostly little nebula with a visible central star, lying close to γ Aquilae in the rich Milky Way of this region. NGC 6804 is extended, gray in color in low powers and is flanked by two 12th mag stars, which make identifying its location easier. NGC 6804 is quite a nice planetary reminiscent of NGC 6781 in some way, as it forms a little shell that has some detail in its periphery with high powers and averted vision With careful observation a "ring" can be seen surrounding the central star and a hint of an "atmosphere" outside of this.

NGC 6807
Aquila
RA: 19 h 34 m 34 s
Dec: +05.41.0
Size: 3″
Magnitude: 12.2
Class: 2

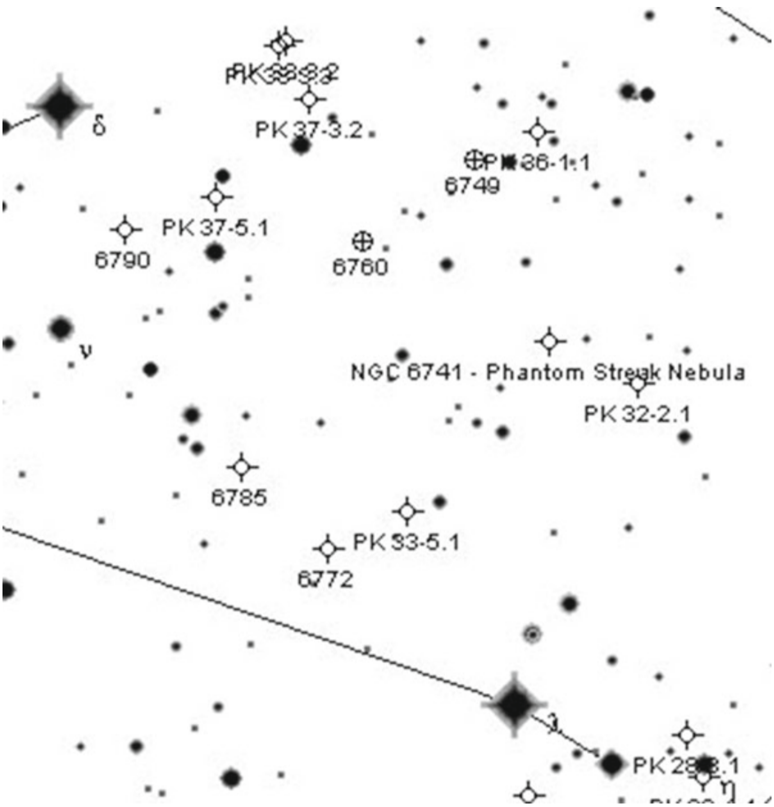
This is a small planetary in a good star field almost directly south of μ Aquilae by 2°. Use of an OIII filter will bring it out immediately, revealing itself as a little star in low power. Going to moderate or higher powers shows a tiny disk, though beware of loss of contrast and color. NGC 6807 seems a bit brighter than it's quoted magnitude of 12 and may make an acceptable target for telescopes of 150 mm aperture and under if the conditions are right. The proximity of an orange star SF gives the field away and a careful search will find it almost immediately.

General view of Aquila

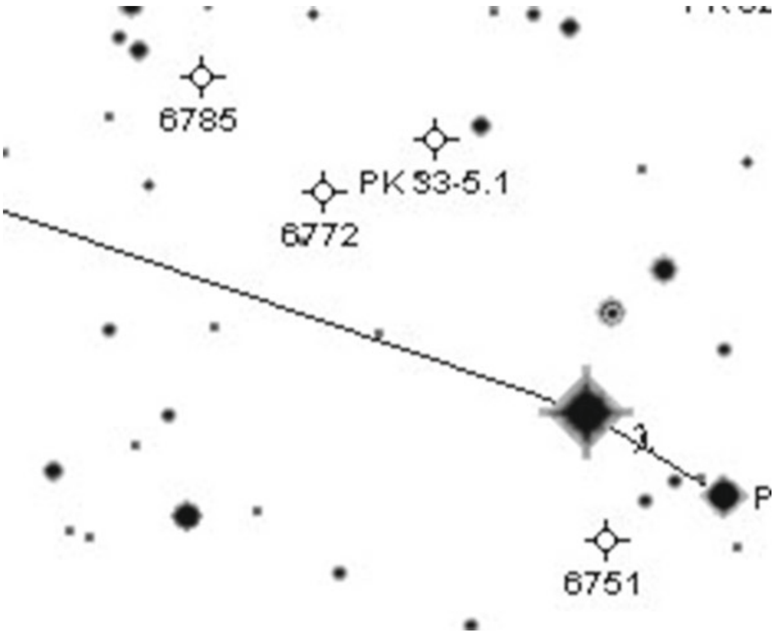
Finder chart for Sh 2–71



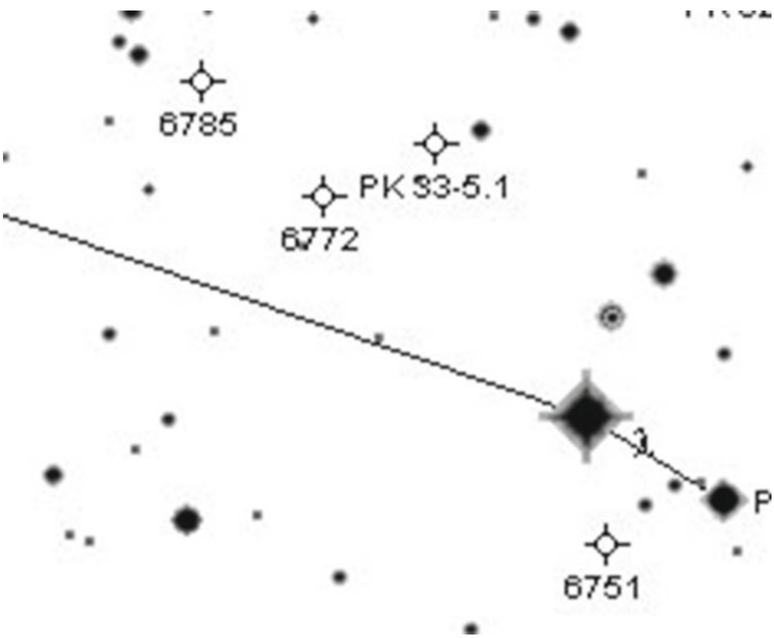
Finder chart for NGC 6741



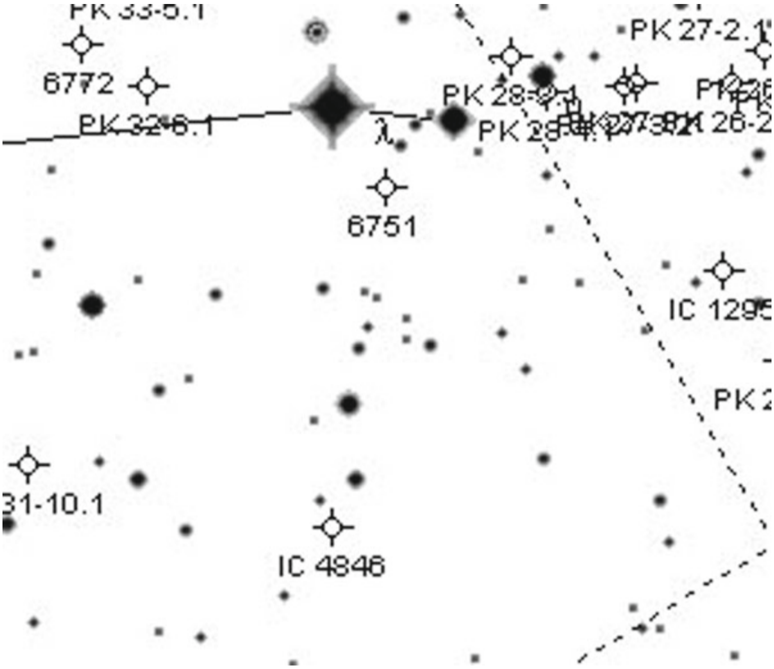
Finder chart for NGC 6751



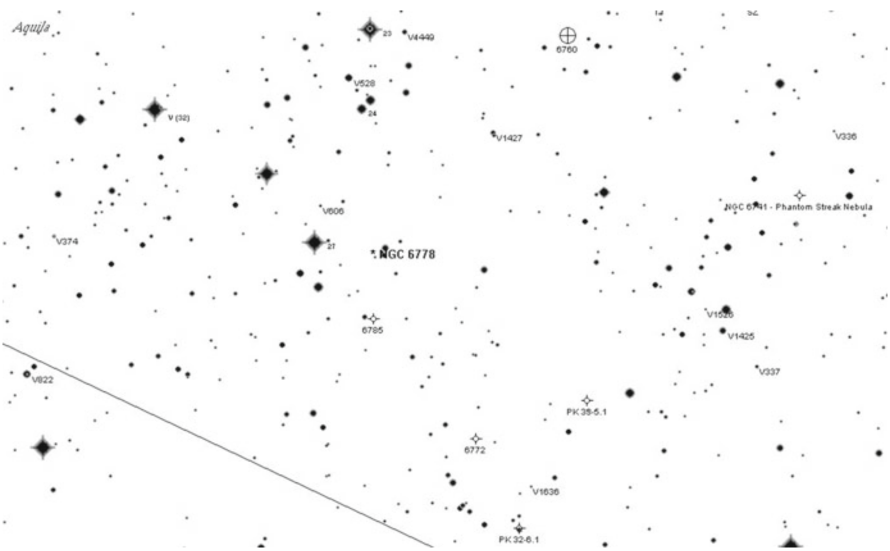
Finder chart for NGC 6772



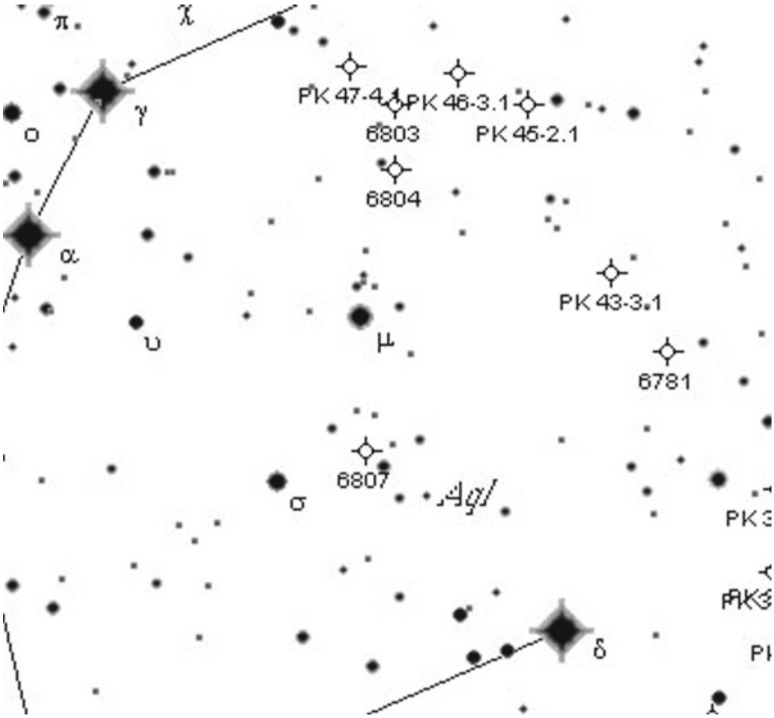
Finder chart for IC 4846



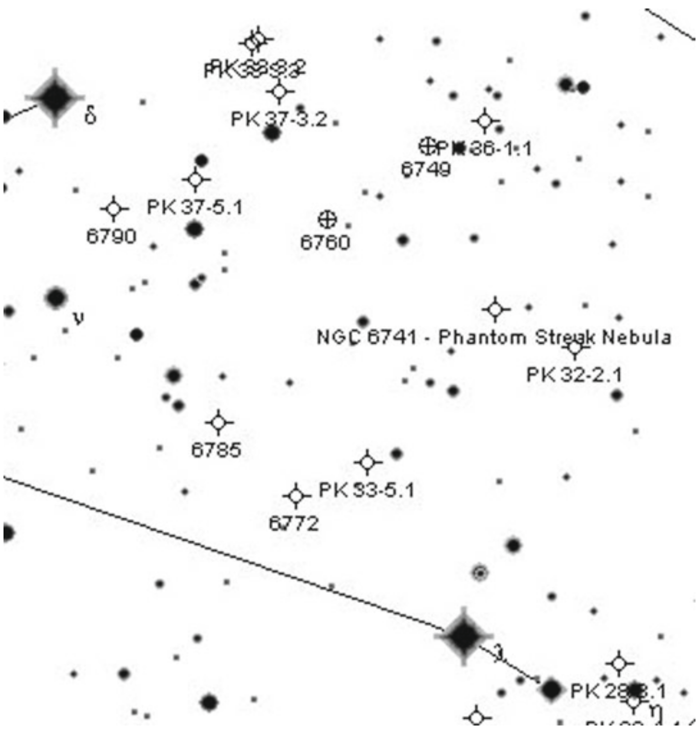
Finder chart for NGC 6778



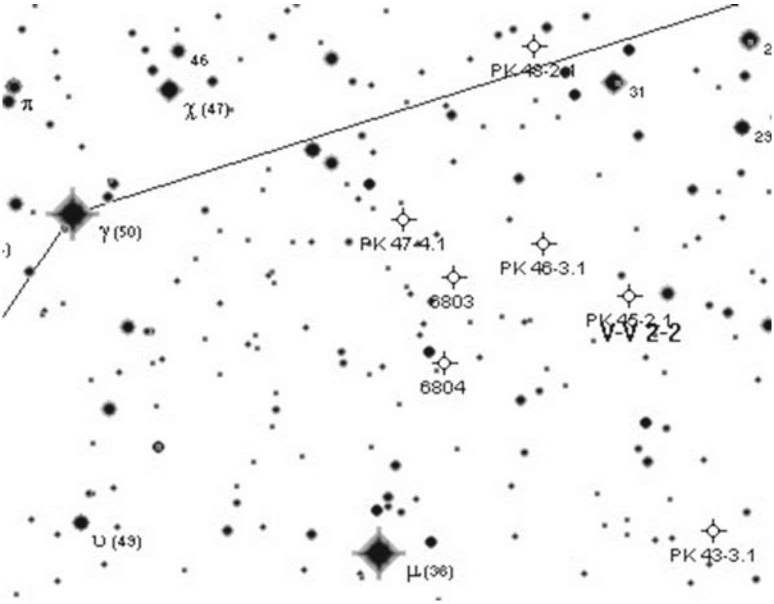
Finder chart for NGC 6781



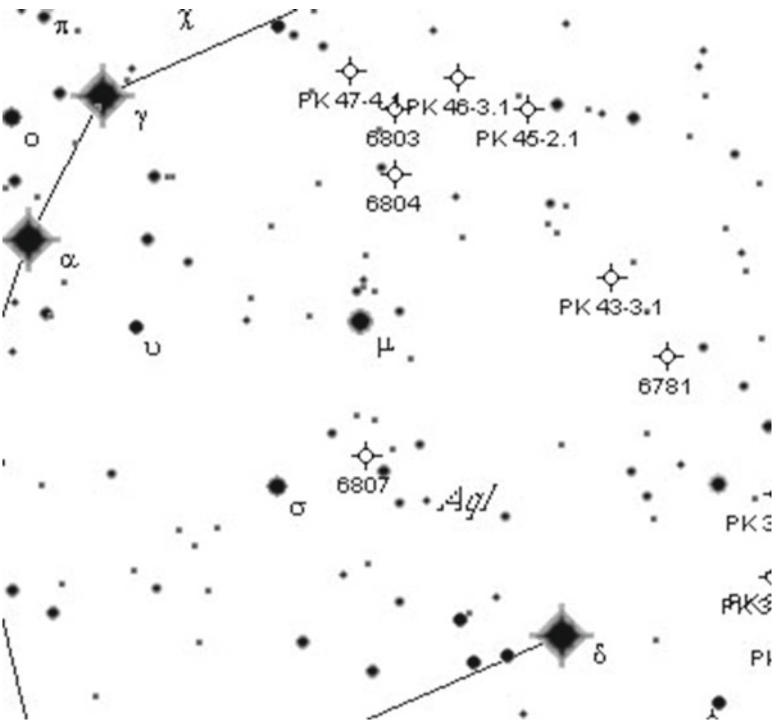
Finder chart for NGC 6790



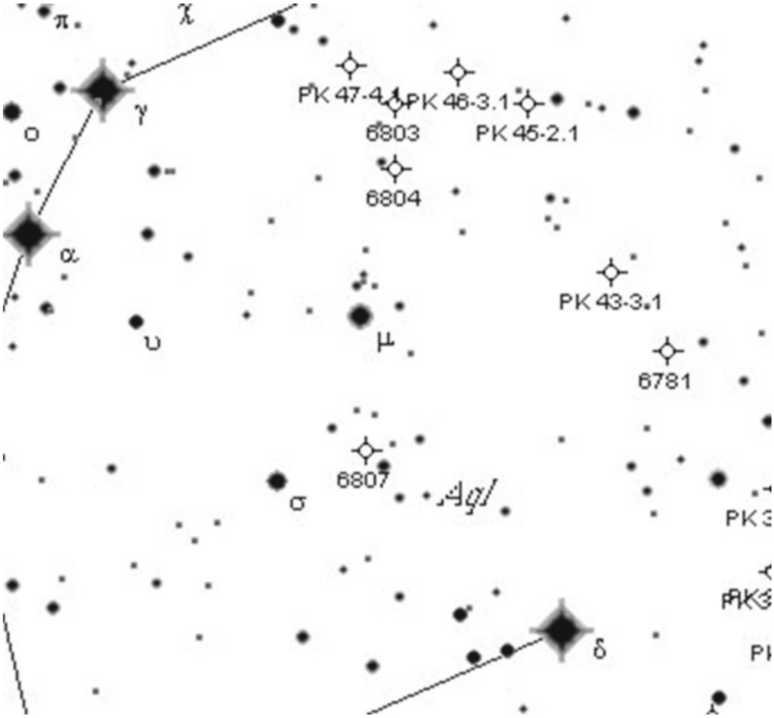
Finder chart for Vy 2–2



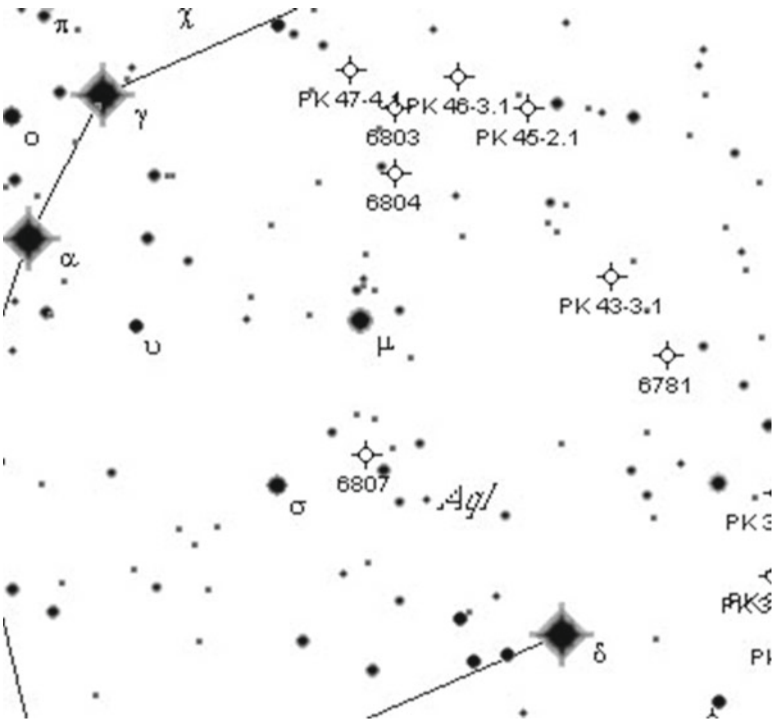
Finder chart for NGC 6803



Finder chart for NGC 6804

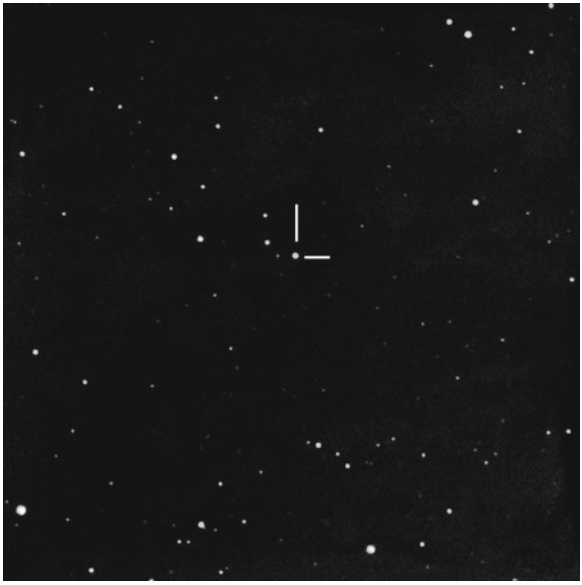


Finder chart for NGC 6807



Ara

Henize 2–172
Ara
RA: 16 h 37 m 07 s
Dec: −55.42.24
Size: 6″
Magnitude: 12.6
Class: 2a

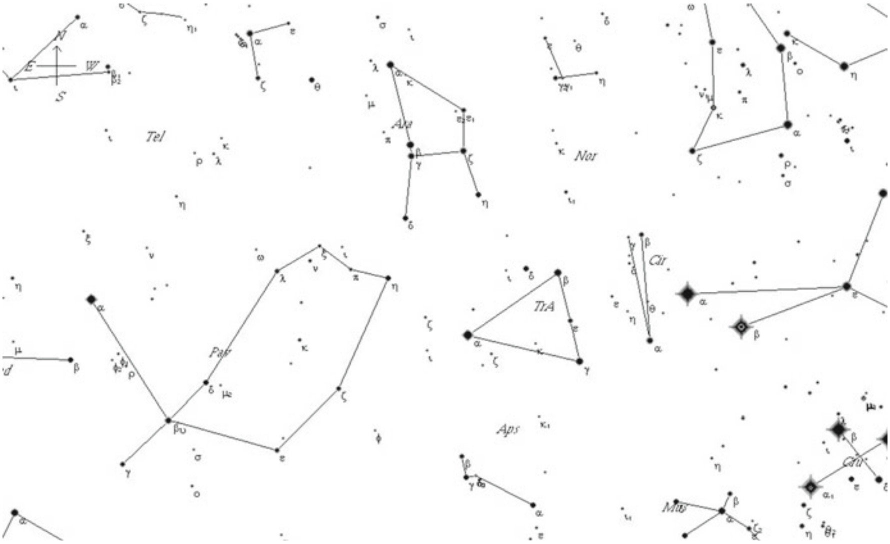


Small planetary nebula found to the east of the scattered star cluster NGC 6208. An observer equipped with a Dobsonian or similar can star hop eastwards from ε Ara to the cluster and locate the planetary just to the NE of the group. He 2–172 is a tiny point of white light that, upon first glance, shows a slight blue color in higher magnifications and gives a moderate response to an OIII filter. It also seems to be a little brighter than its quoted magnitude, but this is little help in locating it in this rich star field of the southern Milky Way.

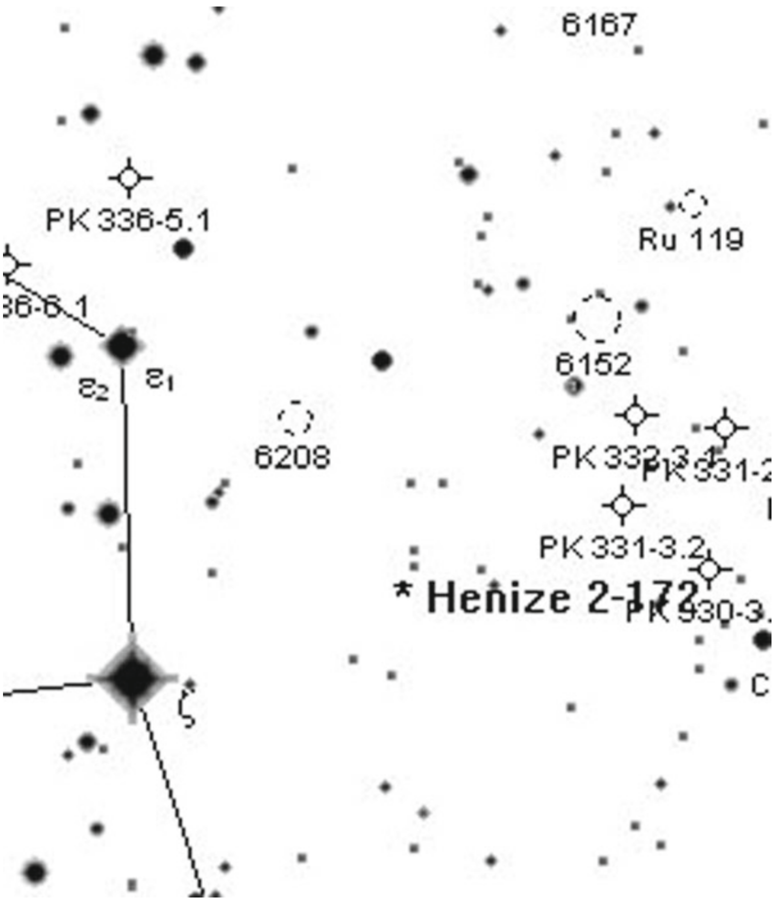
NGC 6326
Ara
RA: 17 h 21 m 40s
Dec: −51.45.49
Size: 12″
Magnitude: 12.1
Class: 3a + 5

NGC 6326 is surprisingly bright for its quoted magnitude and is immediately evident in the field despite the rich field stars of the Milky Way here. At 12′ across, it is small but evidently different from its stellar neighbors and shines with a blue glow that is destroyed with the use of an OIII filter, though using one makes locating the object easier. The nebula is a round disk and has an 11th mag star close to the south and is a very nice object for most telescopes due to its high surface brightness and compact area. Users of large telescopes may resolve some irregularities within the disk.

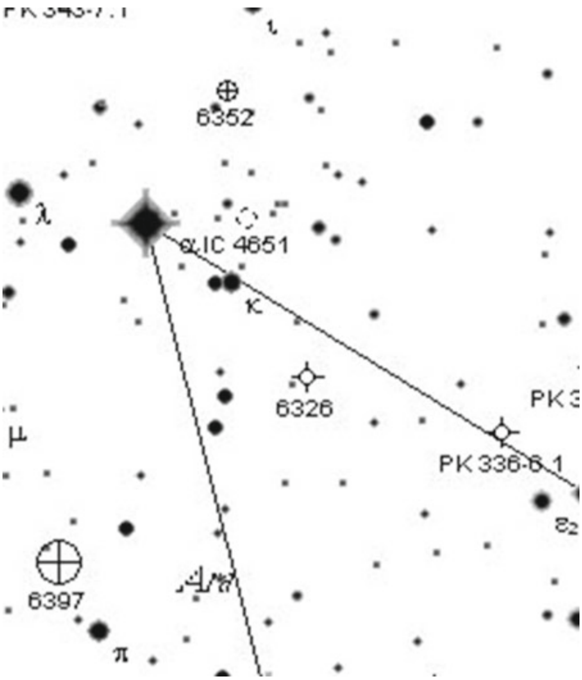
General view of Ara



Finder chart for He 2–172



Finder chart for NGC 6326

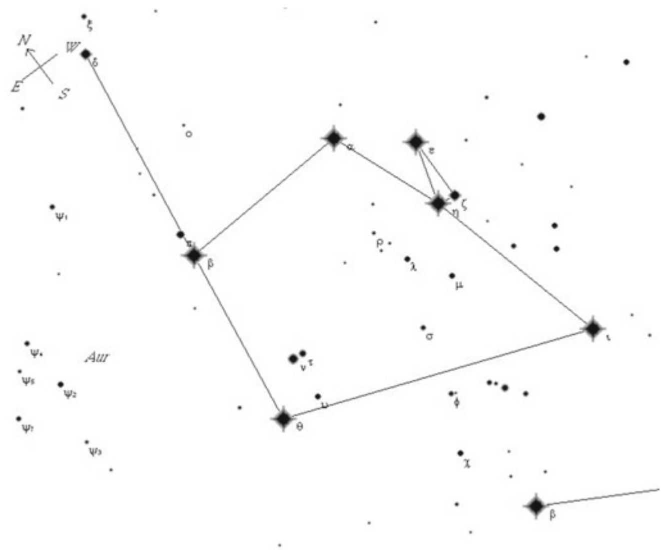


Auriga

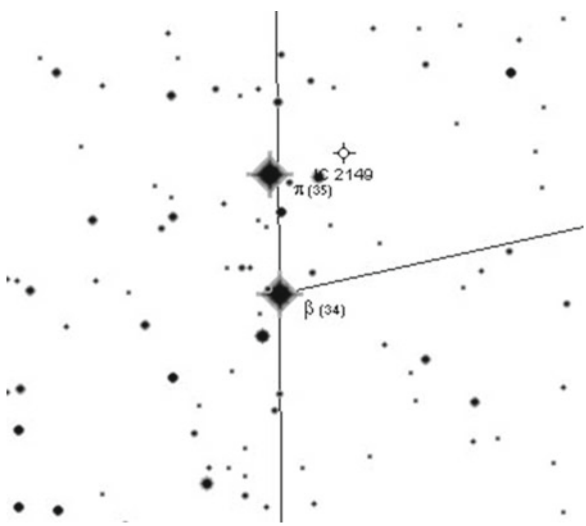
IC 2149
Auriga
RA: 05 h 56 m 24 s
Dec: +46.06.3
Size: 15″
Magnitude: 10.7
Class: 3b + 2

This object is a tiny, almost stellar object close to β Auriga in a low power eyepiece field. It is recommended that the observer uses higher powers and puts Menkalina (β Aur) out of the way. Even in higher powers IC 2149 is still almost stellar with a hint of extension but nothing more, no central star visible, but its color changes slightly, going from gray to a slight blue cast. Not a difficult object to see in most 'scopes as the integrated magnitude is under 11, but it's so small that the observer could easily miss it in the star fields here.

General chart of Auriga



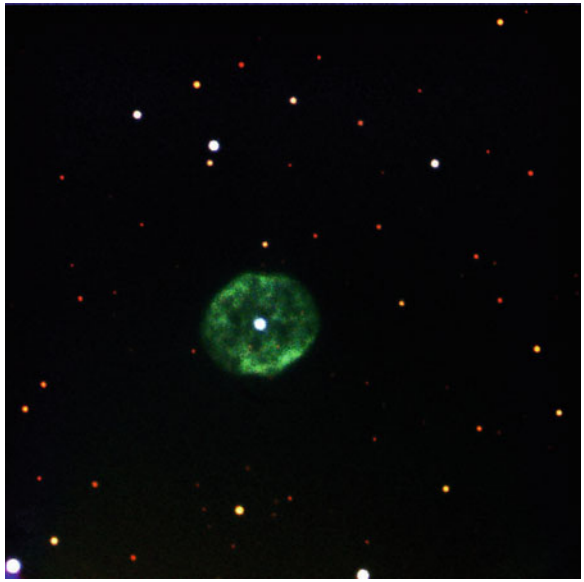
Finder chart for IC 2149



Planetary Nebulae by Constellation

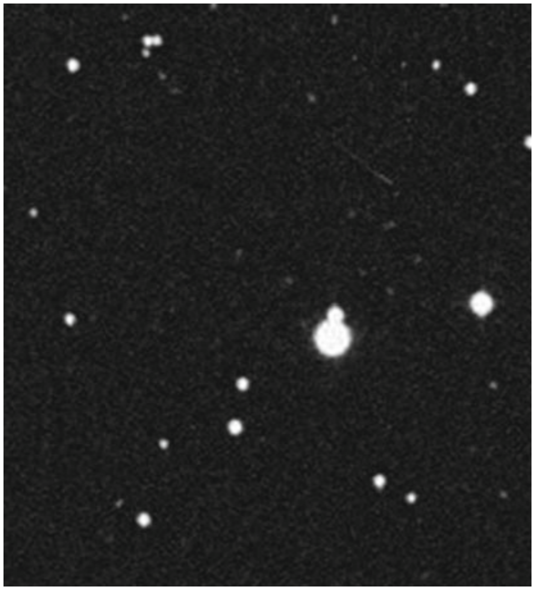
Camelopardalis

NGC 1501
Camelopardalis
RA: 04 h 06 m 59 s
Dec: +60.55.2
Size: 56″
Magnitude: 11.4
Class: 3



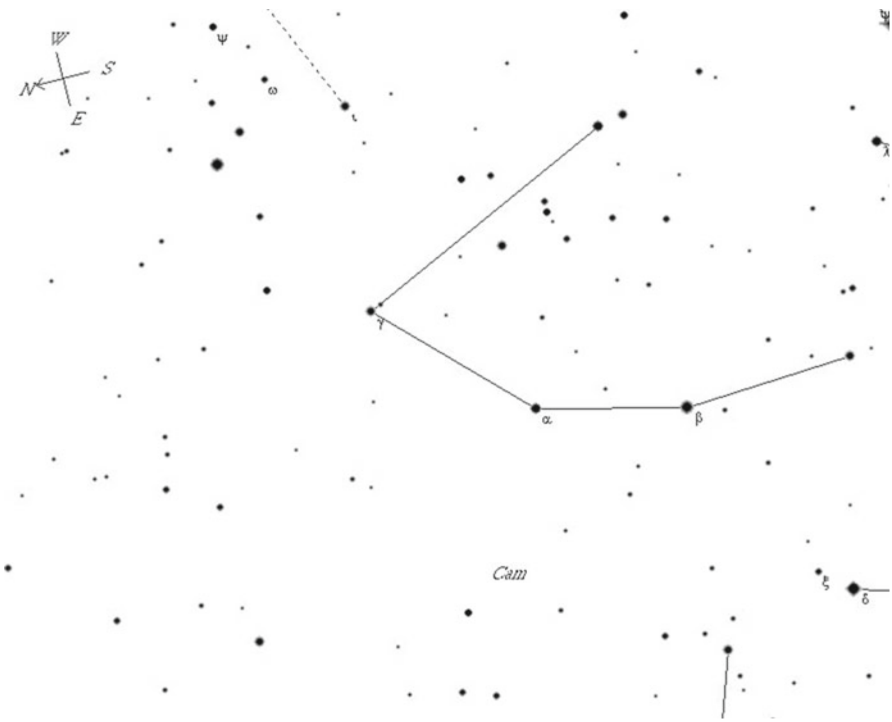
A beautiful planetary nebula that is a visual "deep sky double," in a low power field with the star cluster NGC 1502 at the end of "Kemble's Cascade." It's also a Herschel 400 object, which reveals itself as a smooth blue-gray, round, well defined object that seems filled and even across its surface with no central star visible. In higher powers the surface of the nebulae appears a little mottled, and it responds to an OIII filter well, though it is an easy direct visual target in telescopes over 150 mm aperture. No central star is visible in higher magnifications; however there is a central knot that hints at the star.

IC 3568
Camelopardalis
RA: 12 h 33 m 07 s
Dec: +82.33.8
Size: 18″
Magnitude: 11.1
Class: 2a



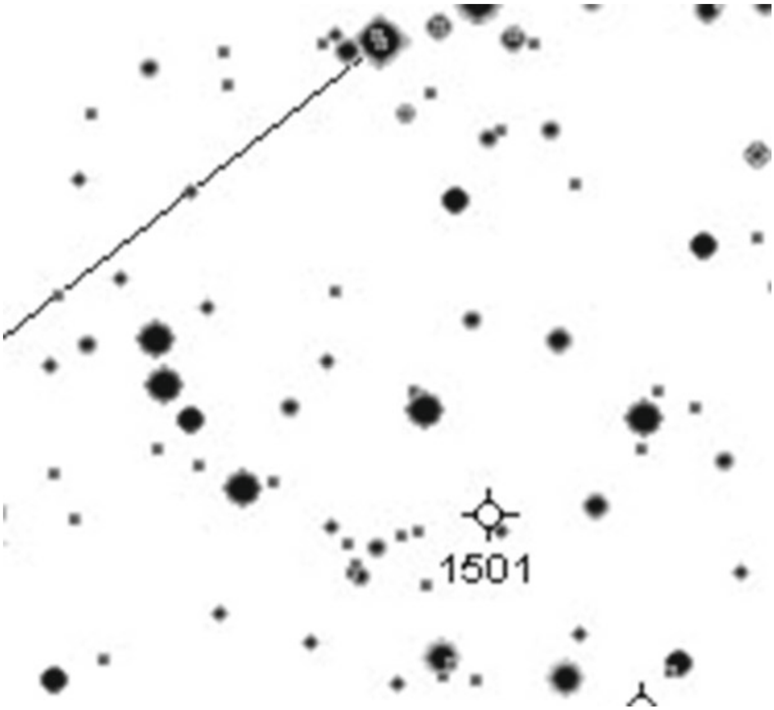
This is the closest accessible planetary nebula to the north celestial pole, but IC 3568 is relatively faint and remains star-like in low and moderate powers. However, higher magnifications and averted vision reveal it as rounder and larger than some of the stars in the field. IC 3568 is visible in a small field of stars and has a 12th mag star on its E edge. In higher powers there is a subtle color shift from white to blue-gray, and the nebula shows a marked response to use of an OIII filter, thus aiding identification and location.

General view of Camelopardalis

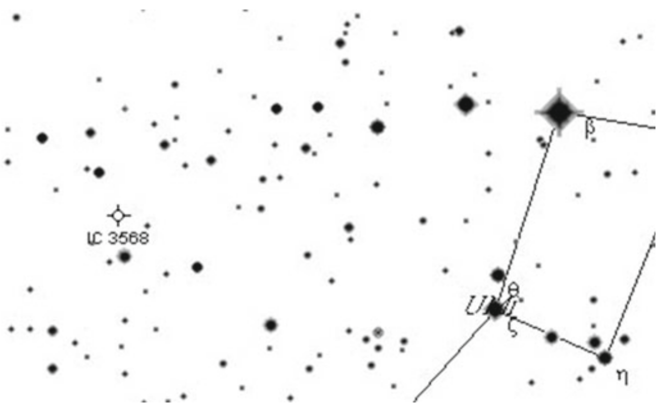


Planetary Nebulae by Constellation

Finder chart for NGC 1501

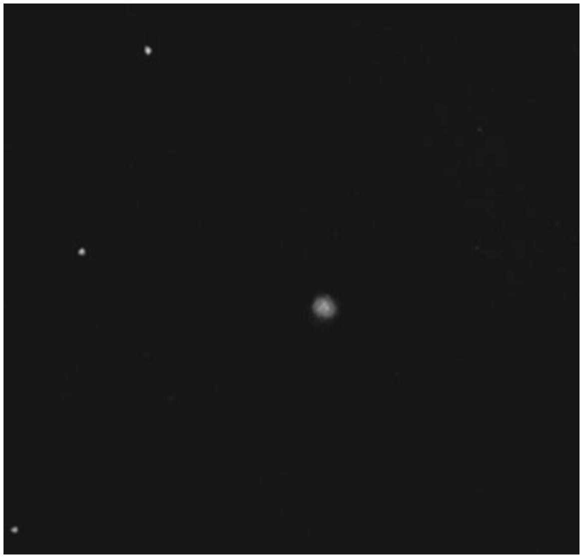


Finder chart for IC 3568



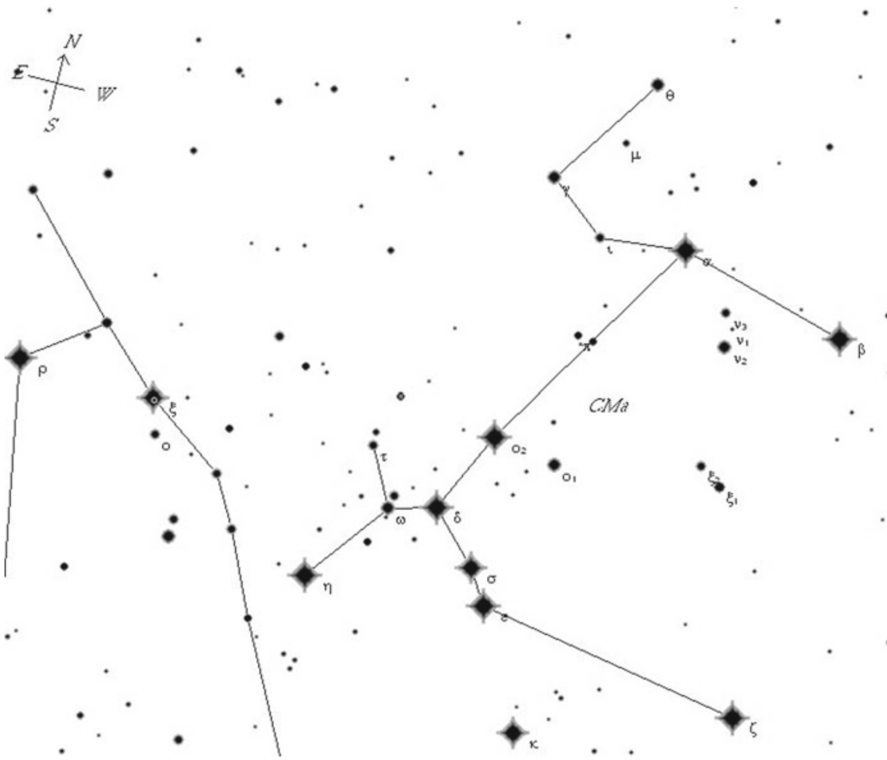
Canis Major

IC 2165
Canis major
RA: 06 h 21 m 43 s
Dec: −12.59.2
Size: 9″
Magnitude: 10.6
Class: 3b

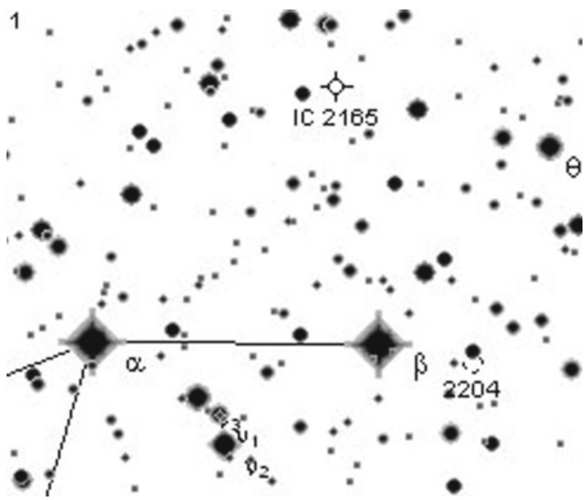


IC 2165 reveals itself as a stellar disk of faint 11th mag light in northern Canis Major. Traditional users can star hop from β Canes to a fifth mag star directly north; with a line of ninth mag stars running N/S to the E of this star, you go NE from top of line. The planetary is visible in low power as a white point of light; very star-like in a field of Milky Way stars, but there is something a little extended about IC 1265 that can be seen with careful attention. In higher powers visually it is a faint gray blob, definitely not star-like but having no other color to make detection easier. The nebula responds well to an OIII filter, thus aiding identification.

General view of Canis Major



Finder chart for IC 2165

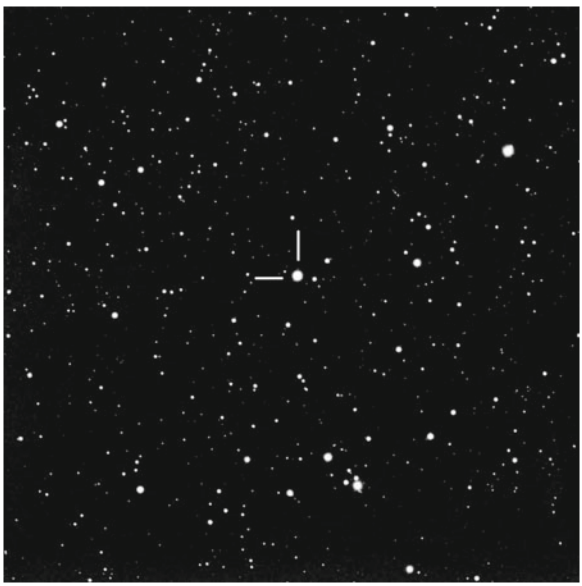


Carina

NGC 2867
Carina
RA: 09 h 21 m 25 s
Dec: −58.18.40
Size: 14″
Magnitude: 9.7
Class: 2a

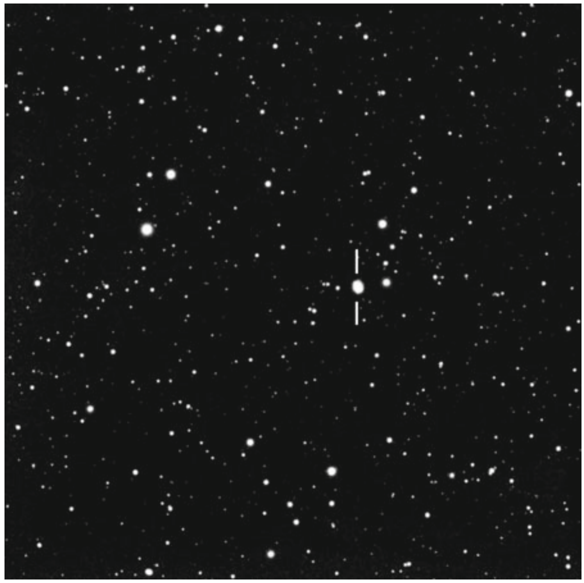
This wonderful planetary was discovered by John Herschel on April 1, 1834 – and fooled him into thinking it was a planet! NGC 2867 is located in a densely packed starry field but is immediately obvious as a round, sharply defined disk of green light with a mottled center at higher powers. It responds beautifully to use of an OIII filter, though this is unnecessary, as its directly observable anyway and makes an excellent target for a small aperture telescope. It is one of the most prominent and wonderfully colored nebulae in the southern skies and almost resembles the “Ghost of Jupiter” in Hydra.

IC 2501
Carina
RA: 09 h 38 m 08 s
Dec: −60.05.0
Size: 20″
Magnitude: 11.1
Class: 1



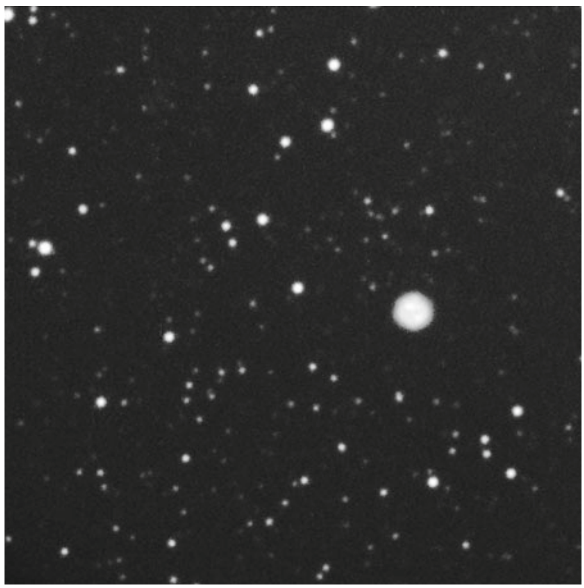
A small planetary nebulae that responds well to use of an OIII filter but remains quite stellar in low powers. In higher magnifications it appears as a round fuzz of light with a slight extension in a NE–SW axis. It remains a filled shell of slightly bluish color and is visible even in a small telescope, though sufficient resolution of the object may be a problem in smaller apertures.

IC 2553
Carina
RA: 10 h 09 m 35 s
Dec: −62.40.09
Size: 12″
Magnitude: 13
Class: 2 + 5



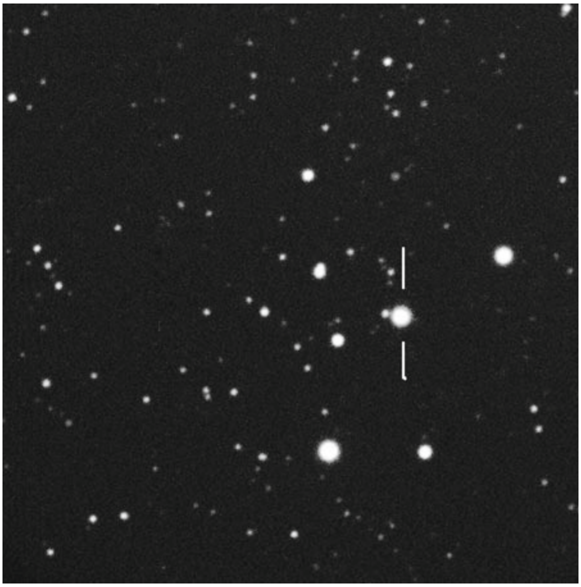
Small stellar looking planetary nebula that seems a little brighter than its quoted magnitude here and is a vivid green in color. The nebula responds well to use of an OIII filter, which may be necessary to track it down in such a rich field of stars. In low powers it appears star-like and off white in color, whereas higher powers bring out the green hue with a little more contrast and also hint at a slight elongation along a N–S axis.

NGC 3211
Carina
RA: 10 h 18 m 06 s
Dec: −62.43.13
Size: 12″
Magnitude: 12.1
Class: 2a



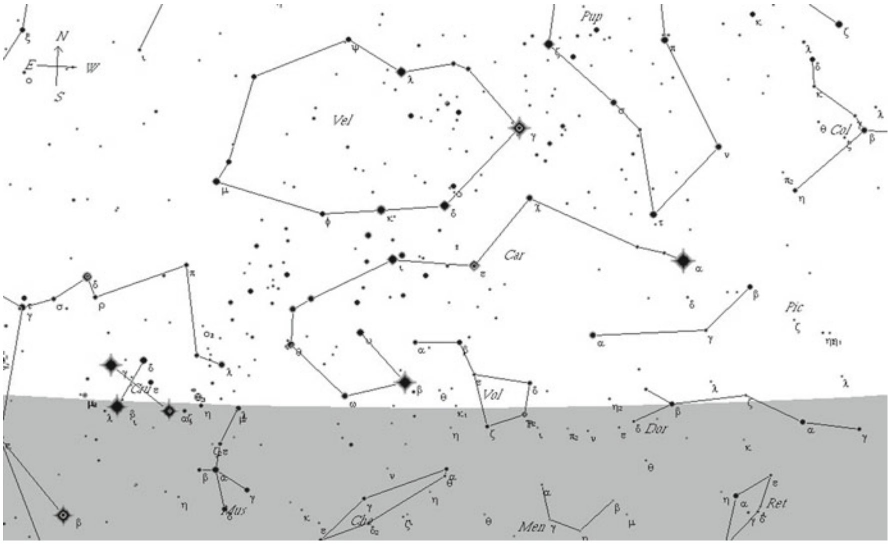
Small but fairly bright planetary nebulae just under 2° from a third magnitude star, which gives a good starting point for star hopping. NGC 3211 is blue in color, round in general shape but revealing a slight elongation E-W in higher magnifications and is an easy target for a 20 cm telescope. It responds well to use of an OIII filter and larger ‘scopes will show that the edges of the nebula are a little hazy in outline. It is often reported by observers using telescopes of less than 150 mm aperture.

IC 2621
Carina
RA: 11 h 00 m 40s
Dec: −65.18.31
Size: 5″
Magnitude: 13.2
Class: 2a

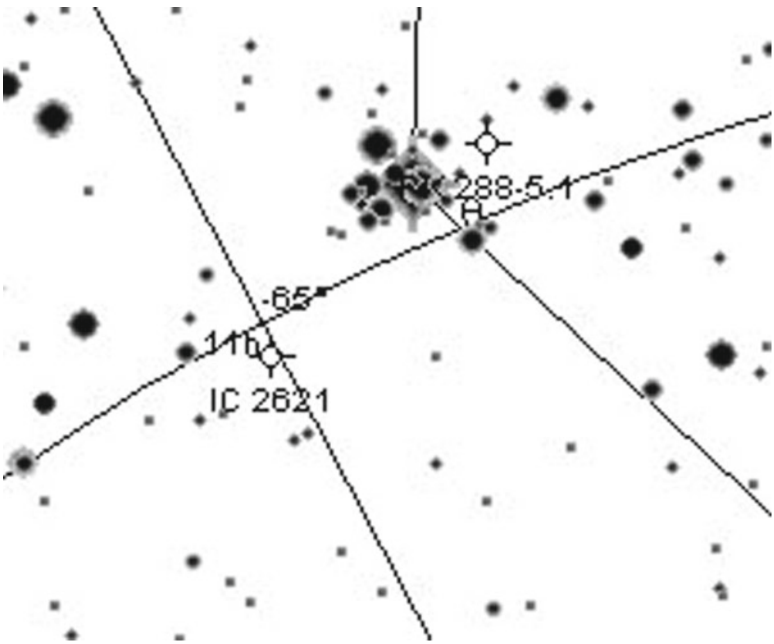


IC 2621 is a good example of a "real" stellar planetary nebula, and the magnitude quoted here (from many sources) ranges from 10.2 to 13.5 across on this object, though it is probably closer to 11.5. It's not too difficult an object to spot, but it does require an OIII filter to identify first before direct vision can be used. The nebula is white, a starry point and shows little detail no matter what magnifications are used. It can be found as part of a triangle of three faint stars.

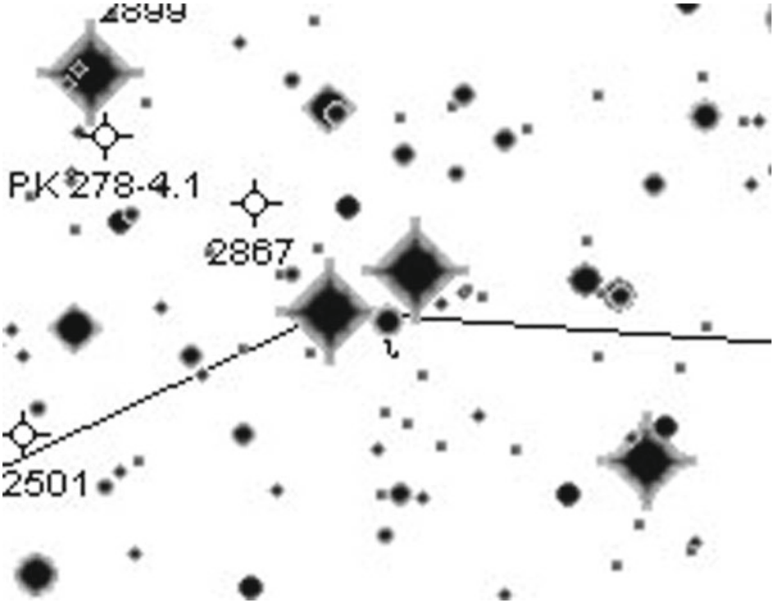
General view of Carina



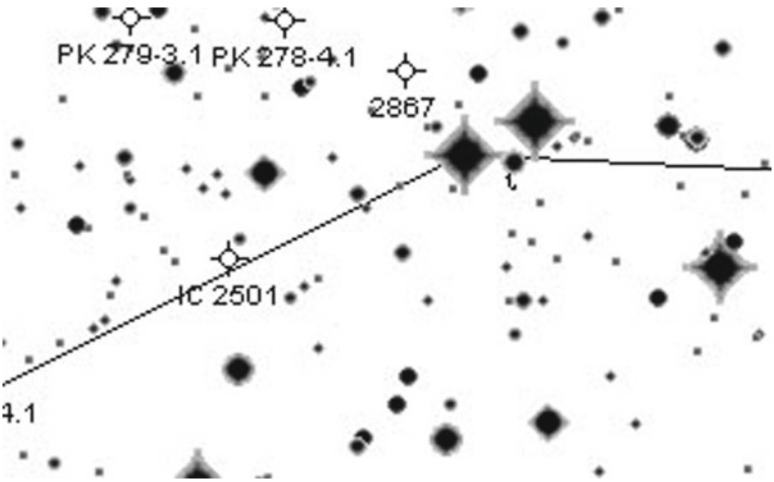
Finder chart for IC 2621



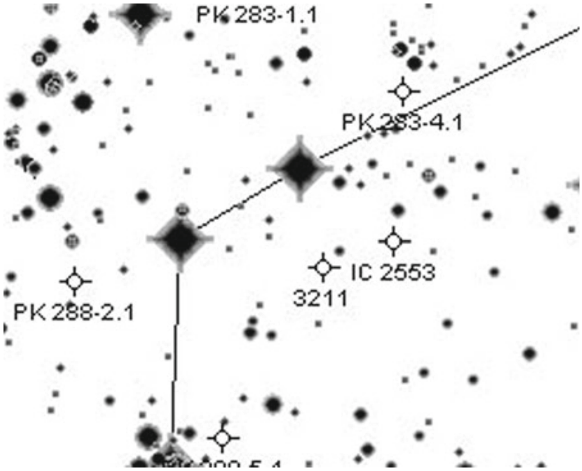
Finder chart for NGC 2867



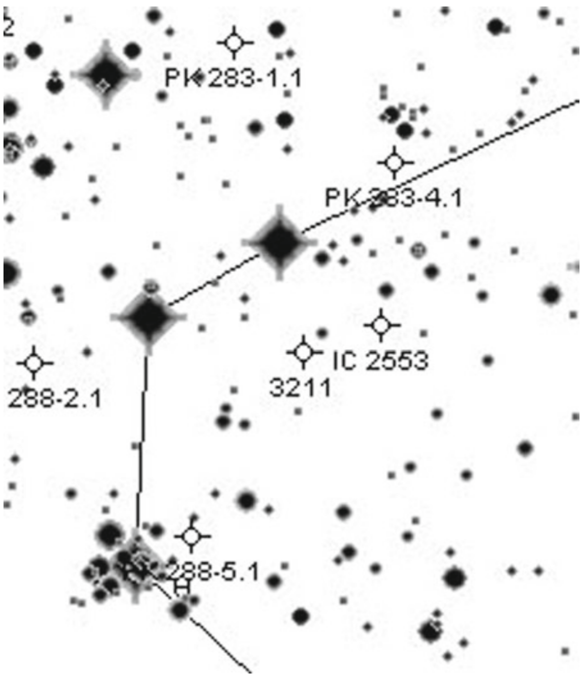
Finder chart for IC 2501



Finder chart for IC 2553



Finder chart for NGC 3211



Cassiopeia

IC 1747
Cassiopeia
RA: 01 h 57 m 36 s
Dec: +63.19.3
Size: 13″
Magnitude: 12.1
Class: 3b

A tiny planetary nebula SF ε Cassiopeia. Not difficult to see in a modest telescope but just looks stellar and faint in most low power fields. Higher magnifications do it some justice, revealing a slight extension to the object, which separates it from the other stars in this rich Milky Way field. Visually it appears about 10″ across, and with averted vision a slight blue hue begins to come into view. Don't be put off by the fact that it seems such a faint object by magnitude, as once the field is identified it becomes an easy little planetary that most observers overlook. It responds well to an OIII filter to aid in identification.

