

C.V. Vishveshwara

Universe Unveiled

The Cosmos in
My Bubble Bath

 Springer

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*To the loving memory of my elder siblings
My sister Rathna
and
My brothers Puttanna and Chandru*

Praise for *Einstein's Enigma or Black Holes in My Bubble Bath*

Beautifully written and thoroughly entertaining, Vishveshwara's "Einstein's Enigma" provides an authoritative but distinctly original approach to an explanation of basics and subtleties of Einstein's general relativity and of the astrophysics of black holes. I warmly recommend it to beginner and expert alike.

Sir Roger Penrose, *Author of Shadows of the Mind and The Road to Reality*

The main dish in this feast is a clear and sound presentation of the science underlying black holes from a distinguished scientist who has been contributing to their study since before they were named. Furthermore this science is presented in a sauce of philosophy, history, literature, gastronomy and imagination from an entertaining personality who needs several alter egos to show all the different ways he can think about his subject. Among the cartoons and drawings are the few lines of optional mathematics which are included for those who like that approach.

Prof. Charles W. Misner, *Co-author of Gravitation by Misner, Thorne and Wheeler*

The unusual format and whimsical style of "Einstein's Enigma" should not obscure the fact that this is a serious book, which aims to get across the essentials of the theory of general relativity and some related topics to a readership which is not assumed to be fluent in advanced mathematics. I believe the author, who has a long experience in presenting this