IC 289
Cassiopeia
RA: 03 h 10 m 19 s
Dec: +61.19.0
Size: 40″
Magnitude: 13.3
Class: 4 + 2

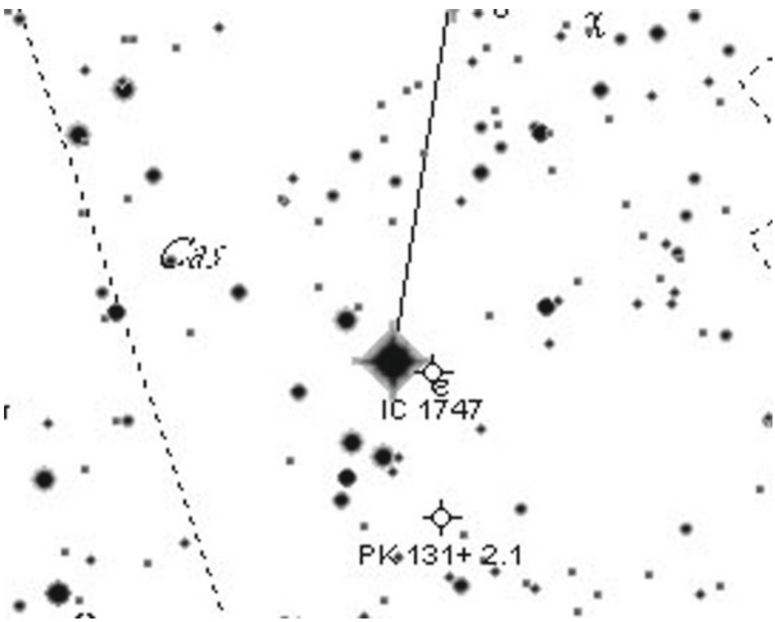
A challenging object for observers with 'scopes in the 20 cm + range. IC 289 is a barely visible, small planetary, resembling a very faint star; for observers equipped with simple Dobsonian telescopes it is located in a difficult star field to hop to, thus compounding the problem of seeing this little nebula. Visually, the object is uniformly gray and having a tenth mag star in the field SF the nebula spoils the view a little. The star fields of the Milky Way in this area are a horrifying location to find such a faint little thing in, but consolation can be taken in the fact that it responds well to an OIII filter and identification is rendered easier.

Abell 82
Cassiopeia
RA: 23 h 45 m 42 s
Dec: +57.04.0
Size: 94″
Magnitude: 12.7
Class: 3b

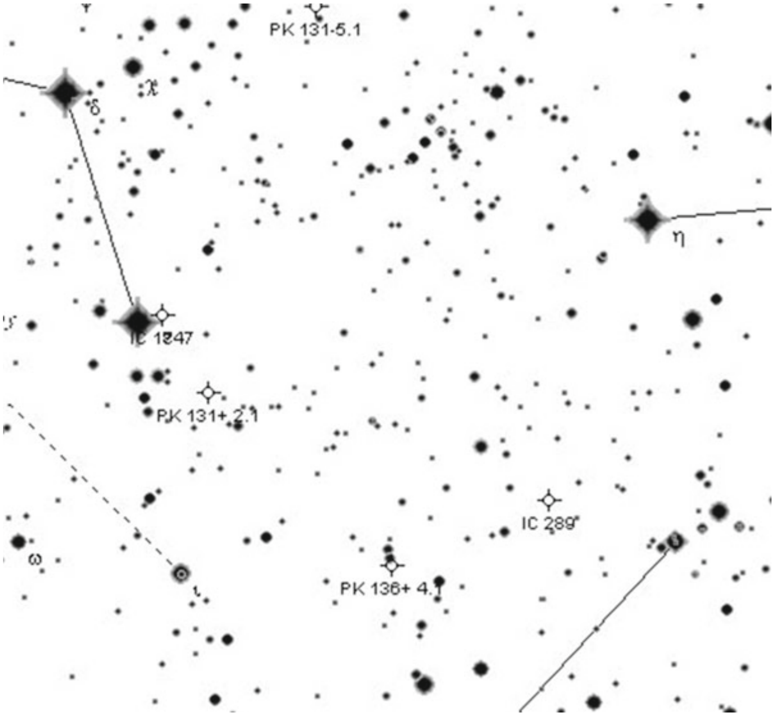
Horrifically faint planetary (typical of the Abell class) in Cassiopeia west of the star cluster NGC 7789. In comparison to the glory of NGC 7789, this nebula is faint, difficult to find and takes very careful viewing. There is little to see with direct vision and even use of an OIII filter does not let the nebula jump out immediately, though there may be a hint of something there. In a moderate magnification Abell 82 seems to be centered on a faint double star (mag 13+) and has an extension E-W of this pair, but the nebula is too faint visually to distinguish how far these gaseous shrouds extend – possibly about 1′ across or more. The color is a milky gray like that of the background Milky Way, and very little can be seen of this object, which is a real challenge for observers with larger apertures.

General view of Cassiopeia

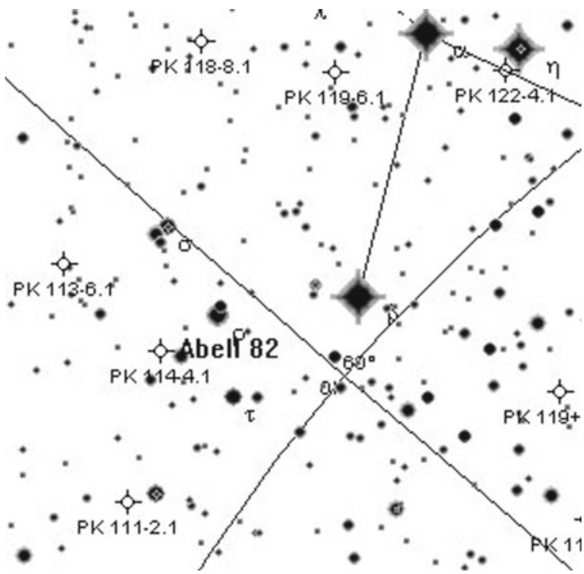
Finder chart for IC 1747



Finder chart for IC 289



Finder chart for Abell 82



Centaurus

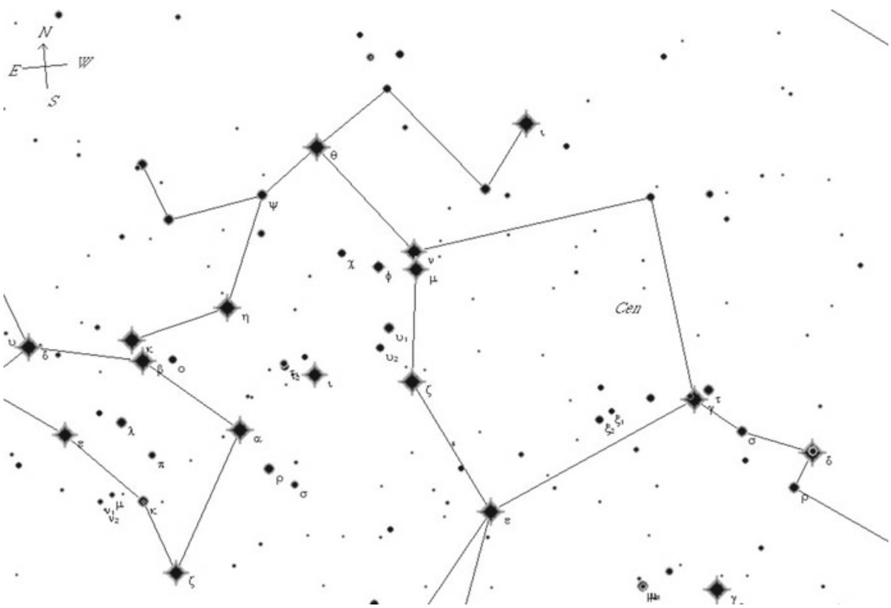
NGC 3918
Centaurus
RA: 11 h 50 m 48 s
Dec: −57.14.41
Size: 12″
Magnitude: 8.2
Class: 2b

A wonderful planetary nebula and the target of many a southern telescope. The "Blue Planetary," as it is known, is remarkably bright and easy to hop to from δ Crucis. It reveals itself as a tiny star in a low power, but with an overwhelming electric blue color that separates it from the star fields immediately. The object is round and quite small at only 12′ across, but its beauty lies in the fact that it is bright and accessible to all sorts of instrumentation. High magnification on a large telescope may reveal a slight elongation to the object on an NE–SW axis, but the effect in most telescopes is very subtle, remaining round for the most part.

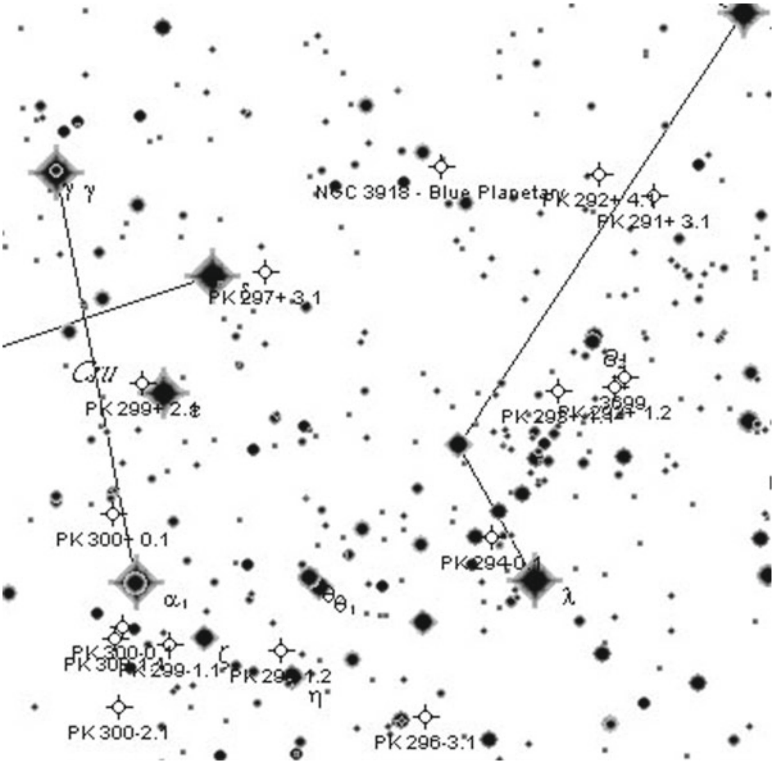
NGC 5307
Centaurus
RA: 13 h 51 m 47 s
Dec: −51.15.22
Size: 15″
Magnitude: 11.9
Class: 3a + 5

A lovely little planetary nebula that is slightly elongated along it N-S axis and is surprisingly bright for its quoted magnitude. The nebula is a point-symmetric object, and this shape comes through if one uses high magnifications on a large telescope, but for most observers, NGC 5307 remains a round blob of light, just distinguishable from the start in low to moderate powers but is a lovely green color and thus stands out a little in a rich field of stars. A showpiece object, to which a close visual counterpart would be NGC 6572 in Ophiuchus.

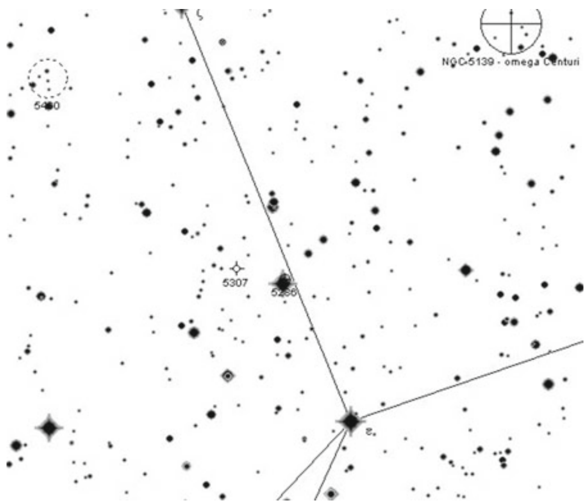
General view of Centaurus



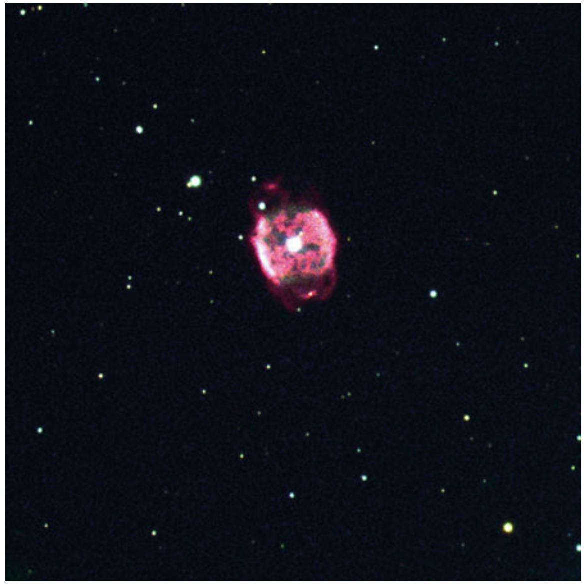
Finder chart for NGC 3918



Finder chart for NGC 5307



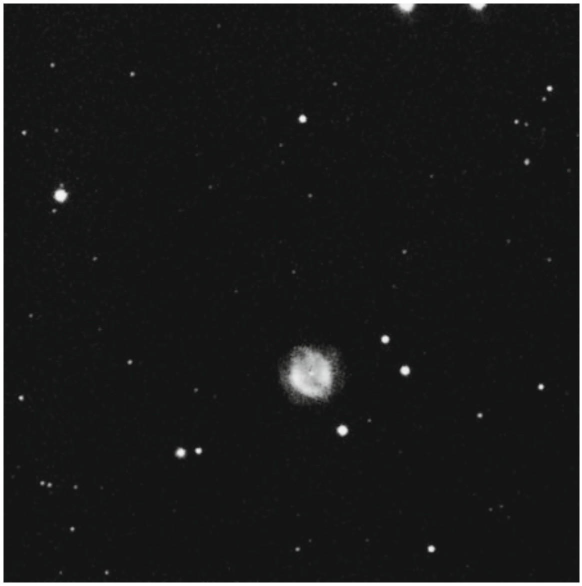
Cepheus



NGC 40
Cepheus
RA: 00 H 13 m 01 s
Dec: +72.31.3
Size: 38″
Magnitude: 12.3
Class: 3b

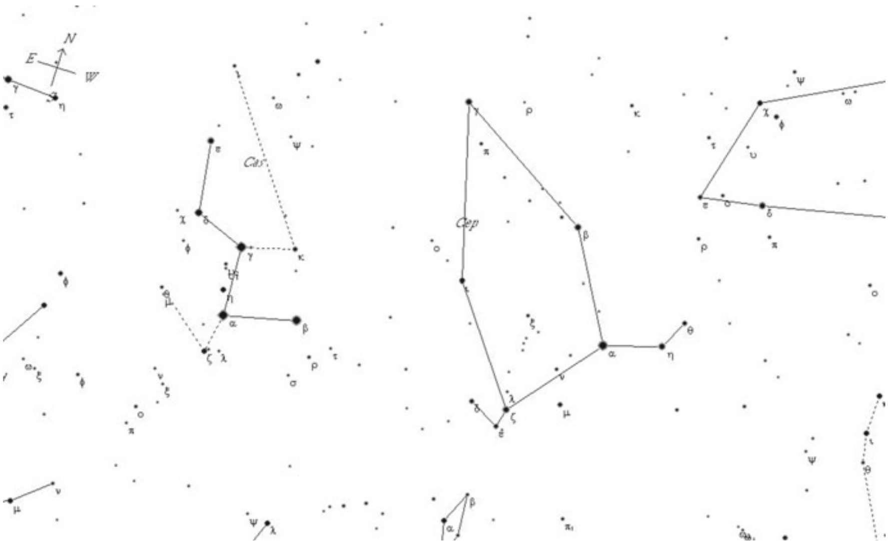
Beautiful, ghostly nebula between two orange-colored stars in northern Cepheus. The planetary is almost 40″ across and very slightly elongated along a NE/SW axis. No central star is visible in direct vision, but there is a central brightening to the object even at low power. Larger apertures or photography may reveal the central star, which has a temperature of 50,000 K. NGC 40 is a lovely filled shell of light, but no color is visible other than an even blue-gray, though some observers remark that a slight hint of red can be glimpsed with averted vision. It responds moderately to an OIII filter but is visible directly even in small telescopes. NGC 40 is also known as Caldwell 2 and is also the first of the catalogue of Herschel 400 objects, being discovered by Herschel in 1788. It has the common name of the "Bow Tie Nebula."

NGC 7354
Cepheus
RA: 22 h 40 m 20s
Dec: +61.17.1
Size: 22″
Magnitude: 12.2
Class: 4 + 3b

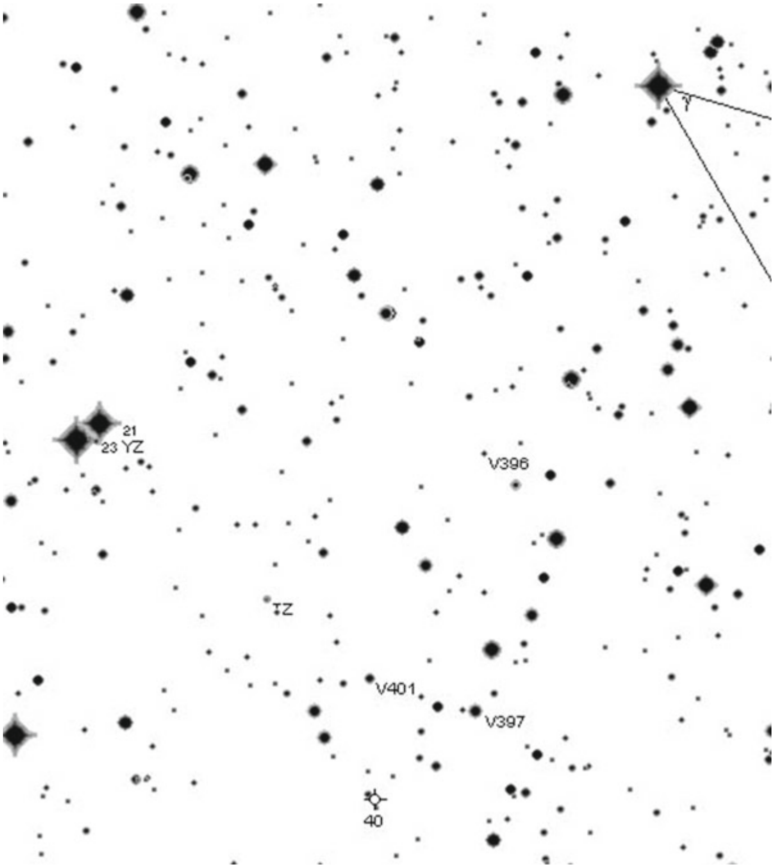


Nice little planetary in Cepheus that is often overlooked. In low power it is quite obvious as a grayish disk-like smudge of light, slightly oval in shape with a small axis NW/SE but no discernable central star at all. The dimensions are about 20″ across, and the planetary lies in a rich Milky Way star field, though it's not difficult to locate, as the object is extended and definitely not stellar. Higher magnifications give a little bit more contrast to the object, but it remains a gray disk of light in most moderate-sized telescopes.

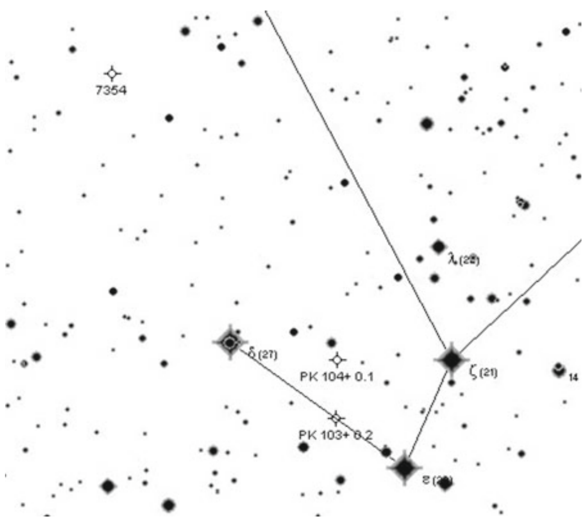
General view of Cepheus



Finder chart for NGC 40

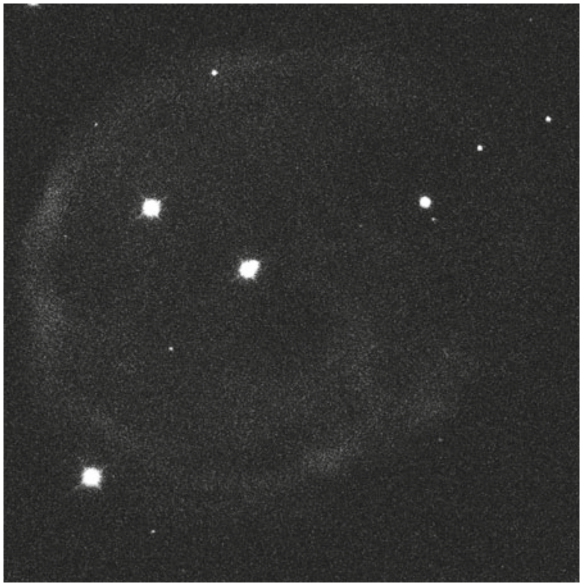


Finder chart for NGC 7354



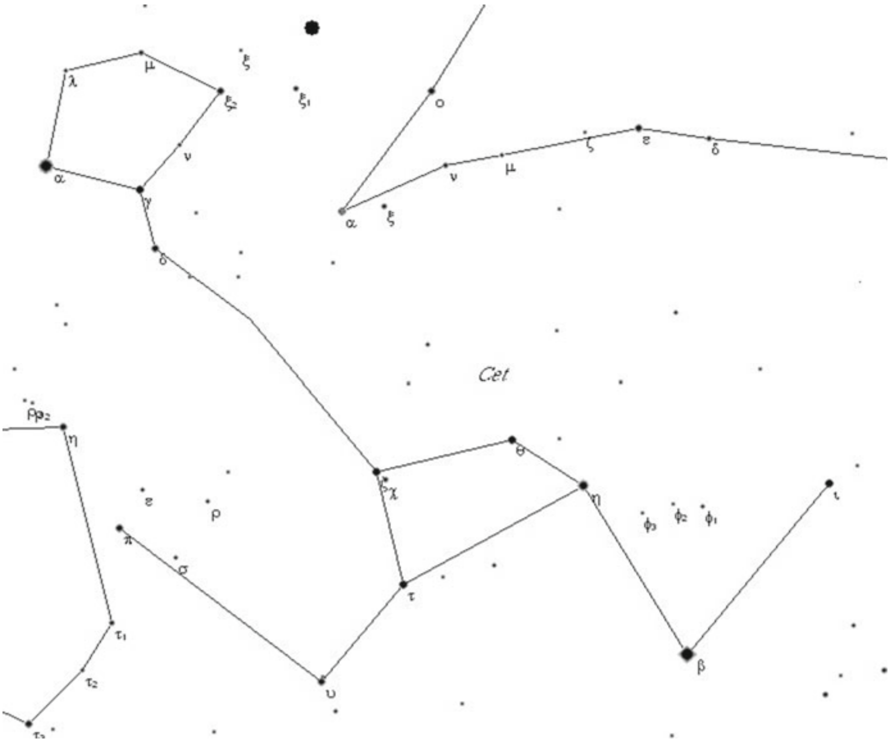
Cetus

NGC 246
Cetus
RA: 00 h 47 m 03 s
Dec: −11.52.3
Size: 4′
Magnitude: 10.8
Class: 3b

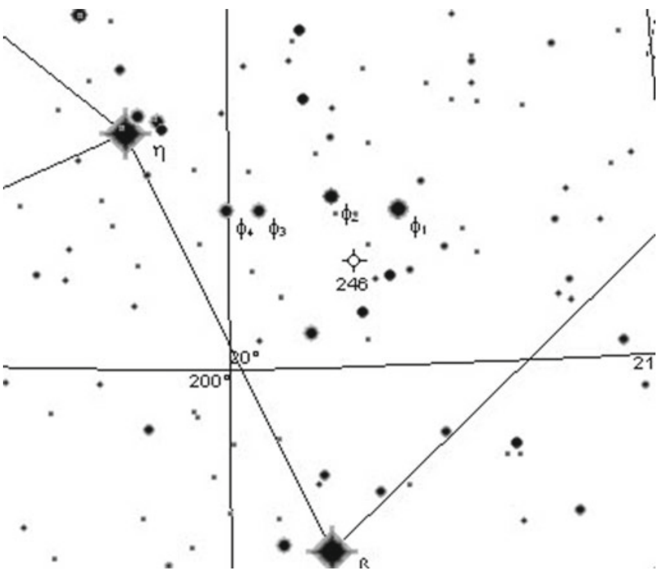


Visually this is a diffuse, white glow in the body of Cetus about 4′ across, slightly structured into arcs with the SW side slightly the brighter part of the nebula and has three stars clearly visible on the body, with a central one glowing white in a gray cast of nebulosity. Not a difficult object if sky conditions are good. Averted vision gives a hint more nebulosity, but it is not needed to see the object directly depending on the size of the telescope in use. This could be a difficult object for someone using an aperture lower than 150 mm. NGC 246 is also one of the Herschel 400 objects and has the common name of the "Skull Nebula."

General view of Cetus



Finder chart for NGC 246

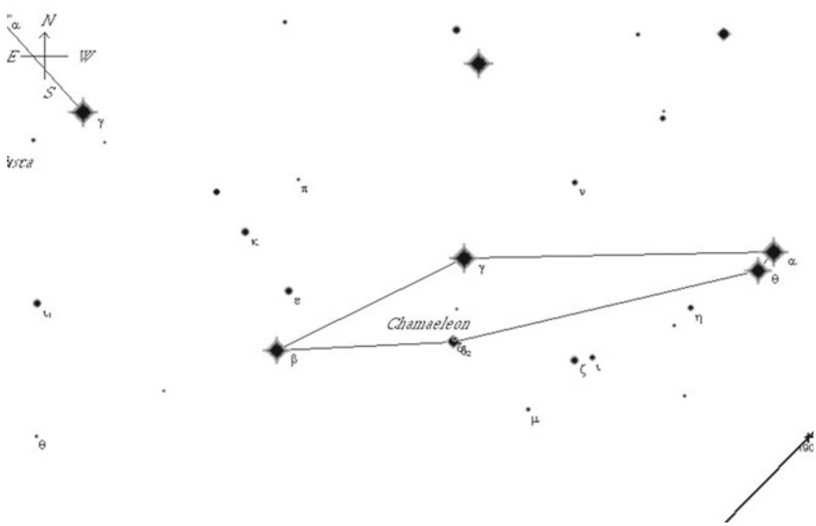


Chameleon

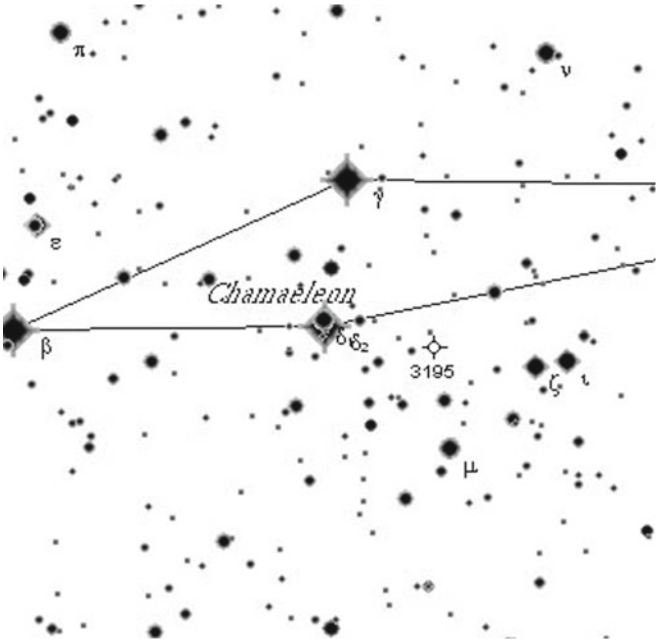
NGC 3195
Chameleon
RA: 10 h 09 m 12 s
Dec: −80.55.11
Size: 35″
Magnitude: 10.1
Class: 2a

A wonderfully bright oval nebula that is an easy target for modestly equipped observers and very high in the southern circumpolar sky. NGC 3195 is a bright filled shell at low powers, which stands revealed as a planetary that some observers have described as rather like M97 with two prominent dark bays at higher magnifications and use of averted vision. At high powers the object is mottled in appearance and is evenly filled with a greenish light. NGC 3195 can be found midway between ζ and δ Chameleon and responds well to OIII filters, though no central star is to be seen.

General view of Chameleon



Finder chart for NGC 3195

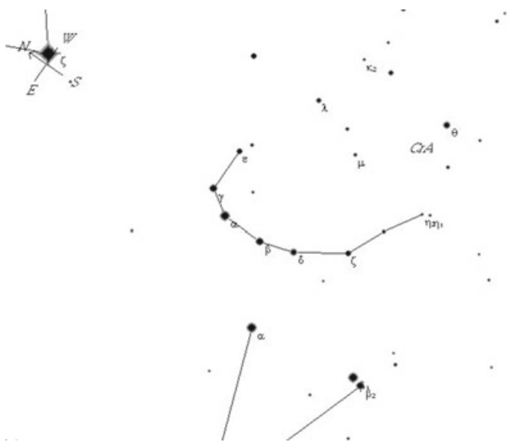


Corona Australis

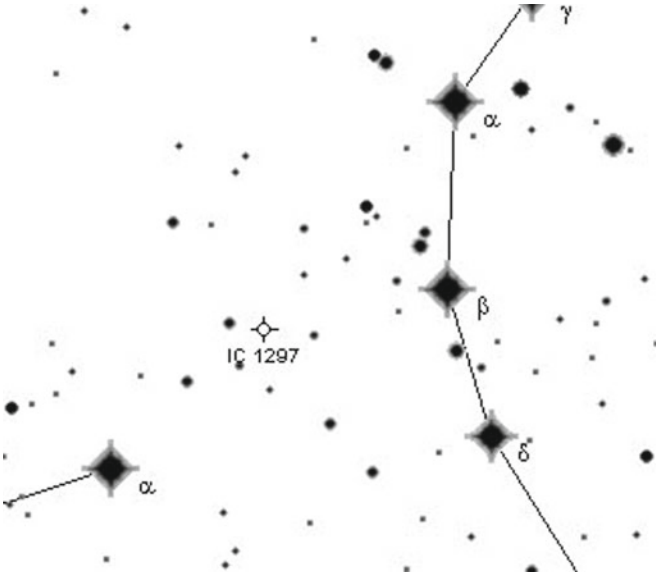
IC 1297
Corona Australis
RA: 19 h 17 m 23 s
Dec: −39.36.8
Size: 12″
Magnitude: 10.7
Class: 2a

This small planetary is immediately obvious in direct vision and can be seen in most apertures under good conditions. IC 1297 is a round ball-like point of light in low powers, which resolves into a little green blob at higher magnifications with a brighter center and hints of some irregular features within the disk. It is obvious and definitely different from the stars of the region at first glance. IC 1297 is a lovely object, about 10″ across with a tenth magnitude star just NF.

General view of Corona Australis



Finder chart for IC 1297

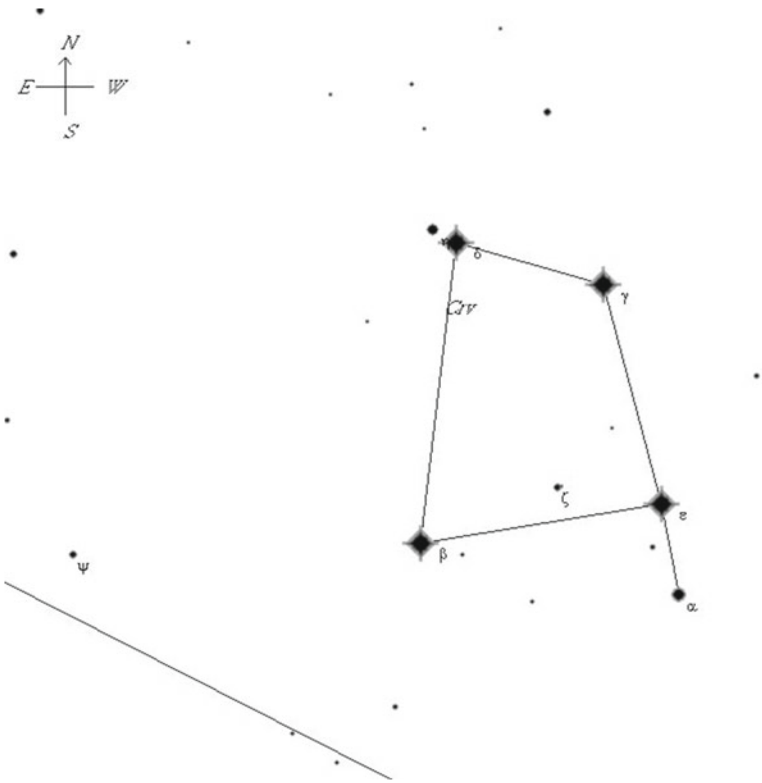


Corvus

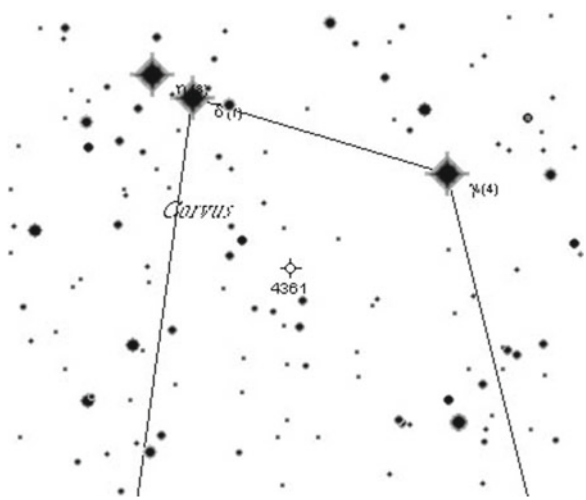
NGC 4361
Corvus
RA: 12 h 24 m 31 s
Dec: −18.47.1
Size: 70″
Magnitude: 10.9
Class: 3a + 2

A lovely object that is easy to find as the peak of a scalene triangle from δ Corvi. The nebula is immediately apparent as a dual-lobed shell around a faint star in low powers, while higher magnifications increase the separation of star and nebula a little more, filling in the concentric gas cloud around the star. The nebula is blue-gray in color and remains that hue no matter what magnification is used. A pleasing object, though often overlooked for its more obvious neighbor NGC 3242 in Hydra. It's also a Herschel 400 catalogue object and quite a lovely planetary in its own right.

General view of Corvus

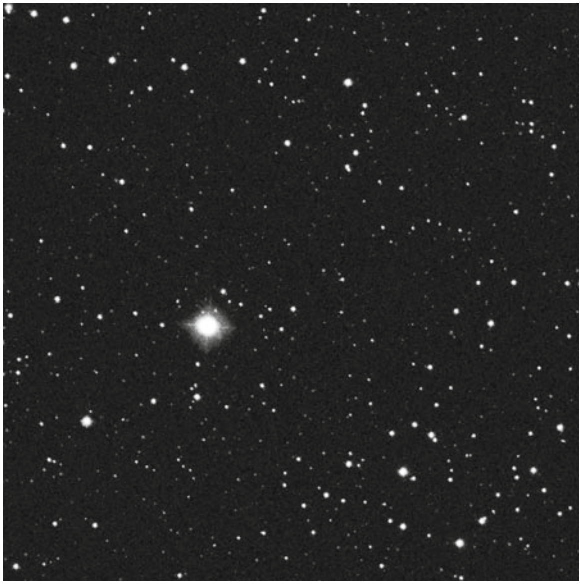


Finder chart for NGC 4361



Cygnus

BD +30 3639
Cygnus
RA: 19 h 34 m 45 s
Dec: +30.31.0
Size: 13″
Magnitude: 9.9
Class: 4

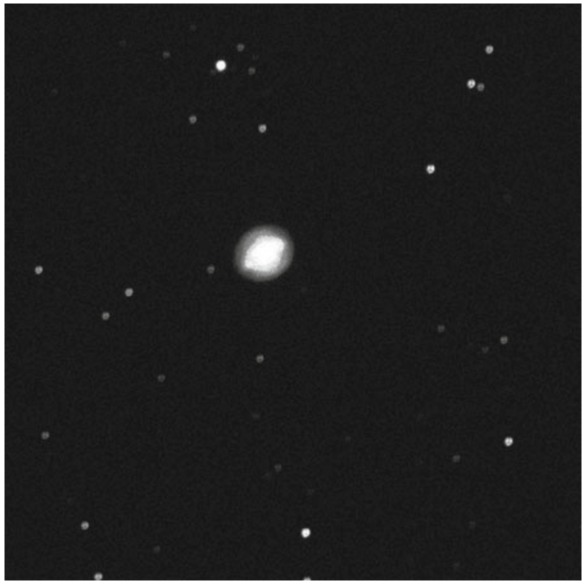


This planetary reveals itself as an orange-white star about 5 min W of ϕ Cygni but does not respond to use of an OIII filter or to a UHC. It just remains an orange star even in higher powers, with no hint of a halo or anything else that would distinguish it, which includes its color, which is so un-planetary like. The object is also known as "Campbell's Hydrogen Star" and at tenth magnitude is bright enough to be seen in most telescopes. Some observers report a halo around the star, hinting at the atmosphere of a planetary nebula. A strange object, but visible to most observers.

Minkowski 1–92
Cygnus
RA: 19 h 36 m 18 s
Dec: +29.32.8
Size: 3″
Magnitude: 11.0
Class: 5 + 6

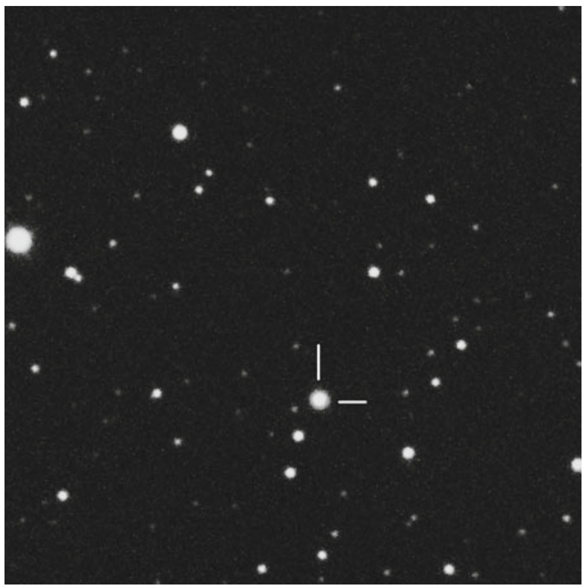
"Minkowski's Footprint" is a small and difficult planetary nebula that requires a moderate to high magnification to view and is a little confusing, as the object is quite close to a ninth magnitude star. In high powers it is easier to see, elongated in a NW-SE direction but merely white in color and no evidence of the separation into parts is visible – it resembles a little white stretched cotton wool blob. Surprisingly bright at mag 11 and easier to see than some objects recorded here, it a pity that the star is so close to it as it overwhelms it a little. It is marked, but not notated on Tirion's *Cambridge Star Atlas.* Direct vision brings it out, but there is no response to the use of an OIII filter.

NGC 6826
Cygnus
RA: 19 h 44 m 48 s
Dec: +50.31.5
Size: 30″
Magnitude: 8.8
Class: 3a + 2



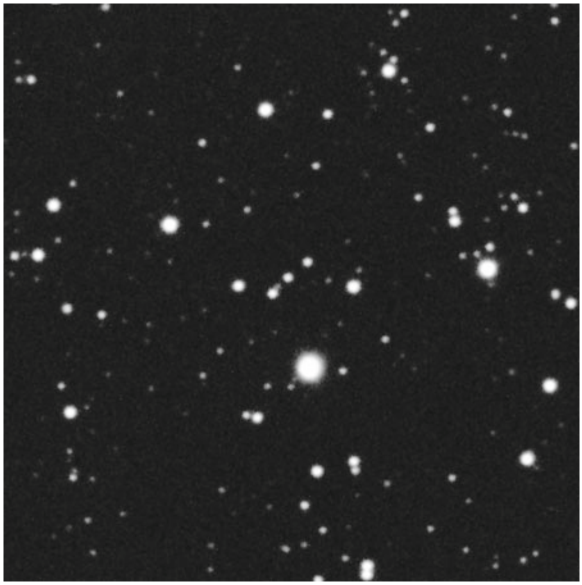
The fabulous "Blinking Nebula" in NE Cygnus discovered by William Herschel. In a low power the turquoise color is beautiful and contrasts wonderfully with the yellow binary 16 Cygni in the same low power field of view. In higher powers the nebula is a little elongated along a N/S axis, and there is a central bright concentration but no glimpse of the central star. Under high magnifications the outer part of the nebula does have a slight "atmosphere" or edge even in direct vision. NGC 6826 is a spectacular object with a vivid color that should be visible in telescopes of all apertures.

NGC 6833
Cygnus
RA: 19 h 49 m 47 s
Dec: +48.57.7
Size: 3″
Magnitude: 11.1
Class: 2



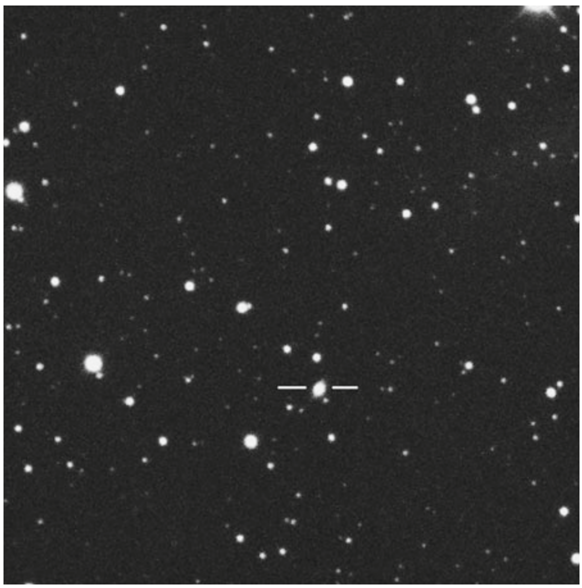
A small planetary nebula in NW Cygnus, not far placed from the previous object, the Blinking planetary NGC 6826. It is immediately obvious due to its lovely green color and responds very well to use of an OIII filter, though for the most part a visual observer will see the color of this vivid planetary without a problem. NGC 6833 looks just like a green star! Although the nebula is small, it should present few problems to users of small aperture telescopes, as it seems brighter than its quoted magnitude here.

NGC 6884
Cygnus
RA: 20 h 10 m 24 s
Dec: +46.27.7
Size: 6″
Magnitude: 11.0
Class: 2b



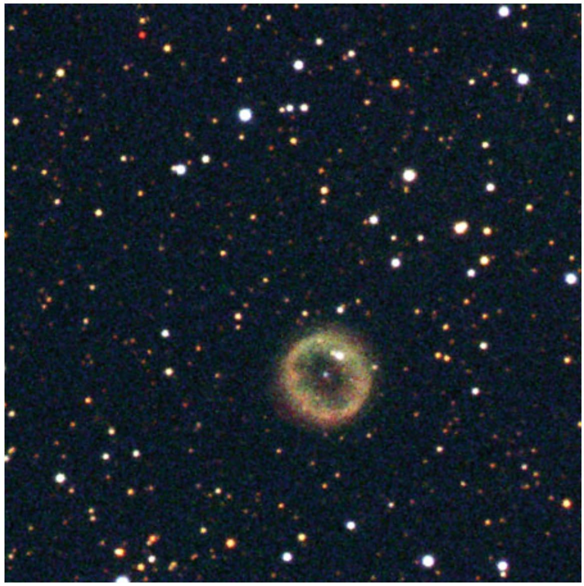
Tiny planetary that is easy to locate if one star hops off 31 Cygni, which remains in the same low power field and is visible immediately if one uses an OIII filter. Most observers can see the nebula directly in moderate powers, while higher magnifications make the image a little clearer, but do not increase the size of this stellar disk. NGC 6884 has a distinct greenish tinge to it with averted vision, but it looks aquamarine in direct vision.

NGC 6881
Cygnus
RA: 20 h 10 m 09 s
Dec: +37.25.0
Size: 3″
Magnitude: 13.6
Class: 2a + 3



A difficult and challenging little object right in the middle of the Cygnus Milky Way. The planetary has a good response to the use of an OIII filter and blinking the filter should reveal this tiny object in this rich sea of stars. Observers equipped with larger telescopes in the 30 cm + range should see the nebula with direct vision, though it is always stellar and displays a slight blue color.

NGC 6894
Cygnus
RA: 20 h 16 m 24 s
Dec: +30.33.9
Size: 45″
Magnitude: 12.3
Class: 4 + 2



NGC 6894 is a faint ring-like planetary located to the south of 39 Cygni. Although it is visible in direct vision, an OIII filter helps identify it, as it shows a good response, rendering it as a faint spot that can then be magnified. It is revealed in moderate powers as a ring-like small patch with a darker center but no visible central star. The nebula itself is just under 1′ across, and the darker interior is quite clear in larger telescopes, though users of apertures smaller than 150 mm may find this one to be out of their range.

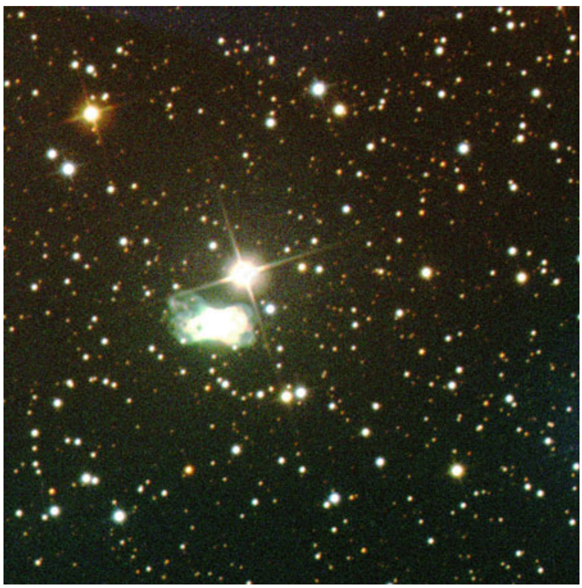
NGC 7008
Cygnus
RA: 21 h 00 m 33 s
Dec: +54.32.6
Size: 100″
Magnitude: 10.7
Class: 3

A fantastic nebula in northern Cygnus revealing itself as a white, smallish, hook-shaped object on first appearance in low powers and lying close to a ninth mag star on its S edge. Moderate to high magnifications bring out finer detail connecting the two lobes together and rendering the object a little rounder. However, in most ‘scopes the object remains a rather disappointing grayish-white in color. NGC 7008 is amenable to direct vision, though it does respond quite well to use of an OIII filter. It is also a Herschel 400 object that is visible through modest apertures.

CRL 2688
Cygnus
RA: 21 h 02 m 19 s
Dec: +36.41.6
Size: 16″
Magnitude: 13.5
Class: 6

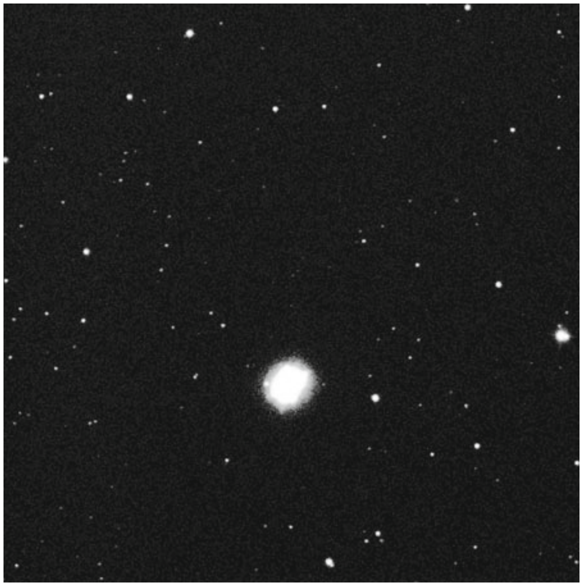
The famous "Cygnus Egg" is a tiny, faint, star-like object, which reveals a little extension in a moderate magnification in a N-S direction. To most observers it first resembles a tiny binary system with a twin structure to it, which hints at the double-lobed body visible in observatory photographs. In moderate apertures little more than these details can be seen in this crowded Milky Way field between ε and ν Cygni. Larger apertures add very little to this picture. Use of the OIII filter is to no avail, and only direct vision brings out this faint, small proto-planetary object.

NGC 7026
Cygnus
RA: 21 h 06 m 19 s
Dec: +47.51.1
Size: 27″
Magnitude: 10.9
Class: 3a



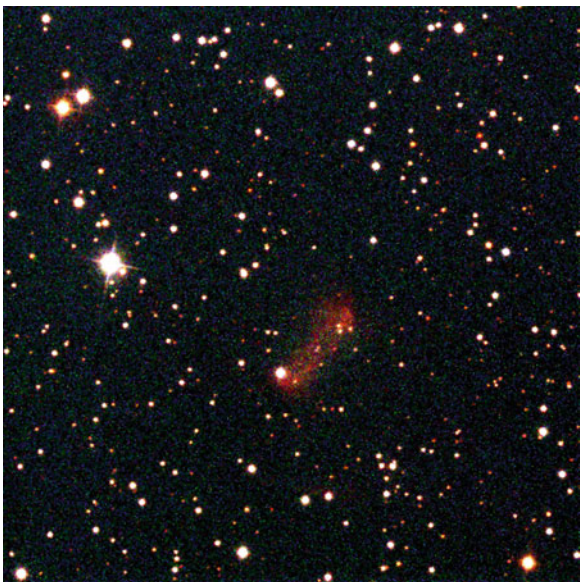
A fairly bright, extended nebula above NGC 7000. This nebula is not too difficult to star hop to from Deneb – follow two fifth magnitude stars to NE and then go E to another fifth mag star, and the nebula is in the same LP field as NP the star. Very nice star fields all around in the Milky Way, and for observers with modest apertures, the use of an OIII filter pulls the nebula out from the background very well. Visually, the planetary is obviously bi-polar and extended NW/SE and is somewhat spoiled in appearance by having a tenth mag star very close to the S. It shows a subtle green color at moderate magnifications and should be visible with some careful observing even in small apertures.

NGC 7027
Cygnus
RA: 21 h 07 m 01 s
Dec: +42.14.2
Size: 18″
Magnitude: 8.5
Class: 3a



Lovely stellar planetary nebula found by following a line SE of χ Cygni across the crowded milky way for 2°. At low power even a small telescope reveals the planetary as a blue green object, small but highly visible due to its color despite a rich field of stars and is a little extended in higher powers with its axis possibly NW/SE. There is a brighter starry concentration to the SW in averted vision very much like an overlapping star. It is bright enough to be seen in most apertures yet needs careful attention if one is star hopping in this rich field.

Sharpless 1–89
Cygnus
RA: 21 h 14 m 09 s
Dec: +47.46.4
Size: 44″
Magnitude: 14.5
Class: 3a

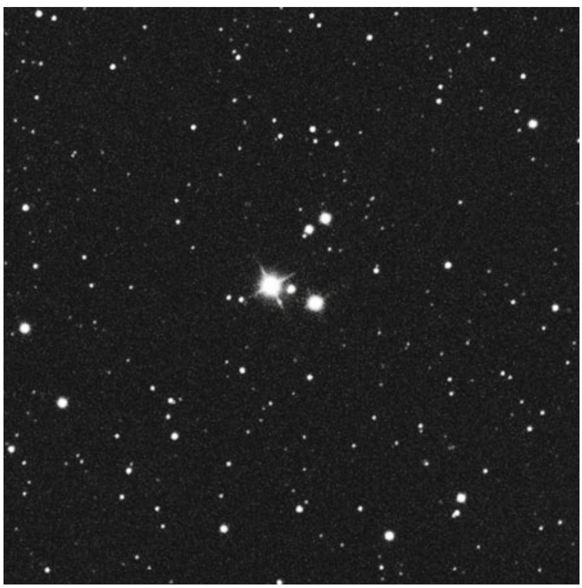


Sh 1–89 is a very faint smudge of light about a degree to the north of NGC 7048 and is best found with an OIII filter. Even in large apertures of 25 cm + it is barely discernable with direct vision and seems to disappear in higher powers. Use of the OIII filter and low power gives the best view of this small, roundish elongation of light, which is quite ethereal and bar like. Even an H alpha filter helps a little. Observers with apertures less than 20 cm will probably find this one to be invisible.

NGC 7048
Cygnus
RA: 21 h 14 m 15 s
Dec: +46.17.3
Size: 60″
Magnitude: 12.1
Class: 3b

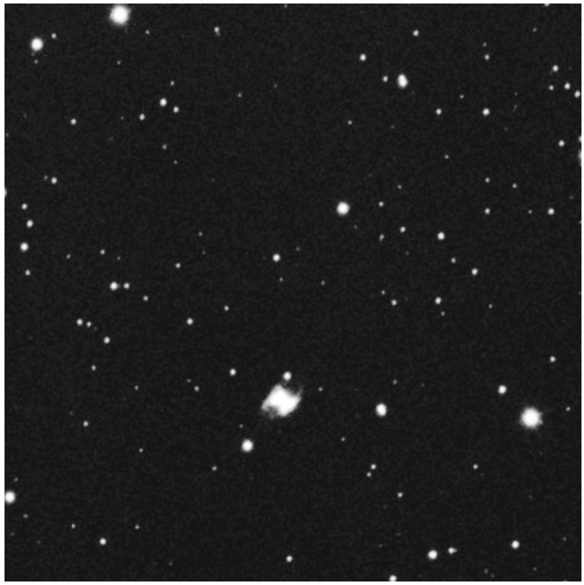
NGC 7048 is a ghostly ring-like object NF of the "North America Nebula" NGC 7000 and appears as a filled shell of gray-blue light visible with direct vision, but use of an OIII filter on a moderate aperture will reveal it if the light grasp just fails. NGC 7048 is similar in size to M57 but without the immediate effect of standing out in the field. There is an eighth mag star SP the nebula, which provides a good marker for the object. In low powers the glow of the nebula is evident, though higher powers hold it well with little drop in contrast. A beautiful yet somewhat neglected object.

IC 5117
Cygnus
RA: 21 h 32 m 31 s
Dec: +44.35.8
Size: 3″
Magnitude: 11.5
Class: 2



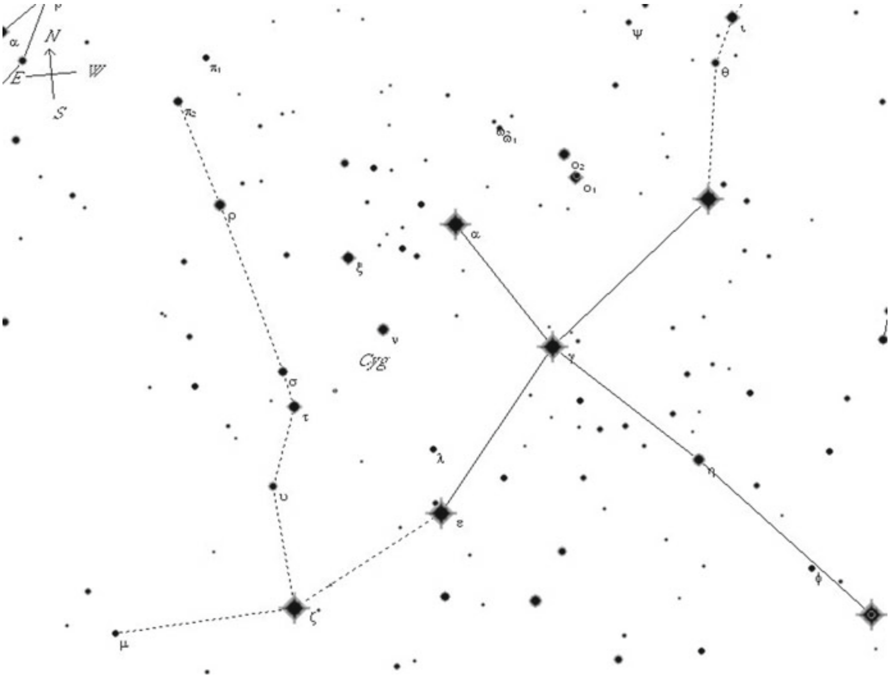
Small star-like planetary in northern Cygnus forming a very long triangle with ρ Cygni and a sixth mag star to the north by about a degree. Once the field is located try blinking with an OIII filter, which makes the object jump out of the very rich star field almost immediately. In direct and averted vision the object looks like a double star with its orange neighbor, and it is easy to dismiss as a wide optical double star. Once seen, the color is a pale green in moderate magnification, and higher powers hold the color contrast well.

Humason 1–2
Cygnus
RA: 21 h 33 m 07 s
Dec: +39.38.18
Size: 5″
Magnitude: 12.1
Class: 2

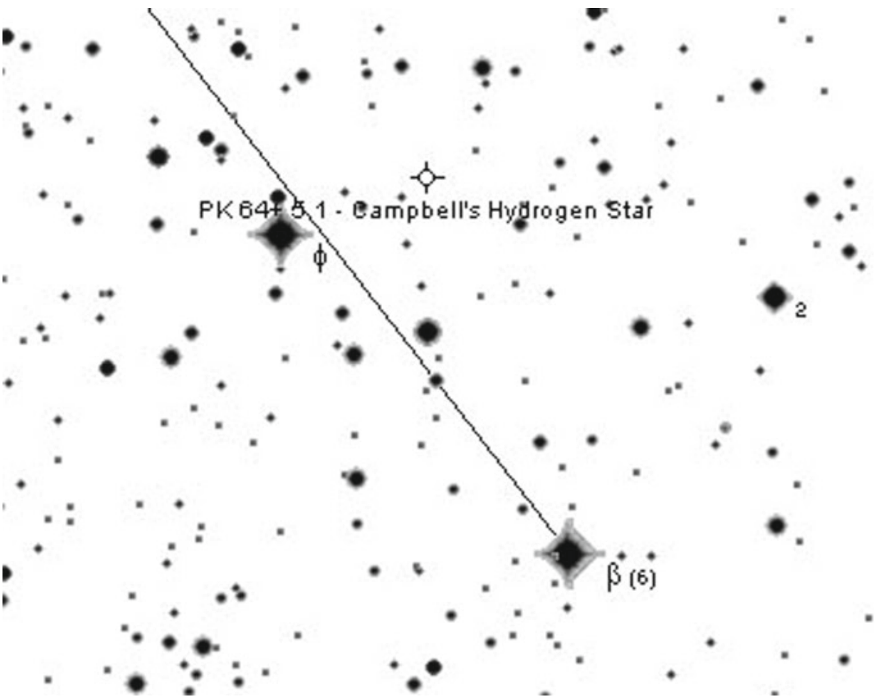


Humason 1–2 is a faint starry bead of light that can be found by following a train of four fifth magnitude stars from ρ Cygni southward in a rich Milky Way field. Use of the OIII filter is essential here, as the field is overrun with faint stars, and the planetary is faint, small and obscure. Shining at 12th magnitude, Hu 1–2 is easy to see with direct vision once its position is known, but like many small faint planetary nebula, one would have passed it by without a second glance were it not for the filter. Small, unassuming and unspectacular but providing a challenge for those with modest to large telescopes.

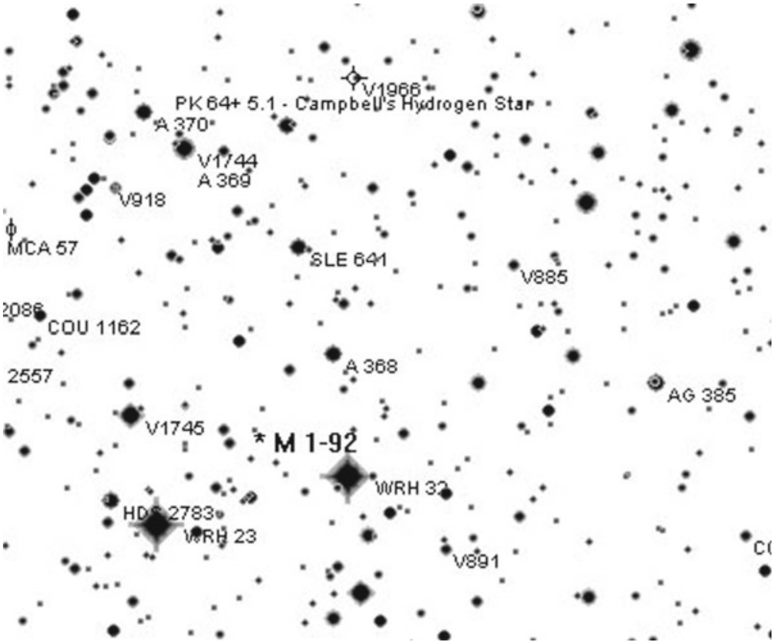
General view of Cygnus



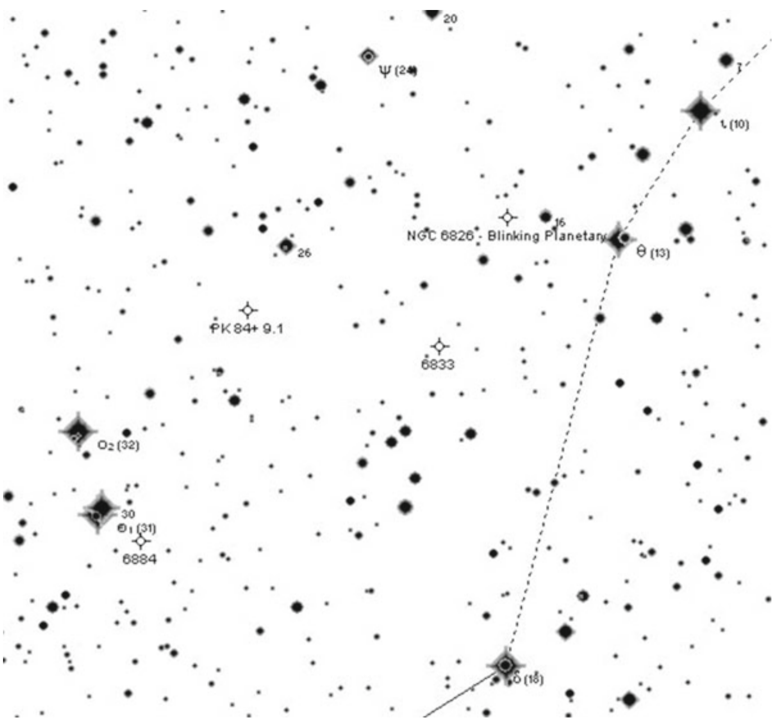
Finder chart for BD 30+



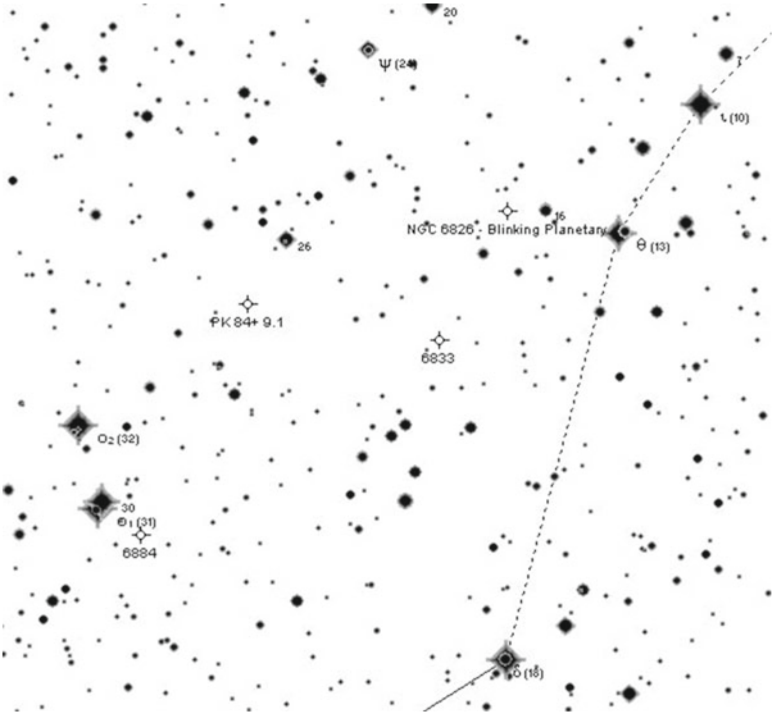
Finder chart for M 1–92



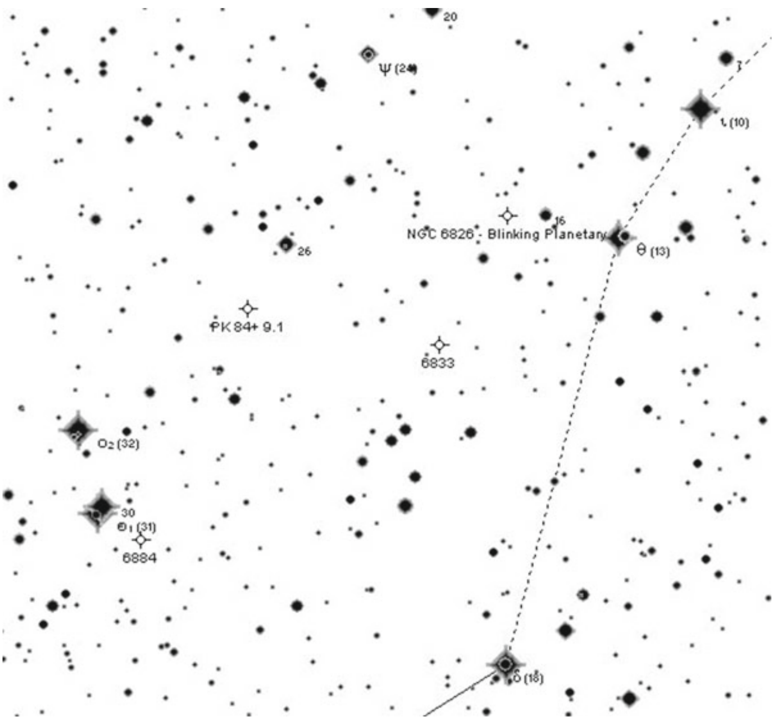
Finder chart for NGC 6826



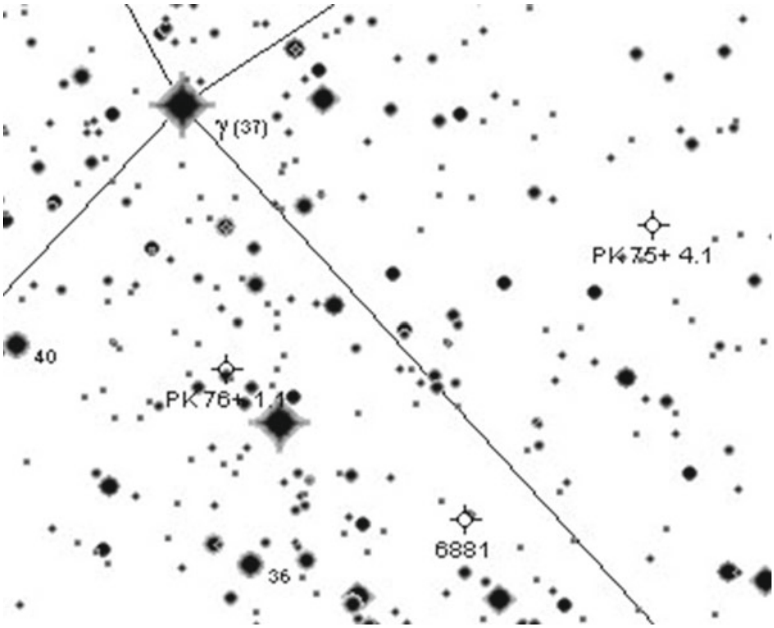
Finder chart for NGC 6833



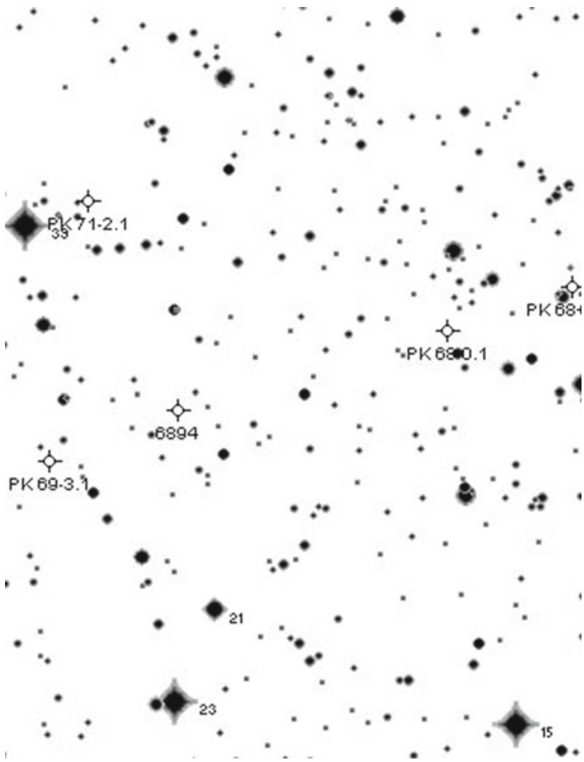
Finder chart for NGC 6884



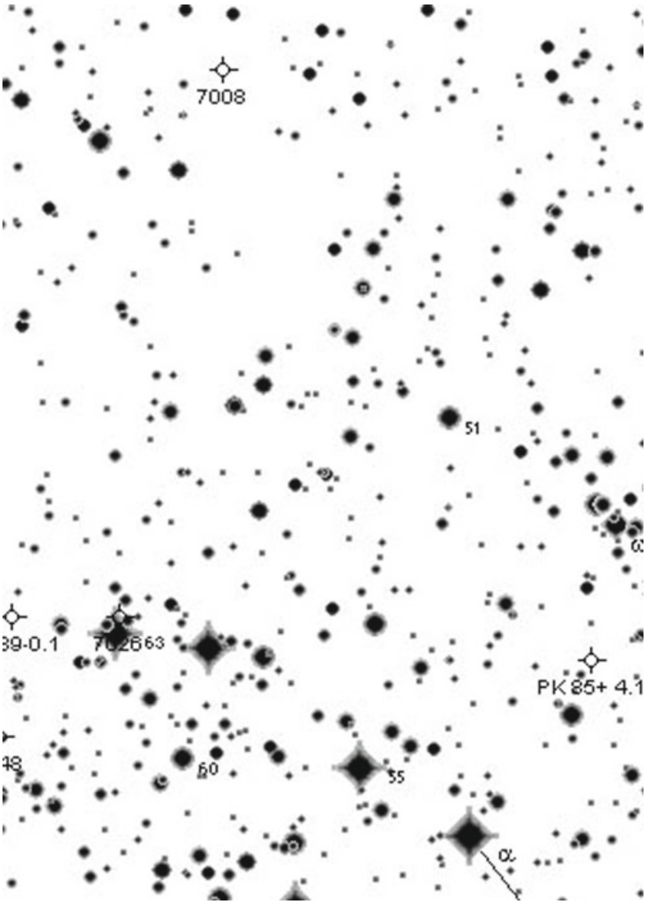
Finder chart for NGC 6881



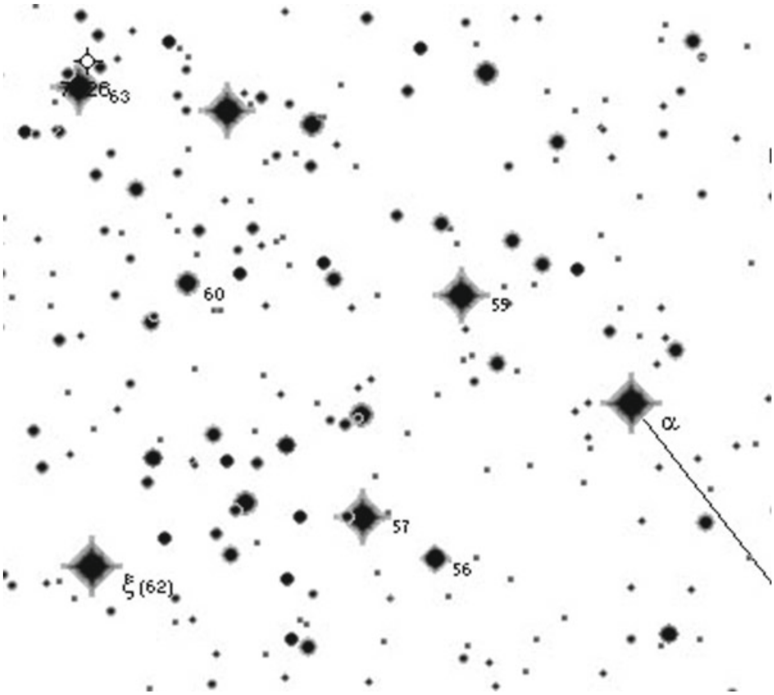
Finder chart for NGC 6894



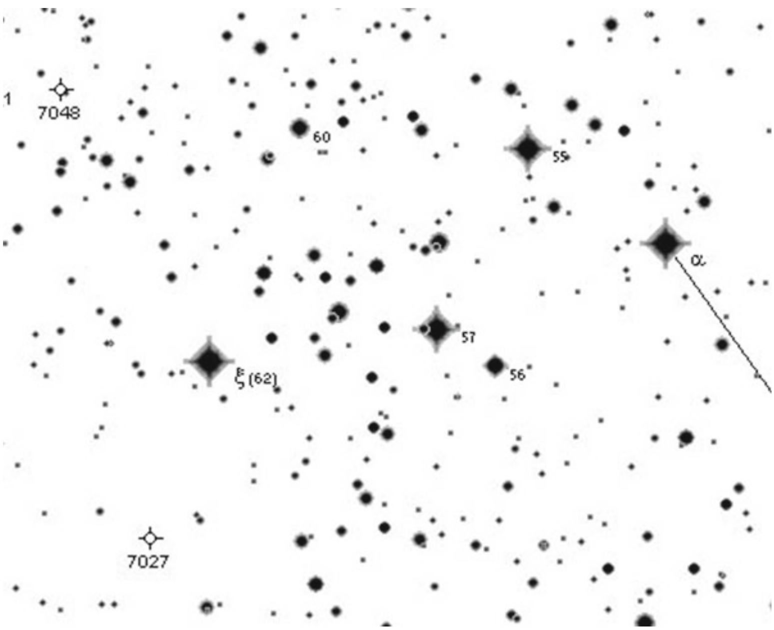
Finder chart for NGC 7008



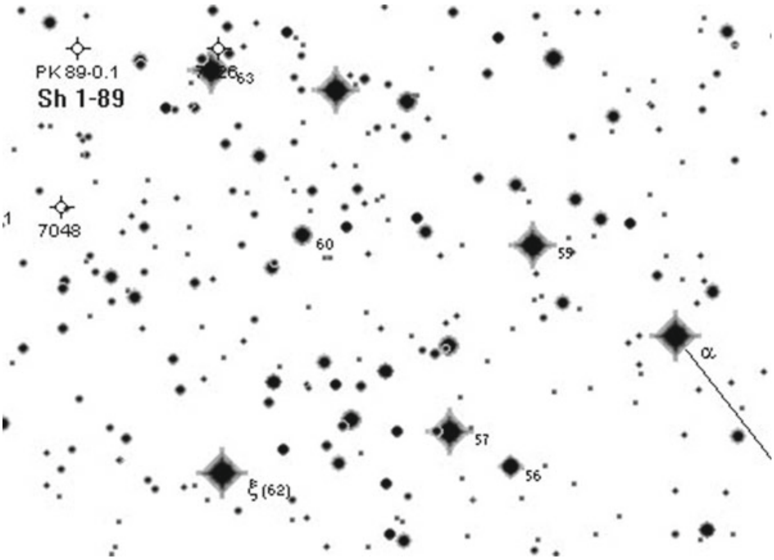
Finder chart for NGC 7026



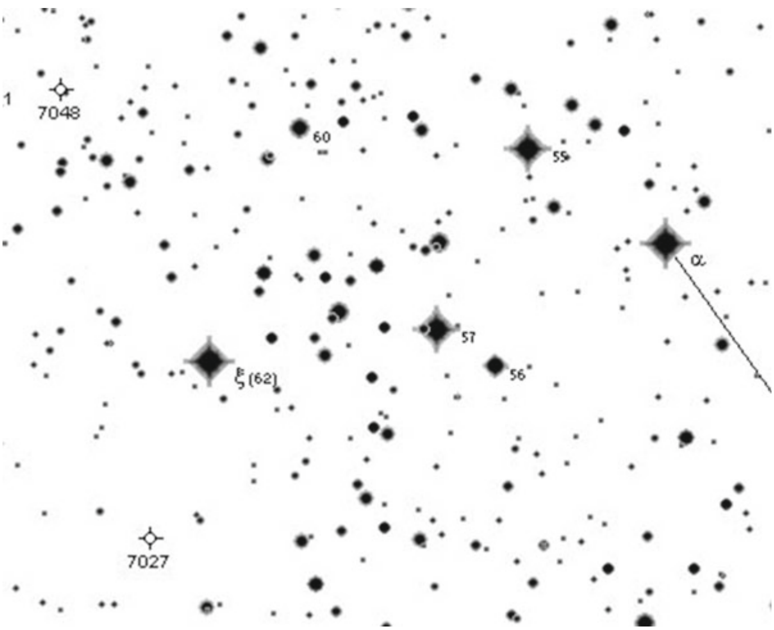
Finder chart for NGC 7027



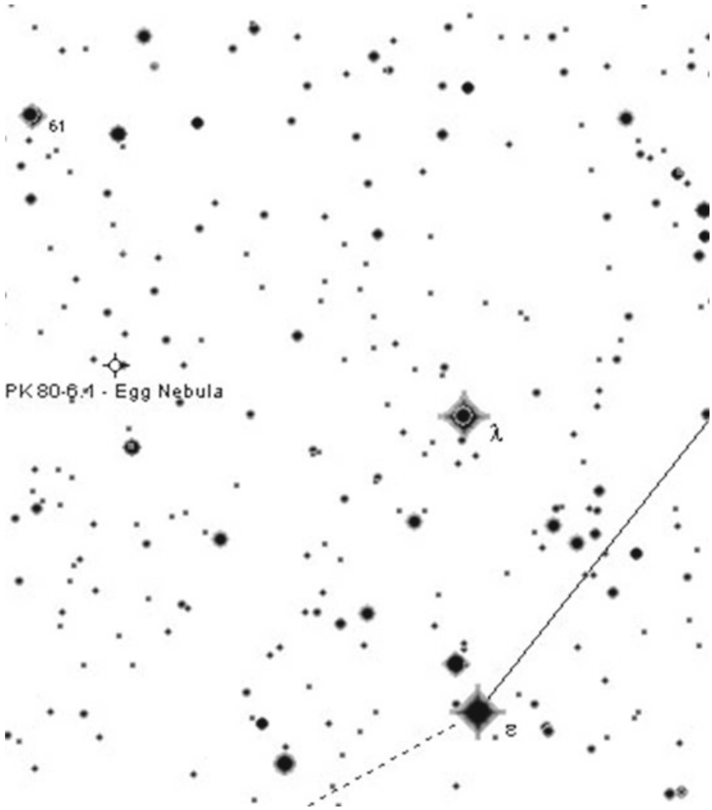
Finder chart for Sh 1–89



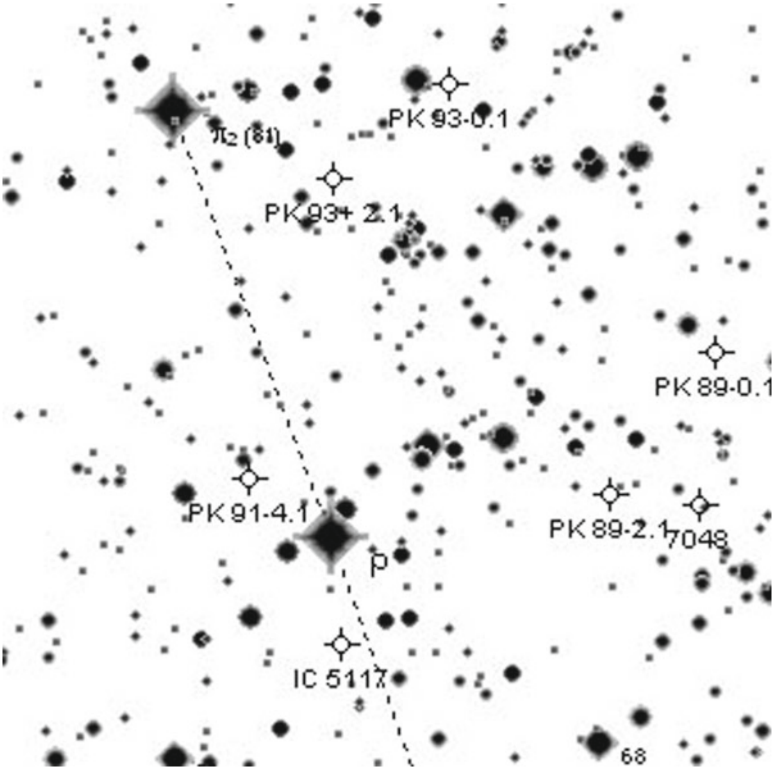
Finder chart for NGC 7048



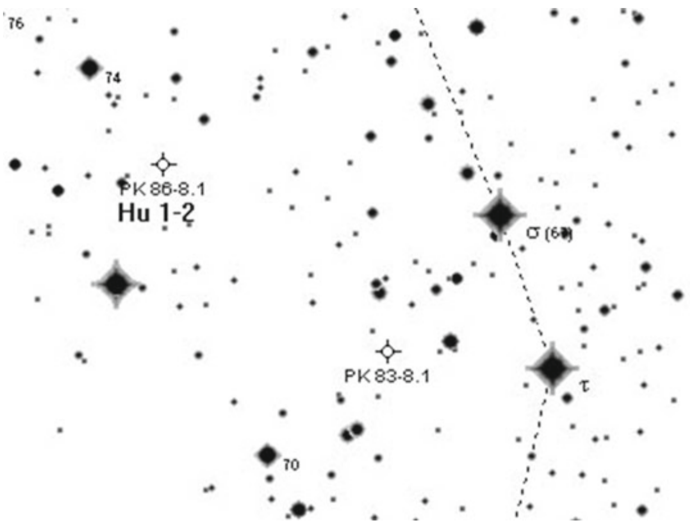
Finder chart for CRL 2688, Cygnus Egg



Finder chart for IC 5117



Finder chart for Hu 1–2

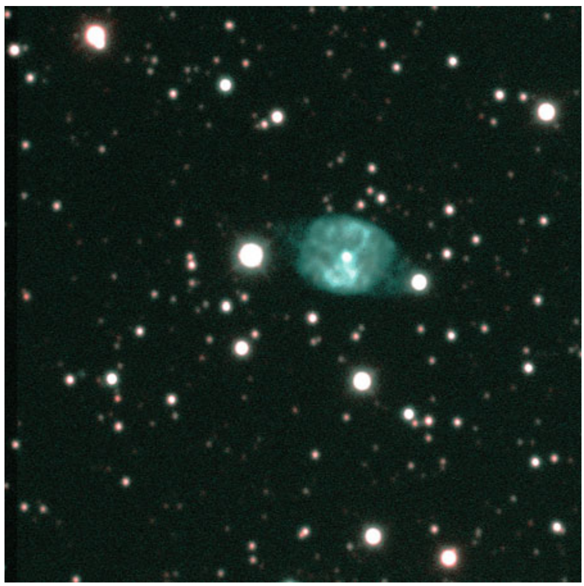


Delphinus

NGC 6891
Delphinus
RA: 20 h 15 m 09 s
Dec: +12.42.3
Size: 74″
Magnitude: 10.5
Class: 2a

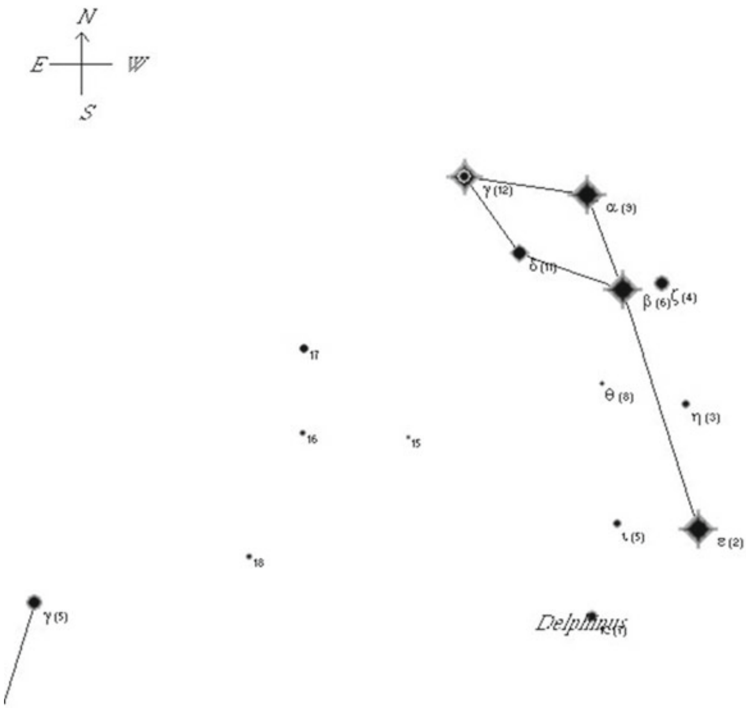
A wonderful disk-like planetary nebula on the Delphinus/Aquila border. The object is instantly visible as a disk of blue light in a field of dim Milky Way stars and is quite large at over 1′ across and glowing blue-white in color. Higher magnifications reveal the disk well, and it really does look like a small planet as it is almost circular in outline and very bright. There is a faint star on the eastern edge, and some observers report seeing a central star. This planetary is visible in most telescopes.

NGC 6905
Delphinus
RA: 20 h 22 m 23 s
Dec:+20.06.3
Size: 42″
Magnitude: 11.1
Class: 3

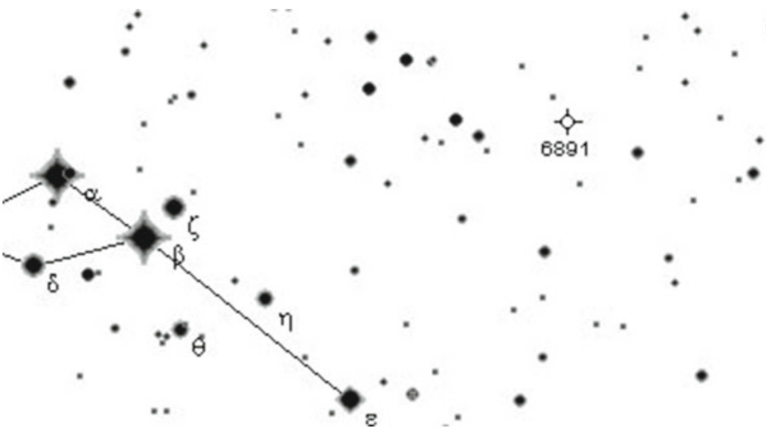


NGC 6905 is a lovely little planetary in Delphinus that enjoys a beautiful Milky Way background, which makes it a little challenging to star hop to but is worth the effort, as this planetary is intensely blue and obvious in the field. A moderate power brings out a slight mottling to its interior and shows the elongation on a N/S axis a little better. With averted vision the center gets brighter, though in direct vision it looks darker! A wonderful deep sky object that is also known as the "Blue Flash." NGC 6905 is a Herschel 400 object, too.

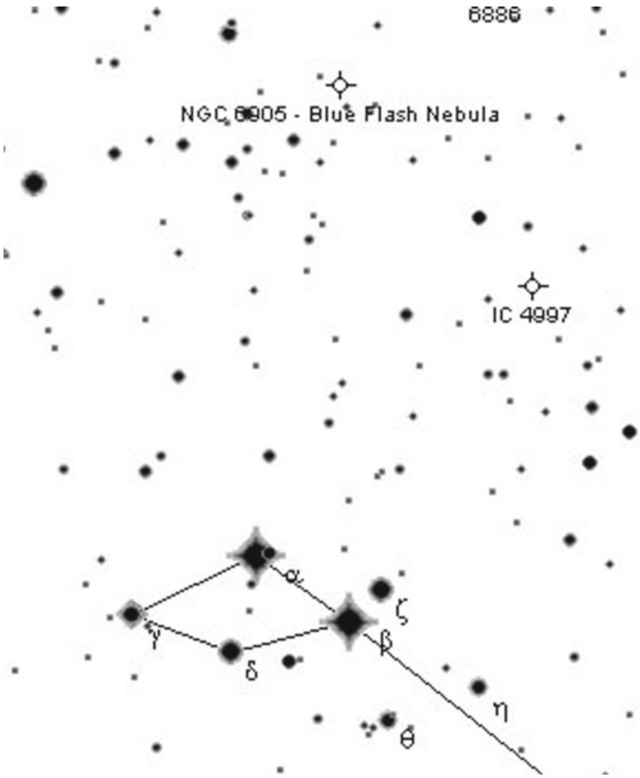
General view of Delphinus



Finder chart for NGC 6891



Finder chart for NGC 6905

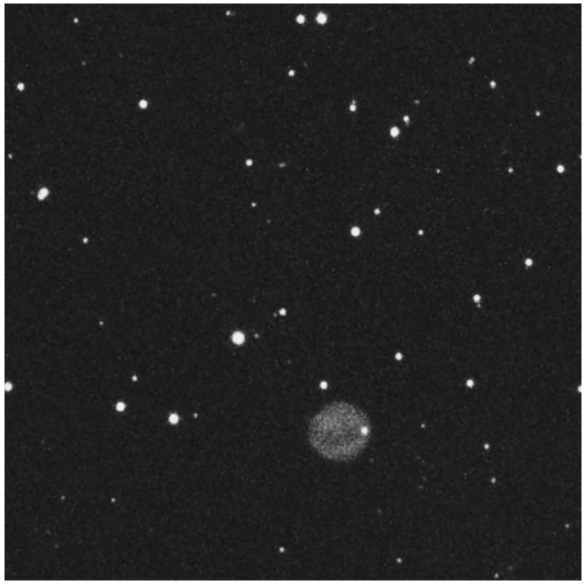


Draco

NGC 6543
Draco
RA: 17 h 58 m 33 s
Dec: +66.38.0
Size: 23″
Magnitude: 8.1
Class: 3a + 2

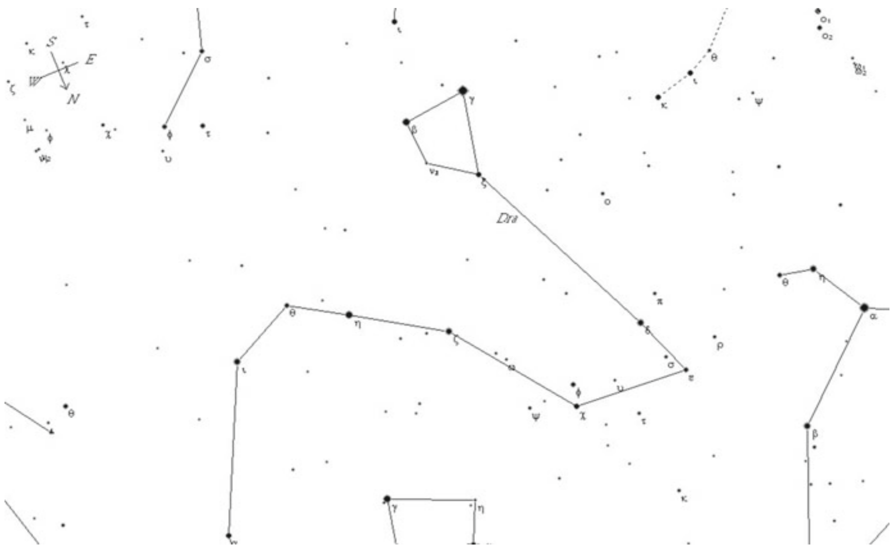
A gorgeous little planetary nebulae that is within easy reach of most telescopes. This planetary became a famous object when William Huggins turned a spectroscope on it and determined planetaries to be made of hot luminous gas rather than the rings of stars they had been previously thought to be. The Hubble Space Telescope has taken beautiful photographs of the "Cat's Eye Nebula," though no visual observer will see such details in this object. NGC 6543 is an obvious round, intensely blue spot of light at low power that maintains its color and shape in higher magnifications, revealing a slight elongation NE/SW and displaying a brighter outer "atmosphere" from the rest of the interior of the disk. No central star is visible, however. This object is also known as Caldwell 6.

NGC 6742
Draco
RA: 18 h 59 m 18 s
Dec: +48.28.0
Size: 31″
Magnitude: 13.4
Class: 2c

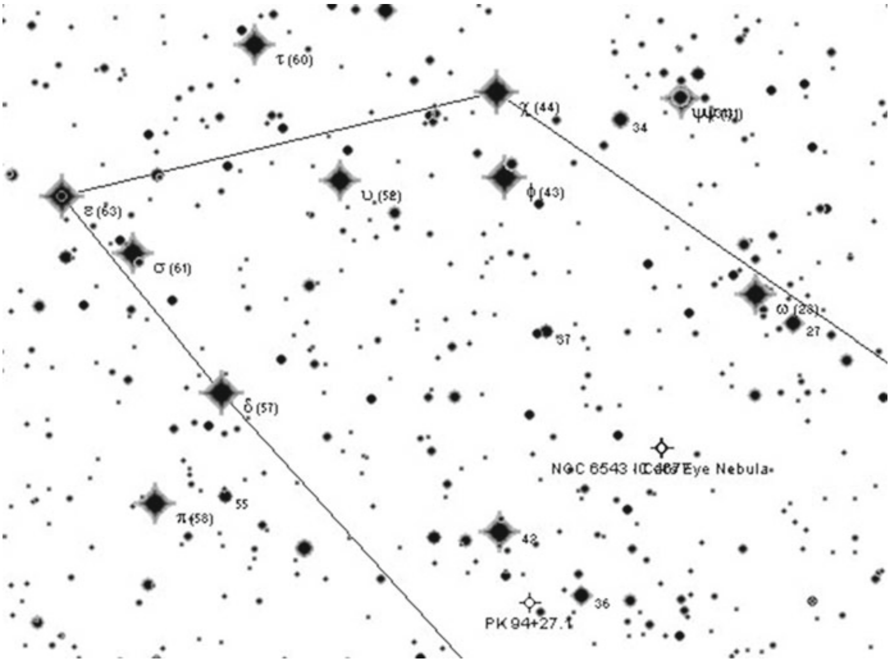


NGC 6742 is a faint, round nebula, which is easy to star hop to if one remembers that it lies midway between 31 Lyrae and κ Cygni in the "corner" of the boundary of Draco and Lyra amid a crowded field of Milk Way stars. It is flanked to the N/S by two stars of fifth to sixth magnitude, which are nice pointers to its location. The planetary is very faint, as befits one of the Abell numbers (50), and averted vision is needed to see it properly once it has been located with the OIII filter. In low powers it is a dot of gray light about 30′ across, while in higher magnifications it is more discernable as a disk, almost perfectly round with a star on its eastern edge. NGC 6742 is quite a challenge even for a large aperture, due to its magnitude and size.

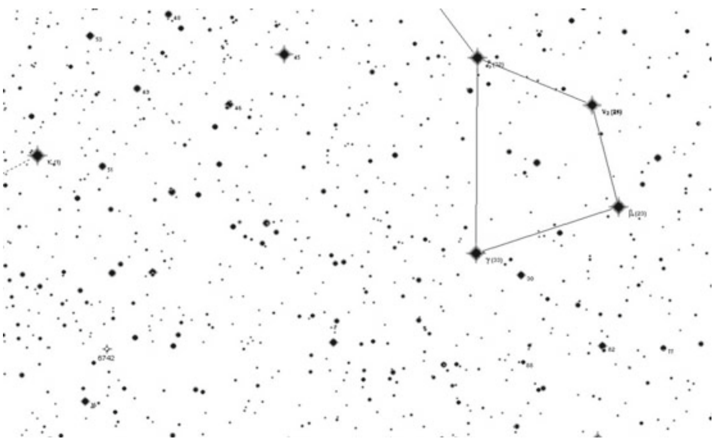
General view of Draco



Finder chart for NGC 6543

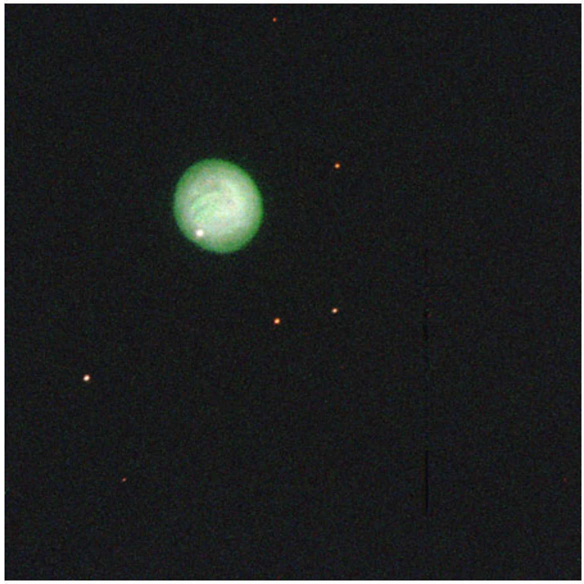


Finder chart for NGC 6742



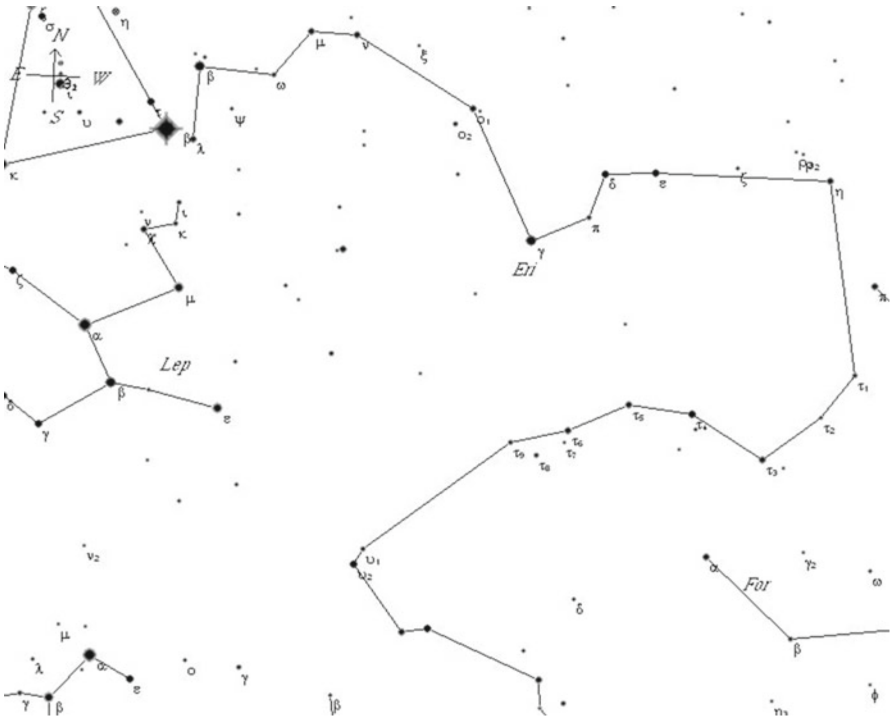
Eridanus

NGC 1535
Eridanus
RA: 04 h 14 m 16 s
Dec: −12.44.4
Size: 50″
Magnitude: 9.6
Class: 4 + 2c

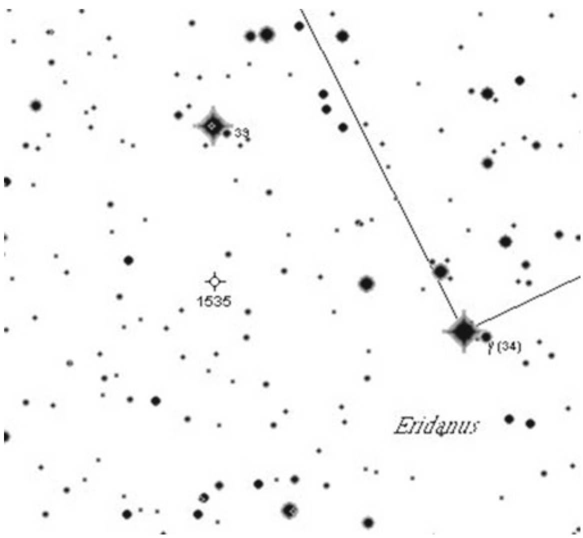


"Cleopatra's Eye" is a fabulous planetary in Eridanus, a real showpiece winter object and so easy to star hop to from γ Eridani. In a low power eyepiece it is a smooth blue-green shell, but many observers have reported it as either blue or green, not both! The nebula is a little elliptical, with the axis lying NE/SW but no central condensation and no hint of a central star. In most telescopes it reveals itself as a nicely filled shell of light over 1′ across, giving itself away as one of the obvious objects in the region. NGC 1535 is also one of the Herschel 400 objects and is one of the best planetary nebulae targets of the NGC catalogue for any small telescope. A deep sky delight.

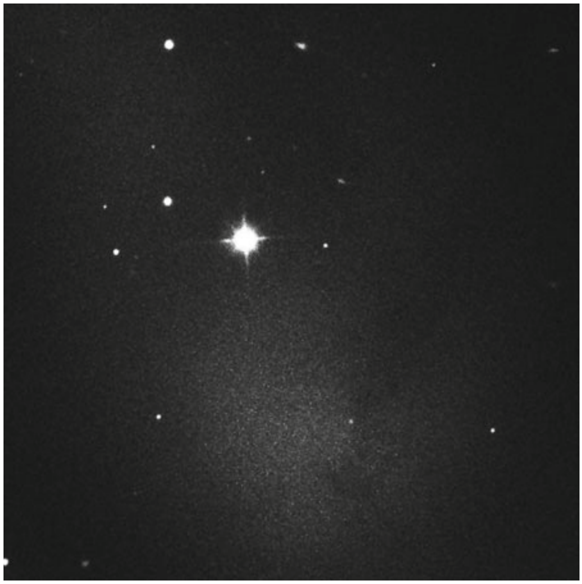
General view of Eridanus



Finder chart for NGC 1535



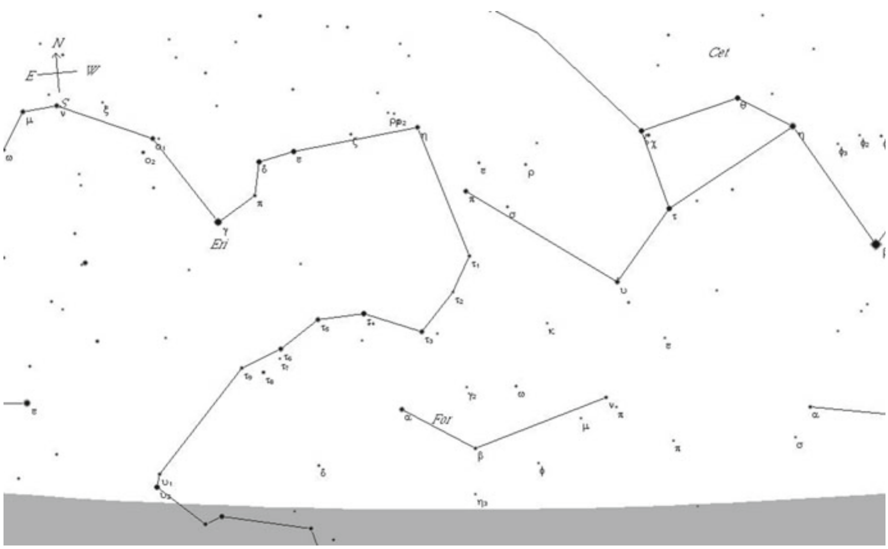
Fornax



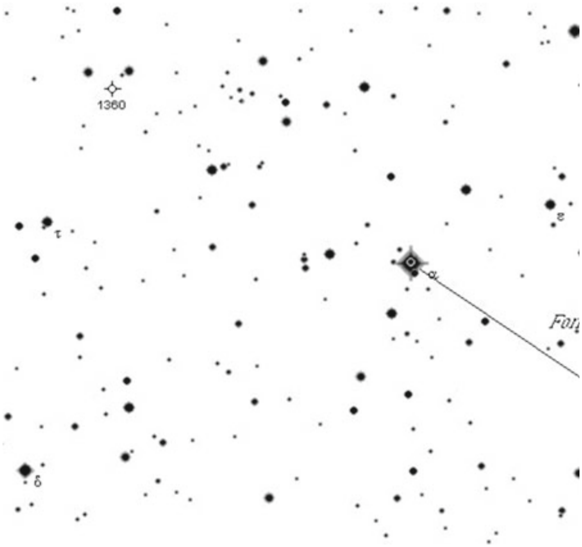
NGC 1360
Fornax
RA: 03 h 33 m 15 s
Dec: −25.52.3
Size: 8′
Magnitude: 9.4
Class: 3

Faint, large nebula in Fornax that is not too difficult to find, but the planetary has a very low surface brightness, making it a little difficult to see with direct vision. Averted vision brings out more detail in that the glow of the object increases, but there is little more than a smooth shell visible close to a ninth mag star. It is also rather low in the sky for observers in high northern latitudes, though those in the southern hemisphere will have no problems at all! The nebula responds moderately to use of an OIII filter, is elongated in a NE–SW direction, and the sheer size of this planetary will render the object fainter than its quoted magnitude here. A challenging object for observers with apertures of 150 mm and under.

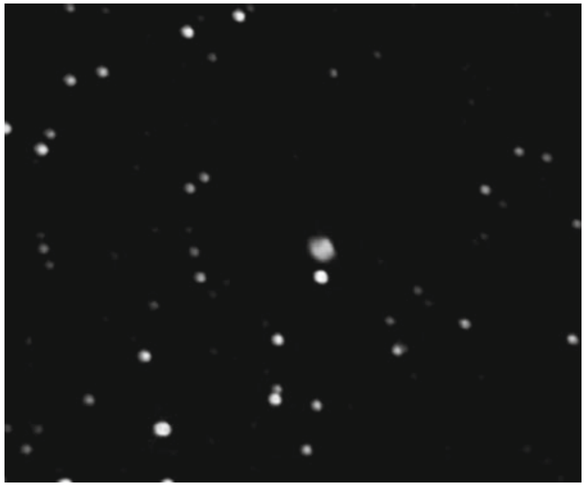
General view of Fornax



Finder chart for NGC 1360



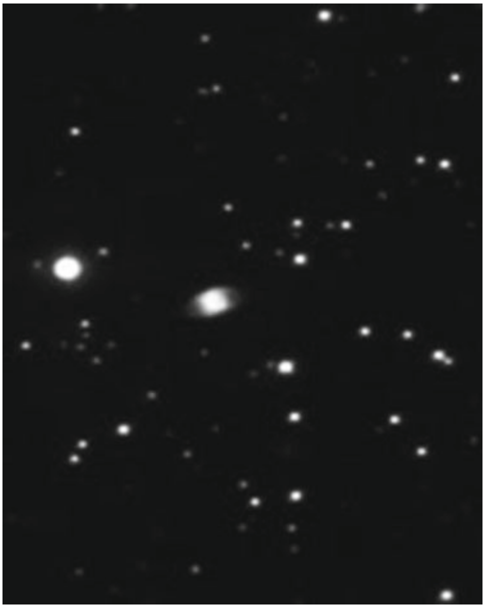
Gemini



J900
Gemini
RA: 06 h 25 m 57 s
Dec: +17.47.27
Size: 12″
Magnitude: 11.8
Class: 3b + 2

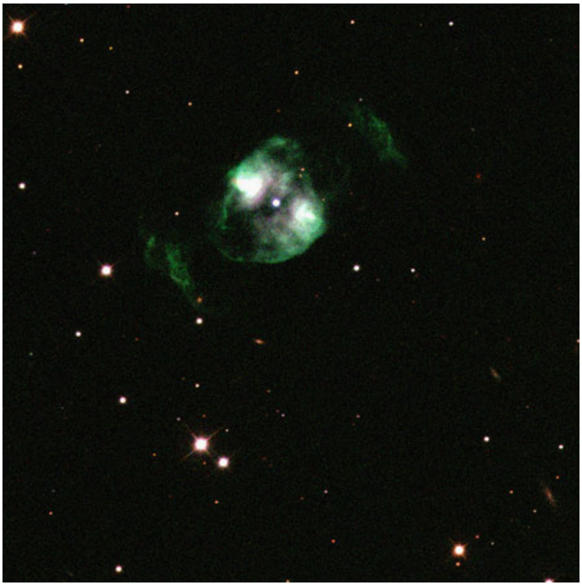
Jonckheere 900 is a tiny, faint, star-like planetary in Gemini, forming a flat triangle with γ and ν Geminorum in a very crowded Milky Way field, which makes its identification difficult in this field of faint stars. Jonckheere 900 gives itself away by resembling a small double star, though moderate to high powers are necessary to see this once the field has been identified. Many observers report that J900 remains star-like no matter what magnification is used, but others report a faint nebulosity to the object and a slight elongation on a NE-SW axis. Apart from this J900 remains a uniformly white, faint and difficult object that is a good challenge!

Minkowski 1–7
Gemini
RA: 06 h 37 m 21 s
Dec: +24.00.4
Size: 29″
Magnitude: 13.0
Class: 2



Rudolph Minkowski was adept at finding some of the most interesting planetary nebula from a morphological point of view – and unfortunately they are some of the smallest and faintest. M 1–7 is no exception and is a tiny, faded and difficult nebula. It can be located by hopping from ε Geminorum to a trio of sixth mag stars SP ε. In low power the field is crowded with faint Milky Way stars, and the nebula remains difficult to pin down until the observer uses an OIII filter, which obtains a good response, revealing a small, slightly elongated patch of light, which in higher powers glows slightly brighter and hints at elongation on a NE/SW axis. M 1–7 remains very faint and almost stellar and is a challenging object.

NGC 2371/2
Gemini
RA: 07 h 25 m 35 s
Dec: +29.29.4
Size: 115″
Magnitude: 11.4
Class: 3a + 2

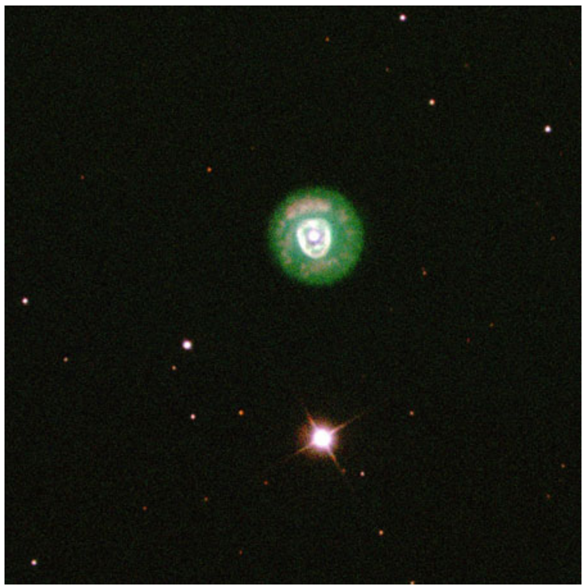


Despite its magnitude of 11.4 NGC 2371/2 is horridly faint and is small and hidden in a loose field of stars. In low power the size of the object does not come over well, as most of its extensions are faint and the central portion of the nebula is a gray smudge. In higher powers there is some resolution of features. NGC 2371/2 is bipolar and easily separated into two objects with a clear NE/SW axis and no central star; the disk is fairly even in brightness, though averted vision does hint at deeper features on either side of the nucleus of the nebula. A challenge for observers using apertures less than 150 mm, NGC 2371/2 is also one of the Herschel 400 objects.

Abell 21
Gemini
RA: 07 h 29 m 04 s
Dec: +13.15.2
Size: 14′
Magnitude: 11.3
Class: 3a

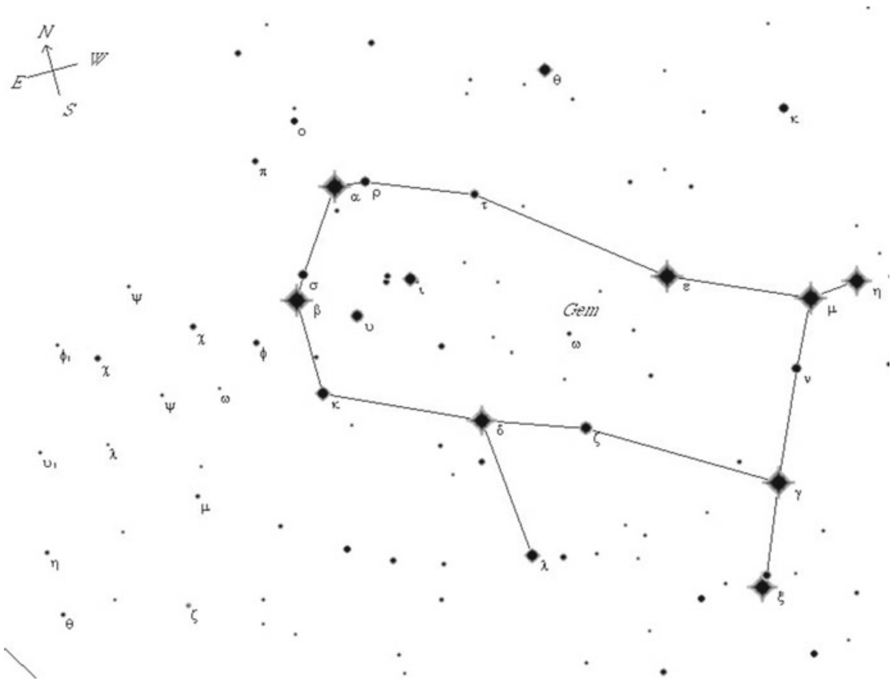
Abell 21 is a faint amorphous nebula in southern Gemini bordering on Canis Minor. For an observer equipped with a Dobsonian, star hop from β C.Min (Murzim) and head through γ and ε to two 4.5 mag stars, the eastward of which makes the right-angled turn of a triangle with Abell 21 at the apex. It appears as a faint luminescence, about magnitude 12 in a low power field with some extension to the NE, which makes that side of the object rather brighter than the rest. In a higher power, it looks like a bite has been taken out of it. Abell 21 remains a faint and difficult object that is a challenge to modestly equipped observers but has been imaged by some as it makes a nice target. It is otherwise known as the "Medusa Nebula."

NGC 2392
Gemini
RA: 07 h 29 m 11 s
Dec: +20.54.7
Size: 50″
Magnitude: 9.2
Class: 3b

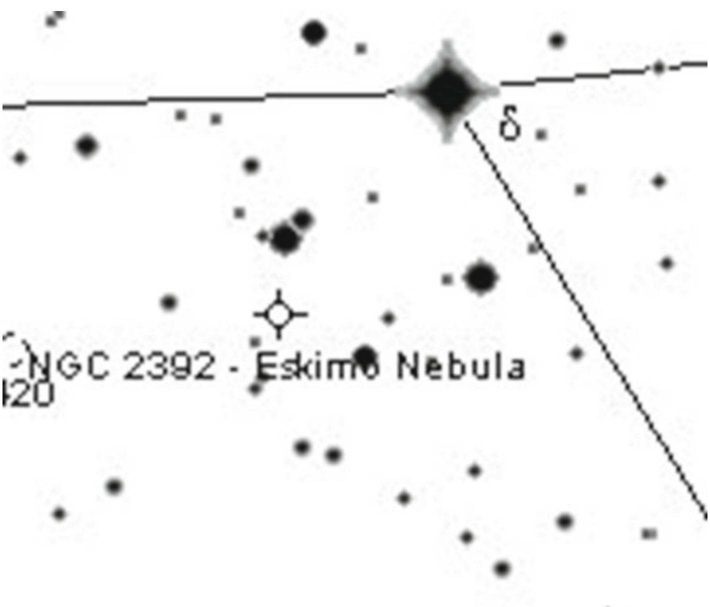


A superb planetary in southern Gemini; the "Eskimo Nebula" is beautifully green and immediately obvious no matter what size telescope is used. It is an evenly illuminated disk at first glance, but under higher powers it easily separates into two distinct layers, a bright core with a slightly resolved central star and fuzzy outer layer representing the "hood" of the Eskimo. The hood should be readily apparent with averted vision, and the little face is almost there and can be glimpsed in high power with averted vision. NGC 2392 is a wonderful planetary, a favorite with many observers due to its magnitude, visibility and detail. Unsurprisingly, it is a Caldwell object (No 39) and Herschel 400 catalogue object, too.

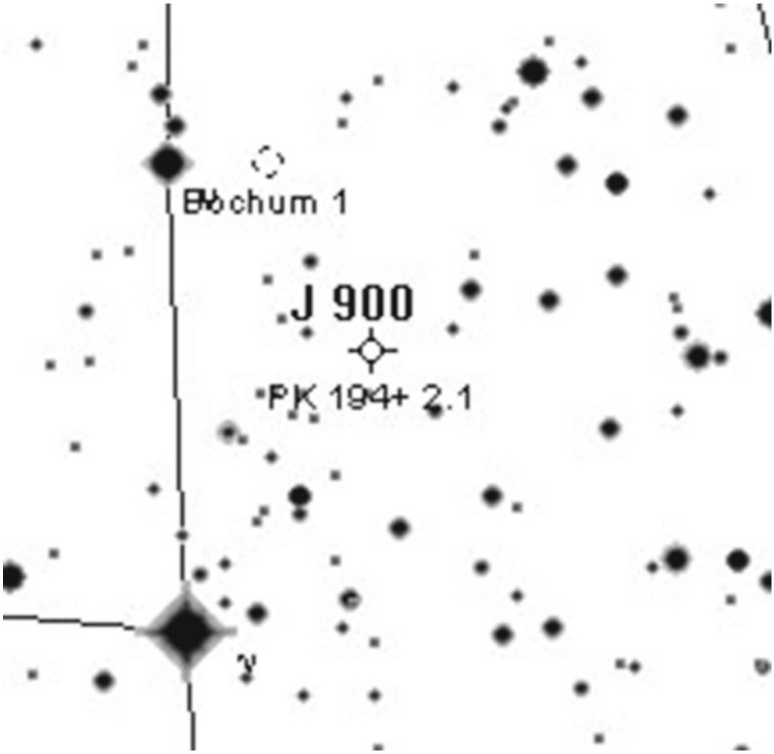
General view of Gemini



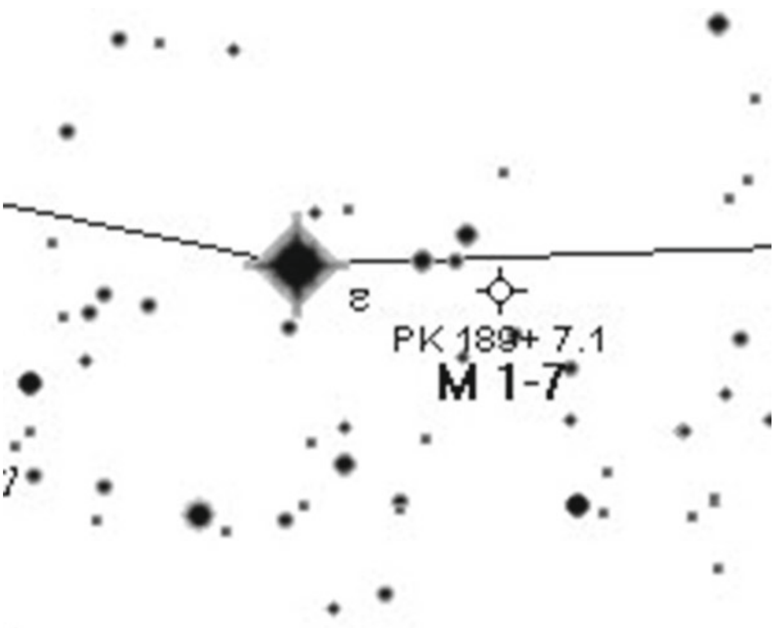
Finder chart for NGC 2392



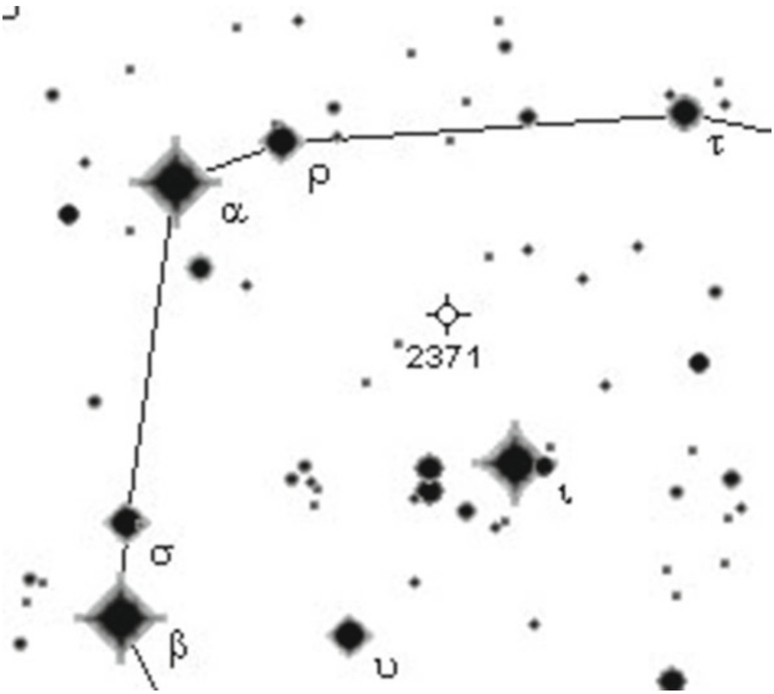
Finder chart for J 900



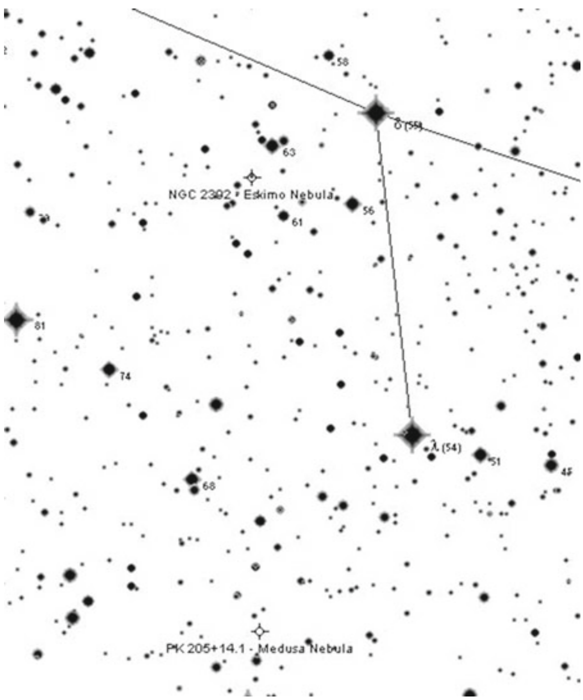
Finder chart for M 1–7



Finder chart for NGC 2371/2

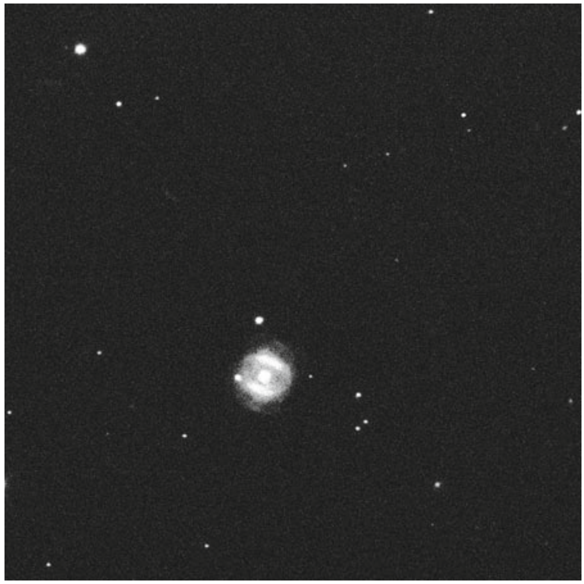


Finder chart for Abell 21



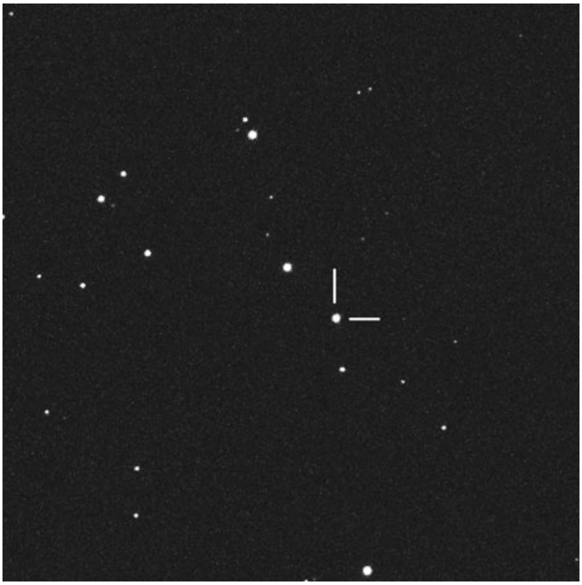
Hercules

NGC 6058
Hercules
RA: 16 h 04 m 27 s
Dec: +40.41.00
Size: 25″
Magnitude: 13.1
Class: 3 + 2



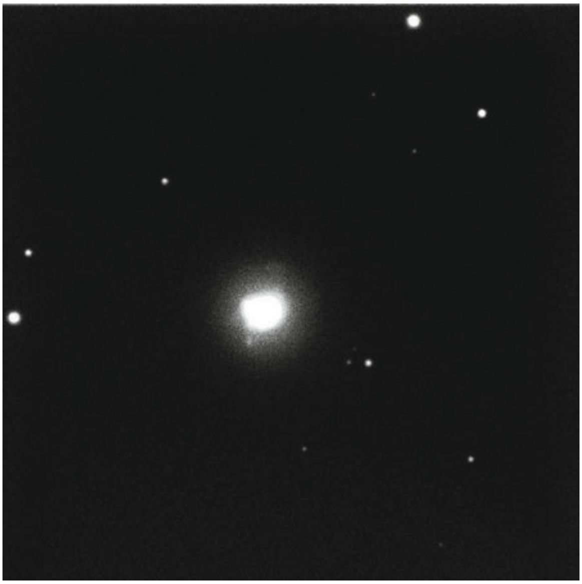
A nice if rather inconspicuous planetary in NW Hercules that reveals itself as a faint condensation around a 12th mag star, with the nebula being visible as two arcs on N & S sides of the star in medium power. In higher powers the arcs are better defined, close to the central star, but the nebulosity rapidly fades at both ends E–W. It looks white at first, but in averted vision it does hint at a greenish color and has a good response to use of an OIII filter. It needs careful attention to discern these arcs, as the brightness of the star and the faintness of the nebulae work against the observer.

IC 4593
Hercules
RA: 16 h 11 m 45 s
Dec: +12.03.3
Size: 12″
Magnitude: 9.8
Class: 2



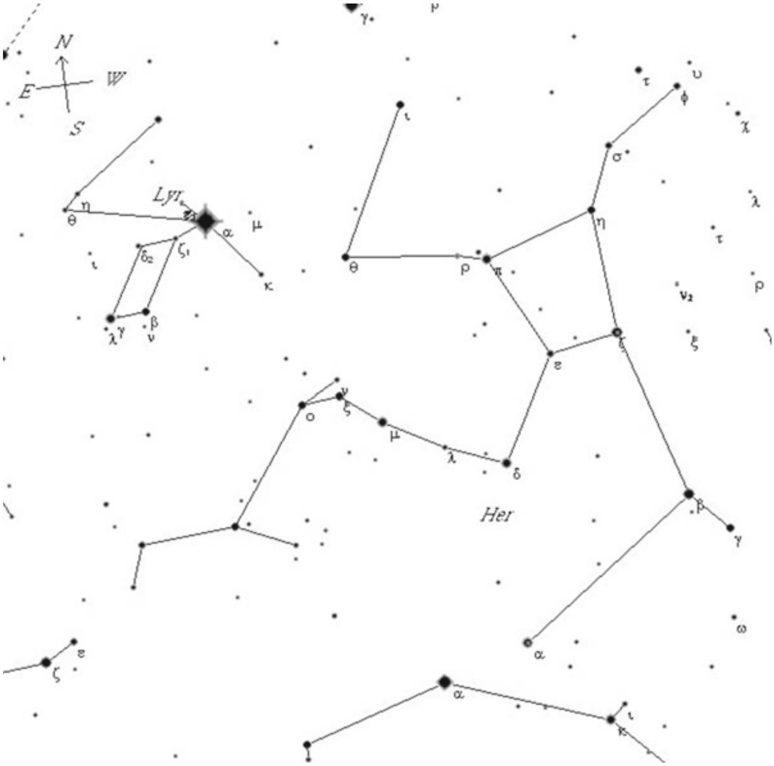
Tiny, almost stellar planetary in southern Hercules that responds well to an OIII filter, thus distinguishing it from the star field. It is surprisingly bright, and direct vision brings out a dim blue color that separates it from the stars in the field. In medium powers it is slightly elongated, but this feature is more apparent in higher magnifications, where it seems a little oblate with a N/S axis. The initial blue color turns to an even white in higher power. This planetary is even marked on Tirion's double star atlas and can be seen as a tiny star with good binoculars! It is called the "White Eyed Pea" in some sources.

NGC 6210
Hercules
RA: 16 h 44 m 30s
Dec: +23.48.0
Size: 50″
Magnitude: 8.8
Class: 2a + 3b

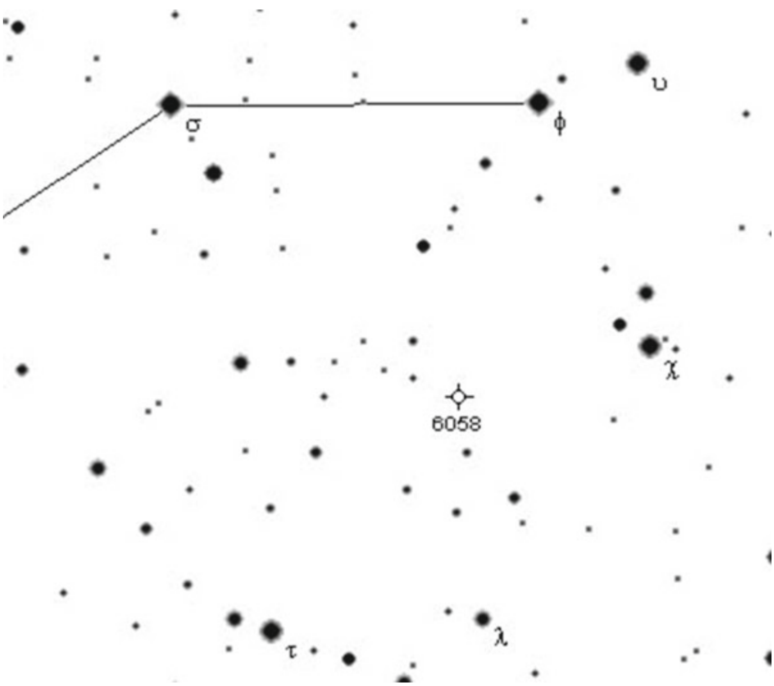


Lovely little planetary revealed as part of a small "triangle" of stars between 51 and β Herculis. Round in appearance at low powers, NGC 6210 is intensely green in color, not emerald but aquamarine in hue. It bears higher powers well, but they don't reveal anything more than a filled shell about 50″ across with a slight central condensation but no central star visible. NGC 6210 is bright enough to be seen in all kinds of instruments, including a good pair of binoculars, where it can be seen as a greenish "star." It is a beautiful sight in a small telescope and makes a nice contrast with the wonderful Messier objects (13 and 92) for observers looking for something other than balls of stars!

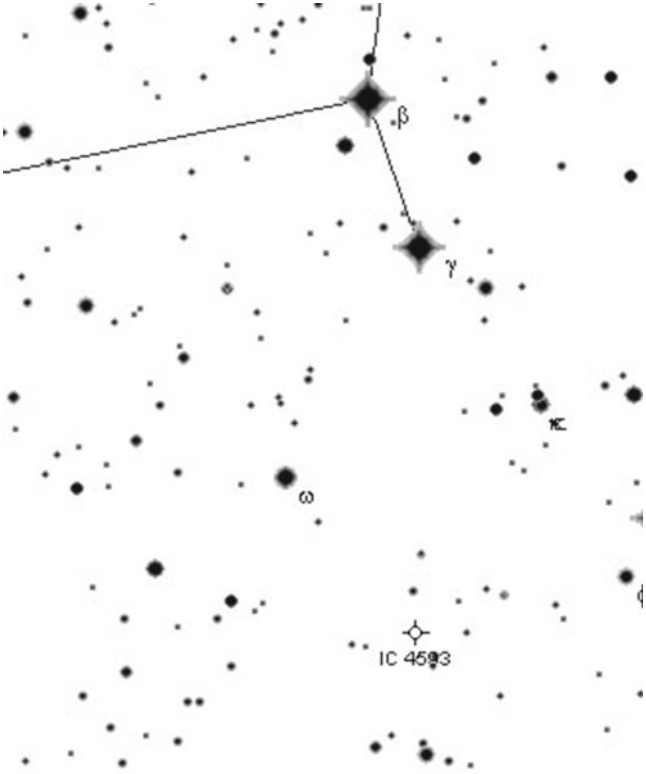
General view of Hercules



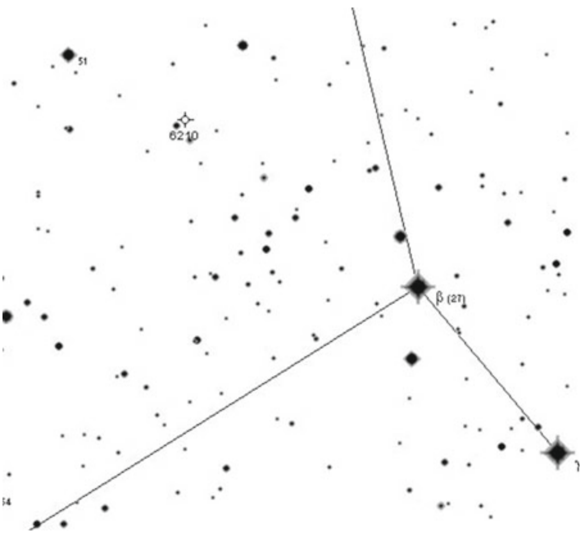
Finder chart for NGC 6058



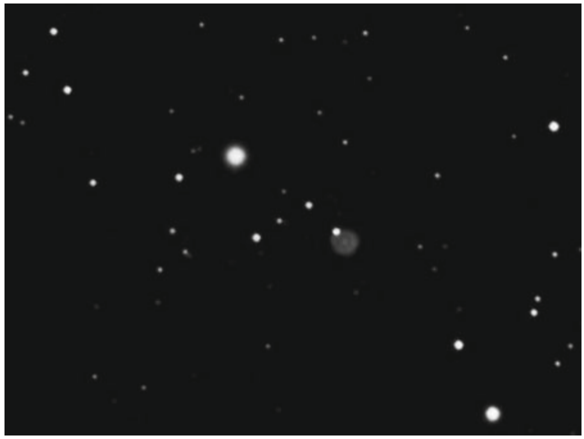
Finder chart for IC 4593



Finder chart for NGC 6210

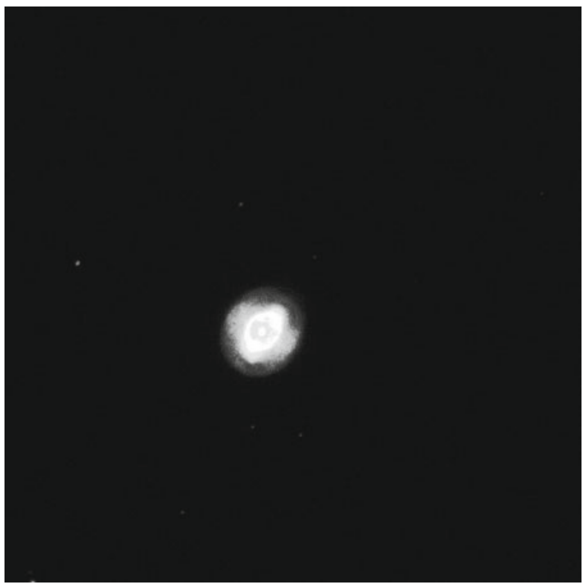


Hydra



NGC 2610
Hydra
RA: 08 h 33 m 23 s
Dec: −16.09.0
Size: 50″
Magnitude: 12.8
Class: 4 + 2

NGC 2610 is a faint small haze of light SP a seventh mag star, which indicates the field well but is a little troublesome when one needs to see the object. This planetary is a small puffball of blue-gray light with a faint star on its northern tip and in larger telescopes has a distinct inner dark area, which hides the central star. In high powers the planetary seems evenly illuminated and a little mottled in appearance. It also shows some moderate response to an OIII filter, which could render it visible on a good night with a telescope of 150 mm aperture.



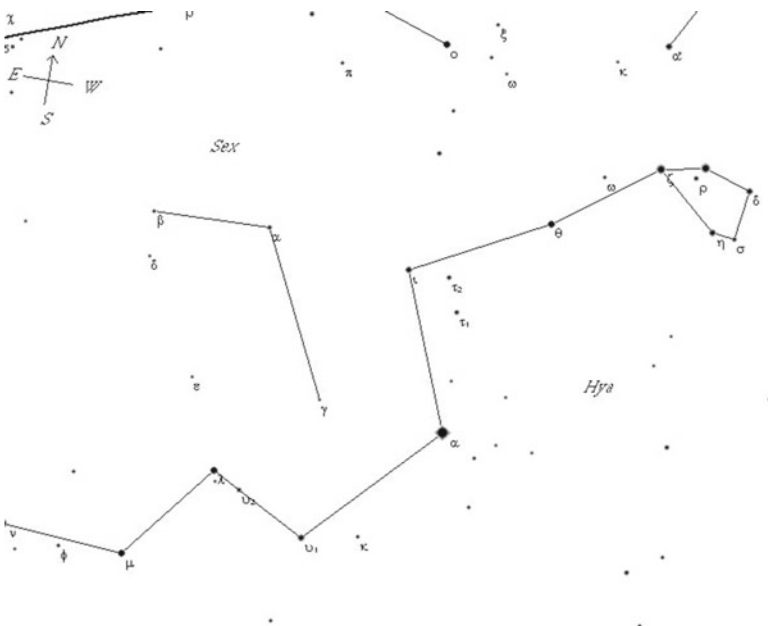
NGC 3242
Hydra
RA: 10 h 26 m 46 s
Dec: −18.38.5
Size: 45″
Magnitude: 7.8
Class: 4 + 3b

The wonderful "Ghost of Jupiter Nebula" that is an easy target south of μ Hydra, revealing itself as a round filled shell in a lovely aquamarine color and has some slight ellipsoid structure with an E–W axis. It is almost 1′ across and at only eighth magnitude is visible in binoculars and definitely visible in telescopes of most apertures. NGC 3242 is in a rather lonely field and thus stands out rather well. This object is also known as Caldwell 59 and is also in the Herschel 400 catalogue. NGC 3242 remains one of the brightest and best planetaries in the sky, which was sadly overlooked by Messier and his observing colleagues.

Abell 35
Hydra
RA: 12 h 53 m 34 s
Dec: −22.52.3
Size: 12′
Magnitude: 12.7
Class: 3a

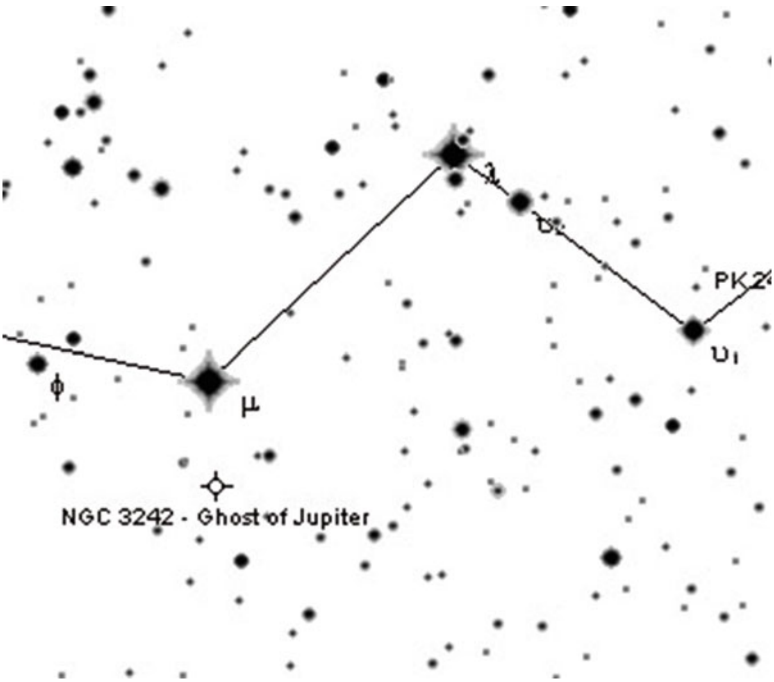
Abell 35 is typical of the Abell planetaries – large and very faint. A large telescope reveals an amorphous wispy structure almost midway between β Corvi and γ Hydrae, with two 6.5 mag stars to west in the low power field. Abell 35 comes out of the dark a little more with an OIII filter, and it is best to use the lowest power available to look for this elusive object, due to its large size and low surface brightness. The observer should detect a faint bar-like wisp of light about 20″ in length with an eighth mag star south of it, which is the center and densest part of this nebula. Quite difficult and something of a challenge for most observers.

General view of Hydra

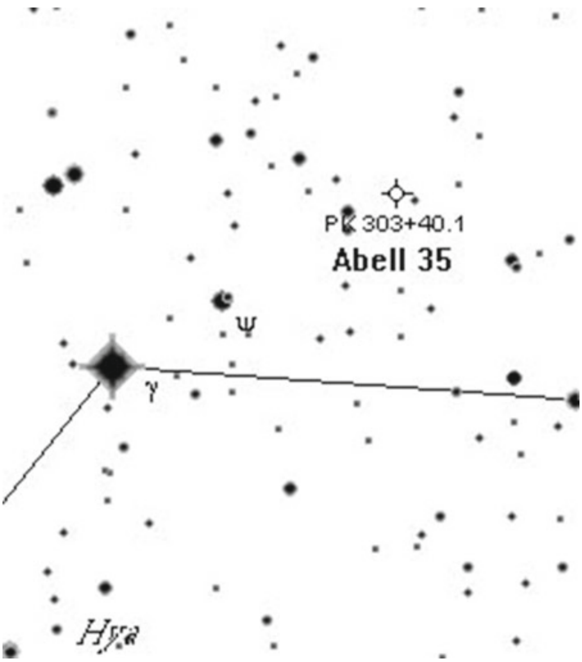


Finder chart for NGC 2610

Finder chart for NGC 3242

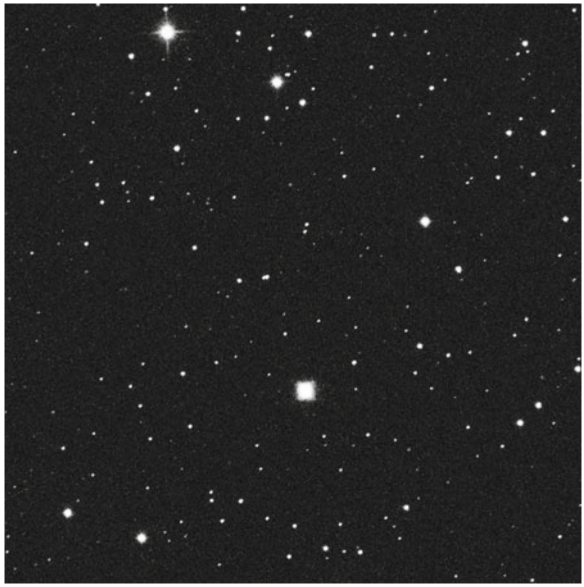


Finder chart for Abell 35



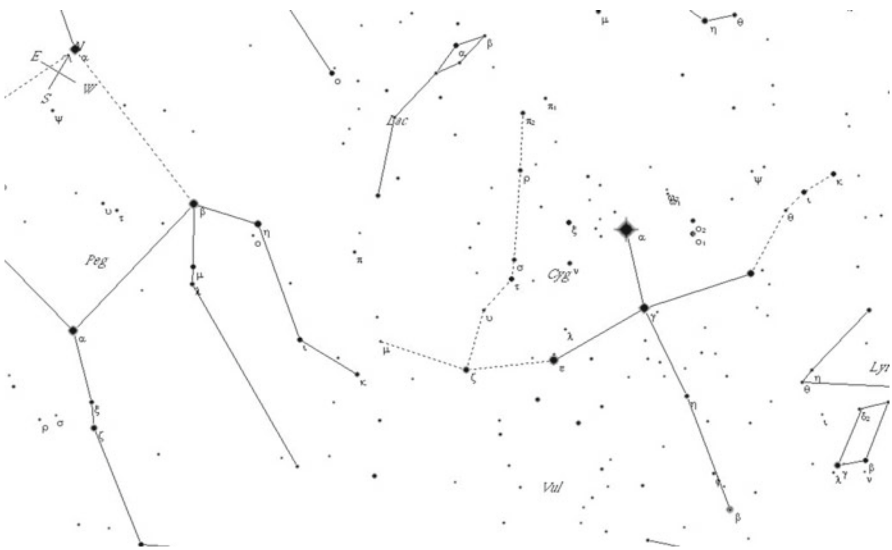
Lacerta

IC 5217
Lacerta
RA: 22 h 23 m 56 s
Dec: +50.58.0
Size: 7″
Magnitude: 11.3
Class: 2

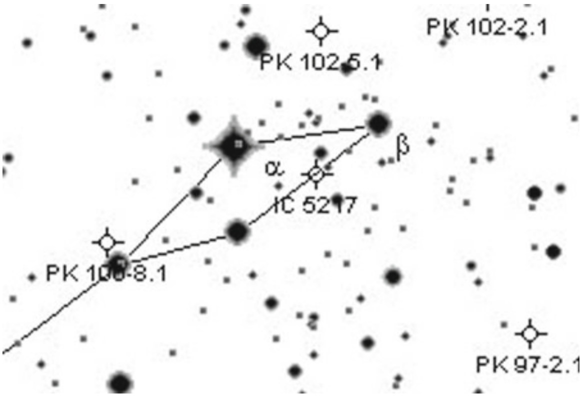


IC 5217 is surprisingly easy to find almost midway between the stars 4 and β Lacertae, where it can be identified as a bright 11th mag little star with a green tinge. Moderate magnifications reveal a small blurry disk, which is even and round in appearance, and the green cast seems to increase a little. Although the planetary is small, it should not be a problem for telescopes of less than 20 cm aperture, as it's quite bright and stands out of the field well, responding to an OIII filter very nicely. A lovely nebula, despite its stellar appearance in low powers.

General view of Lacerta

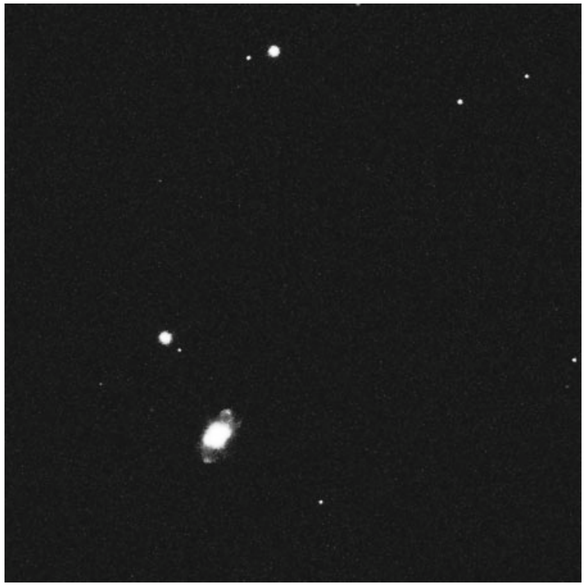


Finder chart for NGC 5217



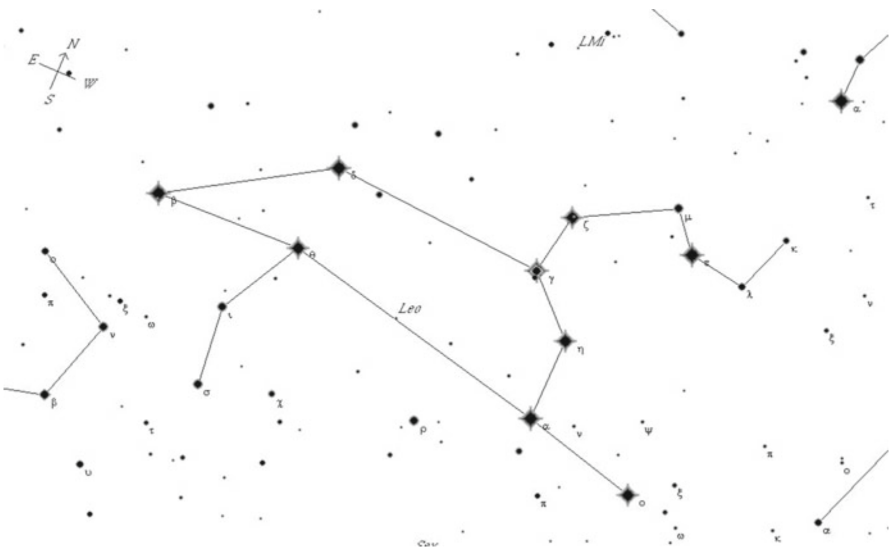
Leo

IRAS 09371 + 1212
Leo
RA: 09 h 39 m 53 s
Dec: +11.58.8
Size: 25″
Magnitude: 11.2
Class: 1

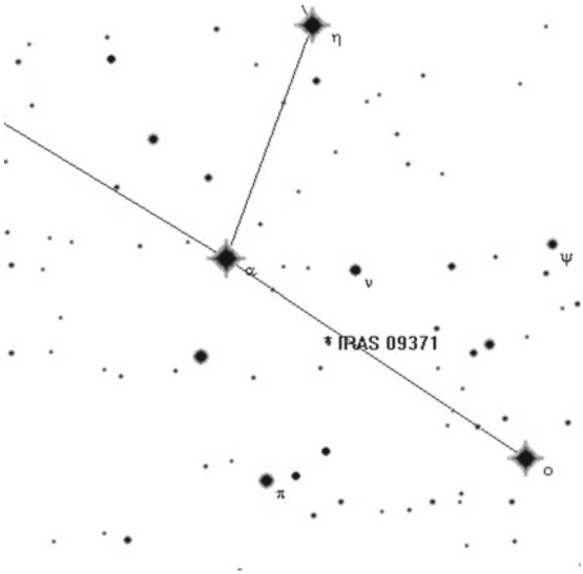


The so called "Frosty Leo Nebula" is a stellar object with a high surface brightness that was first discovered by the Infra-Red Astronomy Satellite (IRAS), due to its sharp dust absorption features. It is one of the few planetary nebulae that show spectral lines of water ice – hence the name. Visually it is just a white star, showing no response to use of an OIII filter but can nevertheless be seen in relatively modest telescopes. In larger apertures at high magnifications, it is possible to see an elongation to the body with an E-W axis. It is really a proto-planetary nebula, and the body is an evenly filled shell of light. It lies close to a 12th magnitude star, thus making the nebula appear like a dim binary system.

General view of Leo



Finder chart for IRAS 90371 + 1212

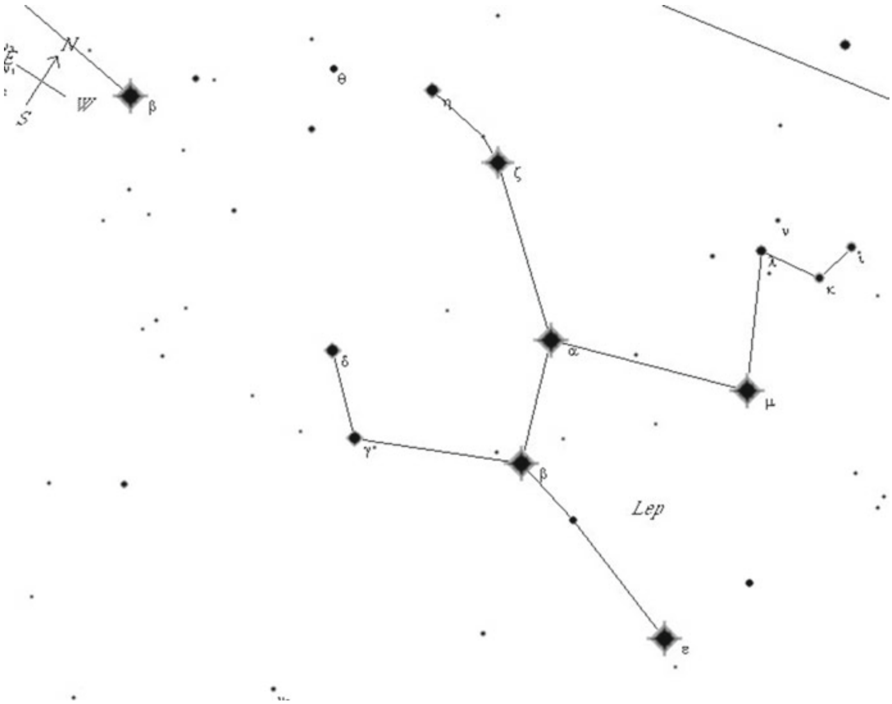


Lepus

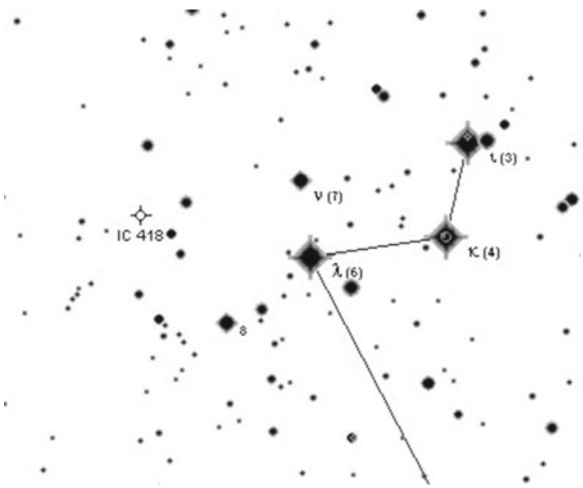
IC 418
Lepus
RA: 05 h 27 m 28 s
Dec: −12.41.8
Size: 14″
Magnitude: 9.3
Class: 4

The famous "Spirograph Nebula" imaged with the Hubble Space Telescope. To a visual observer this fantastic object is a tiny greenish-white planetary revealed as a little dot of light, easily found by star hopping from α Lepus to γ and λ Lepus and is a surprisingly bright object, oval in higher powers and showing a slight N/S elongation but little in the way of color, though some observers have reported this as pink. No central condensation is noticeable and no central star visible either. The planetary is simply a filled dot that is quite obvious in a nice star field and is one of the brighter of the IC objects. Its small size in most amateur telescopes do not make it a prime target, though once seen it is never forgotten and is bright enough to be seen in any size telescope.

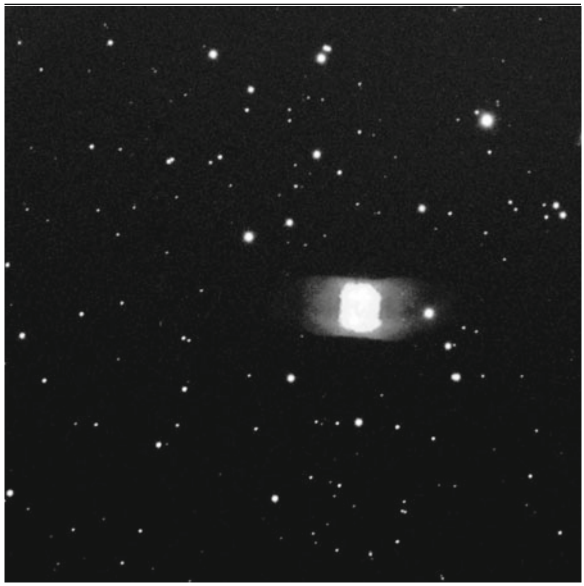
General view of Lepus



Finder chart for IC 418

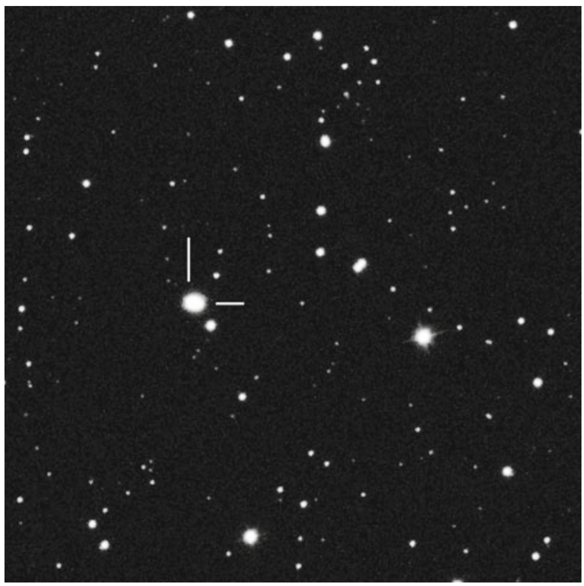


Lupus



IC 4406
Lupus
RA: 14 h 22 m 46 s
Dec: −44.09.04
Size: 25″
Magnitude: 12.3
Class: 5

This large and elongated planetary nebula is quite faint for its quoted magnitude but is easy to spot to the NE of the "double" star τ Lupae, where it appears in low power as a gray smudge of light with a noticeable E–W extension. In higher powers on large telescopes it exhibits a rectangular gray mottled surface. There is some response to use of an OIII filter and one should have little difficulty identifying the nebula if one is using an aperture of around 150 mm + .



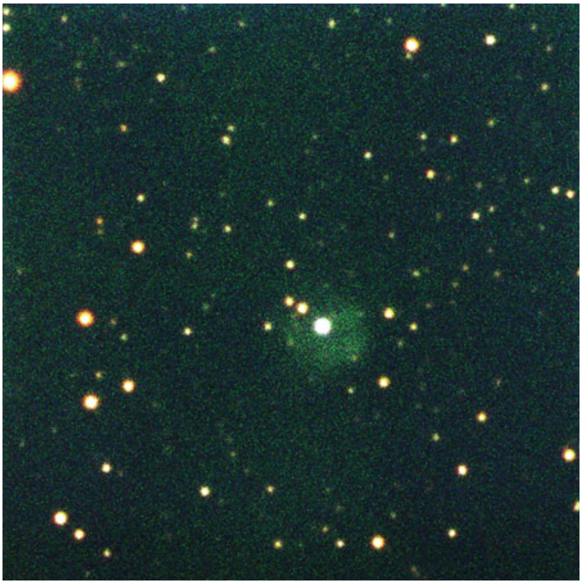
NGC 5873
Lupus
RA: 15 h 12 m 15 s
Dec: −38.07.5
Size: 3″
Magnitude: 11.2
Class: 2

A very small, faint, planetary nebula in a rich Milky Way field that forms a triangle with δ and ψ Lupae. It reveals itself as a tiny star-like point in direct vision, but an OIII filter is necessary to confirm its presence. High magnifications on this small object are essential for locating it properly. NGC 5873 has no real color at all; it remains a faint grayish-white point of light and is one of the smallest planetaries visible in moderate telescopes. At high powers it also resembles a close binary with a star to its immediate south.

NGC 5882
Lupus
RA: 15 h 16 m 49 s
Dec: −45.38.9
Size: 33″
Magnitude: 9.8
Class: 2

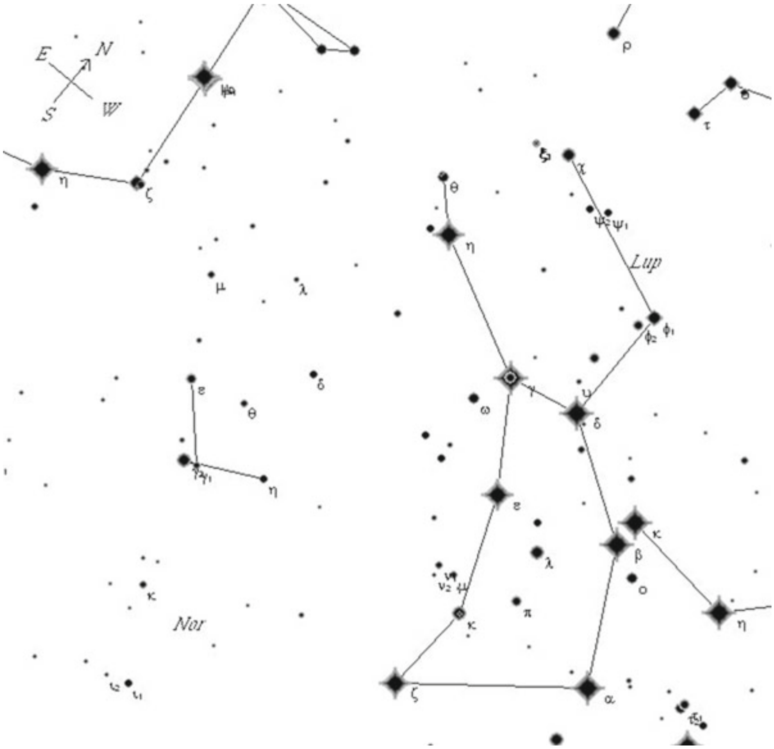
This tiny planetary nebulae is found in the same low power field as NP ε Lupi and reveals itself as a bright turquoise star upon careful observation of the field, although other observers have thought it to be slightly green. High power is necessary to make out its little disc, which is round and sharply defined but featureless, with no central star visible within this small object and a blank, smooth face staring back at the observer. An OIII filter brings it out nicely if one is having trouble separating it from the background stars.

NGC 6026
Lupus
RA: 16 h 01 m 21 s
Dec: −34.32.6
Size: 55″
Magnitude: 12.1
Class: 4

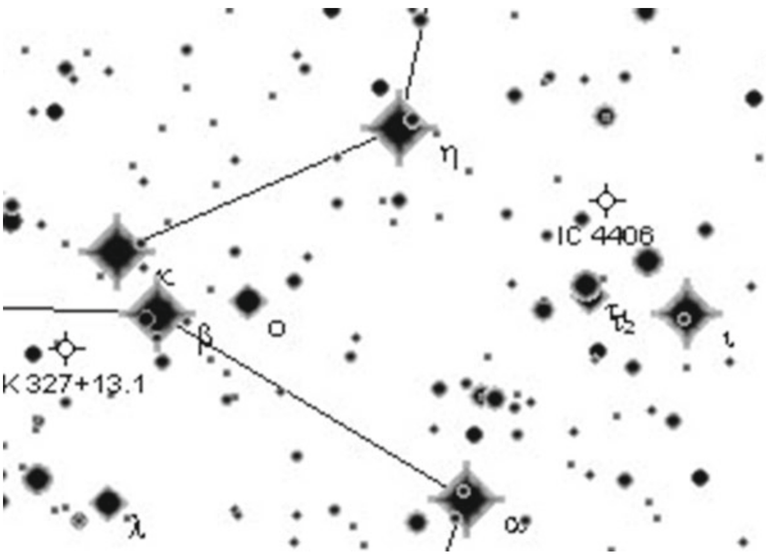


NGC 6026 is an obvious smudge among the stars of Lupus in a low power field and reveals a central star in higher powers, though it is quite a faint object at the center of the nebula. As a planetary, NGC 6026 is about as large as M57, the Ring Nebula, but lacks the color and detail of this object, looking more like a smoky disk of gray light fading into the Milky Way but having a well defined edge on the western side. The whole structure becomes more amorphous with averted vision and hints at mottling, and further structure are visible in larger telescopes. There is a fair response with an OIII filter.

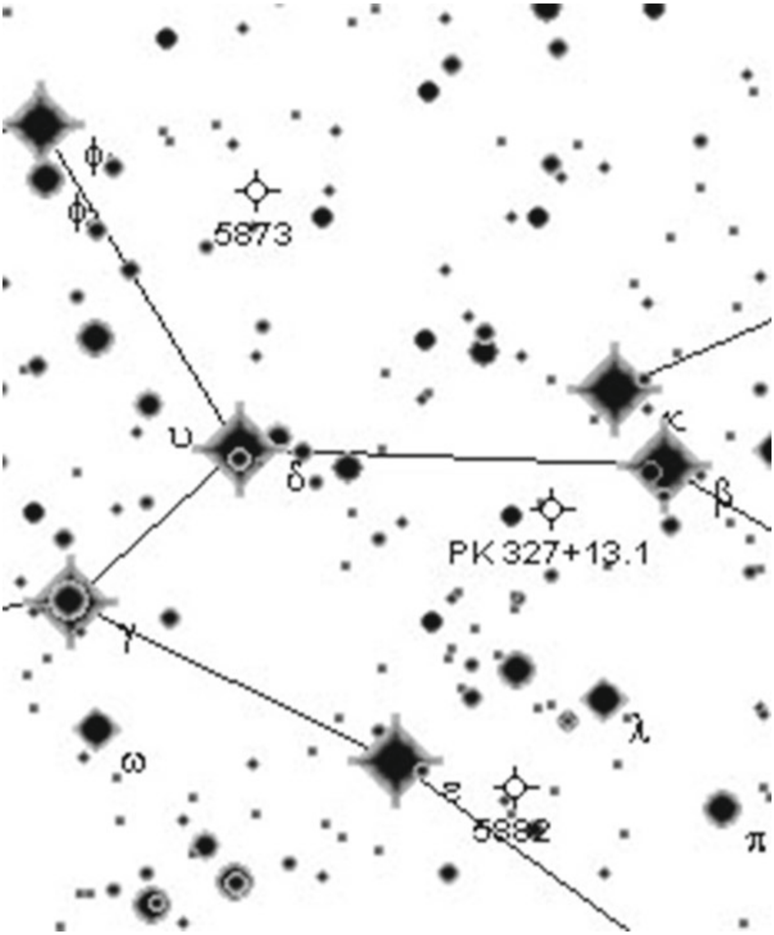
General view of Lupus



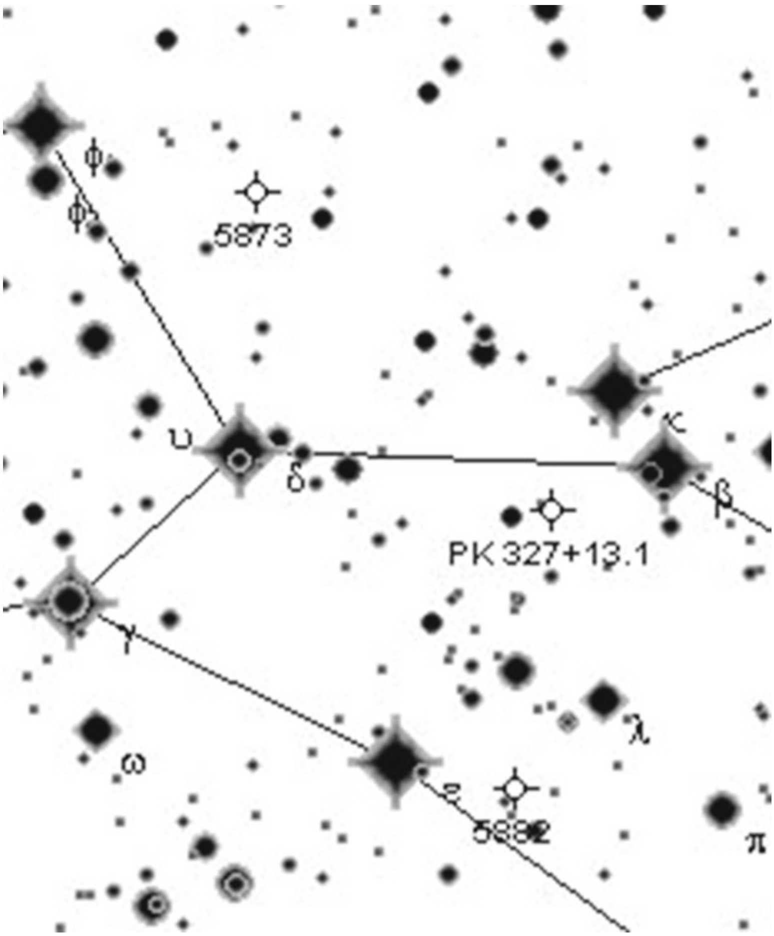
Finder chart for IC 4406



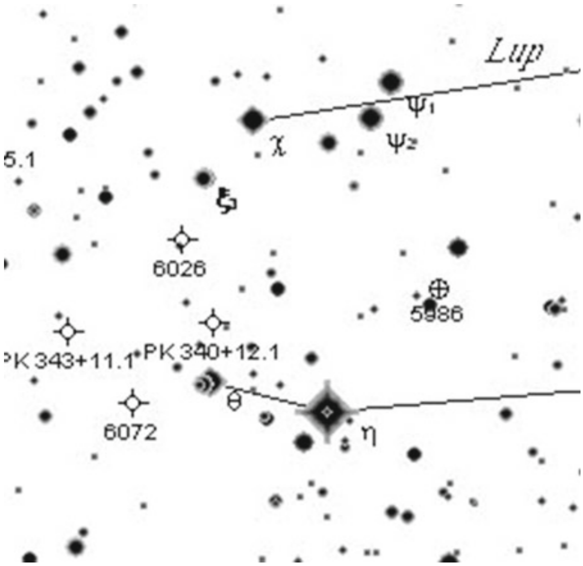
Finder chart for NGC 5873



Finder chart for NGC 5882



Finder chart for NGC 6026

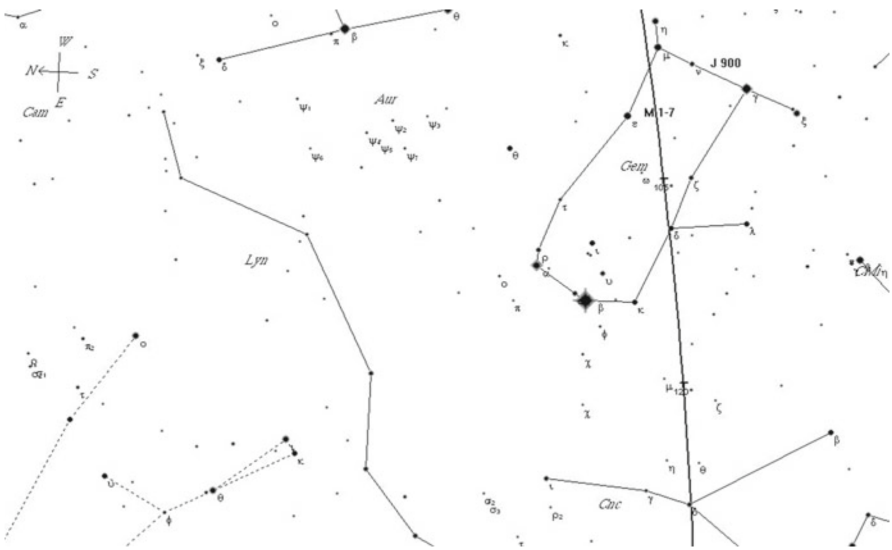


Lynx

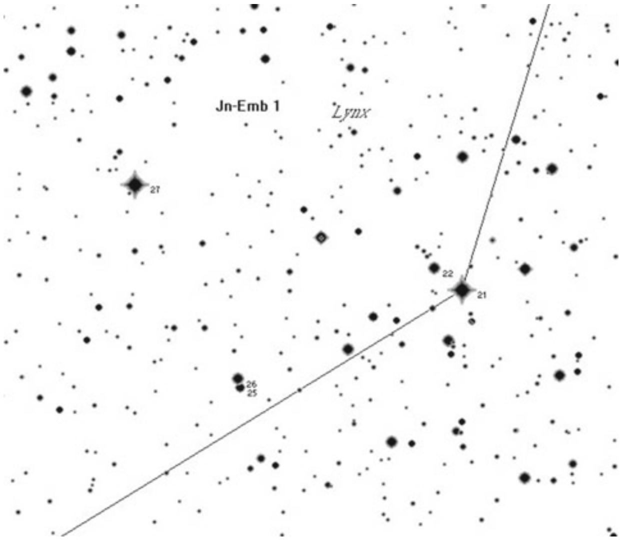
Jones-Emberson 1
Lynx
RA: 07 h 57 m 50s
Dec: +53.25.0
Size: 405″
Magnitude: 12.5
Class: 4

A very large and difficult nebula to examine even though the field is relatively devoid of faint stars to distract your view. This object has the common name "Headphones Nebula," as it resembles this everyday object in observatory photographs. However, this is a faint planetary with a huge area, making it much fainter than its quoted magnitude and presents a visual challenge to users of scopes in the 25–40 cm range. It also requires an OIII filter to locate and see visually, as it is not bright or well separated from the background sky glow, and use of a low power eyepiece is recommended. A challenge to observe, although it is easier to image given modern equipment.

General view of Lynx



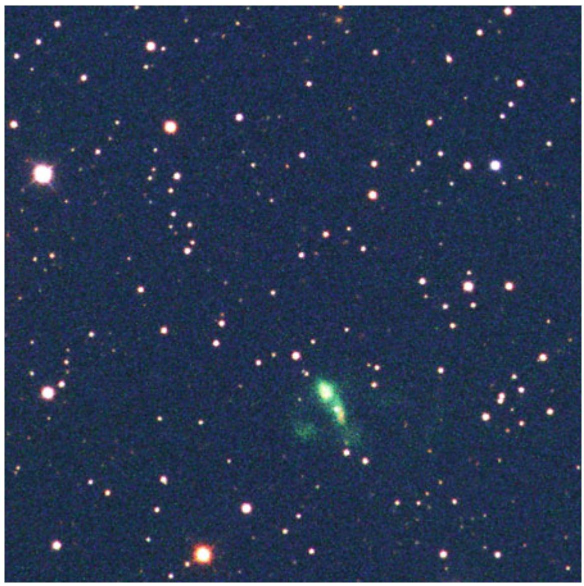
Finder chart for Jn-Eb 1



Lyra

NGC 6720
Lyra
RA: 18 h 53 m 35 s
Dec: +33.01.7
Size: 86″
Magnitude: 8.8
Class: 4 + 3

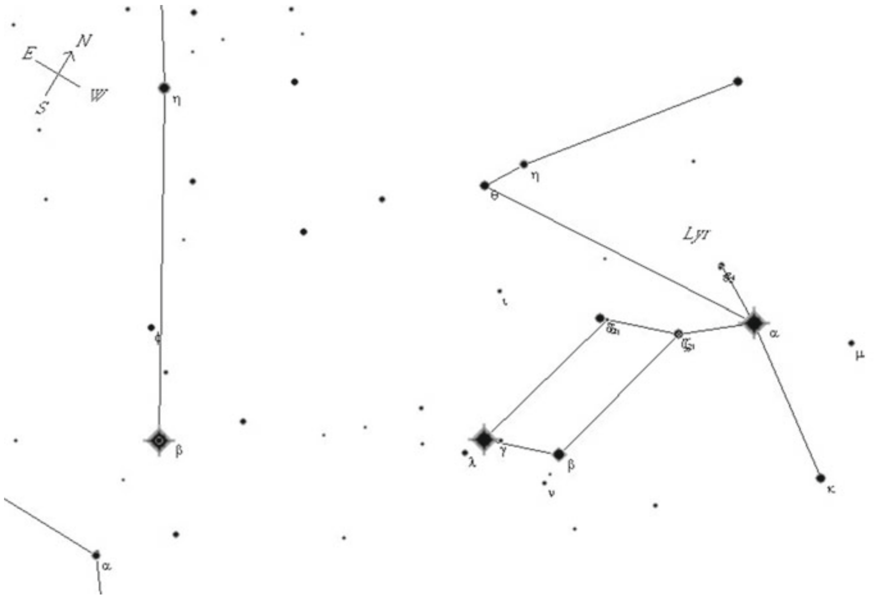
The superb "Ring Nebula," Messier 57, in Lyra. Even in small apertures the ring shape is immediately evident as is the slightly purple hue to it that tends to red at the outer edges in higher magnifications, with a well-defined dark, crisp center but no hint of the central star in small apertures. In larger telescopes the color is more greenish, and the proportions of the ring are clearer and revealed as slightly oblate E/W under careful scrutiny, with a filled, veiled center, through which is visible the 14th magnitude central star. Fabulous!



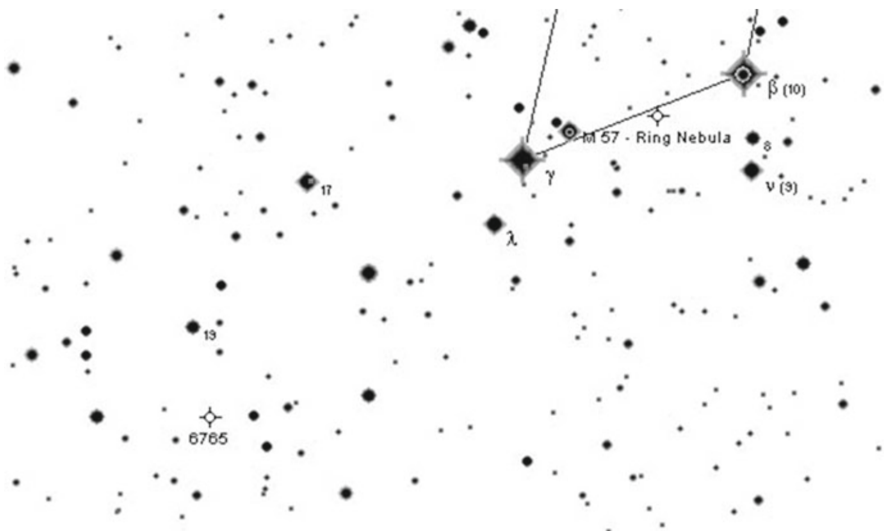
NGC 6765
Lyra
RA: 19 h 11 m 01 s
Dec: +30.33
Size: 38″
Magnitude: 13.1
Class: 5

NGC 6765 is a faint planetary close to the globular cluster M56 and forms a triangle with two sixth mag stars. The planetary is faint, small and almost bar like in moderate power with an obvious extension on a N/S axis. In low powers it can be glimpsed with use of an OIII filter, allowing the observer to zoom in on a small white glow that does not really alter substantially no matter what the magnification. Quite small and faint though slightly brighter than the quoted magnitude above (12.5?). NGC 6765 is almost hidden in a rich Milky Way field, and so requires careful attention.

General view of Lyra

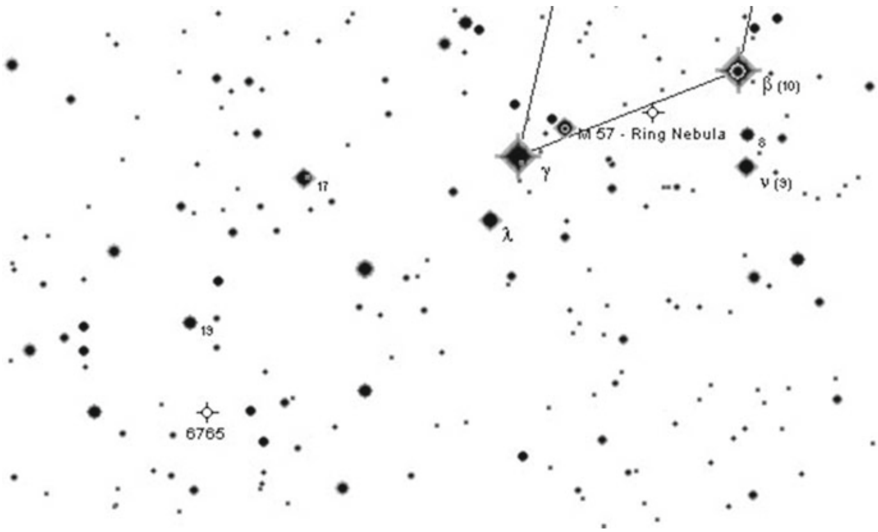


Finder chart for NGC 6720



Planetary Nebulae by Constellation

Finder chart for NGC 6765

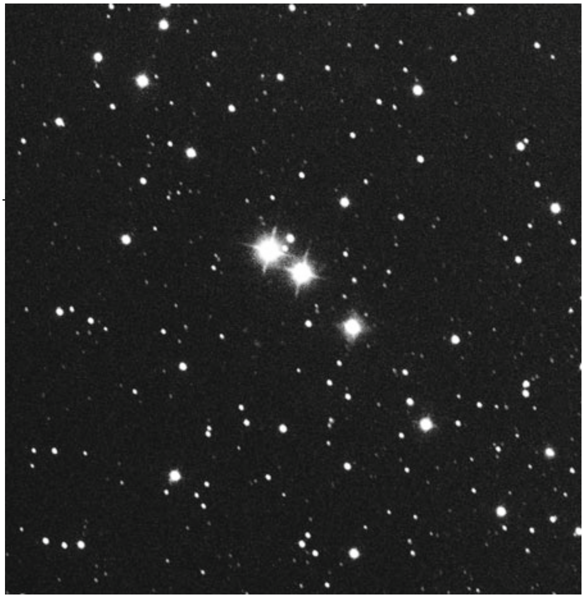


Monoceros

NGC 2346
Monoceros
RA:07 h 09 m 23 s
Dec: −00.48.4
Size: 60″
Magnitude: 11.8
Class: 3b + 4

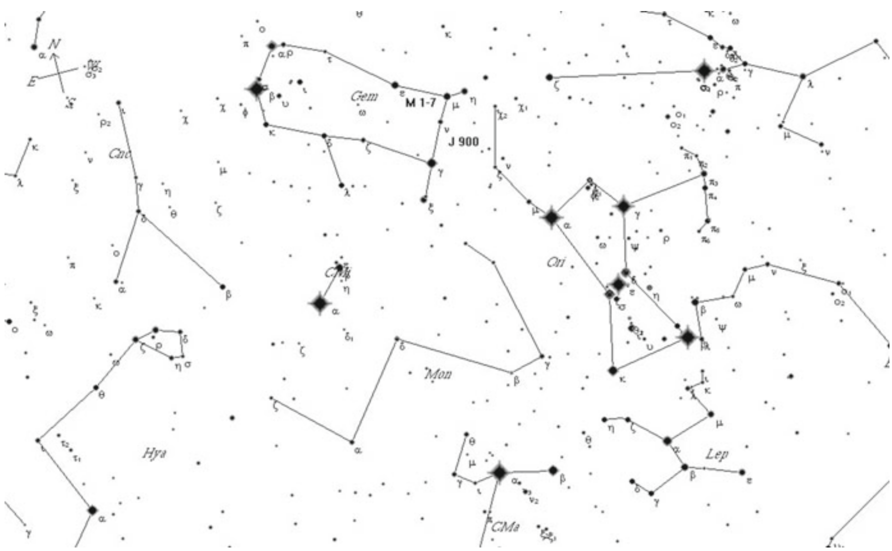
A nice but faint planetary in Monoceros but a little difficult to star hop to in this wonderfully rich Milky Way field! Known as the "Butterfly Nebula," this object is visible as a white "box" of light in low power and shows some fainter structure to N/S with higher powers, hinting at the hourglass figure that this nebula displays on observatory photographs. Occasionally with larger apertures and good steady seeing, the central star becomes visible. NGC 2346 is a lovely object often overlooked in the rush for the Rosette or Hubble's variable nebula to the north.

HD 44179
Monoceros
RA: 06 h 19 m 58 s
Dec: −10.38.2
Size: 1.5″
Magnitude: 9.2
Class: 1

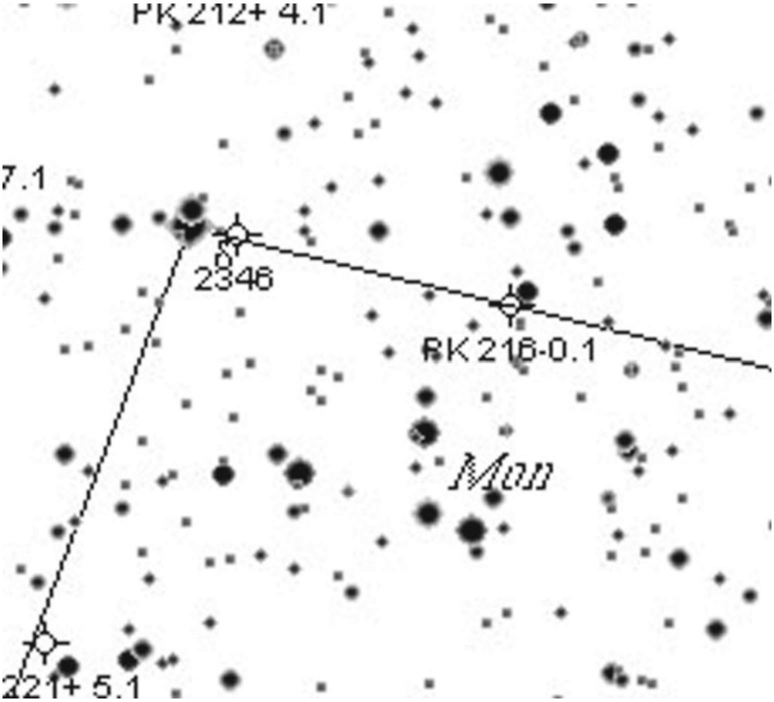


The fantastic "red rectangle," which is just to the southeast of the seventh magnitude star six Monocerotis, which makes a handy pointer to this nebula, close to a seeming double star. Unfortunately what any small telescope will reveal is basically a star-like object with a slight orange tinge appearing with careful inspection, which under high power on a larger aperture hints at a square structure with a bright centre and rapidly fading edges. It is a fairly bright object and an excellent representative of a star in the proto-planetary nebula stage.

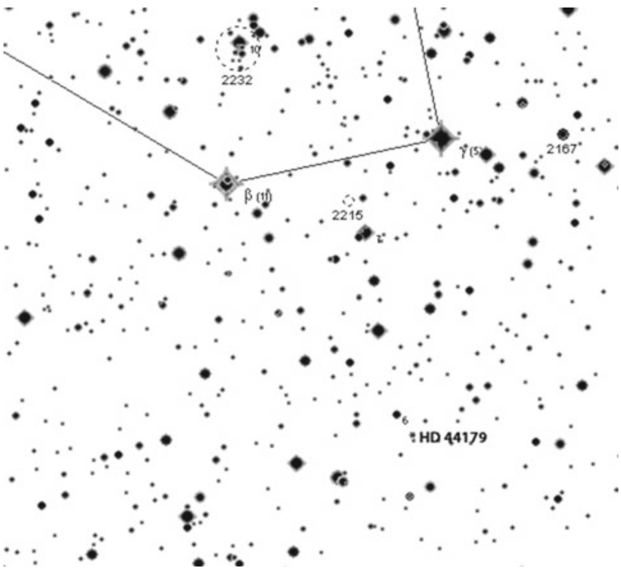
General view of Monoceros



Finder chart for NGC 2346

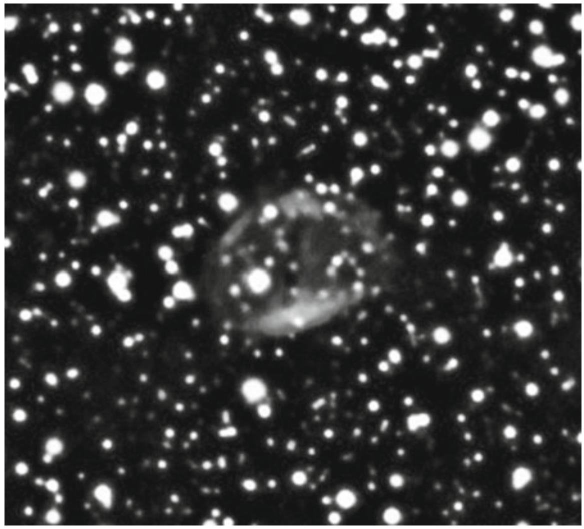


Finder chart for HD 441179



Musca

NGC 4071
Musca
RA: 12 h 04 m 18 s
Dec: −67.18.3
Size: 75″
Magnitude: 12.7
Class: 3b

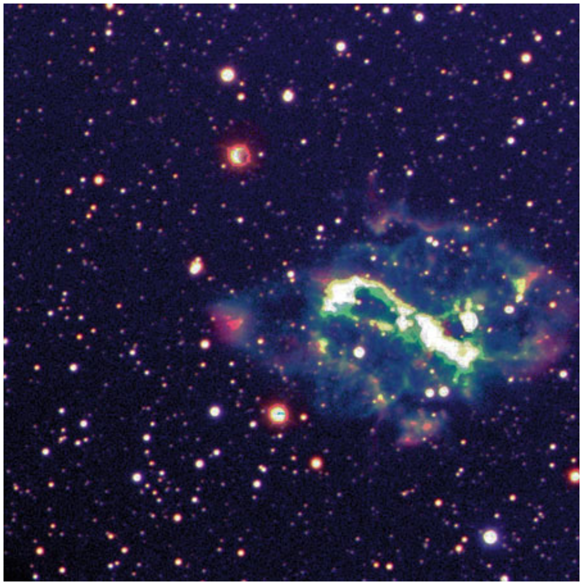


A large and relatively faint planetary nebula, which has a distinct central star that is bright enough to overwhelm the nebula if the telescope has a moderate aperture. NGC 4071 is a halo of grayish-white light surrounding a 12th magnitude star, and the gas shroud appears a little irregular on the northern edge. The object fades into obscurity quite quickly at the edges and requires a medium to high power to see well. NGC 4071 responds quite well to use of an OIII filter and is quite a nice planetary nebula for southern observers.

IC 4191
Musca
RA: 13 h 08 m 47 s
Dec: −67.38.3
Size: 5″
Magnitude: 10.6
Class: 2

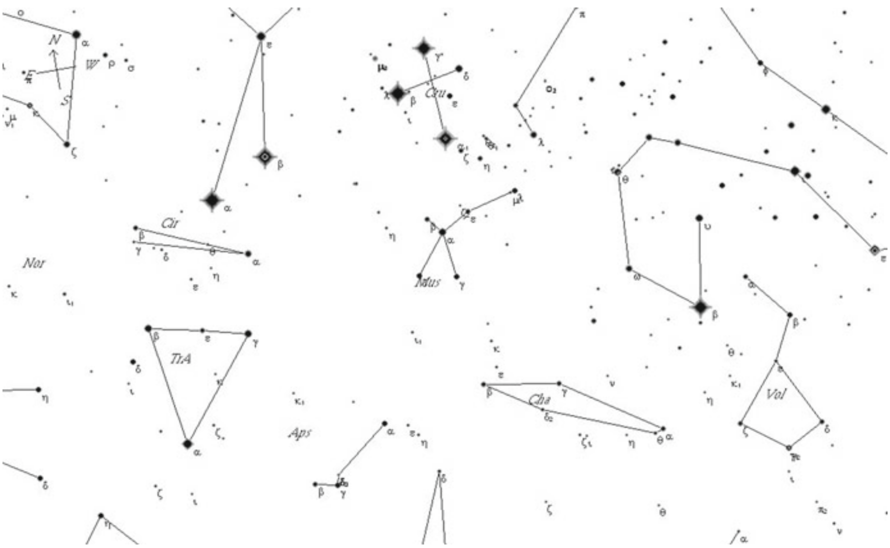
IC 4191 is a tiny, star-like object that is a beautiful blue color, though some observers report it as green. It lies at the apex of a triangle with two 11th magnitude stars and responds very well to use of an OIII filter; it can be seen even with small apertures, though careful attention to the field is required as the planetary is barely bigger than the stars. A moderate to high magnification brings out a small round body of light that is now noticeably larger than its stellar companions. Quite a lovely planetary for most sized telescopes.

NGC 5189
Musca
RA: 13 h 33 m 32 s
Dec: −65.58.2
Size: 90″
Magnitude: 10.1
Class: 3b + 6

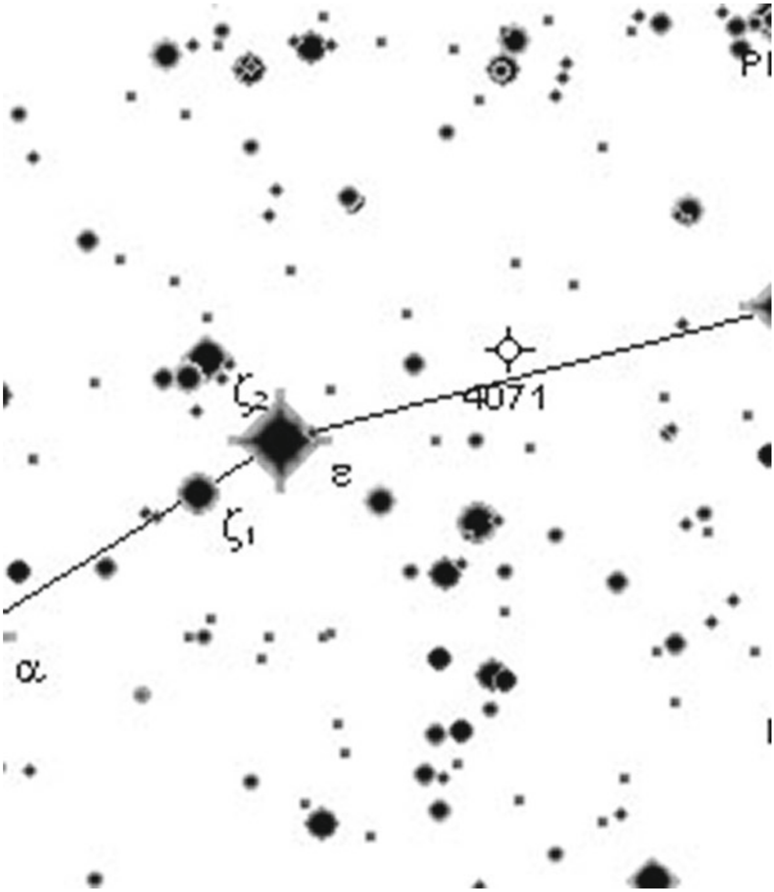


This is a large amorphous body that is often marked on star charts as a small nebula rather than a planetary, though it is included in the P–K catalogue and is placed here as an example of an emission nebula with Hα excess; it is probably a distended object that mimics aged planetary nebulae. In low power the nebula is gray-blue in color, elongated on a NE/SW axis and in higher magnifications on larger telescopes exhibits a distinct "S" shape with a brighter bar of material across the centre obscuring the central star. Although observable directly, it does show a moderate response to use of an OIII filter. It lies in a rich field of stars to the SE of μ Centauri and has the common name the "Spiral Planetary," despite questions over its classification. A nice object for most telescopes.

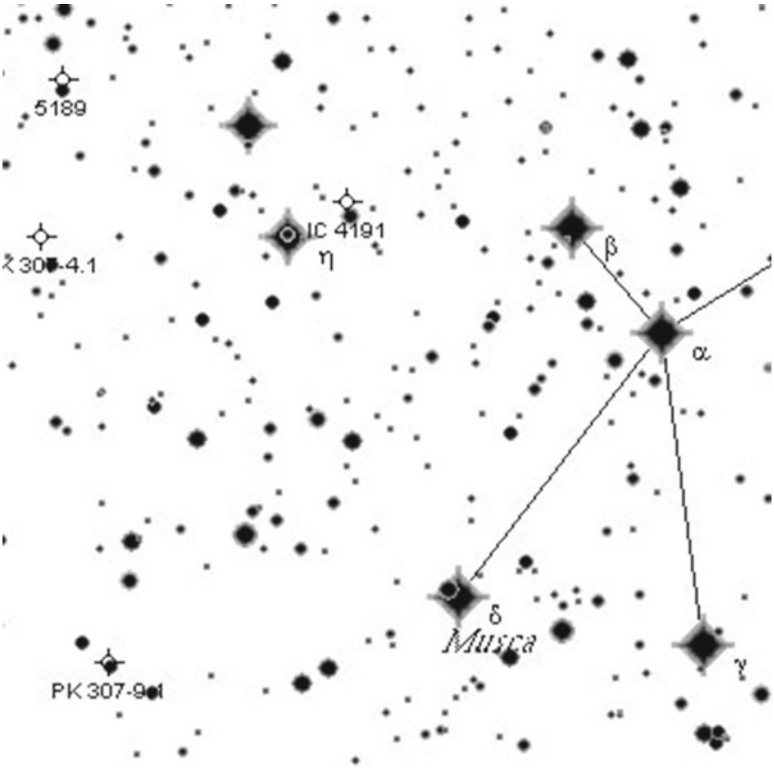
General view of Musca



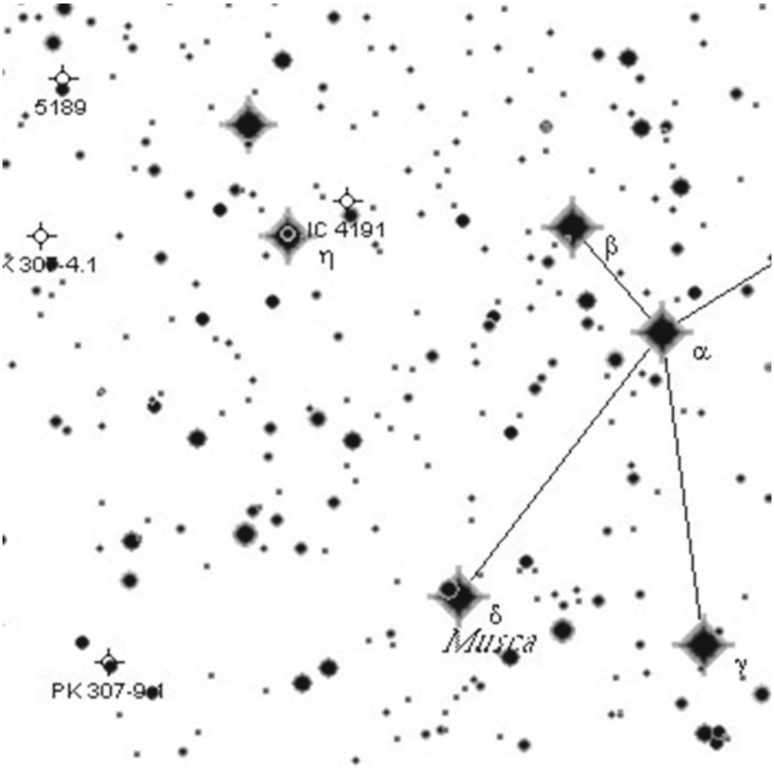
Finder chart for NGC 4071



Finder chart for IC 4191



Finder chart for NGC 5189

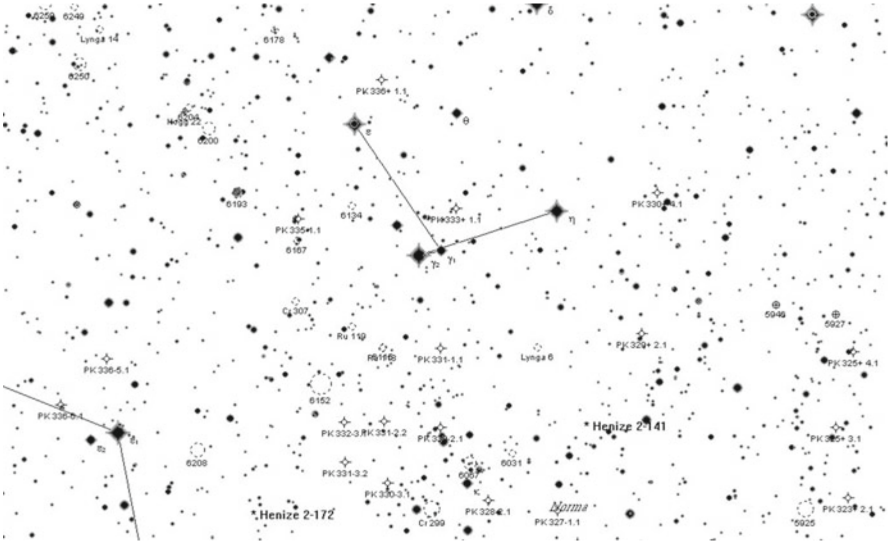


Norma

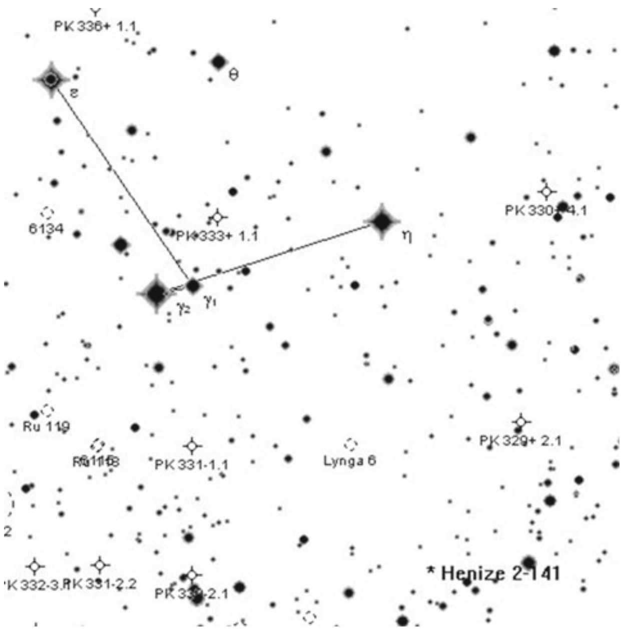
Henize 2–141
Norma
RA: 15 h 59 m 14 s
Dec: −53.23.08
Size: 4″
Magnitude: 12.2
Class: 1 + 2a

Tiny and star-like planetary nebula to the SE of γ Norma; again quite lost in the rich Milky Way here. High power is necessary to separate He 2–141 from the field stars, where it reveals itself as a tiny whitish disk of light, almost fading into obscurity yet showing a good response to use of an OIII filter, which does provide a good aid to identification. Not an easy object and probably invisible to those using an aperture less than 150 mm.

General view of Norma



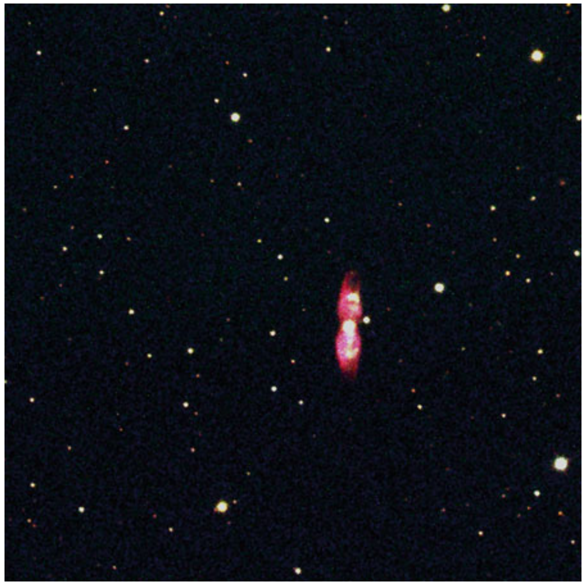
Finder chart for Henize 2–141



Ophiuchus

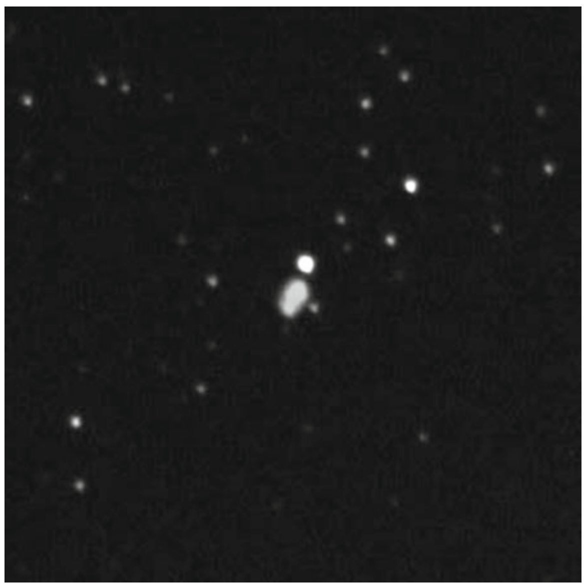
IC 4634
Ophiuchus
RA: 17 h 01 m 34 s
Dec: −21.49.6
Size: 10″
Magnitude: 10.9
Class: 2a + 3

Small yet bright planetary nebula that is only 10″ across and so is almost star-like at low powers. IC 4634 is blue in cast and slightly elongated in a NW/SE direction when viewed in higher magnifications. The field is quite sparse in stars but it can be located not far to the west of a trio of ninth magnitude stars. Less than a degree to the southeast is the ninth magnitude globular cluster NGC 6287, which has some interesting outliers in its starry halo. The planetary is west of ξ Ophiuchi and lies west of a train of four sixth to seventh magnitude stars, with NGC 6287 at the southern end.



Minkowski 2–9
Ophiuchus
RA: 17 h 05 m 38 s
Dec: −10.08.04
Size: 20″
Magnitude: 14.6
Class: 6

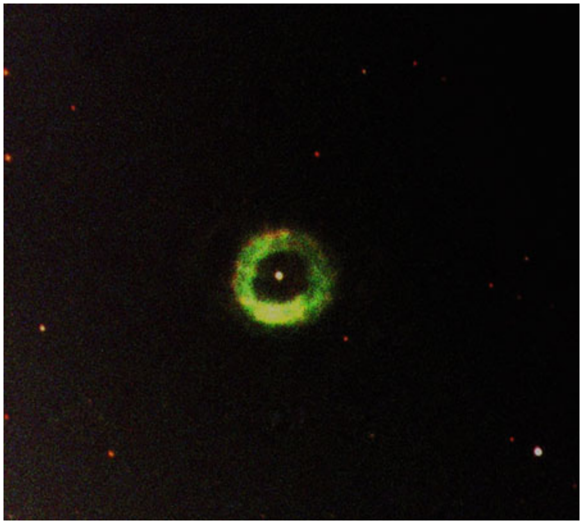
"Minkowski's Butterfly" is a superb planetary nebula in large observatory photographs but is a faint and challenging object for most observers equipped with moderate telescopes. It reveals itself in medium powers as a tiny N/S-oriented strip of light, a faint whitish-gray smudge that use of averted vision brings out as a distinct two-lobed object that hints at a central star in the condensation at center. This needs direct vision, as there is no response to the OIII filter. M2–9 remains a horribly faint and demanding object even for seasoned observers.



NGC 6309
Ophiuchus
RA: 17 h 14 m 04 s
Dec: −12.54.6
Size: 52″
Magnitude: 11.3
Class: 3b + 6

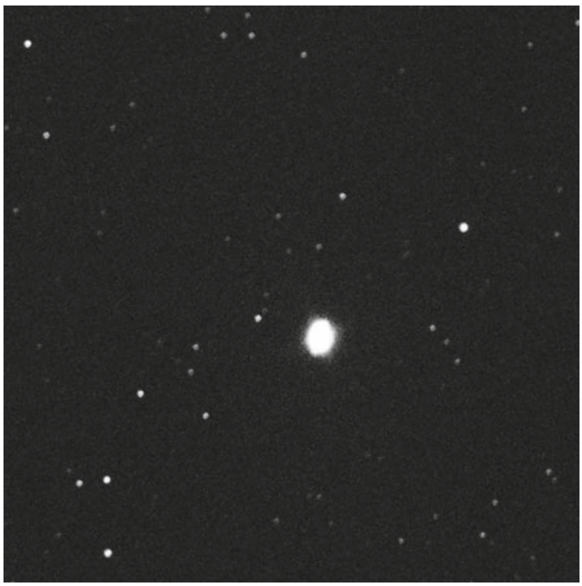
The "Box Nebula" is small and initially faint, located in a field filled with Milky Way stars but is easy to hop to from η Ophuchi and is close to a tenth mag star just to N of it. Even at low power it appears slightly elongated on a N/S axis; greenish in color, and higher powers reveals its boxy shape well but show nothing of the central nucleus or star. At less than 1′ across it is very reminiscent of Hubble's variable nebula (NGC 2261), due to an evident wedge shape when seen with averted vision.

NGC 6369
Ophiuchus
RA: 17 h 29 m 21 s
Dec: −23.45.6
Size: 60″
Magnitude: 11.4
Class: 4 + 2



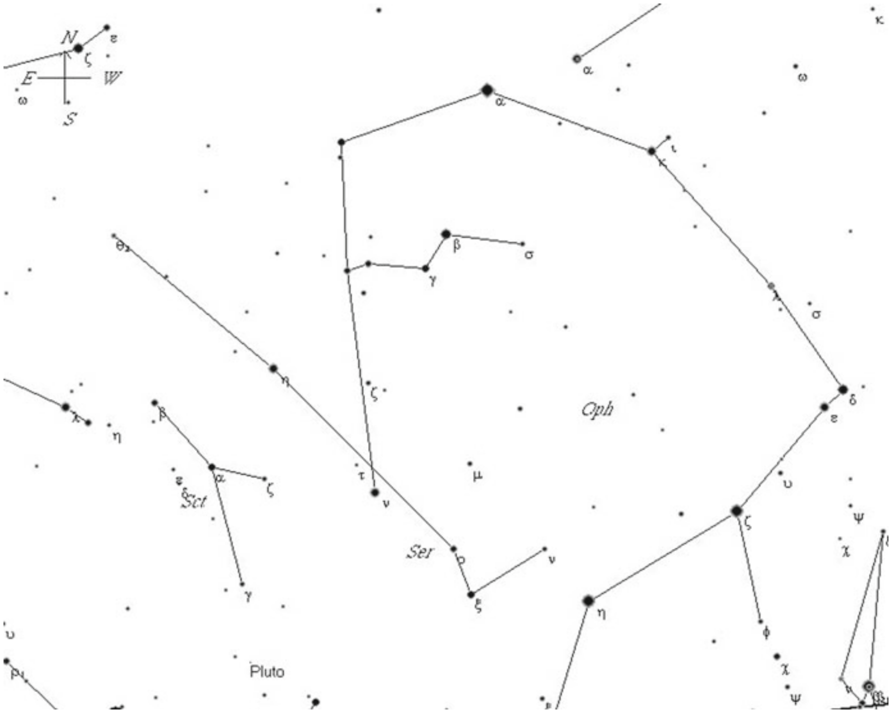
The "Little Ghost Nebula" in Ophiuchus. NGC 6369 initially looks like a filled shell of light at low power, but careful inspection reveals a little ring separated from the central portion, and higher powers reveal this feature even more. The center of the nebula is quite dark, and observers with large telescopes may make out that the central star. NGC 6369 is surrounded by the rich star fields of the Milky Way, making it a little difficult at first to obtain the field, but it lies a few field widths NF θ Ophiuchi and is quickly apparent as an extended object. It is catalogued as a Herschel 400 object, also.

NGC 6572
Ophiuchus
RA: 18 h 12 m 06 s
Dec: −06.51.2
Size: 16″
Magnitude: 8.1
Class: 2a

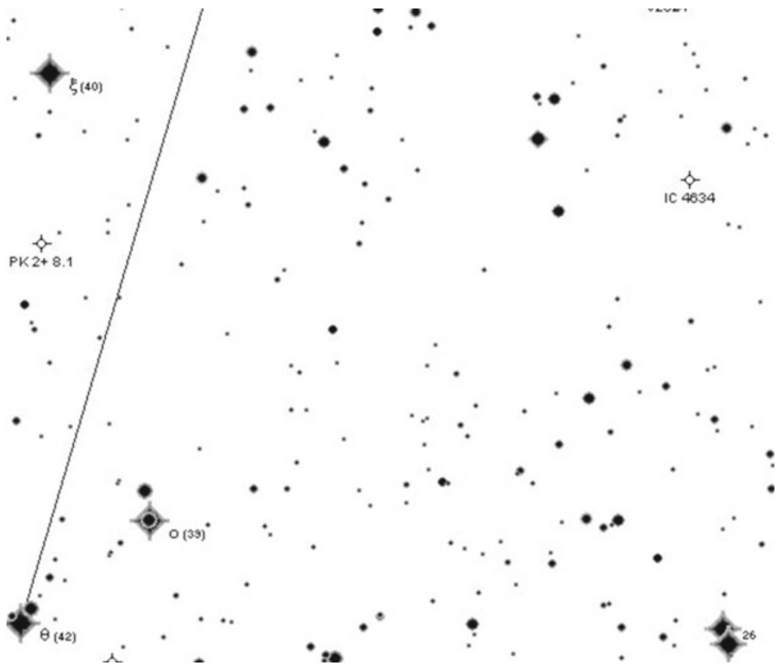


Although this planetary has the common name "Blue Racquetball" it is also known as the "Emerald" or "Turquoise" orb! It seems disparate observers see it slightly differently. NGC 6572 is obvious at first glance in the field south of 71 Ophiuchi. Observing it with low power reveals it to many as a wonderful light emerald green in color. In higher powers the nebula is extended across a N/S axis, and the interior seems to separate a little from its outer edges. A lovely object as the color makes up for its small size! It always seems a little larger than the quoted dimensions of 16″ – it may actually be over 25″ across.

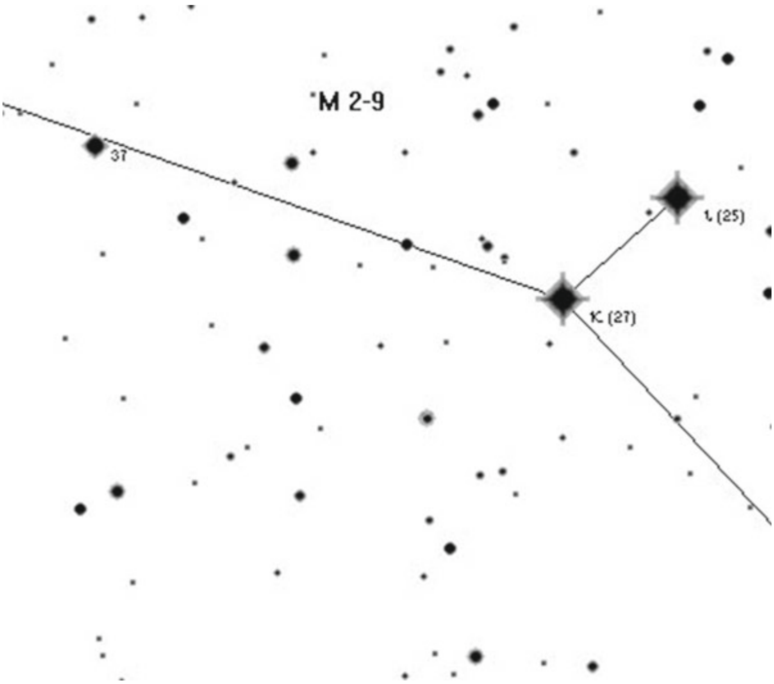
General view of Ophiuchus



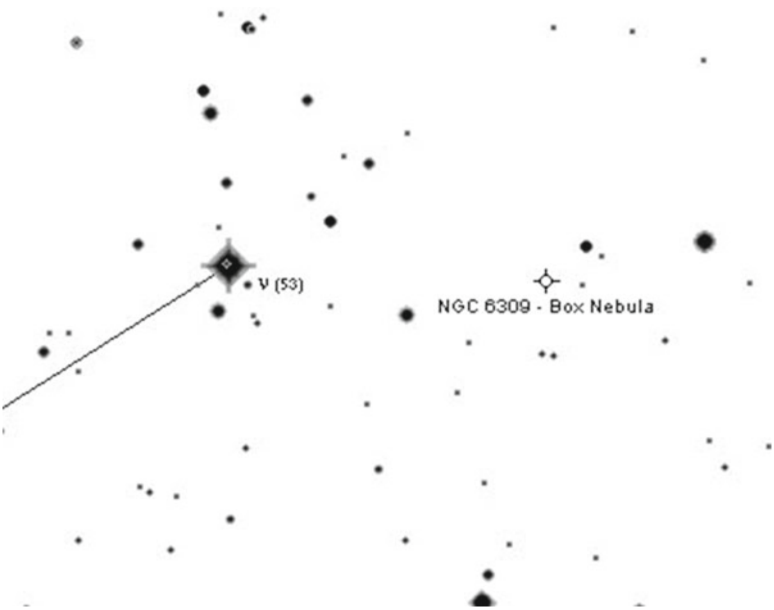
Finder chart for IC 4634



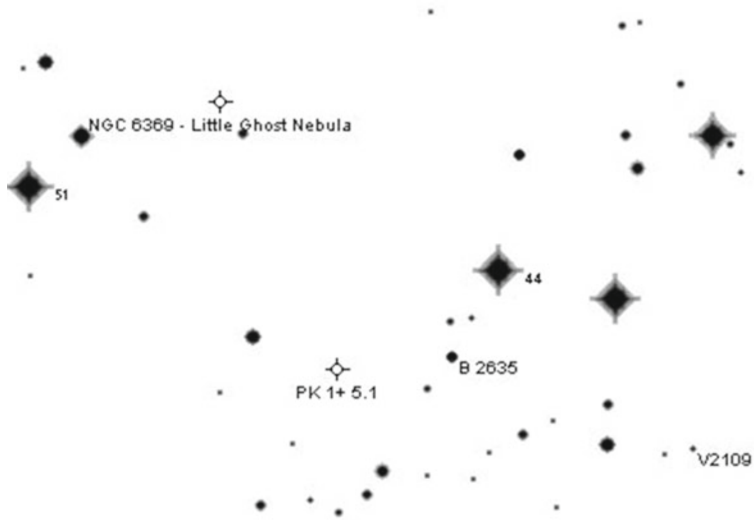
Finder chart for M 2–9



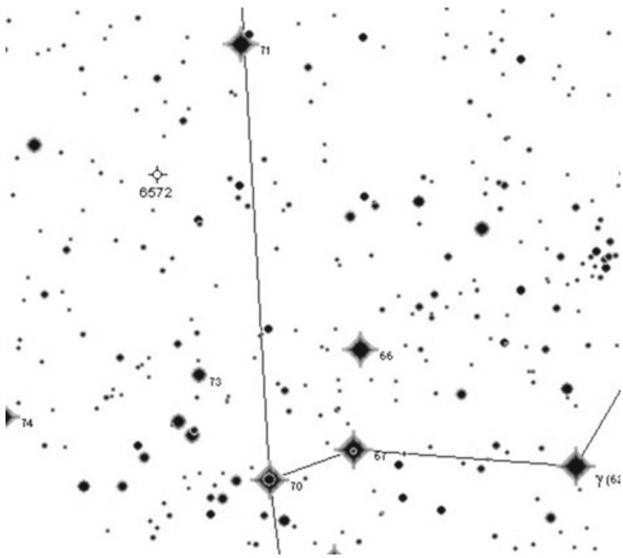
Finder chart for NGC 6309



Finder chart for NGC 6369

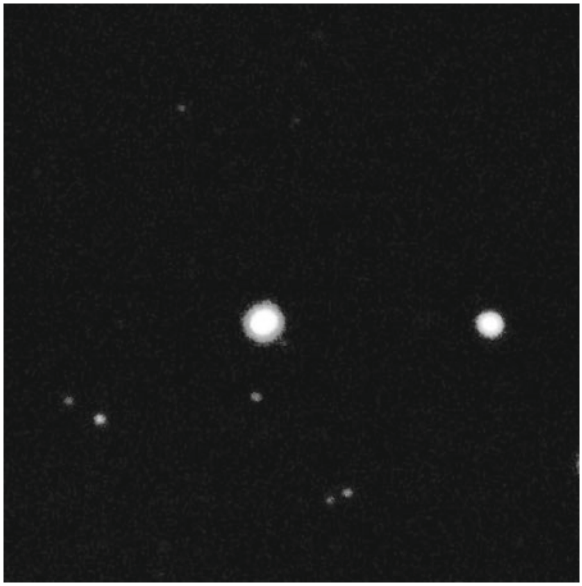


Finder chart for NGC 6572



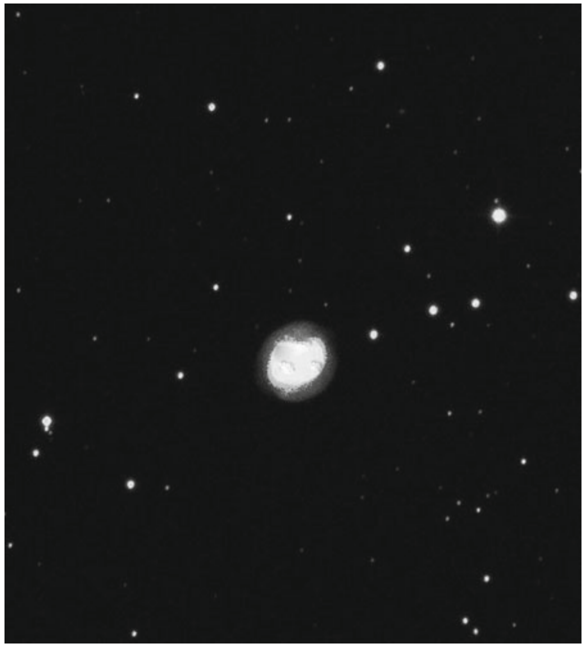
Orion

J 320
Orion
RA: 05 h 05 m 34 s
Dec: +10.42.0
Size: 7″
Magnitude: 11.9
Class: 2 + 4



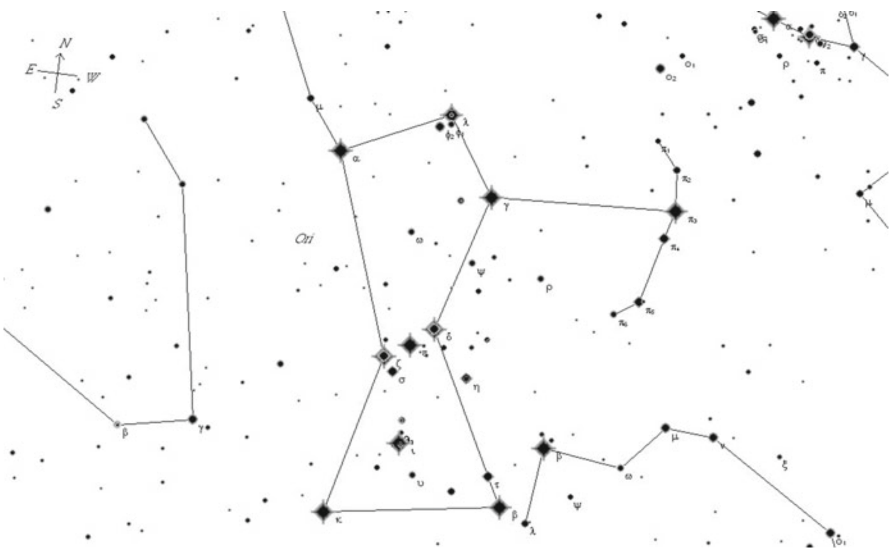
Jonckheere 320 is a small, faint and virtually stellar object that is best found by locating the field of the nebula by hopping from 16 Orionis to two eighth mag stars one on top of the other – J 320 is just E of these but is small and faint, with a ninth mag star SF it as an indicator. Use of an OIII filter is essential to bring out this tiny object, and higher powers make the image contrast a little. J320 is nothing but a stellar point of white light in a rich star field and once located can be seen directly, though it appears elongated in observatory photographs – which is exactly how Robert Jonckheere discovered it.

NGC 2022
Orion
RA: 05 h 42 m 06 s
Dec: +09.05.2
Size: 28″
Magnitude: 11.9
Class: 4 + 2

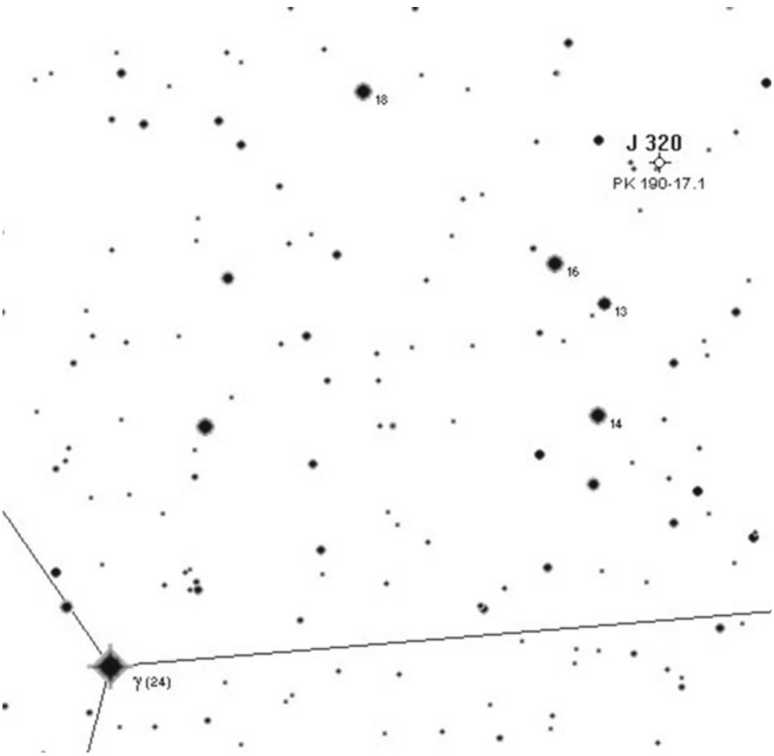


Tiny planetary in northern Orion (part of the "head"), easy to overlook in the field of stars, though with careful observation the object is slightly larger in size. NGC 2022 shines with an even blue-gray glow in moderate power with no central star or condensation visible; it remains a filled shell in a starry field. Not difficult to star hop to, but attention is needed to discern it in low power. Some observers report a good response to using an OIII filter, and this is recommended, as the object can be a little difficult to see occasionally. NGC 2022 is also one of the Herschel 400 objects.

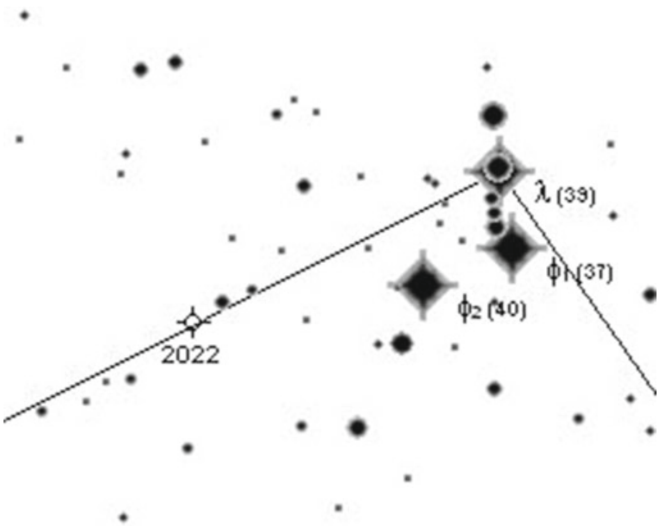
General view of Orion



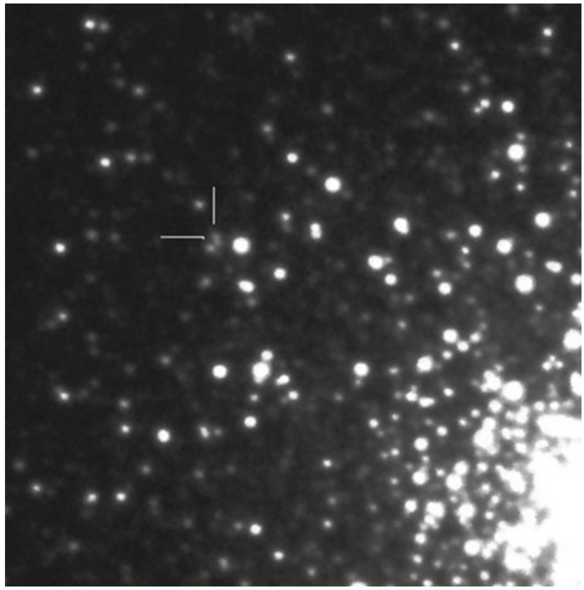
Finder chart for J 320)



Finder chart for NGC 2022



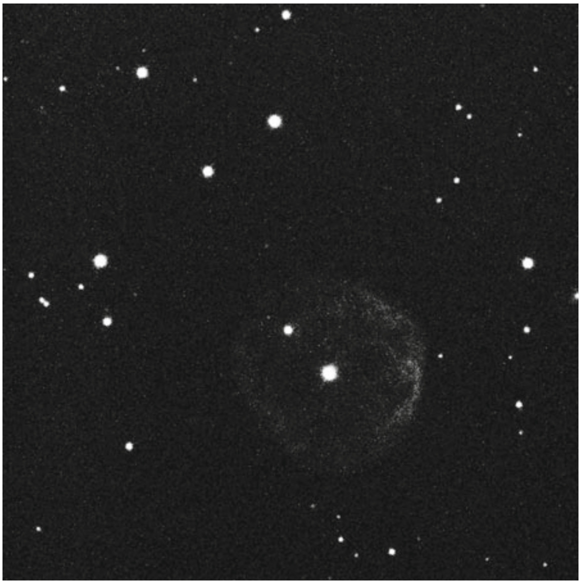
Pegasus



Pease 1
Pegasus
RA: 21 h 30 m 0 s
Dec: +12.10
Size: 1″
Magnitude: 15.1
Class: 1

This is a very difficult planetary nebula and is included here to present a challenge to observers equipped with large telescopes. Pease 1 lies on the fringes of the globular cluster Messier 15 and is associated with the cluster as one of its old evolved stars. The nebula is very small at 1″ across and differs only slightly from the plethora of stars in the outlying halo of the globular cluster, making it a faint and difficult object to spot. It does show some moderate response to use of an OIII filter, which is probably necessary to see it in the rich field of the cluster. A high magnification is also helpful in separating it from the background, where its proximity to a star on its southern edge makes it look like a faint binary. Very challenging!

NGC 7094
Pegasus
RA: 21 h 36 m 53 s
Dec: +12.47.3
Size: 100″
Magnitude: 13.4
Class: 4

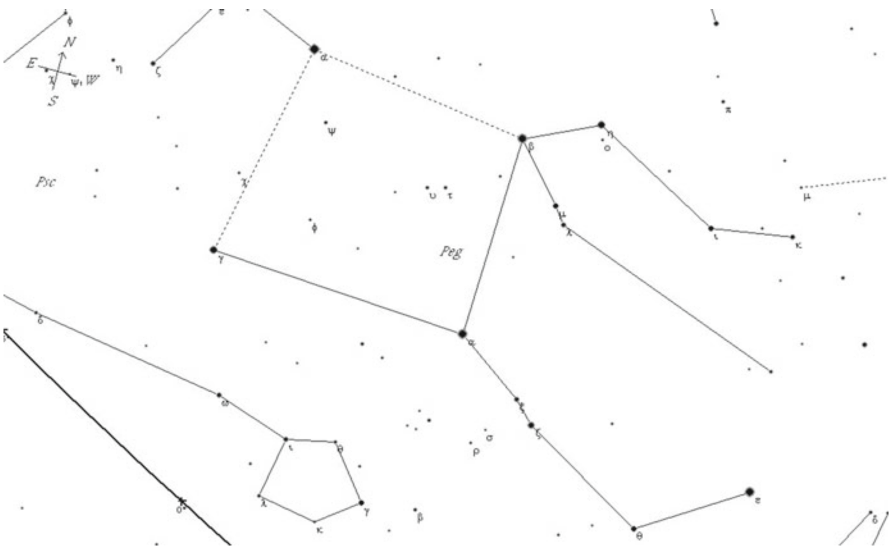


NGC 7094 is a faint halo of gray-blue light, lying close to M15 in a field SF the globular cluster. It can be seen as an amorphous glow around a 12th magnitude star with the gas of the nebula being at least a magnitude fainter. With averted vision it seems to have a denser lobe to the N of the star, though for the most part the glow is fairly even. There is a second star in the nebula to the SE of the central one, and there may be two or three faint stars scattered across its disc. Low powers may be better to seek this one out, and there is some response from use of an OIII filter, but the nebula is large, faint and quite weak, resolving as an irregular dull gray glow.

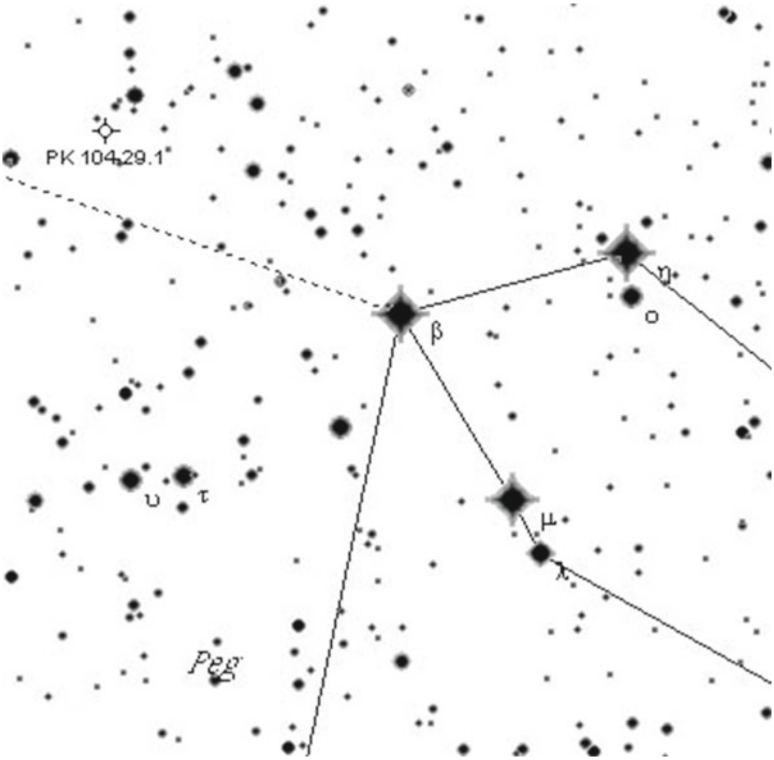
Jones 1
Pegasus
RA: 23 h 35 m 09 s
Dec: +30.28.0
Size: 314″
Magnitude: 12.1
Class: 3b

Jones 1 is not a difficult object in a large telescope, but users of equipment below 150 mm in aperture will find it to be invisible. In low powers it has an amorphous white glow but responds a little to use of an OIII filter. Visually, the nebula seems to "come and go" as one examines the field. The stars 72 and 78 Pegasi are useful guide stars, and the nebulae is about a third of the way from 72 to 78. It looks like a smoke ring but is not completely whole, as with averted vision on moderate magnification it splits into a north and south component.

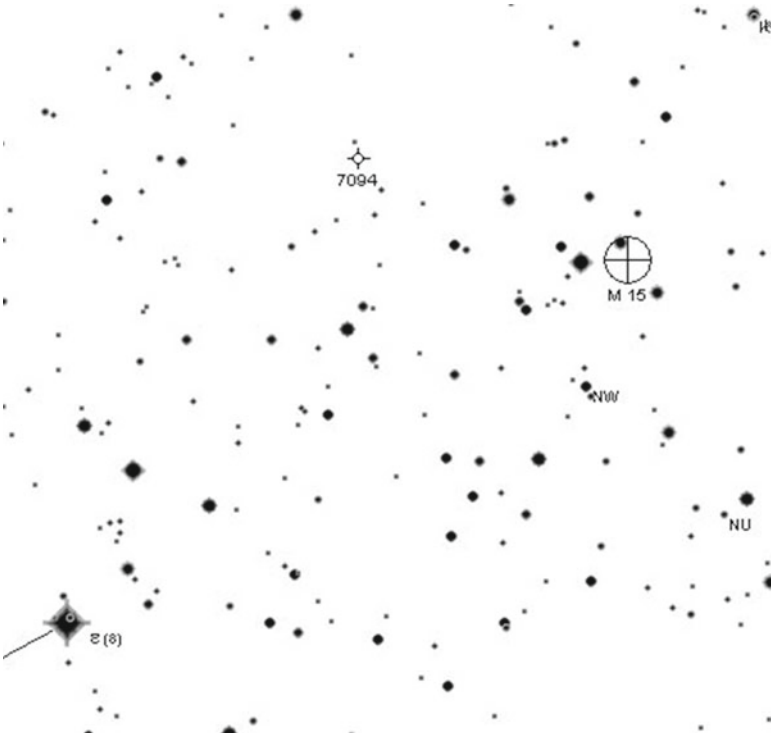
General view of Pegasus



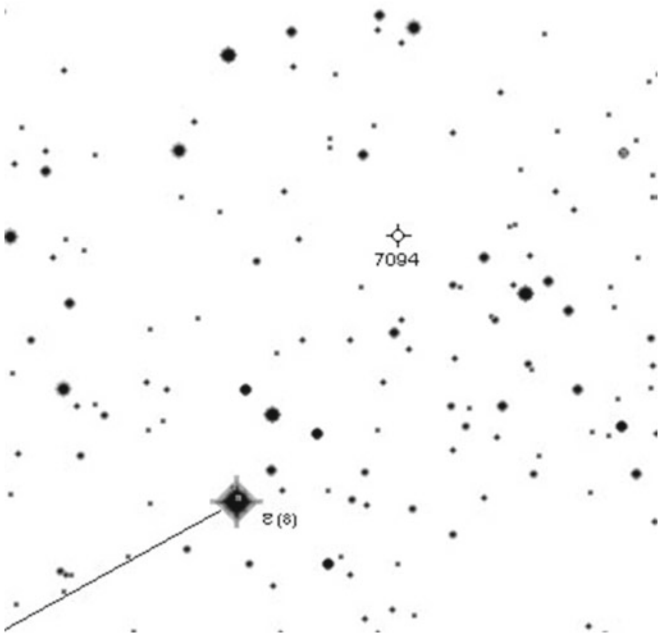
Finder chart for Jones 1



Finder chart for Pease 1

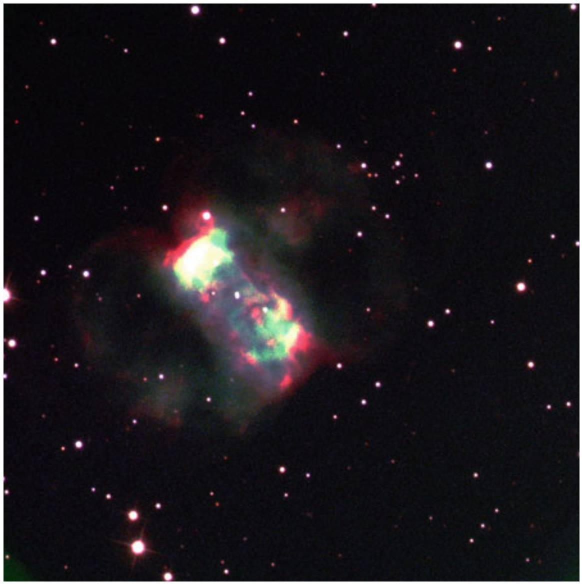


Finder chart for NGC 7094



Perseus

NGC 650/1
Perseus
RA: 01 h 42 m 20s
Dec: +51.34.5
Size: 2.7′
Magnitude: 10.1
Class: 3 + 6



This beautiful bipolar planetary nebulae was recorded as Messier 76 in 1780 and has the epithet of the "Little Dumbbell Nebula." It was discovered to be a planetary by Isaac Roberts in 1891, although Heber Curtis finalized this classification in 1918. Visually, it should not present a problem to most observers although it's meant to be the faintest in the Messier catalogue; it has been observed in instruments as small as 60 mm refractors, in fact. M76 is elongated and evenly gray at first impression, resolving itself into a two-lobed structure oriented NW/SW with some faint markings on the northern lobe and the S one being slightly brighter. At higher magnifications the nebula is filled with light but no hint of color, although there is a distinct thicker edge to the S component.

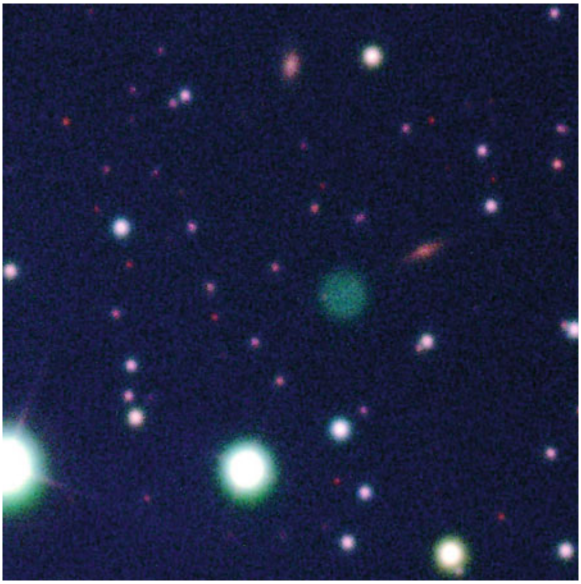
IC 351
Perseus
RA: 03 h 47 m 33 s
Dec: +35.02.8
Size: 8″
Magnitude: 12.3
Class: 2a

Tiny, almost stellar planetary in Perseus that remains a fait star-like object even at higher powers and is located in a rich Milky Way field. It can be seen with direct vision, although use of an OIII filter locates the nebula nicely, allowing such direct views. IC 351 can be found at the apex of an almost equilateral triangle from two fifth mag stars near the E foot of Perseus above the California Nebula. To the observer, the nebula is evenly colored gray, though it becomes a little blue with averted vision.

IC 2003
Perseus
RA: 03 h 56 m 22 s
Dec: +33.52.5
Size 7″
Magnitude: 11.5
Class: 2

A challenging object for small telescope users. This tiny and faint body lies only a few degrees away from IC 351 and can be located lying midway between ξ and ζ Persei in a rich Milky Way field. Visually it is little more than a stellar disk at first, white in color and lost in the background of a low power eyepiece. Use of an OIII filter on a medium to high power is essential in aiding identification of this tiny body. In high power the object is a little elongated along a N/S axis. It has a small trapezium of tenth mag stars around it, two flanking E–W and the others to NP, which ease identification of this planetary.

Abell 4
Perseus
RA: 02 h 45 m 26 s
Dec: +42.32.5
Size: 22″
Magnitude: 14.4
Class: 3b



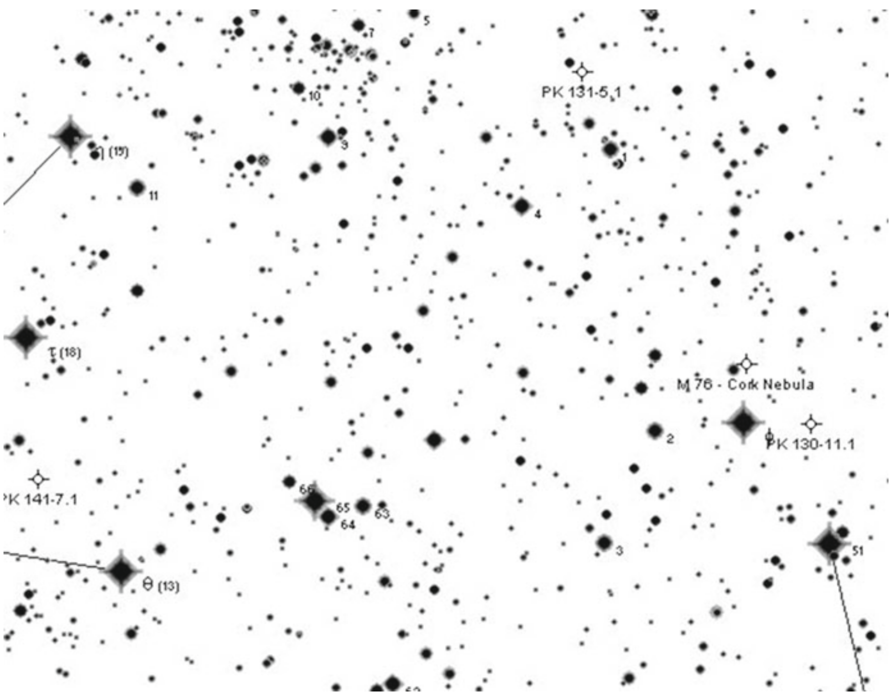
This is a very faint nebula that takes a little finding in a field SF the star cluster Messier 34 in Perseus. The nebula is gray on first finding, but does reveal a faint green color upon closer inspection, although one has to balance magnification with contrast on this object. The proximity to a ninth magnitude star does not help the observer in gaining this faint planetary, but the hunt is well worth it as it is a beautiful deep sky double for those equipped with large telescopes due to a small edge-on galaxy NP the planetary. Abell 4 has a good response to use of an OIII filter.

Sharpless 2–216
Perseus
RA: 04 h 45 m 35 s
Dec: +46.48.5
Size: 100′
Magnitude: 13
Class: 3

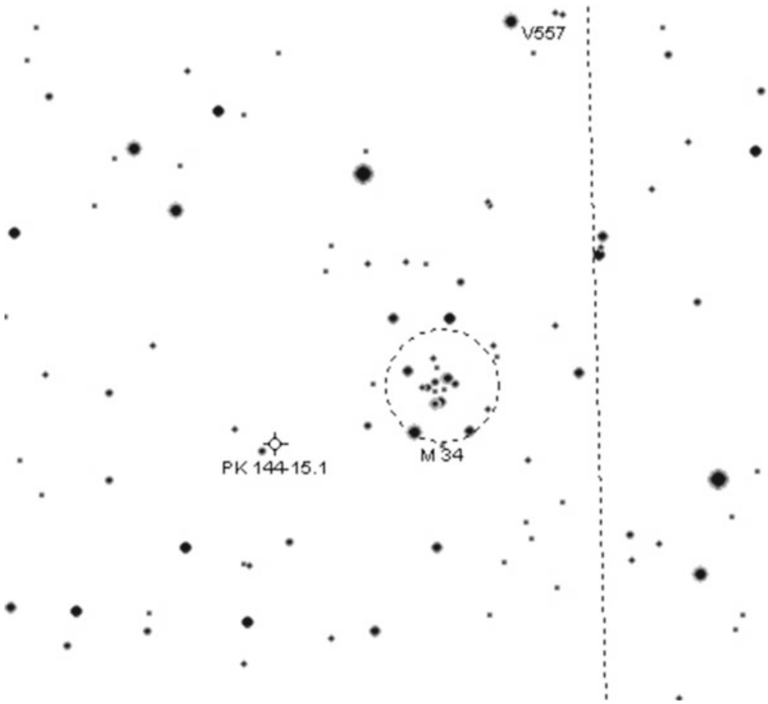
This massive nebulae is a faint and difficult planetary closer to Auriga than Perseus. For observers equipped with Dobsonians it is easier to hop to from ε Aurigae to the open cluster NGC 1664 and then north to two seventh mag stars resembling a small binary and then NE from there in a low power field. Use of an OIII filter should bring out a faint glow of amorphous light, slightly rounded though still ghostly. Observers using averted vision report that it seems irregular on N edge. One requires a low power for this rather ethereal target, as its large dimensions do not concentrate the light sufficiently to see the object well. A challenging nebula for most observers.

General view of Perseus

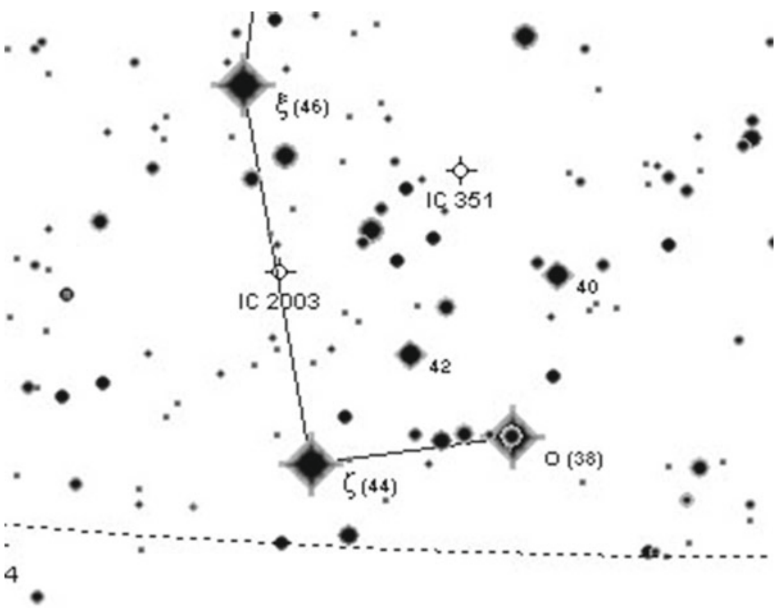
Finder chart for NGC 650/1



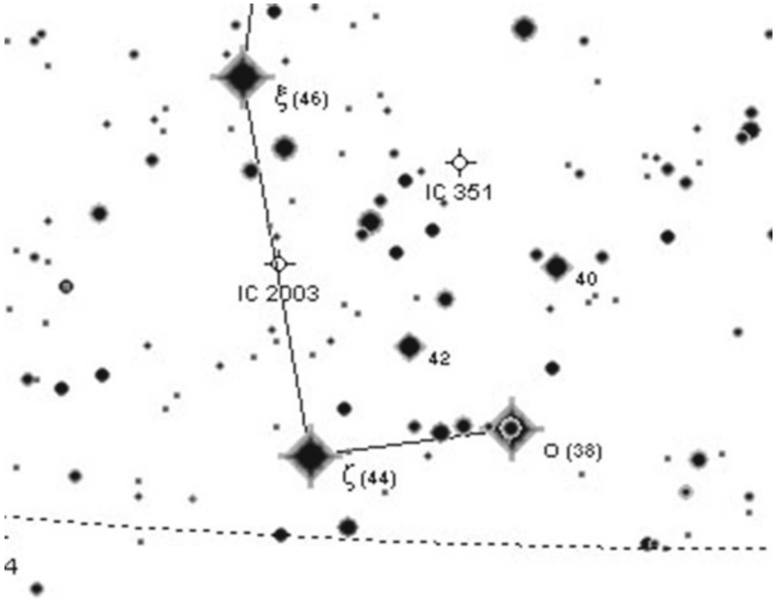
Finder chart for Abell 4



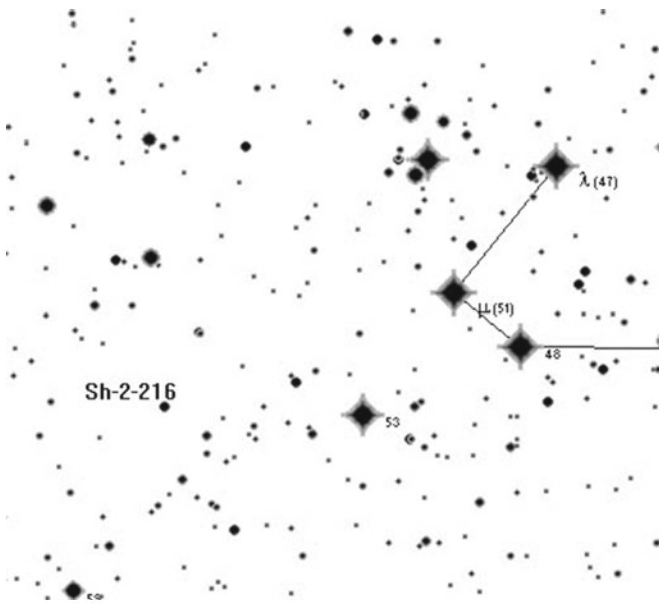
Finder chart for IC 351



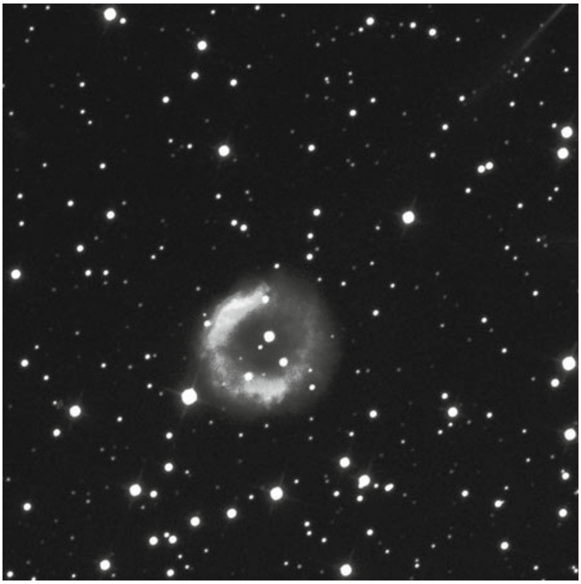
Finder chart for IC 2003



Finder chart for Sh 2–216



Puppis

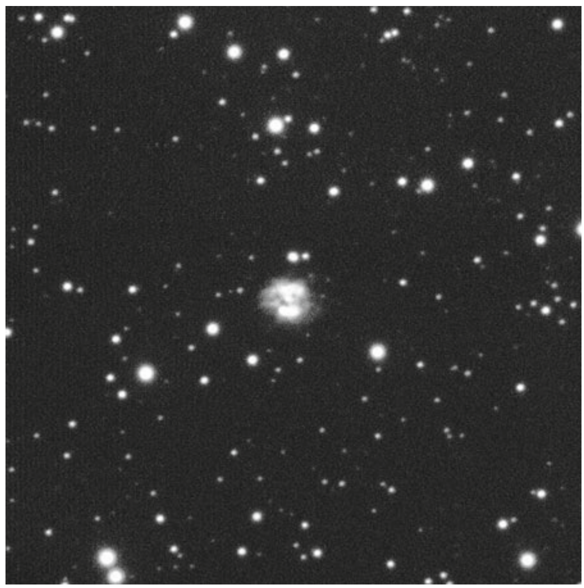


NGC 2438
Puppis
RA: 07 h 41 m 51 s
Dec: −14.44.1
Size: 75″
Magnitude: 11.1
Class: 4 + 2

A wonderful little planetary nebula lying on northern edge of Messier 46. A glorious sight when one takes time to examine the cluster, as this nebula does seem to come out of the dark once one concentrates on not seeing the steady points of light that make up this rich cluster. NGC 2438 is a compact well-defined ring of green-blue light distinct from its starry background even in low powers, though higher powers separate it out a little more and hint at a central star (though this could be a cluster member). It is definitely ring shaped, a little more subtle than M57 for comparison, with less defined edges, less sharpness to the interior but still having that lovely hoop structure. A fabulous object that is included in the Herschel 400 catalogue.

NGC 2440
Puppis
RA: 07 h 41 m 55 s
Dec: −18.12.5
Size: 74″
Magnitude: 9.4
Class: 5 + 3

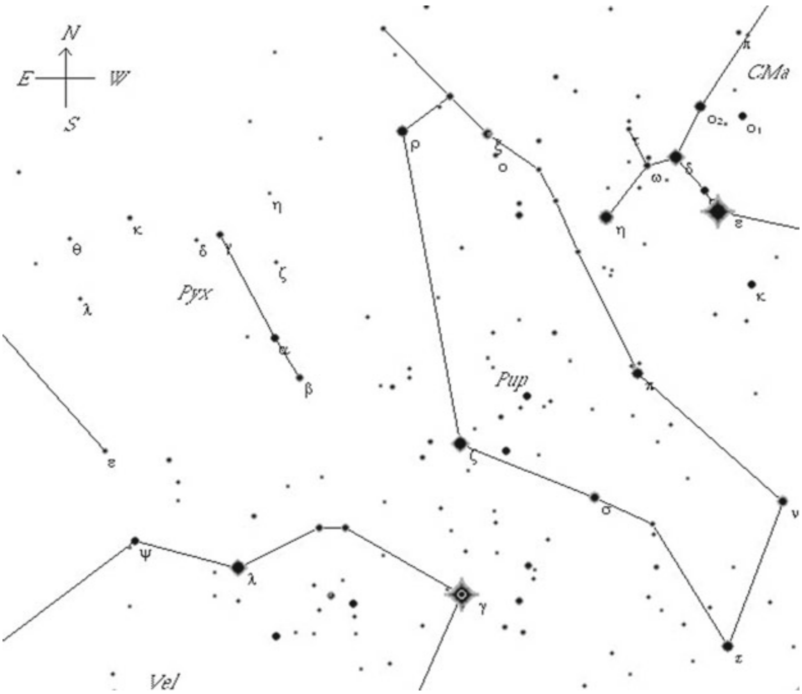
Almost directly south of M46 is this cuboid of white light containing a white dwarf star, one of the hottest known. The central star is not visible, however, due to a dense central concentration, but the nebula does reveal a lovely bipolar form oriented on an E-W axis. In higher powers there appears a nice "bite"-type bay on its N side. There is little difficulty in seeing structure in most telescopes, as the nebula is quite bright at around mag 9.5 and is over 1′ in extent across the main axis. No obvious color is visible apart from the gray-white of the nebula. NGC 2440 is also a Herschel 400 object.



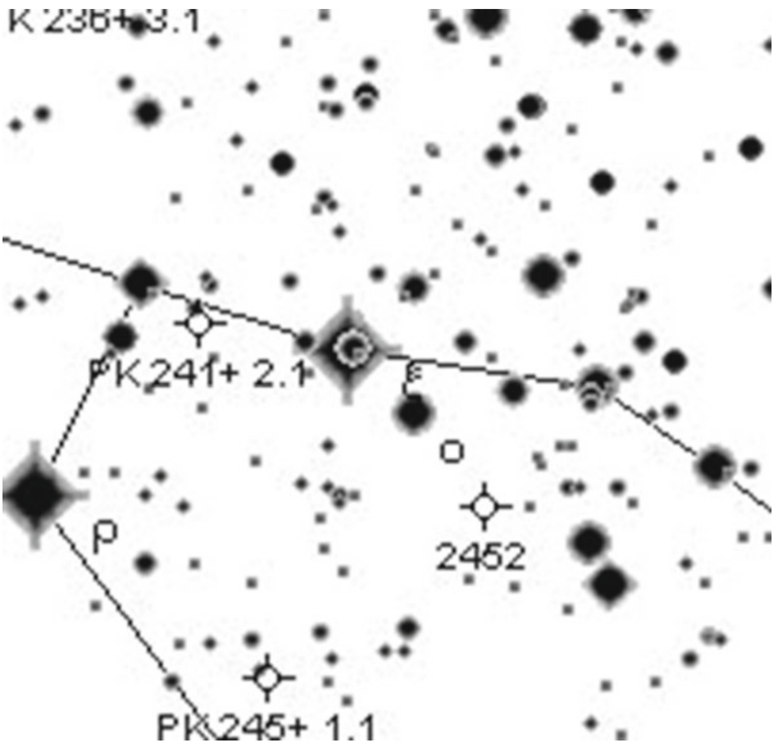
NGC 2452
Puppis
RA: 07 h 46 m 26 s
Dec: −27.20.1
Size: 31″
Magnitude: 12.2
Class:4 + 3

A lovely disk of light in a low power eyepiece, where it appears as a faint dot of light. It increases in size and contrast in higher powers, where its color becomes green white, and the nebula looks puffy and separated from the star field, though it still remains quite faint, possibly requiring averted vision to see best. The nebula is evenly lit, a little elongated along a N-S axis and brighter on its N and S edges. It has a good response to an OIII filter, which may be a useful tool if you are using a 150 mm or smaller aperture telescope.

General view of Puppis

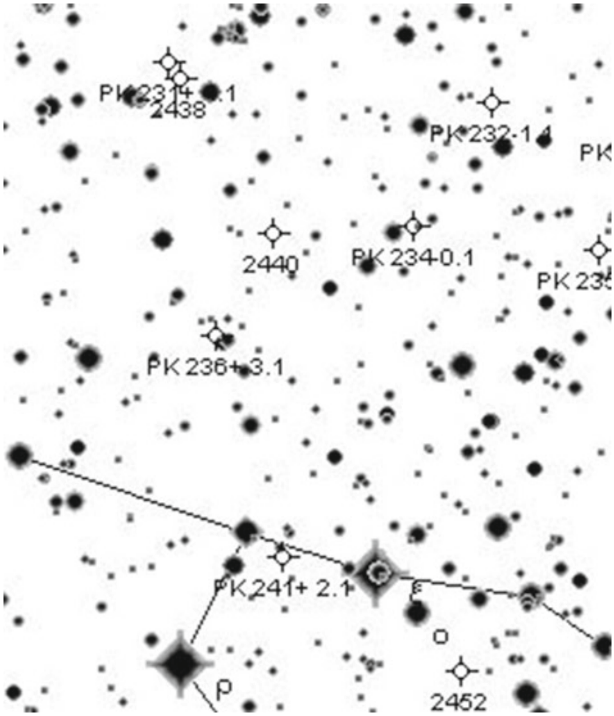


Finder chart for NGC 2452

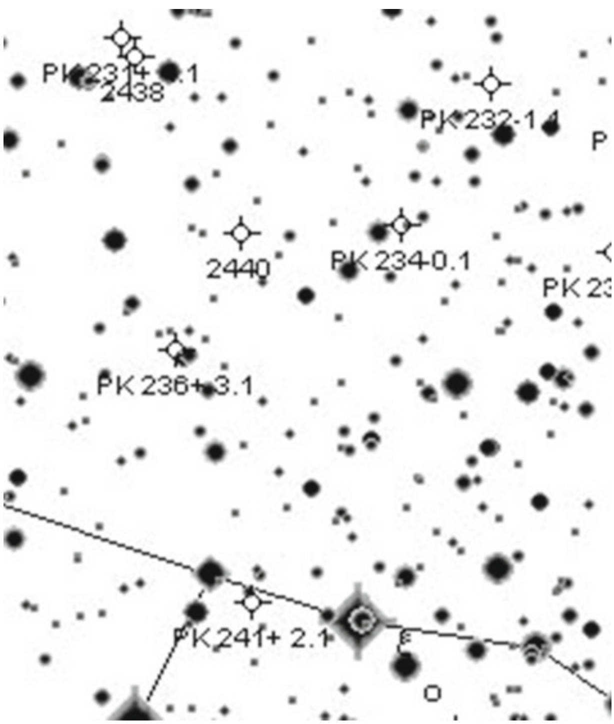


Planetary Nebulae by Constellation

Finder chart for NGC 2438



Finder chart for NGC 2440



Pyxis

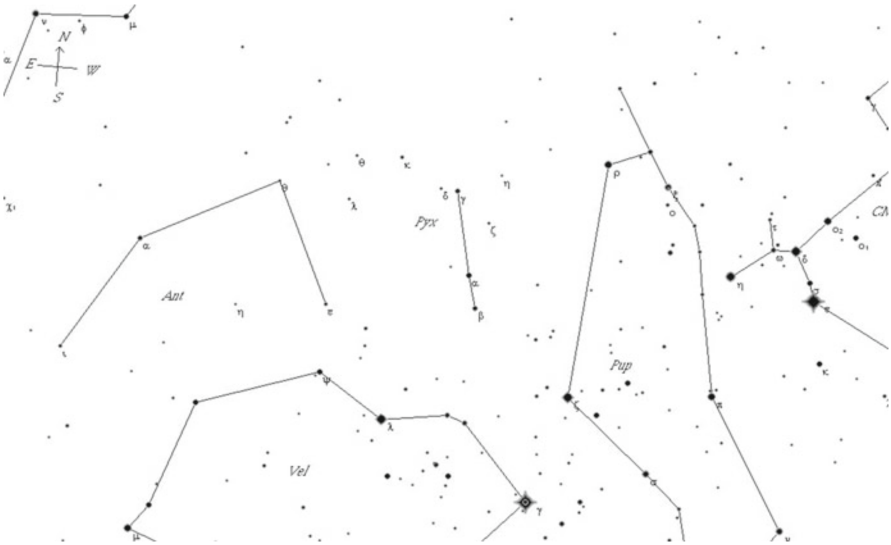
Minkowski 3–6
Pyxis
RA: 08 h 40 m 39 s
Dec: −32.22.1
Size: 8″
Magnitude: 10.7
Class: 2a

M 3–6 is a very small planetary nebula, typical of the Minkowski class in a rich field of faint stars in the southern constellation of Pyxis. It responds quite well to using an OIII filter to separate it from the field stars, and its small size makes it look very stellar in low powers, so moderate to high magnification is a must to see this object well. It looks slightly elongated along a N-S axis and is whitish-green in color. Although its quoted magnitude is 10.7, it appears to be fainter than this visually.

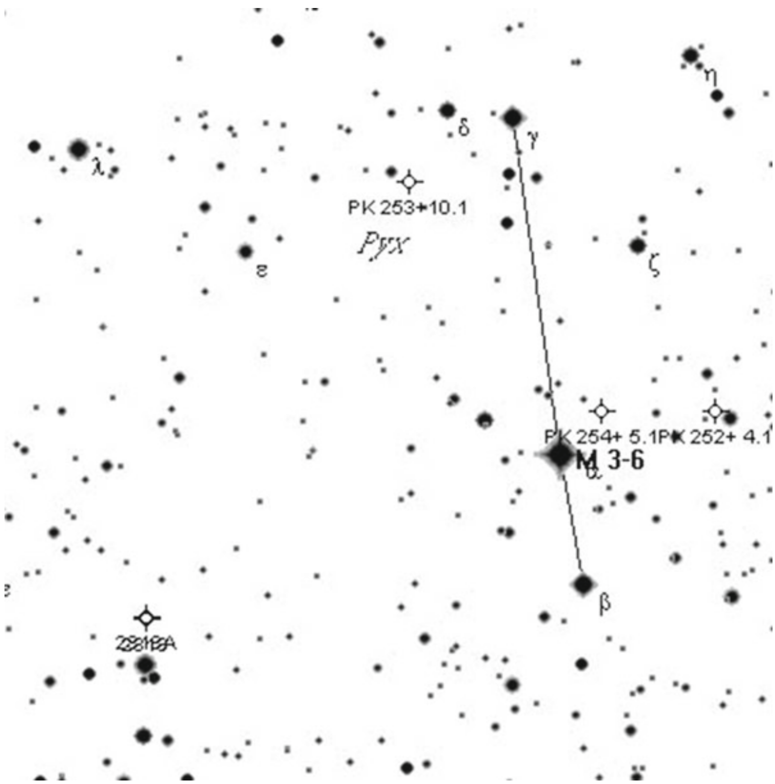
NGC 2818
Pyxis
RA: 09 h 16 m 02 s
Dec: −36.37.6
Size: 35″
Magnitude: 11.9
Class: 3b

This nebula is part of a lovely star cluster immediately visible in most telescopes, and the planetary is superimposed on it as a gray, elongated patch of light about tenth magnitude and 40″ or more in extent along an E-W axis surrounded by the lovely blue-white stars of the cluster. The planetary nebula is on the NW side of the group and is obvious as a whitish patch of light in low power. Higher magnifications render it more detailed, with a dark bay on each side of the dense central portion. Although it is apparent with direct vision, the nebula shows a good response to an OIII filter.

General view of Pyxis

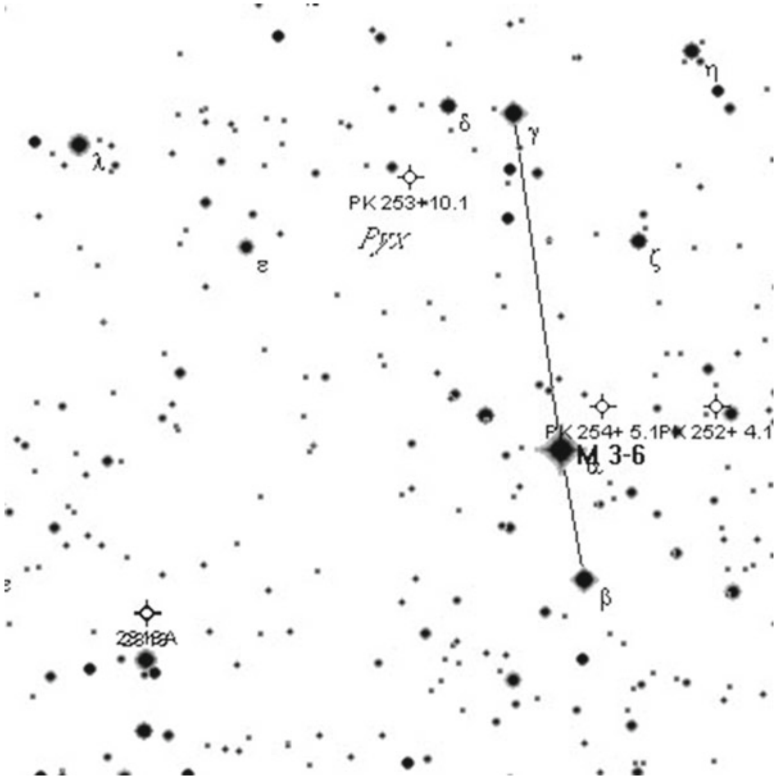


Finder chart for M 3–6



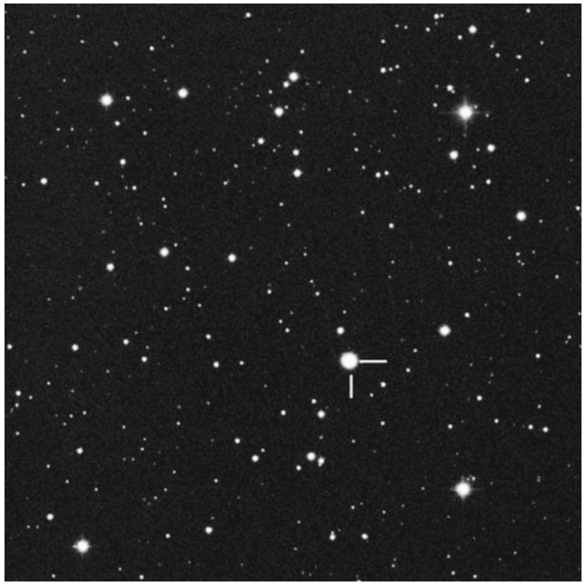
Planetary Nebulae by Constellation

Finder chart for NGC 2818



Sagitta

NGC 6879
Sagitta
RA: 20 h 10 m 27 s
Dec: +16.55.4
Size: 8″
Magnitude: 12.5
Class: 2a

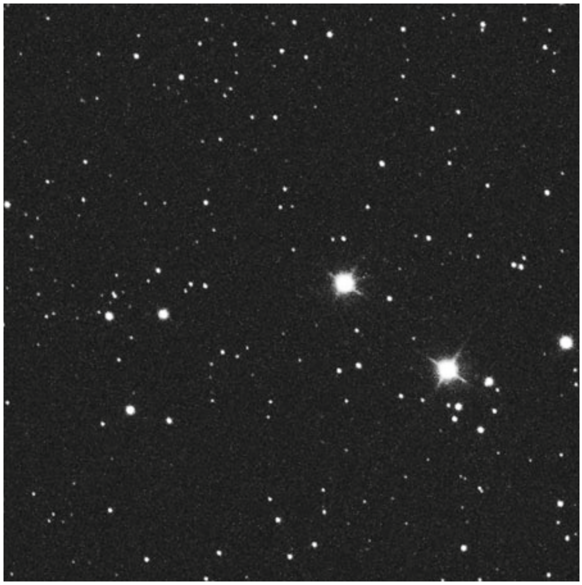


Very small planetary that remains stellar in most magnifications and requires an OIII filter to see the body proper, as in direct vision it resembles a dim star of 12th magnitude. The object is fairly easy to hop to from η Sagittae, then to a trapezium of eighth magnitude stars visible in a finder. Go east from there by about a field width and the nebula should be there, although high powers are needed as the planetary is only 8″ across and lies in a rich part of the Milky Way. Although it is unimpressive and stellar, larger ‘scopes may be able to make out its round shape, and the color seems to be quite blue with the contrast.

NGC 6886
Sagitta
RA: 20 h 12 m 43 s
Dec: +19.59.4
Size: 9″
Magnitude: 11.4
Class: 2 + 3

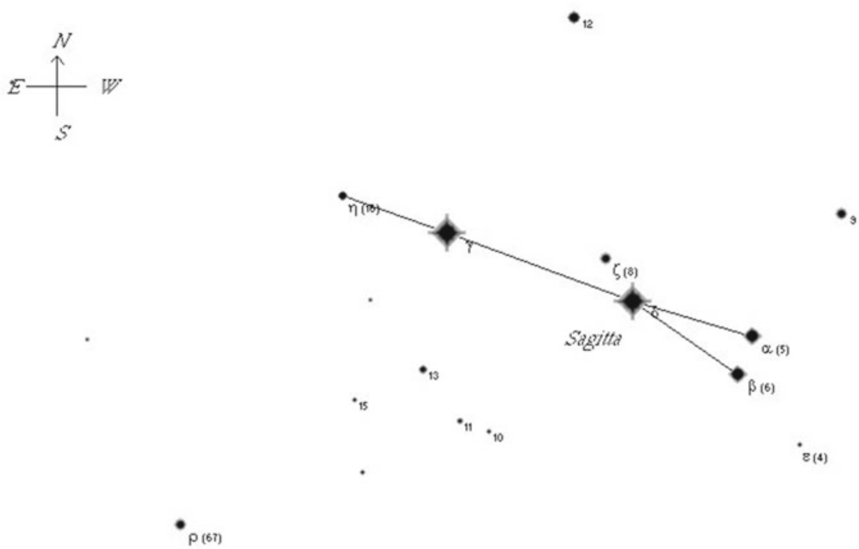
This is a star-like planetary nebula right off the tip of the arrow of Sagitta that can be seen in direct vision, though use of an OIII filter does confirm its presence well. NGC 6886 resembles a hazy star with a slight extension N/S in moderate powers and has a ninth mag star just east of the body itself. There is a slight greenish tinge visible with averted vision, and the body seems much brighter than its quoted magnitude, so it can be recommended to users of most telescopes even though it is small in size.

IC 4997
Sagitta
RA: 20 h 20 m 9 s
Dec: +16.43.9
Size: 2″
Magnitude: 10.4
Class: 1

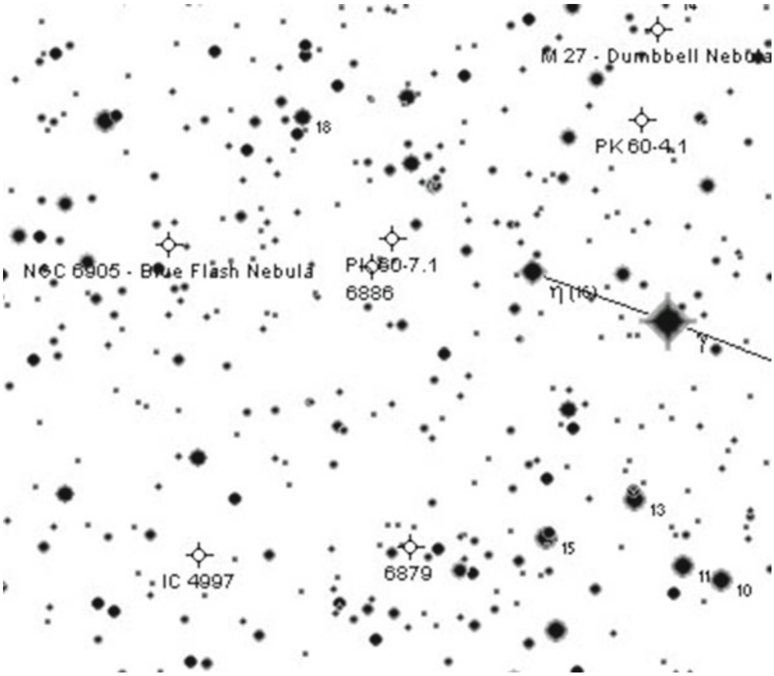


A fairly bright little planetary that many observers overlook. It requires an OIII filter to narrow it down before it can be seen directly as a little star. If you are star hopping to it, then follow a line directly south for 1° from a sixth magnitude star SF η Sagittae and the field becomes obvious, with the nebula just N of a small trio of stars that disappears somewhat with use of the OIII, leaving the planetary visible. In direct vision it is slightly green in color and is quite bright, just very star-like and easy to miss. It is bright enough to be visible even in small 'scopes, but remember that is very small!

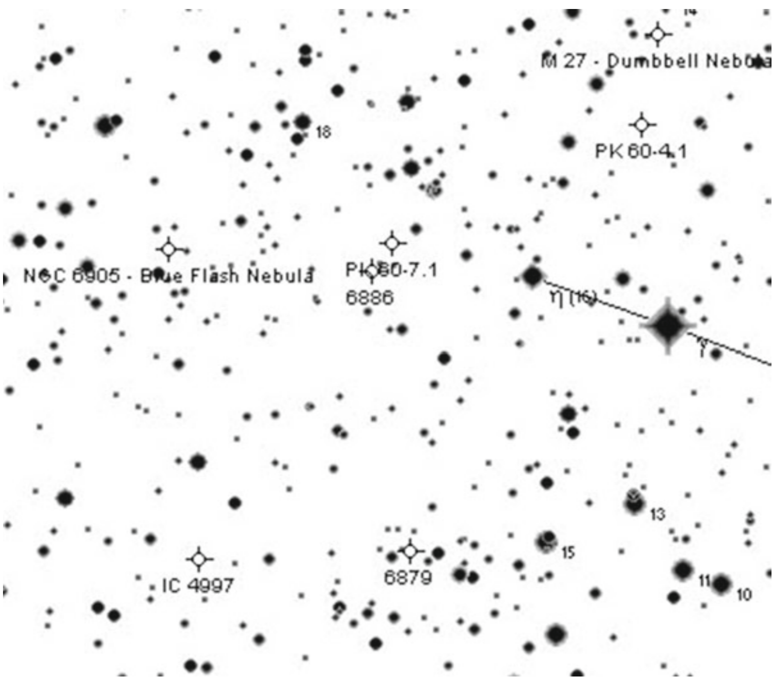
General view of Sagitta



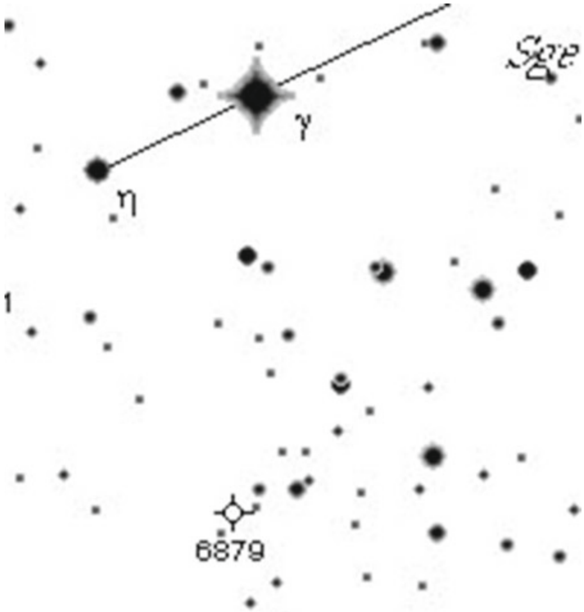
Finder chart for NGC 6886



Finder chart for IC 4997



Finder chart for NGC 6879



Sagittarius

NGC 6445
Sagittarius
RA: 17 h 49 m 15 s
Dec: −20.00.6
Size: 55″
Magnitude: 11.2
Class: 3b

NGC 6445 is a lovely smudge of faint light that is not too far to the SW of the star cluster M23. In low power it looks oval and extended NE/SW, with a definite border brighter than its inner regions. Higher magnifications allow the observer to see the irregular pattern better, though the inner portion of the nebula still remains quite dark. NGC 6445 is also a Herschel 400 catalogue object, and although it is small, it shows some intriguing details at high magnifications in large telescopes. It is also visible in most small telescopes.

IC 4670
Sagittarius
RA: 17 h 55 m 07 s
Dec: −21.44.7
Size: 7″
Magnitude: 13.2
Class: 2

Another faint starry object lost in the star fields of the Milky Way and located to the NW of the nebula M20. Not visible directly in low powers without using an OIII filter. IC 4670 lies NP a seventh mag star that is visible in most finderscopes, which make identifying the field a bit easier. The nebula itself is a white-blue star visible with averted vision, but higher powers allow a concentration on this small, almost stellar object and decrease the color contrast across the field a little. The nebula is a faint blue-green at larger magnifications but is definitely not as interesting as M8/M20 to the SE!

NGC 6537
Sagittarius
RA: 18 h 05 m 13 s
Dec: −19.50.6
Size: 11″
Magnitude: 11.6
Class: 2a + 6

This small but obvious nebula is a little gem in larger telescopes, as the resolved detail goes beyond just the faint square of light visible in smaller apertures. The planetary is almost stellar and has a seventh mag star NF. NGC 6537 is not too difficult to find in rich Milky Way star fields to the north of M20 between the nebulae and the star cluster M23. Visually, it is initially stellar and gray, though moderate powers confirm its appearance as a little square of light with a hint of extensions from its southern "corners" with averted vision. Higher powers render the color blue-gray, though a photograph of the object reveals why it is called the "Red Spider."

NGC 6565
Sagittarius
RA: 18 h 11 m 53 s
Dec: −28.10.7
Size: 10″
Magnitude: 11.6
Class: 4

Small, stellar-looking body with a good green color that is visible in the field, though use of an OIII filter does help to locate it in this mass of faint stars. NGC 6565 is in a dense part of the Milky Way just above the "spout" of the teapot. At moderate powers NGC 6565 is evident in the field as a round blob of light about 10″ across and at mag 11 is quite a bright object, standing out as a round extended object in contrast to the points of light all around. There is some confusion between observers as to the color of this planetary – some describe this one as blue in color, but others perceive it as definitely green. In high powers it looks a little elongated on a NE–SW axis, and the color fades a bit with the contrast. Check this one out and make your own decision on its color.

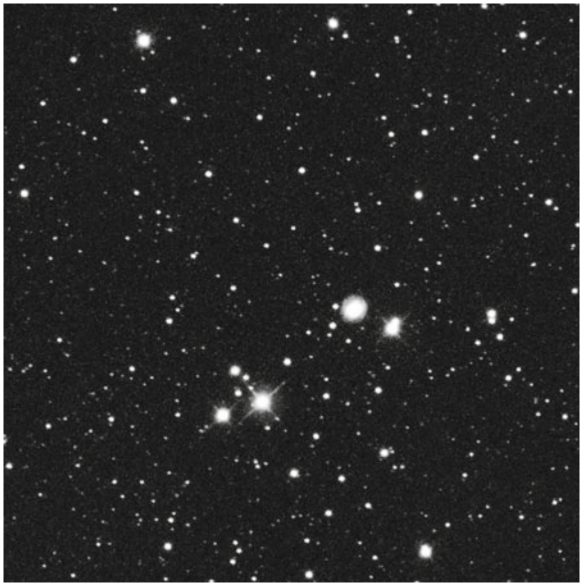
NGC 6563
Sagittarius
RA: 18 h 12 m 03 s
Dec: −33.52.1
Size: 54″
Magnitude: 11.0
Class: 3a

Lovely little faint oval of 11th mag light to the east of the fantastic star cluster M7 and is not too difficult to resolve, as the nebula is a filled white-green shell at low powers against a rich Milky Way background. In moderate and high powers the nebula becomes a little elongated, with an E-W axis visible with averted vision. Use of an OIII filter is recommended to pull this one out of the background, as from high northern latitudes it can be challenging to see this wisp of light clearly without aid.

NGC 6567
Sagittarius
RA: 18 h 34 m 45 s
Dec: −19.04.06
Size: 11″
Magnitude: 11
Class: 2a + 3

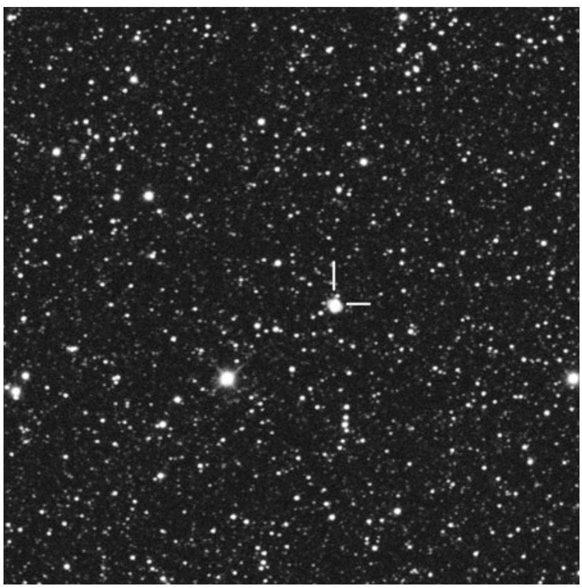
Tiny, stellar planetary that has a high surface brightness and can be seen even in relatively small apertures. In low powers the nebula appears as a small smudge, which is somewhat spoiled by a faint star overwhelming the nebula to its east. Use of an OIII filter can confirm its presence as a faint oval of light elongated slightly NE/SW, while higher magnifications and averted vision enlarge a little on this feature of the body. The more one looks at it, the more one is overwhelmed by the tenth mag star on its edge, though the blue-green color should shine through.

NGC 6578
Sagittarius
RA: 18 h 16 m 17 s
Dec: −20.27.0
Size: 9″
Magnitude: 13.4
Class: 2a



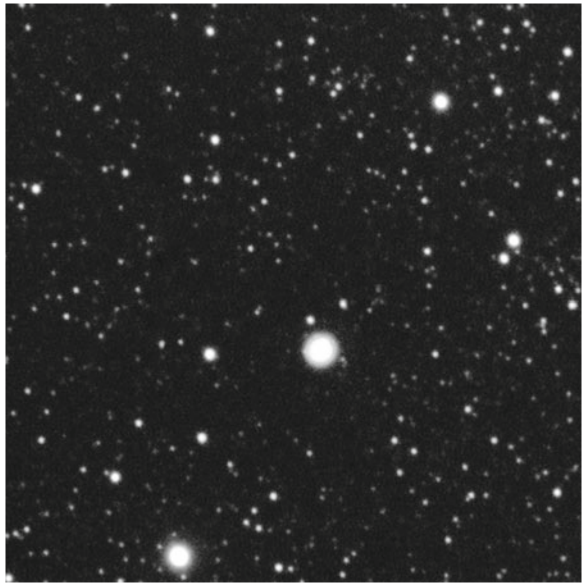
Very small and challenging planetary in northern Sagittarius, which is quite faint and requires a fairly large aperture (20 cm +) to see. Users of large Dobsonian reflectors can star hop from μ Sag NE to 15 and 16 Sag, where the nebula appears as a dim star in the field, made harder to visualize by the seventh mag star to its SE. Use of an OIII filter enables the observer to see the object jump out of the field better, though higher powers are needed to see it well and distinguish any extension to this planetary. It appears as a distinct blue-white or faded green colored stellar point to most observers, depending on their visual acuity. Some report that averted vision expands its star-like state into something rounder and more distinctive.

NGC 6620
Sagittarius
RA: 18 h 22 m 54 s
Dec: −26.49.3
Size: 5″
Magnitude: 12.7
Class: 2b



Another challenging planetary nebula that appears as a horrifyingly faint object, which is stellar even at high powers, though it becomes discernable in lower powers if one uses an OIII filter, as it has a good response to this aid. NGC 6620 seems fainter than its designated magnitude of 12.7 and is located in a rich field of stars roughly halfway down the top of the Teapot from λ Sag. NGC 6620 appears star-like at most magnifications, even with large apertures, where it is visible as an even white blob with no color to be seen.

NGC 6629
Sagittarius
RA: 18 h 25 m 43 s
Dec: −23.12.2
Size: 16″
Magnitude: 11.3
Class: 2a



A lovely little blue planetary nebulae about 2° north of the globular cluster M28, and, as expected of this region, the nebula lies in a rich star field. NGC 6629 is green in color, almost immediately apparent in a low power field, though moderate to high powers will enable the observer to see more of this object by reducing the starry background and resolving it as a small disk. NGC 6629 responds well to use of an OIII filter, and this neglected little planetary is also a Herschel 400 catalogue object.

NGC 6644
Sagittarius
RA: 18 h 32 m 35 s
Dec: −25.07.7
Size: 3″
Magnitude: 10.6
Class: 2

A faint and challenging object, not from the point of view of its magnitude but merely due to its very small size. NGC 6644 is very stellar in all magnifications and is almost impossible to see in a bright field of stars without using an OIII filter. The nebula is blue in color, but the hue is rather pale, and an unsuspecting observer may overlook it as a faint star. Those equipped with GOTO systems should have no problem in locating the field, but locating this tiny object is another matter. Care needed to identify this one.

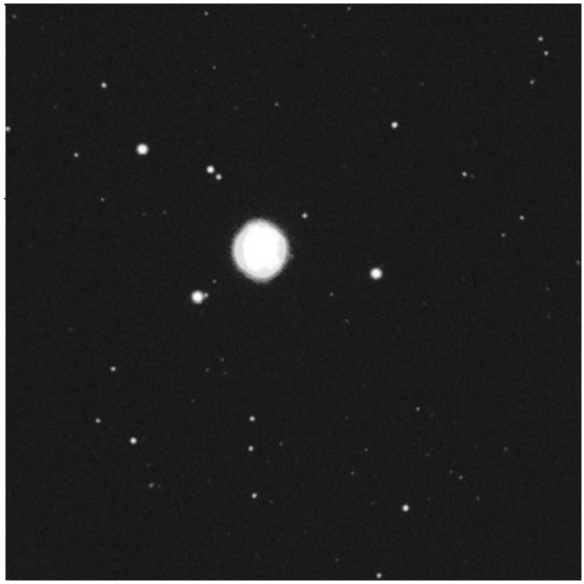
IC 4732
Sagittarius
RA: 18 h 33 m 55 s
Dec: −22.38.7
Size: 3″
Magnitude: 12.1
Class: 1

A very star-like planetary to the north of the globular cluster M22, in a very rich field of stars. Even moderate apertures require an OIII filter to see this small body, as it remains a starry point in low to moderate powers. An OIII filter used at higher magnifications once the field is located is useful as the nebula flashes in and out of vision when blinked. It can be seen directly as a small and indistinct dot in the field, and it looks a pale white-green in color visually.

IC 4776
Sagittarius
RA: 18 h 45 m 51 s
Dec: −33.20.6
Size: 8″
Magnitude: 10.4
Class: 2a

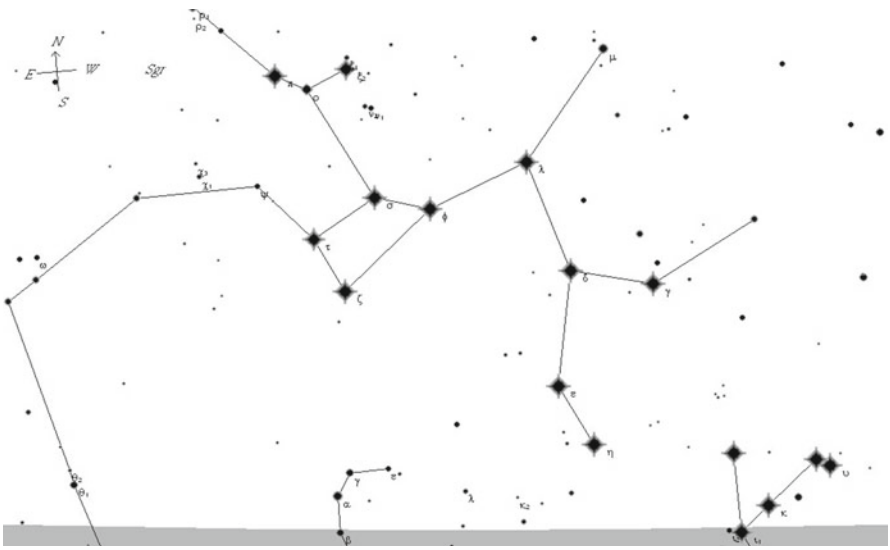
Small and faint green-white colored planetary that is easily seen by blinking the field with an OIII filter. IC 4776 is located just over a degree to the SE of Messier 70, though in low powers the planetary does not stand out, as it is stellar and dim. A higher magnification reveals a little green oval blob that is barely distinct from the stars of the Milky Way and a little elongated NW/SE. Challenging, but not impossible for users of telescopes with apertures smaller than 150 mm.

NGC 6818
Sagittarius
RA: 19 h 43 m 58 s
Dec: −14.09.2
Size: 22″
Magnitude: 9.3
Class: 4

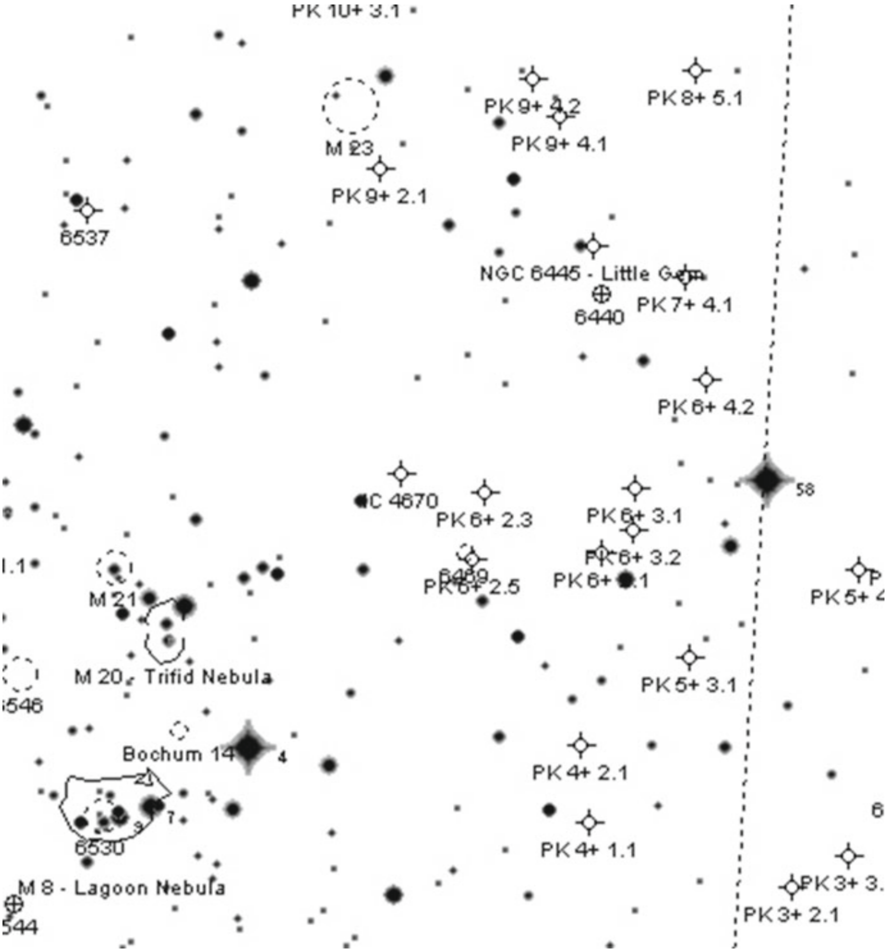


The "little gem" planetary just to the N of NGC 6822 (Barnard's Galaxy) is much easier to see than this extended and faint object! It is revealed as a glowing turquoise object with a slightly elliptical shape, elongated N/S and about 25″ across and plainly evident due to brightness and color even at low power. In moderate powers it looks evenly filled, though averted vision may show a slight central darkening but with no central star visible. NGC 6818 displays a vivid color and can be seen in most backyard telescopes and is a Herschel 400 object, too.

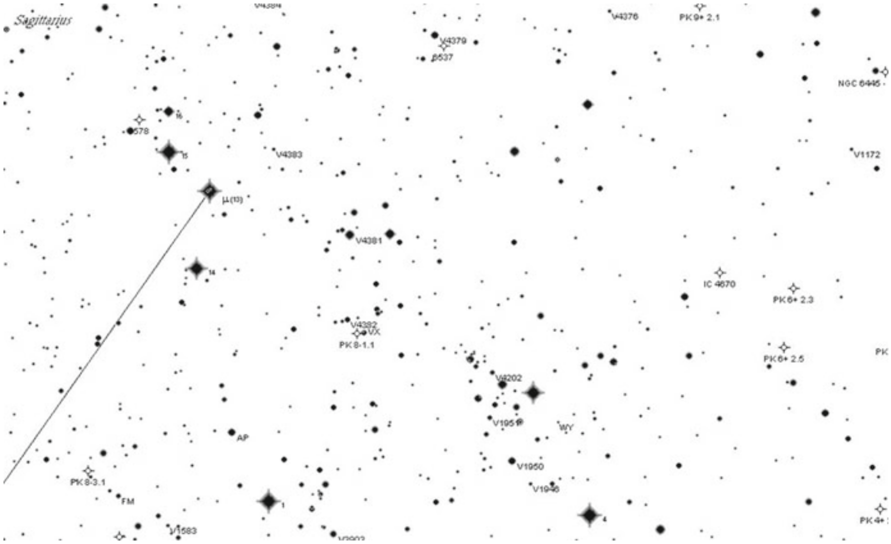
General view of Sagittarius



Finder chart for NGC 6445

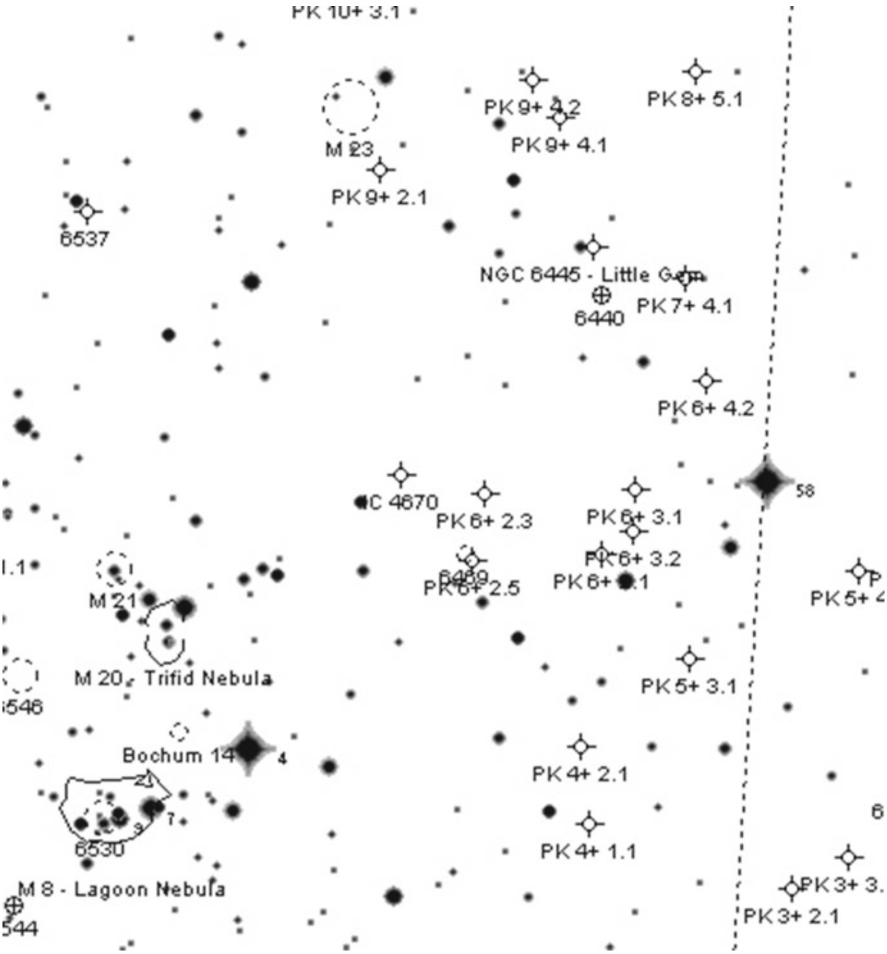


Finder chart for IC 4670

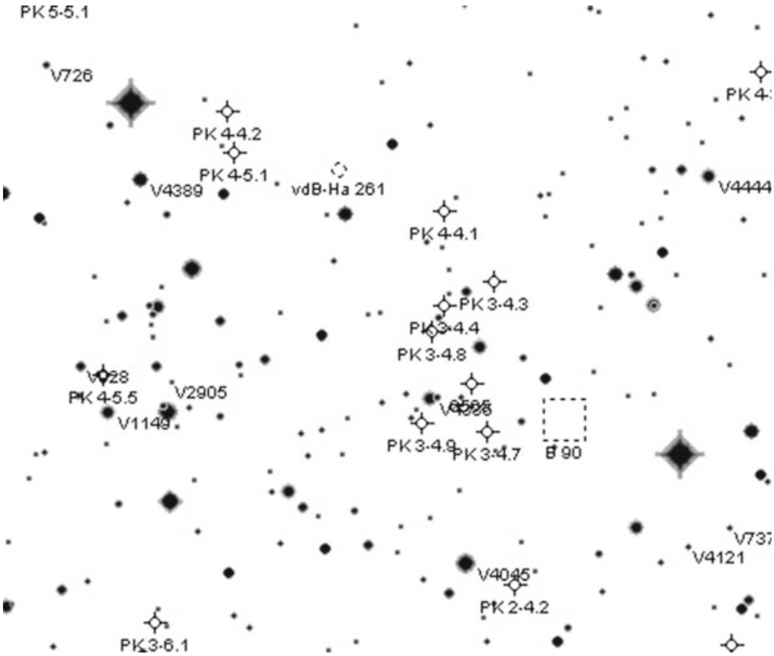


Planetary Nebulae by Constellation

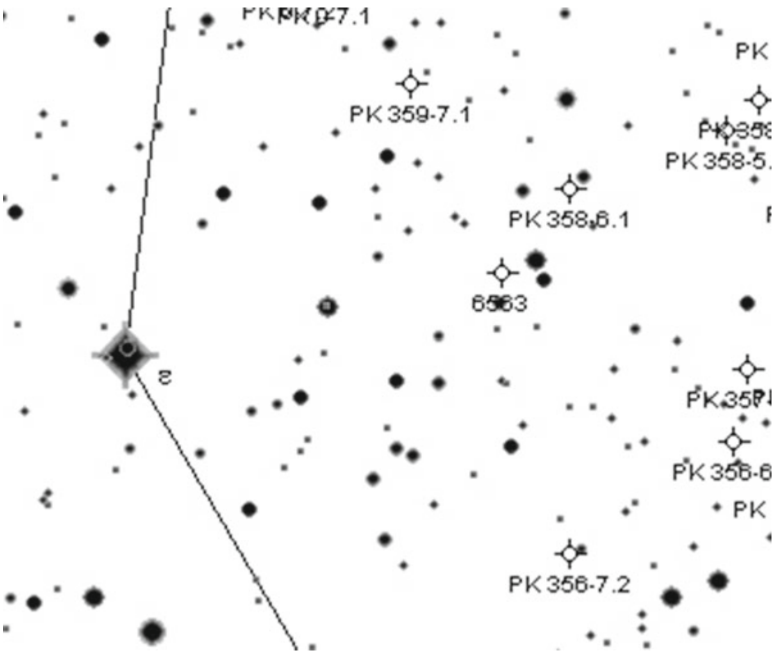
Finder chart for NGC 6537



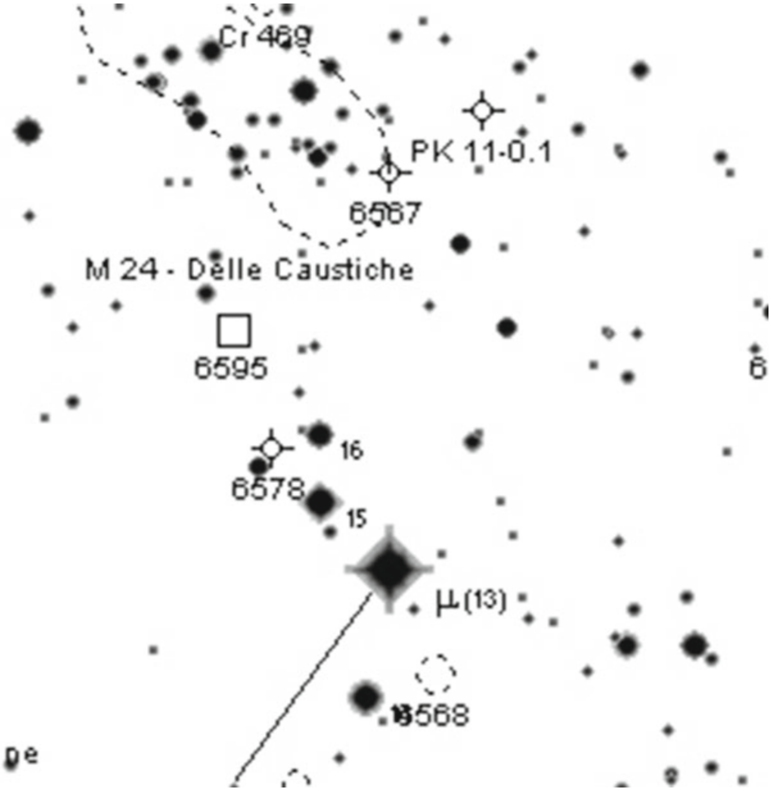
Finder chart for NGC 6565



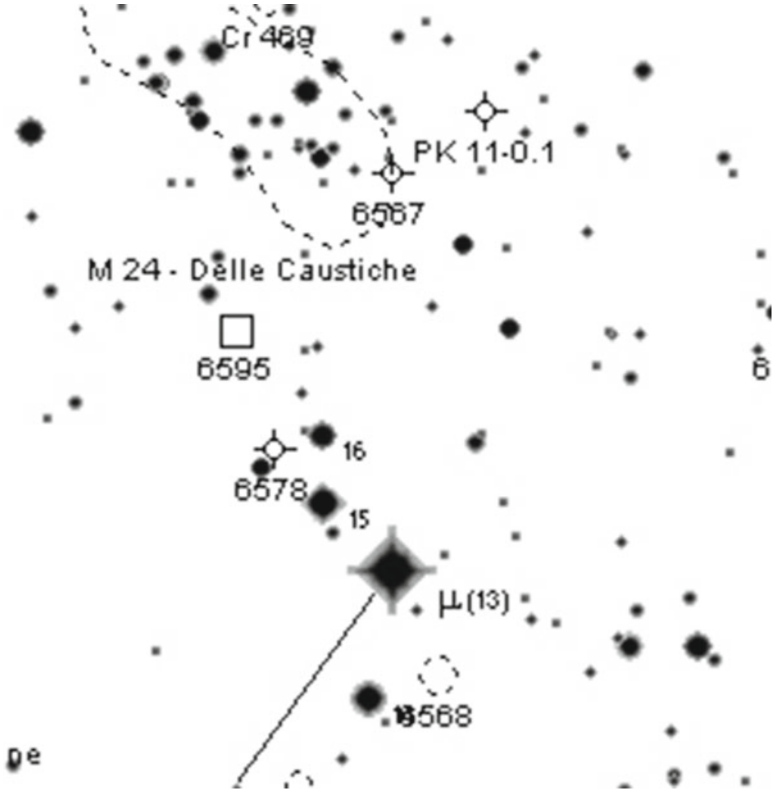
Finder chart for NGC 6563



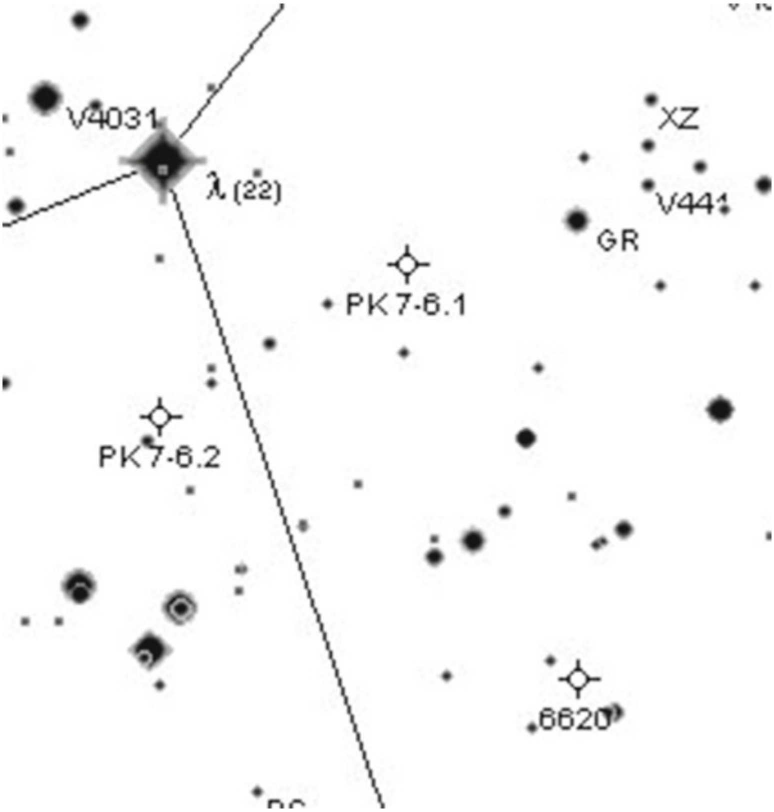
Finder chart for NGC 6567



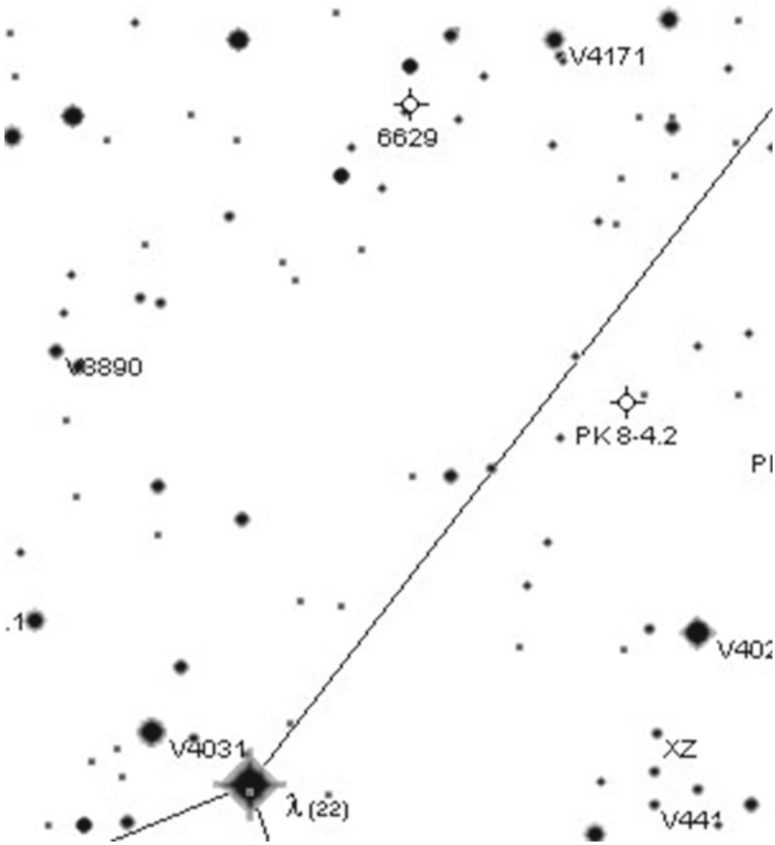
Finder chart for NGC 6578



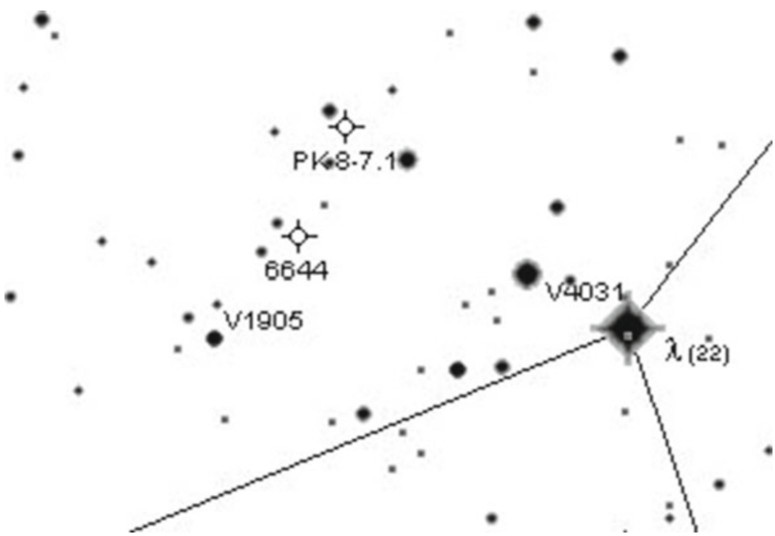
Finder chart for NGC 6620



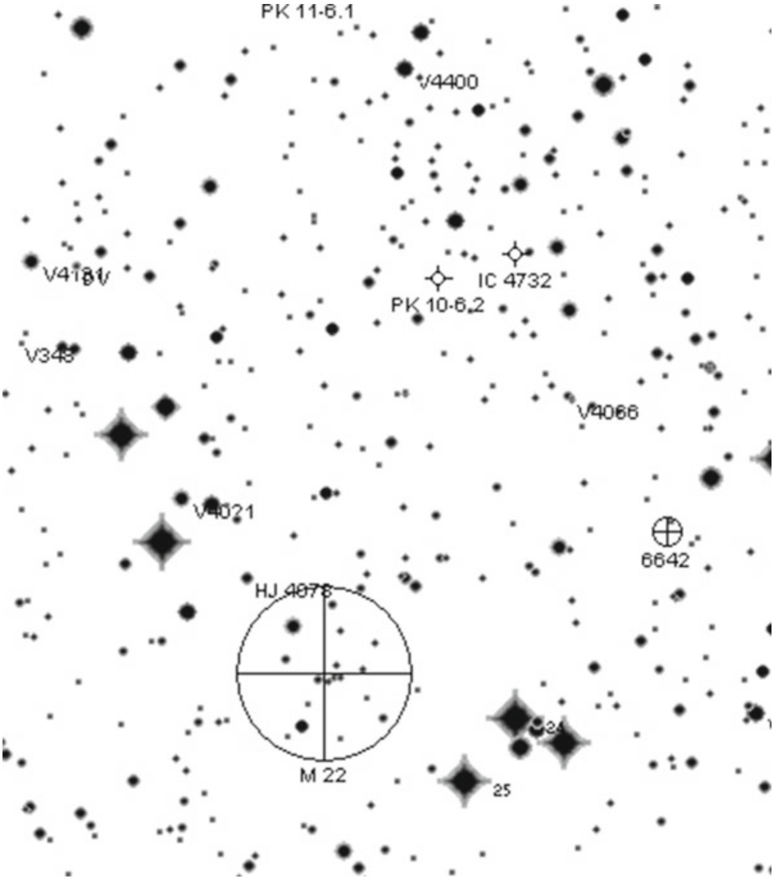
Finder chart for NGC 6629



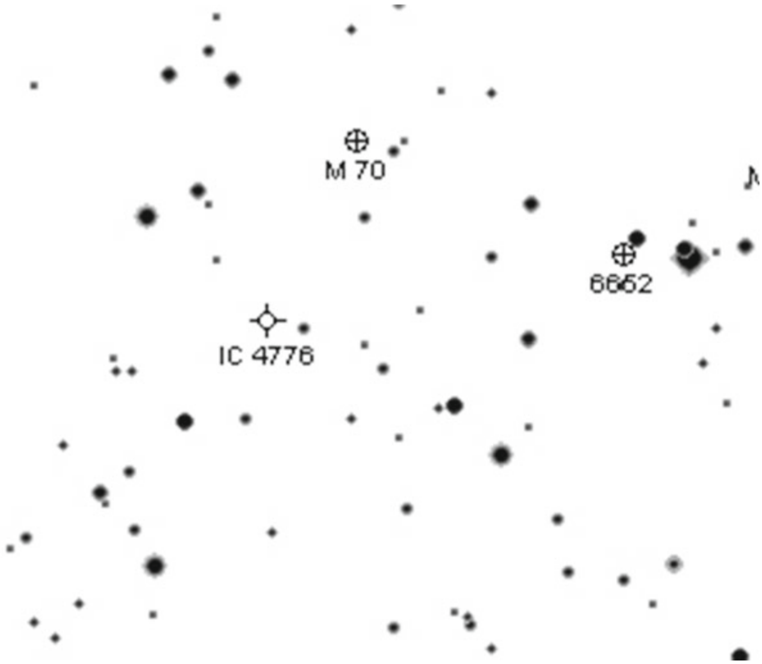
Finder chart for NGC 6644



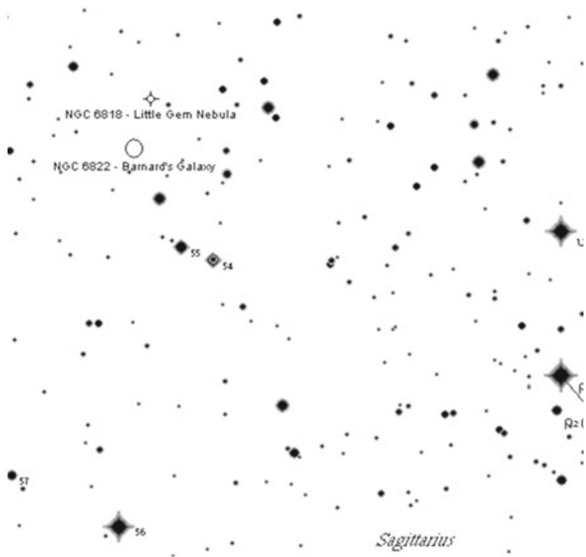
Finder chart for IC 4732



Finder chart for IC 4776

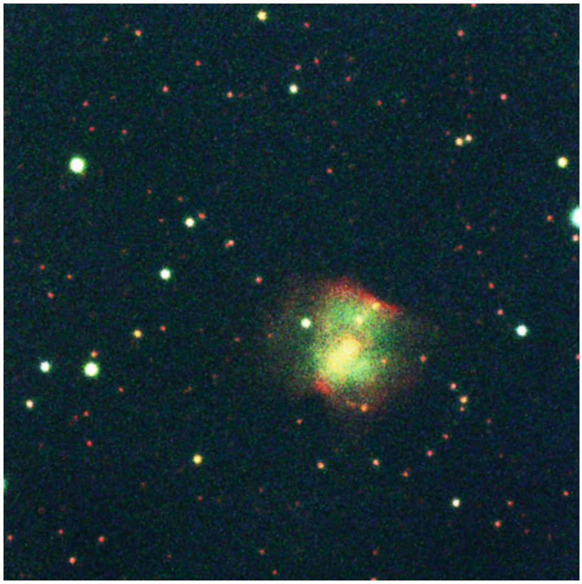


Finder chart for NGC 6818



Scorpius

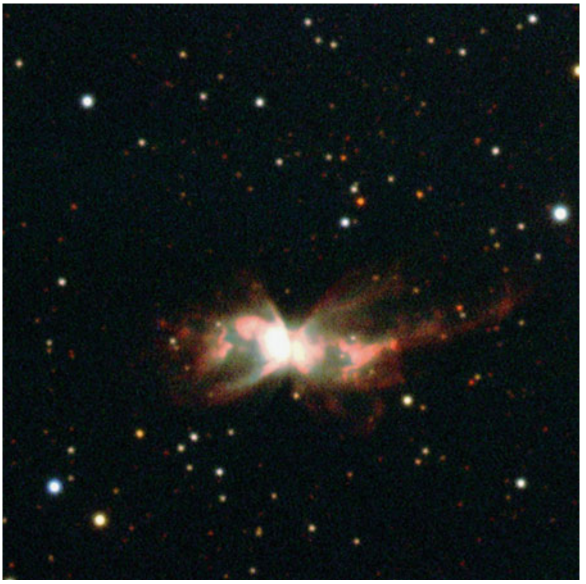
NGC 6072
Scorpius
RA: 16 h 12 m 58 s
Dec: −36.13.8
Size: 70″
Magnitude: 11.6
Class: 3a



NGC 6072 is a superb little nebula on the border of Lupus, not difficult to find and brighter than one would expect. It is revealed as a little puff of light almost immediately in low power, but medium to high powers give one a better view of this extended and quite large object with a high surface brightness. It resembles a little "box" of light initially and has a greenish inner halo outlined by white densities to the N and S. Users of Dobsonian telescopes will find that star hopping to the planetary from θ Lupae presents no problems.

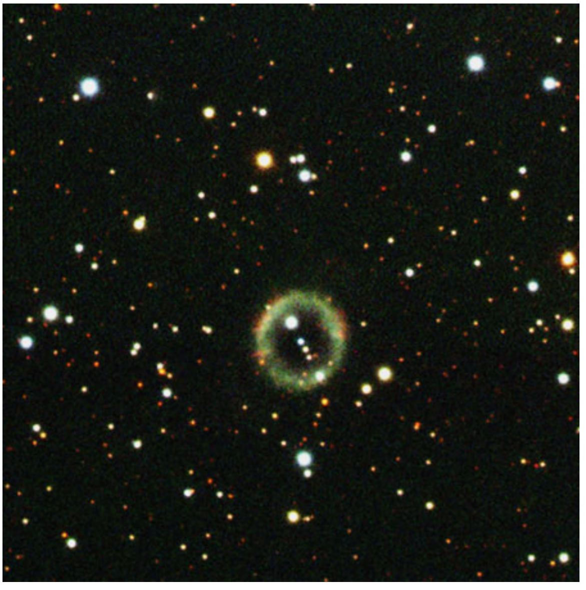
NGC 6153
Scorpius
RA: 16 h 31 m 30s
Dec: −40.15.0
Size: 30″
Magnitude: 10.6
Class: 4

NGC 6153 is a bright but small nebula not too far south of NGC 6072 that requires careful searching and use of an OIII filter to bring it out of the star fields at low powers. In such powers it is almost stellar, while higher magnifications reveal a slight "atmosphere" elongating it N-S with averted vision. The rich Milky Way makes finding it a little difficult, though its proximity to a ninth mag star to SP renders it a little easier. Its color is quite vivid, too, a rich white-green that comes through even in relatively small telescopes. Some observers report seeing NGC 6153 in instruments as small as 80 mm.



NGC 6302
Scorpius
RA: 17 h 13 m 44 s
Dec: −37.06.2
Size: 83″
Magnitude: 9.6
Class: 6

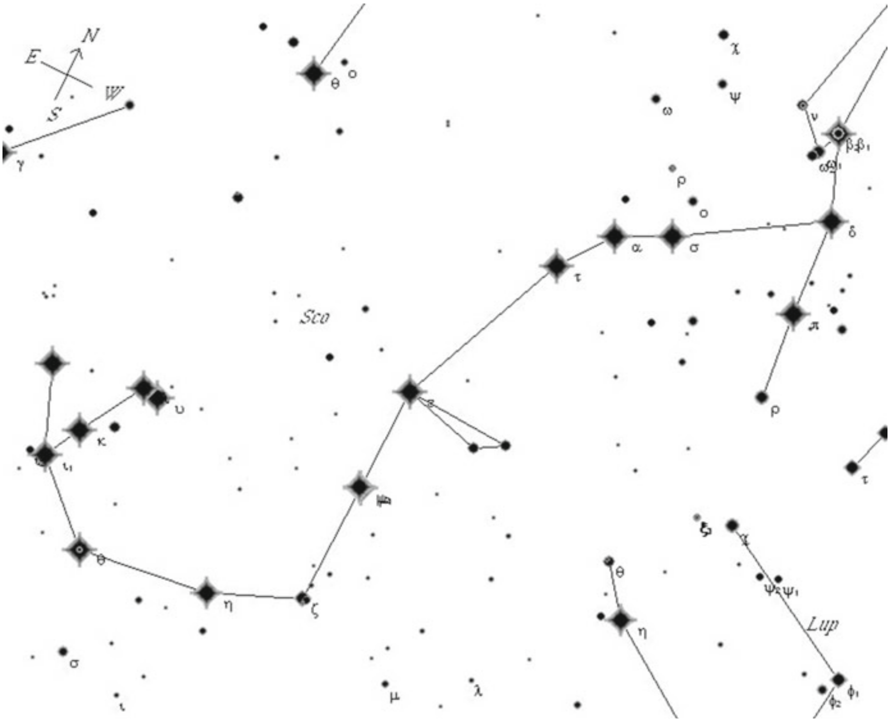
The fantastic "Bug Nebula" is a beautiful complex of gray-blue gas extended on an E–W axis and shining at ninth mag. The nebula has obvious extensions that can be seen directly in a low power that extend the object to over 1′ across. Careful observation reveals the W side to be the brighter part after the central condensation, which looks star-like at first glance but is in fact a block of white light with no starry object within. NGC 6302 is a wonderful detailed object that higher powers reveal much of, and it is also catalogued as Caldwell 69. A showpiece object that can be viewed in most instruments, although observers in high northern latitudes will be unable to see it, as it will lie below the horizon.



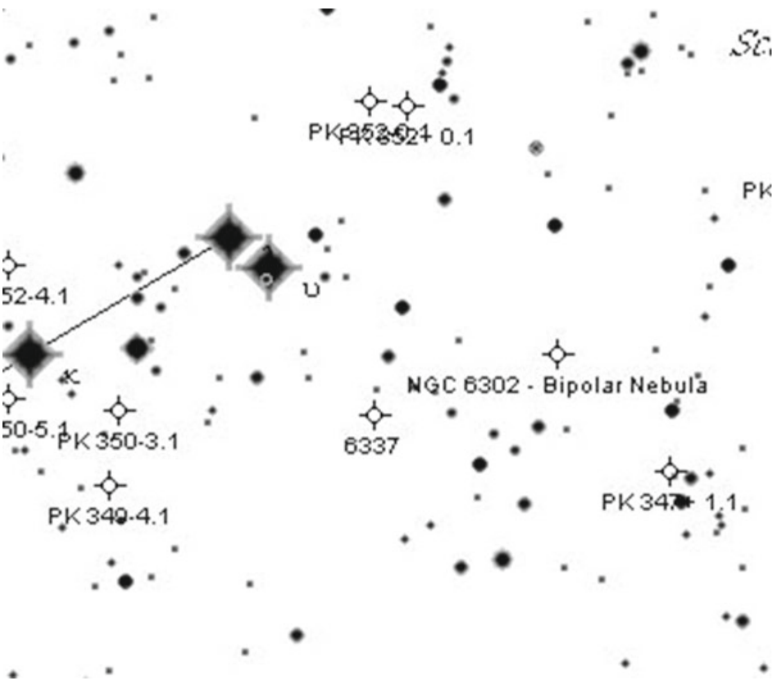
NGC 6337
Scorpius
RA: 17 h 22 m 16 s
Dec: −38.29.00
Size: 50″
Magnitude: 12.3
Class: 4

NGC 6337 is invisible from high northern latitudes as it lies just 2.5° west from Shaula in the tail of the Scorpion and takes some finding in this rich field of stars, as the shape is indistinct in a low power field. Use of an OIII filter is helpful and delivers a lovely ring-like object that is obvious but faint. Higher magnifications bring out this ring feature more clearly and allow the observer to see why this object is known as the "Cheerio Nebula" in the United States. Due to its area and shape, it seems a little fainter than its quoted magnitude. Ghostly.

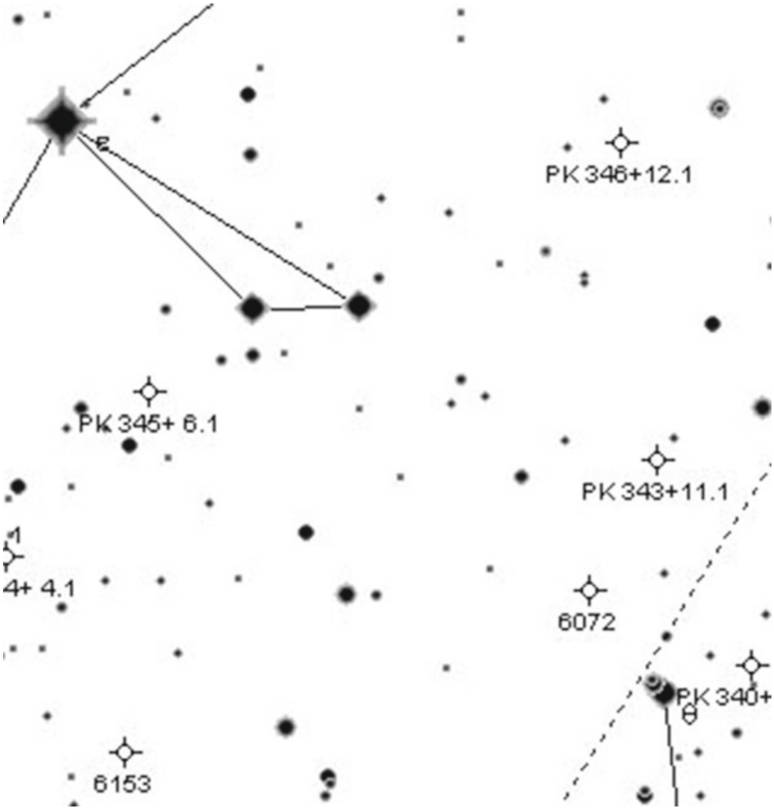
General view of Scorpius



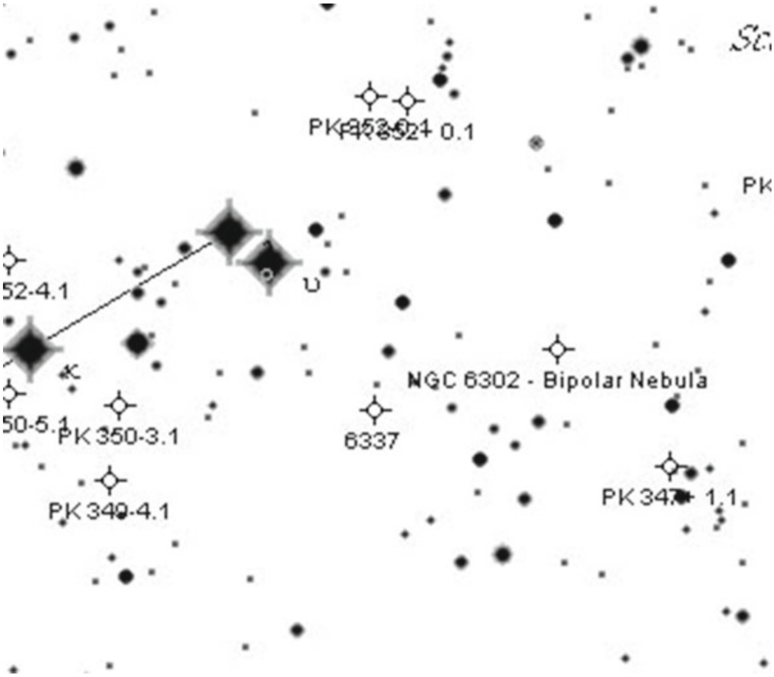
Finder chart for NGC 6302



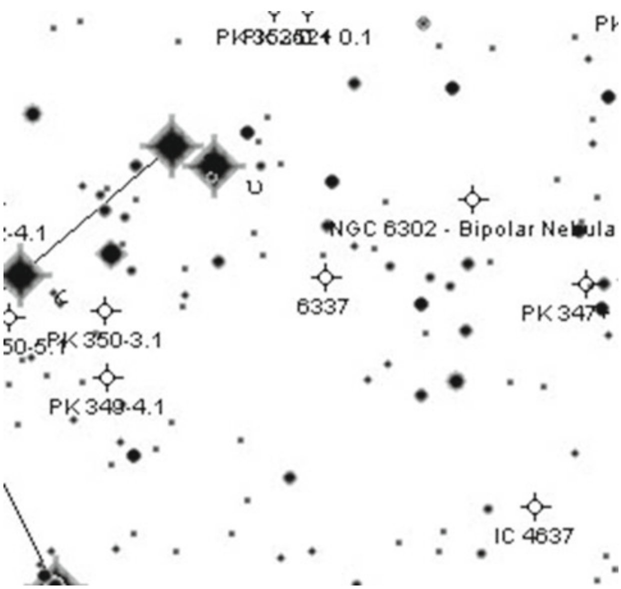
Finder chart for NGC 6072



Finder chart for NGC 6153



Finder chart for NGC 6337

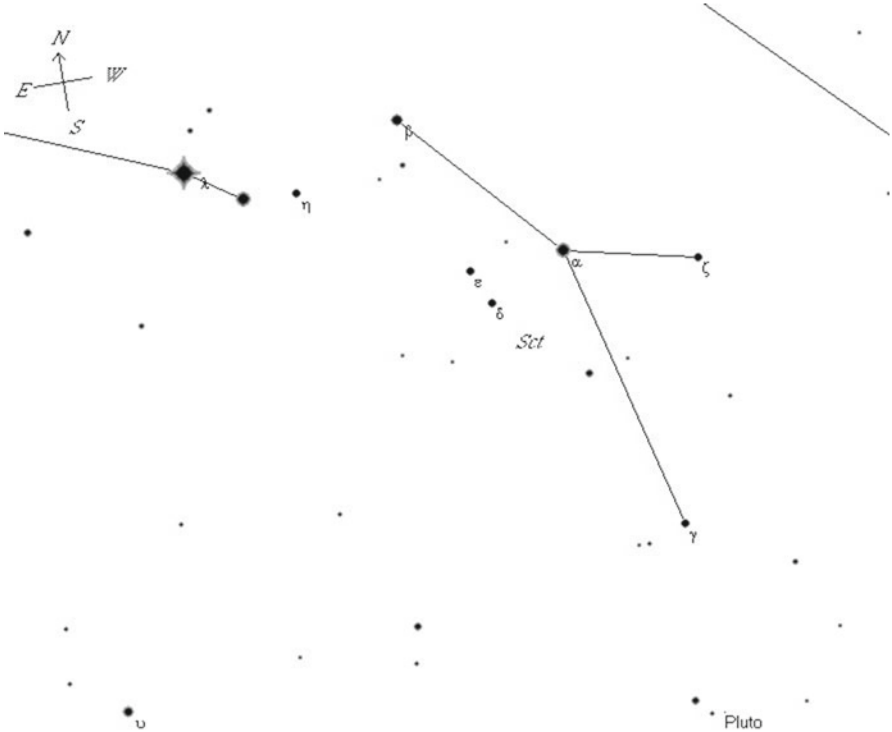


Scutum

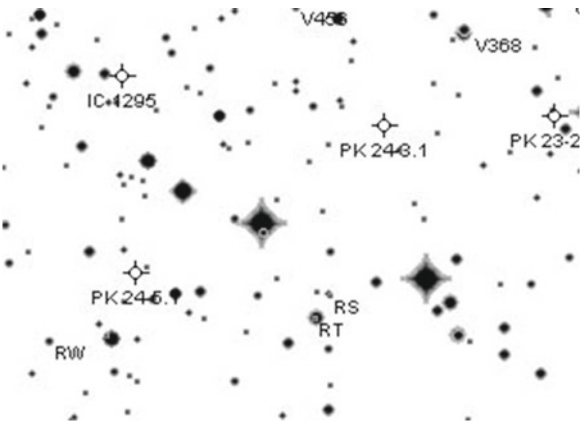
IC 1295
Scutum
RA: 18 h 54 m 37 s
Dec: −08.49.6
Size: 90″
Magnitude: 11.7
Class: 3b + 2

IC 1295 is an oval ghostly glow of light in a large telescope, but its sheer size may render it invisible to users of apertures below 150 mm, though it has been seen under exceptional conditions with an 80 mm refractor. Use of an OIII filter is necessary here to bring the object out from the star fields where, with averted vision, it's a milky, wispy glow of white-green light trapped among the stars.

General view of Scutum

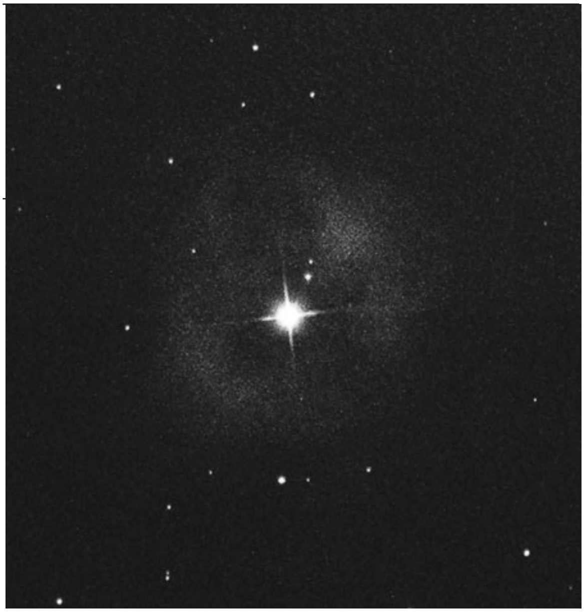


Finder chart for IC 1295



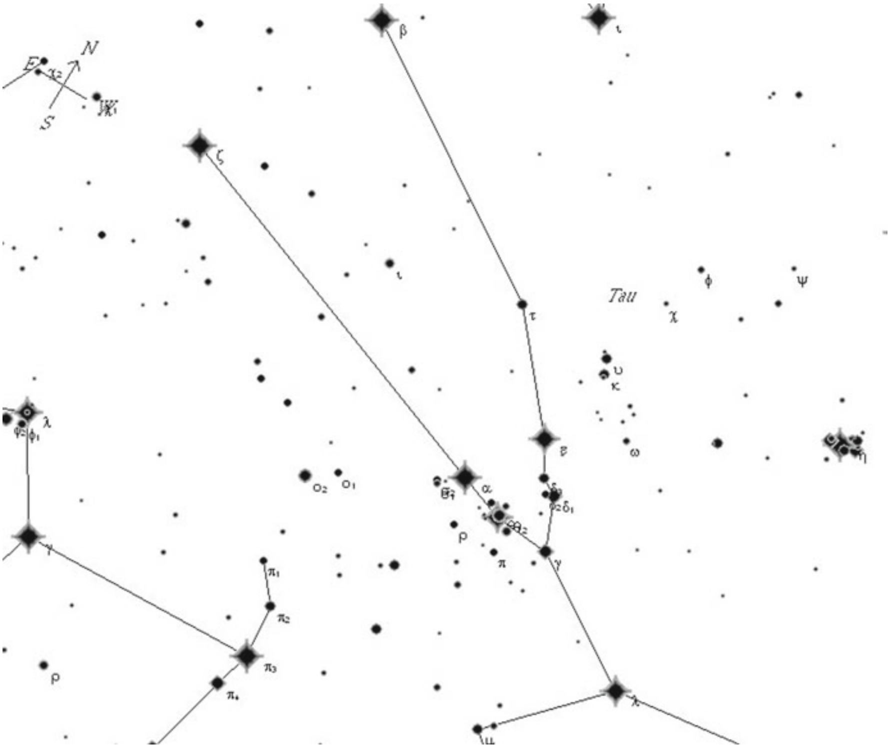
Taurus

NGC 1514
Taurus
RA: 04 h 09 m 17 s
Dec: +30.46.6
Size: 130″
Magnitude: 10.9
Class: 3 + 2

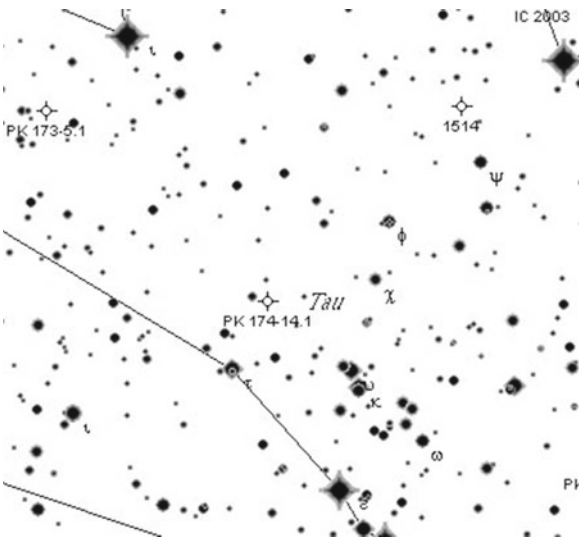


This nebula is known as the "Crystal Ball" and is a rather difficult object due principally to the bright central star that drowns out the nebula a little until the observer gets used to looking around the field with averted vision. It's also in a relatively barren location for star hopping! NGC 1514 reveals itself as an amorphous concentric gray wash of milky gas that has better definition at higher powers but has no further increase in color or detail apart from being slightly brighter on the NP side. Observers equipped with apertures smaller than 20 cm may see a faint smudge about 1′ across surrounding a tenth magnitude star. It was this objet that enabled William Herschel to link nebulae and stars together, paving the way for future developments in many fields of astrophysics.

General view of Taurus



Finder chart for NGC 1514



Triangulum Australe

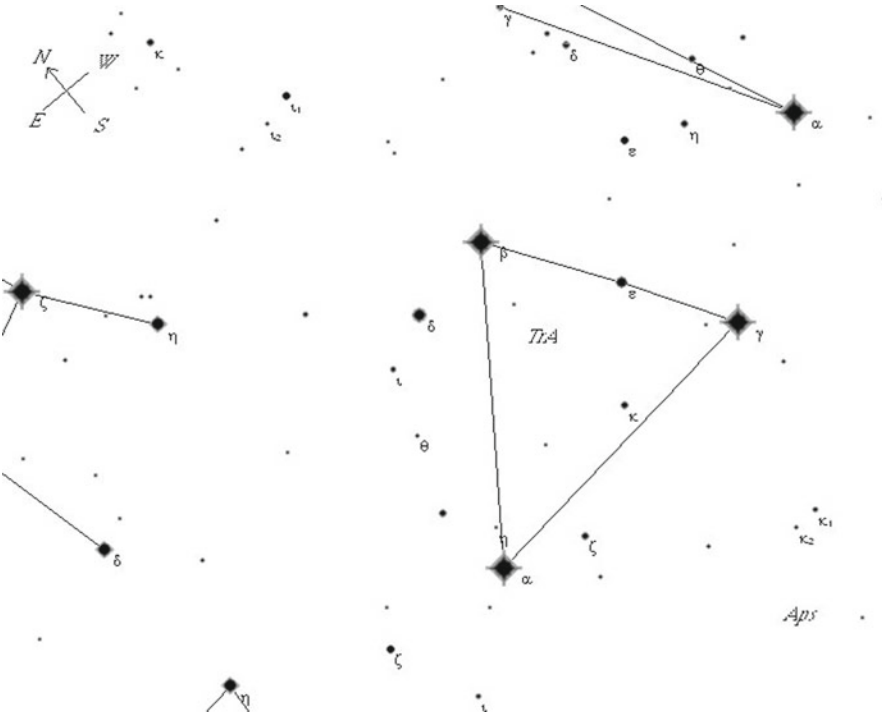
NGC 5979
Triangulum Australe
RA: 15 h 48 m 37 s
Dec: −61.15.14
Size: 15″
Magnitude: 12.3
Class: 3a + 2c

This is quite a bright planetary nebula in a very starry field, which makes initial identification in low power a difficulty. Moderate magnifications bring out this lovely blue-green object that is slightly extended E-W and has a mottled appearance at high power, which fades rapidly to the edge. There is moderate response to the OIII filter, which can aid in identification once the location is found. Most catalogues list NGC 5979 as only 5″ across, but the object is obviously larger than this – probably by 2.5 times at the very least. Users of large telescopes may be able to spot a faint "atmosphere' to the nebula at high powers.

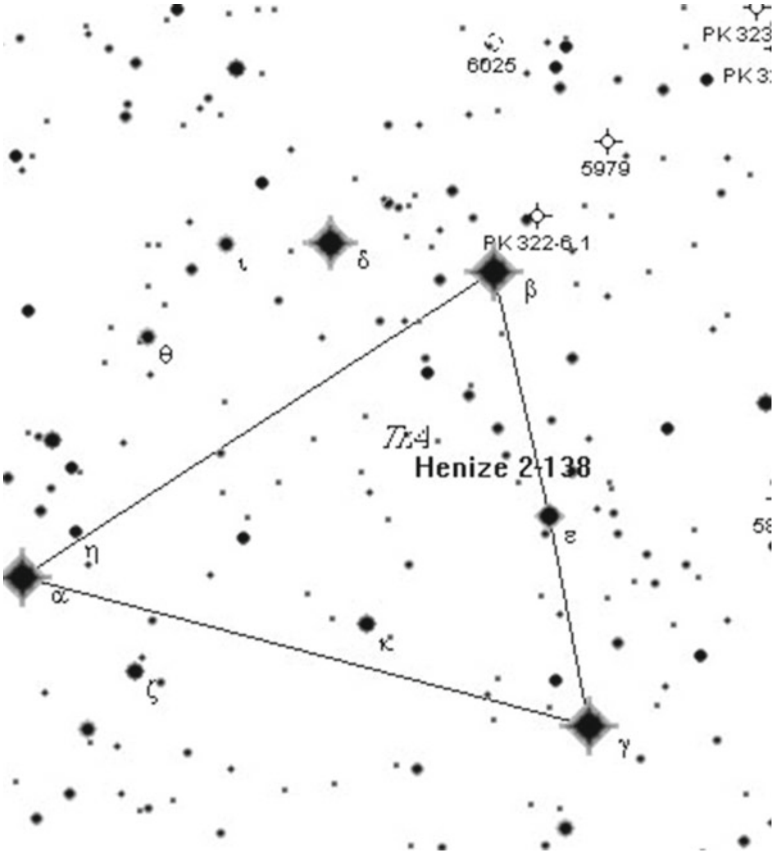
Henize 2–138
Triangulum Australe
RA: 15 h 56 m 00s
Dec: −66.09.00
Size: 3″
Magnitude: 11.0
Class: 2

Small star-like planetary that is lost in a rich field of stars to the south of three sixth magnitude stars below β Tr.A. The Milky Way is particularly rich here, and this small object can become confused with any of these background points of light. There is a moderate response to an OIII filter in a high power, as this is a very small object, and little detail other than a tiny disk is visible even in a moderate-sized telescope. Yet another challenging planetary!

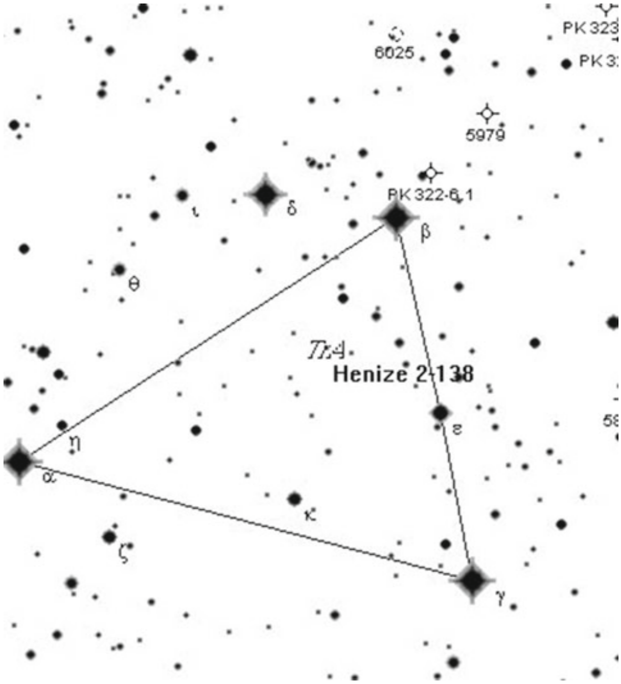
General view of Triangulum Australe



Finder chart for NGC 5979

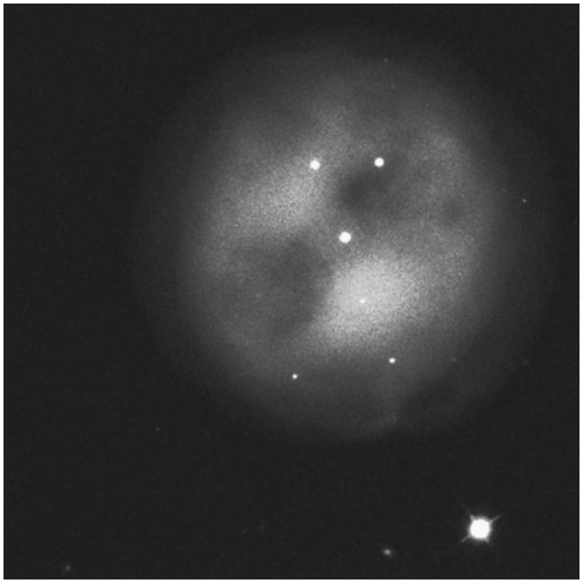


Finder chart for He 2–138



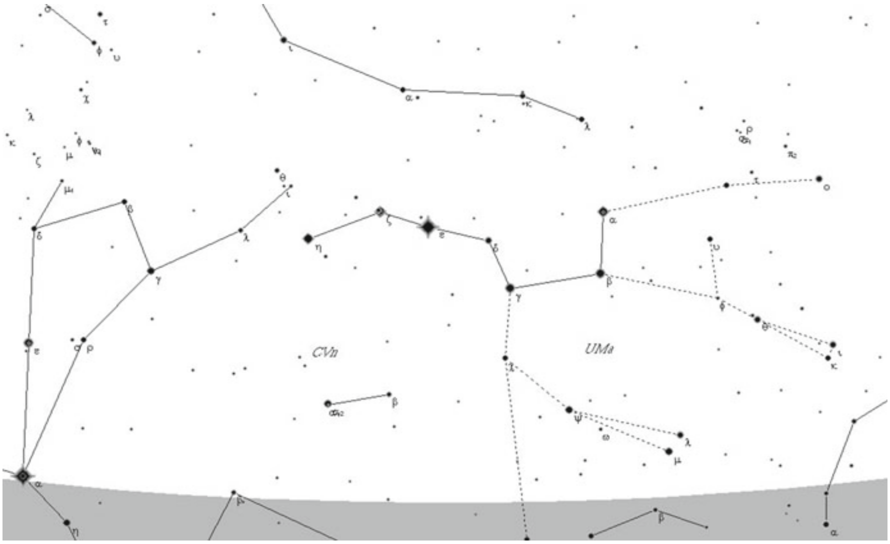
Ursa Major

NGC 3587
Ursa Major
RA: 11 h 14 m 48 s
Dec: +55.01.01
Size: 200″
Magnitude: 9.8
Class: 3a

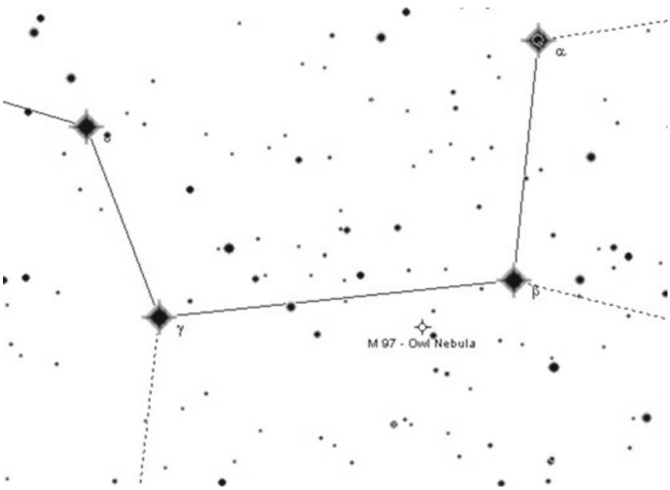


The fabulous "Owl Nebulae" in the Great Bear, which shares the same low power field as the galaxy NGC 3556 and provides a nice contrast between two Messier objects (97 and 108). Messier 97 is a wonderfully detailed object in most telescopes, where it is visible as a ghostly greenish glow against the background stars. It is large and round; though higher magnifications on larger telescopes bring out the two dark bays toward the center and may on good nights reveal the central star. This is a wonderful planetary nebula and always visible in the circumpolar skies of the northern hemisphere.

General view of Ursa Major

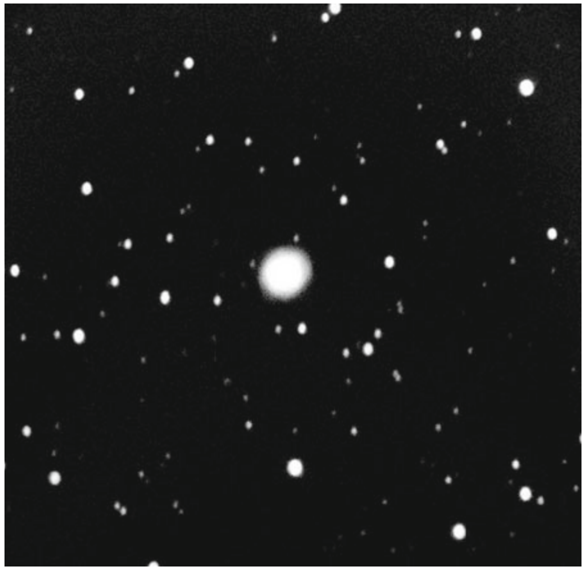


Finder chart for NGC 3587



Vela

NGC 2792
Vela
RA: 19 h 12 m 24 s
Dec: −42.26.2
Size: 21″
Magnitude: 11.6
Class: 2

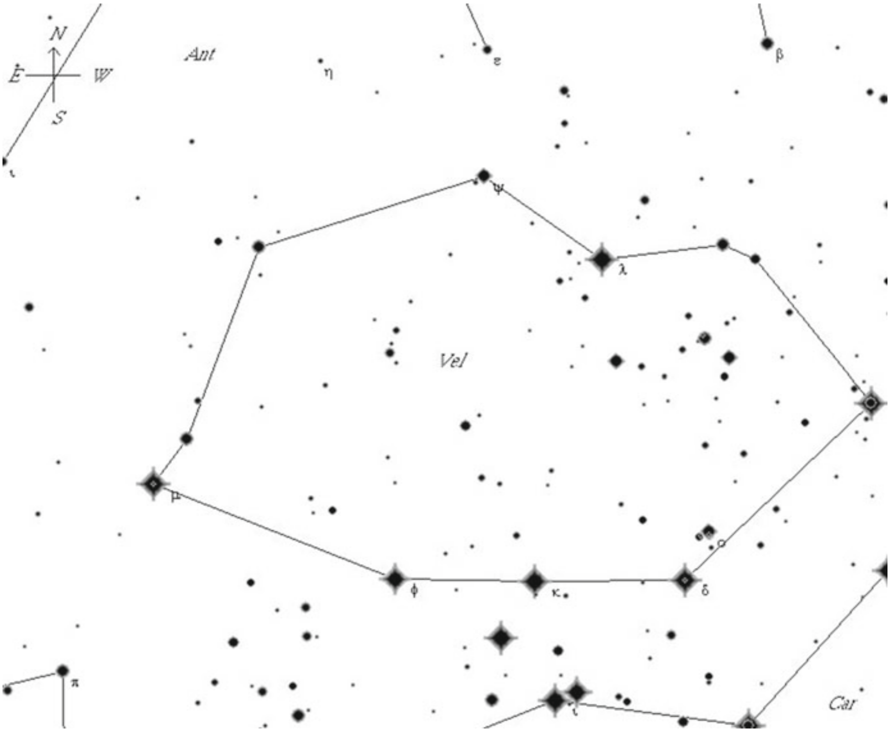


This is a small planetary nebula in the same low power field of view NF λ Vela. It is a little grayish disc of light that is uniformly round, has no visible central star and has a fair response to using an OIII filter. Although not an exciting object, it is easy to see in a crowded field of stars and has a ninth magnitude star just NF it. It is small and unremarkable, yet bright enough to be seen with relatively small apertures.

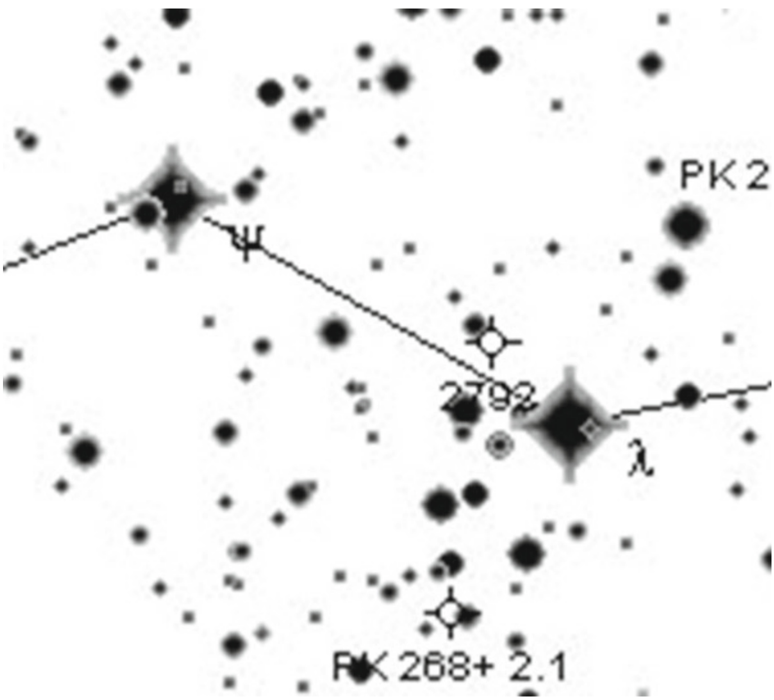
NGC 3132
Vela
RA: 10 h 07 m 0 s
Dec: −40.26.0
Size: 60″
Magnitude: 9.7
Class: 4 + 2

A beautiful planetary known as the "Eight Burst" or the "Southern Ring Nebula" and is an easy object even in small telescopes. In low powers it is obviously elongated with a SE/NW axis, has a thick edge all around its cuboid shape and has a filled core that, with averted vision, reveals a central star. The interior is a gray-white with a hint of blue, but the outer edges seem definitely red tinged (very much like M57's color) with a hint of purple in averted vision at moderate magnification. A wonderful object for all telescopes.

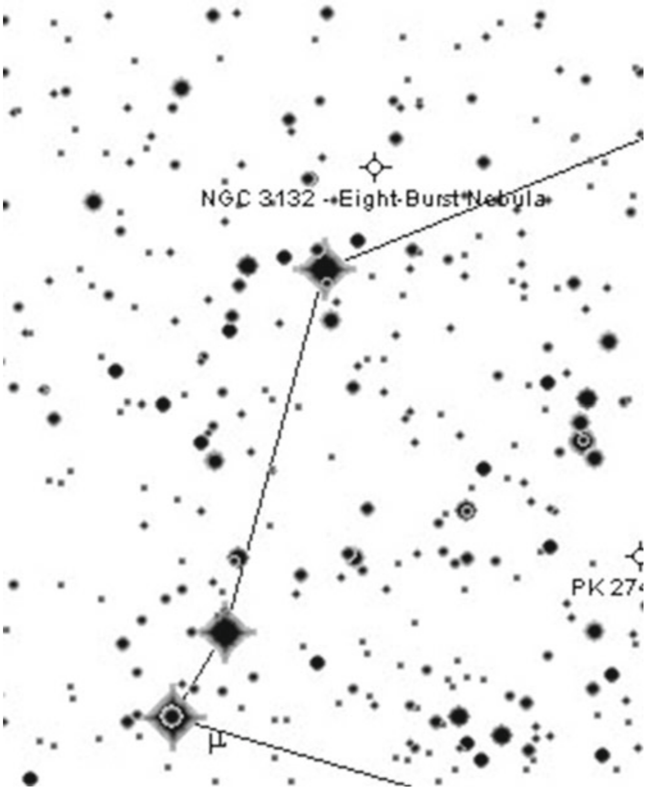
General view of Vela



Finder chart for NGC 2792



Finder chart for NGC 3132

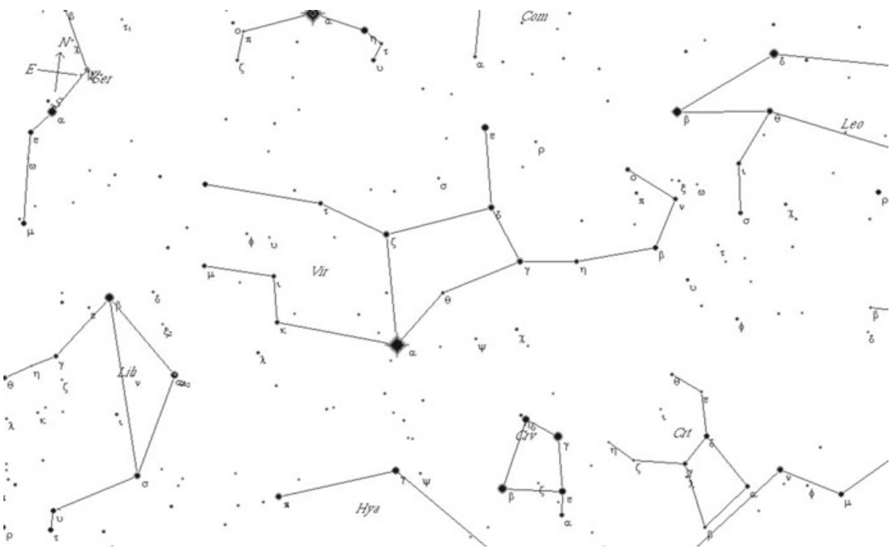


Virgo

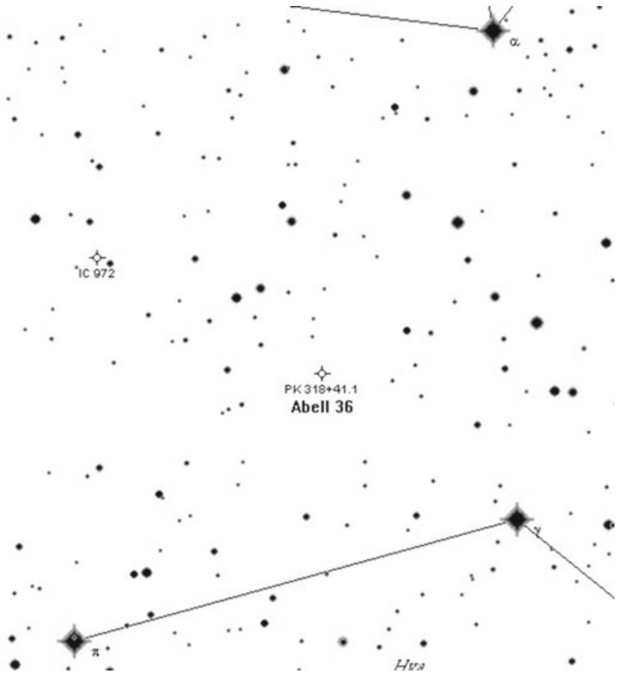
Abell 36
Virgo
RA: 13 h 40 m 41 s
Dec: −19.52.9
Size: 300″
Magnitude: 13.1
Class: 3b

A very difficult, faint planetary, visible southeast of Spica. Those observers using large Dobsonians can find the object by hopping to two fifth mag stars visible in a finderscope and scanning the field to their southwest. Use of an OIII filter is essential, as the nebula is faint and wispy and reveals itself as a collection of gray light around a faint star. In most telescopes it will not be possible to discern the outline, which is irregular and disappears with direct vision. Another one of those challenging objects!

General view of Virgo



Finder chart for Abell 36

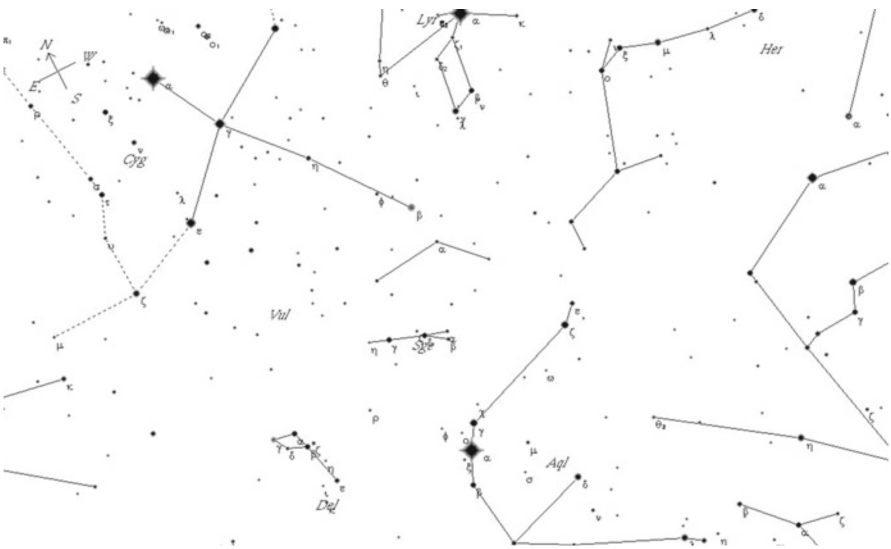


Vulpecula

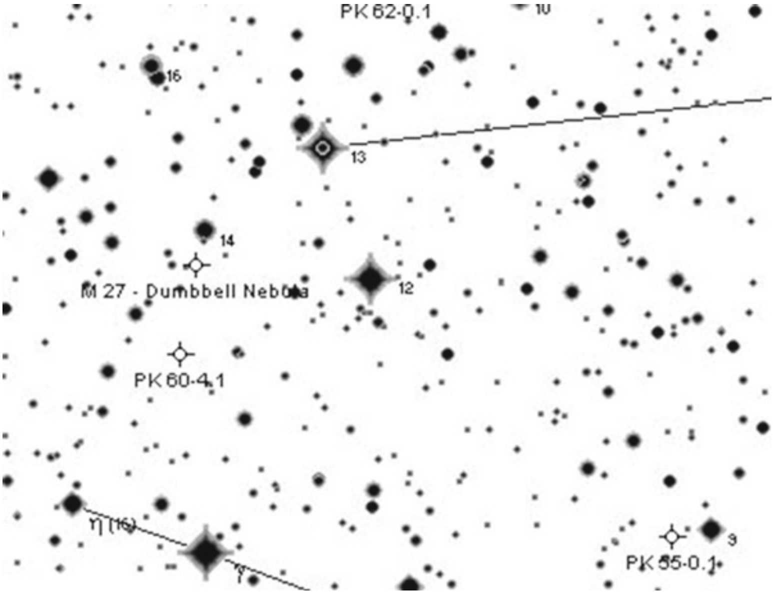
NGC 6853
Vulpecula
RA: 19 h 59 m 36 s
Dec: +22.43.3
Size: 8′
Magnitude: 7.3
Class: 3 + 2

NGC 6853 is otherwise known as the wonderful "Dumb Bell Nebula," Messier 27 in Vulpecula. The double V shape of the planetary is evident at low powers, and the whole shell is blue-gray and fairly bright. The center looks ghostly yet detailed no matter what instrument or power. In most telescopes Messier 27 is an amorphous blob of light with thicker edges to E/W, a great central bar, and a faint central star coupled to a knotty appearance across the disk throughout the thinner sections to N/S of the lobes. It is also filled with at least ten countable stars and is a beautifully detailed object in any telescope.

General view of Vulpecula



Finder chart for NGC 6853



Chapter 7

A Planetary Nebulae Marathon

Each springtime sees amateur astronomers all over the world take on the observing might of the Messier catalogue in an attempt to see all of the objects in one night. It is a dusk to dawn activity that builds bonds, hones skills and enables the observer to grapple with a wealth of different objects that characterize almost all astronomical bodies that can be visually represented.

However, many experienced observers covering such events start to wander around the sky, as they can quickly find most autumn/winter objects and then have to wait for the morass of galaxies in the Virgo cluster to rise. They begin to search out objects that are subtle and overlooked by Messier, or indeed were beyond the resolution of his telescopes. Some of the most beautiful objects that "fill in" their observing time are winter star clusters or nebulae and some of the faint galaxies between Aries-Leo-Ursa Major or in Camelopardalis. This is fine – most practiced amateurs do this – but here we want to encourage a new form of marathon, one in which planetary nebulae are the sole object of the search. This exercise may accompany the traditional Messier session, as all the objects noted are juxtaposed in search time or RA to the rest of the night's observing, or can be done as an independent activity.

The total list is probably not extensive. Observers with large telescopes may find that they will want to add their own favorites to the list, as they can attain fainter objects or reach those planetaries with smaller angular size. For those who wish to do this, the list contained in this book is recommended as a starting point to add to your collection. We have tried to strike a balance between brightness, size and "observability" by concentrating on exciting and challenging nebulae that the author has personally seen in almost 40 years of examining the skies. Purposely ignored are the Messier objects; these would be swept up anyway in a Messier marathon or any seasonal observing endeavor.

Why Introduce Another List?

The point of this list is simple – observers can enjoy an alternate activity that concentrates on a single type of object. This may seem rather limiting in comparison to the wealth of astronomical types on the Messier or NGC lists, but the differences

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides, DOI 10.1007/978-1-4614-1782-8_7, © Springer Science+Business Media, LLC 2012

in appearance, size, color and magnitude should make this list a very effective goal for observers with telescopes between 15 and 30 cm in aperture. Some observers will be equipped with LPR and OIII filters that may make observing such objects a little more worthwhile from light-polluted areas. Indeed, use of such filters can provide a little more "seeing" when it comes to such objects because of their limited spectroscopic output. Additionally, planetary nebulae are fascinating objects in their own right; the death of Sun-like stars – the likely future end of our own Solar System – are fairly rare events in the galaxy.

The Perek-Kohoutek catalogue lists about 1,000 such objects, the great majority of which are beyond the range of most amateur 'scopes. Compare the small sample below to the thousands of galaxies, hundreds of star clusters and plethora of double stars that most telescopes reveal, and one begins to realize the novelty of this list. These objects are very rare indeed.

Following this list will also help modern observers to make the most of their telescopes. Many are quite familiar with the Messier list and some of the brighter NGC objects, but here we want to engage amateurs in stretching themselves and their equipment. Observers with GOTO systems should find such objects easy to slew to, but may require a little more patience to observe and are therefore more demanding than many of the showpiece objects usually sought out. The task is made a little more interesting by placing it in the context of a "marathon." One can theoretically see all the objects in one night of observing, or can take the time to go through the objects on a seasonal basis – it is entirely up to the observer. Indeed, doing such a marathon is going to be an extreme task – NGC 246 and NGC 7293 are going to prove very difficult objects at either end of the marathon, as the former is setting just after sunset and the latter is rising just before the Sun in the month of February, thus giving a very small window of opportunity to observe them all in one go. This only adds to the challenge!

For observers in different latitudes the list could be the foundation of an alternative and interesting observing project in its own right, and of course one can observe as many of these nebulae as one pleases. As noted, both NGC 7293 and NGC 246 present the most obvious challenge, as they are very close to the Sun and the horizon. They have not been removed from the list because it would constrain observers who will use the list on a seasonal basis rather than go through them in one night.

The objects are arranged in right ascension order and are numbered GPL 1–45 for clarity (Griffiths Planetary List). Perhaps the designations will catch on, though more likely they will continue to go by their NGC and IC numbers. It would be nice to leave such a legacy to amateur astronomy, but such acceptance will undoubtedly be up to the body of observers who may attempt to see them all. Those who wish to perform the marathon would be advised to start with the planetaries in Aquarius, Andromeda and Cetus before progressing through the list in RA order, though of course this would depend upon the time of year, setting of the Sun and horizon at their latitude.

Overlaps with Other Object Lists

Sir Patrick Moore chose several of these planetary nebulae for his "Caldwell Objects" list. Given that these planetaries are among the brightest and most beautiful objects in the NGC catalogue, it is inevitable that any list will overlap. Nevertheless, his choices of object are the most obvious ones, as he was attempting to encourage observers to get off the beaten track of the Messier catalogue and to introduce a wider spectrum of challenging items for the amateur. We are attempting to do much the same here.

Descriptions of the planetaries can be found in the *Caldwell Objects*, a book that is part of the series *Deep Sky Companions* by Stephen James O'Meara. The descriptions there are superbly detailed and appropriate to all levels of observing expertise, and his books are highly recommended. For those observers with such a library, NGC 40 in Cepheus is Caldwell 2, NGC 6826 in Cygnus is Caldwell 15; NGC 7662, the "Blue Snowball," is Caldwell 22; NGC 2392, the "Eskimo" in Gemini, is Caldwell 39; NGC 6543, the "Cat's Eye" in Draco, is Caldwell 6; the fantastic "Saturn Nebula," NGC 7009 in Aquarius, is Caldwell 55; NGC 246 in Cetus is Caldwell 56; the "Ghost of Jupiter," NGC 3242 in Hydra, is Caldwell 59; and finally NGC 7293 in Aquarius is Caldwell 63. These designations appear in the list.

The observer does not, of course, require these descriptions or books, but they do add to the background knowledge of each object and even can enhance the wonder of each object when it is found. Details of each object can be found on Internet websites, but these will be noted as individual items rather than a compendium pulled together.

Another 12 of the planetary nebulae on the list that follows are covered by Stephen James O'Meara in his book *Hidden Treasures* (another of the *Deep Sky Companions* series), which again gives ample descriptions of each object. Each nebula covered in this book has been indicated by placing the letters HT after its number.

Outstanding Planetaries

It is difficult to pick any particular planetary nebulae as a personal favorite, as they all have a certain charm. Recommended nebulae outside of the Caldwell or hidden treasures list are the following:

- NGC 2438 in Puppis; a lovely little planetary in the star cluster M46 that is easy to see with a little effort against the wonderful scatter of stars in this cluster. Thankfully the stars are all evenly bright at around magnitude 10+, so the nebula is apparent to the viewer without having to disentangle it from bright stars or be dazzled by the huge contrast in magnitudes.
- NGC 2440 in Puppis is a rather low little nebula from northern climes but is still visible as a square dot of blue light in a rich star field. This object has a central white dwarf that is the hottest known star, with a surface temperature of 200,000 K.
- NGC 6309 in Ophiuchus is a lovely green planetary nebula that shows a double-lobed shape in high magnifications, though it is a relatively small object, best found with a medium magnification first.
- NGC 6781 in Aquila is a beautiful ghostly shell, visible even in small telescopes, surrounded by the rich star fields of the Milky Way. It always appears evenly white to most, though some have recorded a slight blue tinge to the shell.
- NGC 6905 in Delphinus always surprises with its rather vivid turquoise hue and is bright enough to be seen in most telescopes. Remember that some shell-type planetaries can withstand high magnification quite well, and therefore you gain the advantage of contrast and can separate slight "fuzzies" from their star fields.

Observers will have to cover the list themselves to enable them to make their own judgments on which planetaries are the best ones. It is hoped that here we have stimulated an interest in these ethereal shells of gas and prompted observers to try and attempt something new.

Planetary nebulae marathon list

1	NGC 40 (C2)	Cepheus	10.7 (60″)	00 h 11 m +72.23
2	NGC 246 (C56)	Cetus	8.1 (240″)	00 h 45 m −12.17
3	IC 289	Camelopardalis	12.3 (45″)	03 h 08 m +64.14
4	IC 2003	Perseus	12.6 (6″)	03 h 54 m +33.48
5	NGC 1501 (HT)	Camelopardalis	10.2 (56″)	04 h 04 m +60.51
6	NGC 1514	Taurus	9 (120″)	04 h 07 m +30.42
7	NGC 1535 (HT)	Eridanus	9.6 (24″)	04 h 31 m −12.48
8	IC 418	Lepus	12 (14″)	05 h 26 m −12.46
9	NGC 2022	Orion	12.3 (28″)	05 h 40 m +09.04
10	IC 2149	Auriga	9.9 (15″)	05 h 54 m +46.07
11	HD 44179	Monoceros	9.2 (2″)	06 h 19 m −10.38
12	NGC 2346	Monoceros	12.4 (60″)	07 h 08 m −00.46
13	NGC 2371/2	Gemini	12.8 (54″)	07 h 24 m +29.32
14	NGC 2392 (C39)	Gemini	8.9 (47″)	07 h 27 m +20.58
15	NGC 2438	Puppis	9.7 (68″)	07 h 40 m −14.40
16	NGC 2440 (HT)	Puppis	9.1 (54″)	07 h 41 m −18.09
17	NGC 3242 (C59)	Hydra	9.1 (42″)	10 h 23 m −18.31
18	NGC 4361 (HT)	Corvus	12.8 (81″)	12 h 23 m −18.38
19	IC 3568 (HT)	Camelopardalis	9.1 (40″)	12 h 32 m +82.41
20	IC 4593	Hercules	10.2 (15″)	16 h 10 m +12.08
21	NGC 6210 (HT)	Hercules	9.7 (20″)	16 h 43 m +23.50
22	NGC 6309	Ophiuchus	9.7 (20″)	17 h 12 m −12.53
23	NGC 6369 (HT)	Ophiuchus	11.4 (58″)	17 h 29 m −23.45
24	NGC 6445 (HT)	Sagittarius	9.5 (150″)	17 h 47 m −20.00
25	NGC 6543 (C6)	Draco	8.8 (20″)	17 h 58 m +66.37
26	NGC 6572 (HT)	Ophiuchus	9.6 (18″)	18 h 10 m +06.50
27	NGC 6741	Aquila	10.2 (9″)	19 h 01 m −00.29
28	NGC 6751	Aquila	11 (18″)	19 h 04 m −06.02
29	NGC 6781	Aquila	10.4 (104″)	19 h 17 m +06.30
30	NGC 6804	Aquila	12.2 (63″)	19 h 30 m +09.10
31	NGC 6818 (HT)	Sagittarius	9.9 (22″)	19 h 42 m −14.12
32	NGC 6826 (C15)	Cygnus	8.8 (135″)	19 h 44 m +50.28
33	NGC 6857	Cygnus	11.4 (40″)	20 h 00 m +33.27
34	NGC 6891	Delphinus	9.1 (12″)	20 h 14 m +12.38
35	NGC 6894	Cygnus	12.1 (57″)	20 h 15 m +30.30
36	NGC 6905	Delphinus	10.5 (44″)	20 h 21 m +20.02
37	NGC 7008 (HT)	Cygnus	10.7 (86″)	20 h 59 m +54.27
38	NGC 7009 (C55)	Aquarius	8.4 (44″)	21 h 01 m −11.28
39	NGC 7026	Cygnus	12.4 (25″)	21 h 06 m +47.52
40	NGC 7027 (HT)	Cygnus	9.2 (18″)	21 h 07 m +42.14
41	NGC 7048	Cygnus	11.1 (60″)	21 h 13 m +46.10
42	NGC 7139	Cepheus	12.8 (80″)	21 h 45 m +63.32
43	NGC 7293 (C63)	Aquarius	6.5 (900″)	22 h 28 m −20.55
44	IC 5217	Lacerta	10.9 (8″)	22 h 22 m +50.51
45	NGC 7662 (C22)	Andromeda	9.4 (33″)	23 h 24 m +42.24

References and For Further Reading

Observational

D. Allen, E. Barker, Planetary and Gaseous Nebulae. Observing Handbook of the Webb Society. **2** (1978)
M. Bakich, *1001 Celestial Won ders To See Before You Die: The Best Objects for Stargazers* (Springer, New York, 2010)
D. Bushnall, *Observing the Deep Sky* (Crowood Press, England, 2005)
S. Coe, *Deep-Sky Observing: The Astronomical Tourist* (Springer Publishing, New York, 2000)
W.H. Finlay, *Concise Catalogue of Deep Sky Objects* (Springer, New York, 2003)
T. Forte, *Planetary Nebulae Observing Guide*. Back Bay Amateur Astronomers & the Astronomical League (Publications of the Astronomical League, 2008)
M. Griffiths, *Alien Worlds: An Introduction to Observing the Wonders of the Universe.* (University of Glamorgan Press, 2004) Now online at www.LuLu.com
P. Harrington, *Star Ware: The Amateur Astronomers Guide to Choosing, Buying and Using Astronomical Telescopes and Accessories* (Wiley, London, 2007)
S. Hynes, *Planetary Nebulae: A Practical Guidebook for Amateur Astronomers* (Willmann Bell, Richmond, 1992)
C. Luginbuhl, B. Skiff, *Observing Handbook and Catalogue of Deep Sky Objects* (Cambridge University Press, Cambridge, 1998)
M. Mobberley, *Astronomical Equipment for Amateurs* (Springer, New York, 1998)
S. O'Meara, *Hidden Treasures* (Cambridge University Press, Cambridge, 2005)
S. O'Meara, *Herschel 400 Observing Guide* (Cambridge University Press, Cambridge, 2007)
D. Ratledge, *Observing the Caldwell Objects* (Springer, New York, 2000a)
I. Ridpath, *Norton's Star Atlas and Reference Handbook* (Prentice Hall, London, 2002)

Astrophotography

K. Beadman, *DSLR Astrophotography Made Easy* (Beadman Publishing, 2011)
M. Covington, *Astrophotography for the Amateur* (Cambridge University Press, Cambridge, 1999)
M. Covington, *Digital SLR Astrophotography* (Cambridge University Press, Cambridge, 2008)
S. Howell, *Handbook of CCD Astronomy* (Cambridge University Press, Cambridge, 2006)

M. Griffiths, *Planetary Nebulae and How to Observe Them*, Astronomers' Observing Guides,
DOI 10.1007/978-1-4614-1782-8, © Springer Science+Business Media, LLC 2012

J. Lodriguss, *A Guide to Astrophotography with Digital SLR Cameras*. Available as a CD-ROM from http://www.astropix.com/GADC/INTRO.HTM (2002)
J. Lodriguss, *A Beginner's Guide to Digital SLR Astrophotography*. Available as a CD-ROM from http://www.astropix.com/BGDA/INTRO.HTM (2005)
S. Massey, S. Quirk, *Deep Sky Video Astronomy* (Springer, New York, 2009)
G. Parker, *Making Beautiful Images: Astrophotography with Affordable Equipment and Software* (Springer, New York, 2007)
G. Privet, *Creating and Enhancing Digital Astro Images* (Springer, New York, 2007)
D. Ratledge, *The Art and Science of CCD Astronomy* (Springer, New York, 2000b)
S. Seip, *Digital Astrophotography: A Guide to Capturing the Cosmos* (Rocky Nook Publishing, London, 2007)

Astrophysical

L. Aller, Historical Remarks on the Spectroscopic Analysis of Planetary Nebulae, International Astronomical Union Symposium *Planetary Nebulae: Their Evolution and Role in the Universe*. vol 209 (2003)
B. Balick, The evolution of planetary nebulae: Structures, ionizations and morphological sequences. Astron. J. **93**(3), 671–678 (1987)
H. Habling, J. Lamers, Planetary Nebulae. International Astronomical Union Symposium, No. 180 (1997)
A. Hart, J. Hora, *Proto-planetary Nebulae with the Spitzer Telescope*. Asymmetric Planetary Nebula V: The Shaping of Stellar Ejecta. ASP Conference (2010)
S. Kwok, Interacting Stellar Winds and the Shaping of Planetary Nebulae. ASP Conference Series, vol 100 (2000)
S. Kwok, *Cosmic Butterflies: The Colourful Mysteries of Planetary Nebulae* (Cambridge University Press, Cambridge, 2001)
S. Kwok, Planetary nebulae: new challenges for the 21st century. J. Kor. Astron. Soc. **39**, 271–278 (2005)
S. Kwok, *The Origin and Evolution of Planetary Nebulae* (Cambridge University Press, Cambridge, 2007)
S. Kwok, Stellar Evolution from AGB to Planetary nebulae. International Astronomical Union Symposium The Art of Modeling Stars in the 21st Century, vol 252 (2008)
S. Kwok, Morphological structures of planetary nebulae. Publ. Astron. Soc. Aust. **27**(2), 174–179 (2010)
J.A. Lopez, A. Winds, Bubbles and outflows in planetary nebulae. Conf. Ser. Mex. Astron. Assoc. **15**, 7–11 (2003)
M. Magnor, G. Kindlmann, C. Hansen, N. Duric, Reconstruction and visualization of planetary nebulae. IEEE Trans. Vis. Comput. Graph. IEEE Publ. **14**(6), 1627–1634 (2008)
S. Miaji, D. Saito, "On the Origin of Bipolar Planetary Nebulae," *Planetary Nebulae in our Galaxy and Beyond*. Proceedings International Astronomical Union Symposium No. 234 (2006)
M. Mennessier, A. Omont, From Miras to Planetary Nebulae: Which Path for Stellar Evolution? Proceedings of the 7th Centenary Conference of the University of Montpelier (1990)
J. Nordhaus, S. Wellons, D. Speigel, B. Metzer, E. Blackman, Formation of High Field White Dwarfs From Common Envelopes. Proceedings of the National Academy of Sciences, USA, 7 February 2011
M. Peimbert, Planetary Nebulae (Institute of Physics Publishing, vol 53, 1990)
S. Pottasch, *Planetary Nebulae: A Study of the Late Stages of Stellar Evolution* (Springer, Dordrecht, 1984)

A. Renzini, Thermal Pulses and the Formation of Planetary Nebulae Shells. Proceedings of the International Astronomical Union Symposium on Planetary Nebulae No. 195 (1990)
H. Schwartz, H. Monteiro, Properties of bipolar planetary nebulae. Rev. Mex. Astron. Assoc. **15**, 23–28 (2003)
N. Soker, Binary progenitor models for bipolar planetary nebulae. Astrophys. J. **496**, 833–841 (1998)
L. Stanghellini, R. Corradi, H. Schwartz, The correlations between planetary nebula morphology and central star evolution: analysis of the northern galactic sample. Astron. Astrophys. **279**, 521 (1993)
L. Stanghellini, D.A. Garcia-Hernandez, P. Garcia-Lario, J.E. Davies, R.A. Shaw, E. Villaver, A. Manchado, J.V. Perea-Calderon, Spitzer IRS spectra of compact Galactic planetary nebulae: the link between dust, early evolution, and metallicity. Planetary nebulae – an eye to the future. Conference paper, Tenerife, July 2011
G. Stasinska, R. Szcerba, Dust content of planetary nebulae: a reappraisal. Astron. Astrophys. **513**, 2–12 (2008)
K. Werner, F. Herwig, The elemental abundances in bare planetary nebulae central stars and the shell-burning in AGB stars. Publ. Astron. Soc. of the Pac. **118**(840), 183–204 (2006)
W. Van der Veen, H. Habing, G. Geballe, Objects in transition from the AGB to planetary nebulae stage. Astron. Astrophys. **226**, 108–136 (1989)
A. Zijlstra, Binary central stars of planetary nebulae. Astron. Astrophys. arXiv:astro–ph/0610558 (2006)

Index

A
Abell 4, 56, 59, 221, 223
Abell 21, 56, 60, 166, 169
Abell 35, 56, 63, 175, 177
Abell 36, 56, 63, 272, 273
Abell 82, 58, 80, 120, 122
Abell, George, 5
Acker, Agnes, 6
Allegheny Observatory, 4
Alt-Azimuth mount, 26
Ancient City astronomy society, 39
Andromeda, 58, 83–84, 278, 280
Antoniadi scale, 31
Apus, 57, 85–86
Aquarius, 58, 87–89, 278–280
Aquila, 57, 90–102, 154, 279, 280
Ara, 57, 66–72, 103–105
Arequipa, 4
Artemis (software), 48–49
Astronomical League, 39, 40, 81
Asymptotic Giant Branch (c), 10–14, 16–20
Atik, 47, 51
Atlas Novus Celestis, 3
Atlas of Representative Stellar Spectra, 4
Auriga, 56, 106–107, 221, 280
Averted vision, 32–33, 87, 90–92, 95, 109, 119, 126, 129, 131, 139, 142, 143, 154, 158, 162, 165, 166, 170, 185, 206, 215, 216, 220, 221, 226, 232, 236–239, 242, 253, 258, 260, 269

B
BD +30 3639, 57, 77, 137
Binary stars, 19–21, 39
Birkeland currents, 21
Blinking (technique), 37
Blinking planetary nebula, 138
Blue Racquetball nebula, 207
Blue Snowball planetary, 83
Bowen Ira, 5
BRET, 19, 21
British Astronomical Association, 39, 45
Bug nebula, 19, 254
Bunsen, Robert, 3
Butterfly nebula, 195

C
Caldwell catalogue, 39, 81
Cambridge Star Atlas, 38, 137
Camelopardalis, 56, 108–110, 277, 280
Campbell, W.W., 4
Canis Major, 56, 111–112
Canon Annie Jump, 4, 8
Carina, 56, 113–118
Cartes du Ciel, 40
Cassiopeia, 56, 58, 119–122
Centaurus, 56, 57, 123–125
Central stars, 4, 5, 10, 12–14, 16–17, 21, 34, 43
Cepheus, 56, 58, 126–128
Cetus, 56, 129–130, 278, 279
Chameleon, 56, 131–132
CHANDRA, 14
Chandrasekhar limit, 12
Cleopatra's Eye nebula, 160
CNO process, 9
Cones (cells), 32
Corona Australis, 133–134
Corvus, 19, 56, 133–134, 280
Covington, Michael, 45
CRL 2688, 58, 141, 152
Crystal Ball nebula, 260
Curtis, Heber, 4, 18, 33, 219
Cygnus, 13, 18, 57, 58, 137–153, 279, 280
Cygnus Egg, 18, 141, 152

D
Dandelion puffball nebula, 91
Dark adaptation, 32–33
Darquier, Antoine, 1
Dawes limit, 30
Deep Sky Stacker, 49, 52
Delphinus, 58, 154–156, 279, 280
Dewshields, 25
Dew zapper, 25
DMK camera, 48
Dobsonian mount, 25, 26
Draco, 3, 57, 159–161, 279, 280
Dreyer, J.L.E., 3
DSLR camera, 49, 50, 52
Dumbbell nebula, 19, 23, 219
Duncan, John, 5
Dunlop, John, 3

E
Eight burst nebula, 269
Electromagnetic spectrum, 15, 16
Electron degeneracy, 17
Eridanus, 56, 160–161, 280
Eskimo nebula, 19, 166
European Southern Observatory, 6
Eyepieces
  Barlow lens, 28
  Erfle, 28
  Orthoscopic, 28
  Plossl, 28

F
Federation of Astronomical Societies, 39
Feldhausen, 3
Filters (photography)
  Hα, 43, 49
  LPS, 49
  minus violet, 49
  OIII, 49
  RGB, 49
  SII, 49
Filters (visual)
  Blinking Technique, 37
  Hα, 36
  Hβ, 36
  LPR, 36–37
  OIII, 35–36
  S, 141
  UHC, 37
Fleming, Williamina, 92
FLIERs, 19, 21, 34, 87
Forbidden line transitions, 5
Fornax, 56, 162–163
Forte, Ted, 40
Frew, David, 6
Frosty Leo nebula, 13, 180

G
Gemini, 56, 164–169, 279–280
German Equatorial mount, 26
Ghost of Jupiter nebula, 174
GIMP, 48
Grieg, W.H., 33–34
Griffiths Planetary List, 278

H
Hahn, Friedrich Von, 3
Harding, Karl Ludwig, 3
Harvard observatory, 4
Harvard spectral sequence, 9
HD 44179, 13, 56, 196, 280
Helix planetary nebula, 3, 30, 34, 47, 88
Henize 2-131, 85, 86
Henize 2-138, 262
Henize 2-141, 203, 204
Henize 2-171, 103
Henize, Karl, 5, 33
Hercules, 57, 170–173, 280
Herschel 400 catalogue, 87, 93, 135, 166, 174, 225, 236, 240
Herschel, John, 3, 113
Herschel, William, 2, 7, 39, 138, 260
Hertzsprung Russell diagram, 8
Hipparchos, 39
Hubble, Edwin, 4
Hubble space telescope, 5, 18, 34, 157, 182
Huggins, Margaret, 4
Huggins, William, 3, 16, 157
Humason 1-2, 144
Hutech, 50
Hydra, 56, 113, 135, 174–177, 279, 280

I
IC 289, 56, 59, 119, 122, 280
IC 351, 56, 59, 220, 223
IC 418, 56, 59, 182–183, 280
IC 1295, 57, 75, 258, 259
IC 1297, 57, 76, 133, 134
IC 1747, 56, 59, 119, 121
IC 2003, 56, 59, 220, 224, 280
IC 2149, 56, 60, 106, 107, 280
IC 2165, 56, 60, 111, 112
IC 2501, 56, 62, 113, 117
IC 2553, 56, 62, 114, 118
IC 2621, 56, 62, 115, 116
IC 3568, 56, 63, 109, 110, 280
IC 4191, 56, 198, 201
IC 4406, 57, 64, 184, 186
IC 4593, 57, 65, 171, 173, 280
IC 4634, 57, 66, 236, 244
IC 4732, 57, 74, 241, 251
IC 4776, 57, 75, 241, 252
IC 4846, 57, 76, 92, 99
IC 4997, 58, 78, 233, 234
IC 5117, 58, 79, 146, 155
IC 5217, 58, 79, 178, 280
Index catalogue, 3
Interactive winds, 13–14
Interstellar medium (ISM), 7, 13, 21
IRAS 09371+1212, 13, 180, 181

J
J 320, 59, 211, 213
J 900, 60, 168
Jonckheere, 164, 211
Jones 1, 58, 216, 217
Jones-Emberson 1, 190

K
Keeler, James, 4
Kemble's cascade, 108
Kirchoff, Gustav, 3
Kohoutek, Lubos, 6

L
Lacerta, 58, 178–179, 280
Lamont-Hussey observatory, 5
Leo, 13, 56, 62, 180–181, 277
Lick observatory, 4, 33
Limiting magnitude, 29–31
Little Dumbbell nebula, 219
Little gem nebula, 237, 242
Little Ghost nebula, 207
Lodriguss, Jerry, 45
Lumicon, 37, 50
Lupus, 57, 184–189, 253
Lynx, 56, 190–191
Lyra, 1, 11, 57, 160, 192–194

M
Macquarie AAO Strasbourg planetary nebulae catalogue, 6
Magnetic fields, 19–21
Magnitude scale, 29
Main sequence, 8–10, 19
Maksutov-Cassegrain, 23, 25
Maxim DL, 48
Mayall, Margaret, 4
Mechain, Pierre, 1
Mecklenburg observatory, 3
Megastar, 41
Messier 27, 1, 277
Messier 57, 192
Messier 76, 1, 221
Messier 97, 1, 266
Messier, Charles, 1
Messier marathon, 277
Millennium star atlas, 39
Minkowski 1-7, 165
Minkowski 1-92, 137
Minkowski 2-9, 206
Minkowski 3-6, 229
Minkowski, Rudolph, 5
Minkowski's butterfly nebula, 206
Minkowski's footprint nebula, 21
Monoceros, 13, 56, 195–197, 280
Moore J.H., 4
Moore Patrick, Caldwell objects, 39, 278
Mounts
  alt azimuth, 26
  Dobsonian, 25, 26
  equatorial, 25–27
Mount Wilson, 4–5
Musca, 56, 198–202

N
Nebulium, 4, 5, 16
New general catalogue, 3, 39
NGC 40, 56, 58, 126, 128, 280
NGC 246, 56, 58, 129–130, 278–280
NGC 650/1, 56, 219, 222
NGC 1360, 56, 59, 162, 163
NGC 1501, 56, 59, 108, 110, 280
NGC 1514, 2, 3, 56, 59, 260, 261, 280
NGC 1535, 56, 59, 160, 161, 280
NGC 2022, 56, 60, 212, 213, 280
NGC 2346, 56, 60, 195, 197, 280
NGC 2371/2, 19, 56, 165, 169, 280
NGC 2392, 19, 56, 60, 166–167, 279, 280
NGC 2438, 56, 61, 225, 228, 279, 280
NGC 2440, 19, 56, 61, 226, 279, 280
NGC 2452, 56, 61, 226, 227
NGC 2610, 56, 61, 174, 176
NGC 2792, 56, 61, 268, 270
NGC 2818, 56, 62, 229, 231
NGC 2867, 56, 113, 117
NGC 3132, 56, 62, 269, 271
NGC 3195, 56, 62, 131, 132
NGC 3211, 56, 62, 114, 118
NGC 3242, 56, 62, 135, 174, 177, 279, 280
NGC 3587, 56, 62, 266, 267
NGC 3918, 56, 63, 123, 125
NGC 4071, 56, 63, 198, 200
NGC 4361, 19, 56, 63, 135, 136, 280
NGC 5189, 56, 63, 199, 202
NGC 5307, 57, 64, 124, 125
NGC 5873, 57, 64, 184, 187
NGC 5882, 57, 64, 185, 188
NGC 5979, 57, 65, 262, 264
NGC 6026, 57, 65, 185, 189
NGC 6058, 57, 65, 170, 172
NGC 6072, 57, 65, 253, 256
NGC 6153, 57, 65, 253, 257
NGC 6210, 57, 66, 171, 173, 280
NGC 6302, 19, 57, 67, 254, 255
NGC 6309, 57, 67, 206, 279, 280
NGC 6326, 57, 67, 103, 105
NGC 6337, 57, 67, 254, 257
NGC 6369, 57, 68, 207, 210, 280
NGC 6445, 57, 70, 236, 243, 280
NGC 6537, 21, 57, 72, 237, 245
NGC 6543, 3, 57, 71, 157, 159, 279, 280
NGC 6563, 57, 72, 238, 246
NGC 6565, 57, 72, 237, 246
NGC 6567, 57, 73, 238, 247

NGC 6572, 57, 72, 125, 207, 210, 280
NGC 6578, 57, 73, 239, 248
NGC 6620, 57, 73, 239, 249
NGC 6629, 57, 73, 240, 250
NGC 6644, 57, 74, 240, 250
NGC 6720, 57, 75, 192, 193
NGC 6741, 57, 76, 91, 97, 280
NGC 6742, 57, 75, 158–159
NGC 6751, 57, 76, 91, 98, 280
NGC 6765, 57, 76, 192, 194
NGC 6772, 57, 76, 92, 98
NGC 6778, 57, 76, 93, 99
NGC 6781, 32, 57, 76, 93–95, 100, 280
NGC 6790, 57, 76, 94, 100
NGC 6803, 57, 77, 95, 101
NGC 6804, 57, 77, 95, 102, 280
NGC 6807, 57, 77, 96, 102
NGC 6818, 58, 77, 242, 252, 280
NGC 6826, 58, 77, 138, 146, 279, 280
NGC 6833, 58, 77, 138, 247
NGC 6853, 58, 78, 274, 275
NGC 6879, 58, 78, 232, 235
NGC 6881, 21, 58, 78, 139, 148
NGC 6884, 58, 78, 139, 147
NGC 6886, 58, 78, 232, 234
NGC 6891, 58, 78, 154, 155, 280
NGC 6894, 58, 78, 140, 148, 280
NGC 6905, 58, 78, 154, 156, 279, 280
NGC 7008, 19, 58, 78, 140, 149, 280
NGC 7009, 19, 34, 58, 78, 87, 89, 279, 280
NGC 7026, 58, 78, 141, 150, 280
NGC 7027, 13, 58, 79, 142, 150, 280
NGC 7048, 58, 79, 143, 151, 280
NGC 7293, 3, 18, 30, 33, 36, 47, 58, 79, 88–89, 278, 280
NGC 7354, 58, 79, 128, 129
NGC 7662, 58, 79, 83, 84, 279, 280
NGC 8094,
Nordhaus, J., 21
Norma, 57, 203–204
Norton's star atlas, 38

O
Observing procedures, 42–43
OIII, 5, 14, 16, 33–37, 43, 49, 85, 90–94, 96, 103, 108, 109, 111, 113–115, 119, 120, 126, 131, 137–144, 158, 162, 165, 170, 171, 174, 175, 178, 180, 184, 185, 190, 192, 198, 199, 203, 206, 211, 212, 214–216, 220, 221, 226, 229, 232, 233, 236–241, 253, 254, 257, 258, 262, 268, 272, 278
O'Meara Stephen James, Hidden Treasures, 281
Ophiuchus, 57, 124, 205–210, 279, 280
Orion, 4, 28, 56, 211–212, 280
Orion (filters), 37, 50
Owl nebula, 53, 266

P
Paintshop Pro, 48
Palomar observatory, 5
Pauli, Wolfgang, 17
Pease 1, 58, 79, 214, 218
Pegasus, 58, 214–218
Perek-Kohoutek catalogue, 6, 14, 33, 278
Perek, Lubos, 6
Perrine, Charles Dillon, 5
Perseus, 19, 56, 219–224, 280
Photoshop, 48–49, 52, 53, 81
Pickering, Edward, 4
Planetary nebula
  central stars, 3–5, 10–14, 16–18, 21, 30, 34, 43, 91–93, 95, 106, 108, 126, 127, 131, 138, 139, 154, 157, 160, 165, 166, 170, 171, 174, 182, 185, 192, 198, 199, 206, 207, 212, 225, 226, 241, 260, 266, 268, 269, 274
  cometary knots, 19, 34
  emission from, 12, 14
  envelopes, 17–19, 36
  FLIERS, 19, 21, 34, 87
  interacting winds, 13
  microstructures, 19, 34
  morphology, 19, 20, 33–35, 42
  production, 11–13, 21
Proton-proton chain, 9
Proto-planetary nebulae, 12–13, 18
Proto-stars, 7
Puppis, 19, 56, 225–228, 279, 280
Purkinje effect, 33
Pyxis, 56, 229–231

R
Red Giant, 10, 20
Red rectangle nebula, 13, 196
Refractor telescope, 23–28, 88
Resolving power, 29, 30
Roche lobe, 19–20
Rods (cells), 32–33
ROSAT, 14
Royal Society, 3, 4

S
Sagitta, 58, 232–235
Sagittarius, 57, 58, 236–252, 280
Santa Barbara Instruments Group, 47
Saturn planetary nebula, 19, 34, 87, 279
Scorpius, 19, 57, 253–257
Scutum, 57, 258–259
Sharpless 1-89, 142
Sharpless 2-71, 90
Sharpless 2-216, 221
Shklovsky, Ioseph, 5
Sky Atlas 2000, 38–39
Sky Catalogue 2000, 39
Sky watcher telescope, 24
SLR camera, 23, 28, 45
Software
  ALADIN, 42
  Cartes du Ciel, 40
  Megastar, 41
  SIMBAD, 42, 55
  SkyMap, 41
  Stellarium, 40
  TheSky, 40–41
Soker, Noam, 20
Spirograph nebula, 182
Stanghellini, L., 18, 34
Starlight Express, 47
Stellarium, 40
Stellar mass, 12
Struve, Frederick, 3

T
Taurus, 56, 260, 261, 280
Telescopes
  Catadioptric, 25
  Newtonian, 25
  reflectors, 23–26
  Refractors, 23–28, 88
The Sky (software), 40
Transparency scale, 31
Triangulum Australe, 265–268
Tulse Hill, 3

U
Uranometria 2000, 39
Ursa major, 56, 269–270, 279

V
Vela, 56, 268–271
Virgo, 56, 272–273, 277
Vorontsov-Velyaminov, Boris, 35
Vorontsov-Velyaminov scale, 81
Vulpecula, 1, 58, 274–275
VY 2-2, 57, 77, 94, 101

W
White dwarf stars, 5, 10–12, 17–18, 21, 226, 279
Whitman Walt,
Wright, W.H., 4

X
X-ray emission, 14

Z
Zanstra, Herman, 5
Zanstra method, 5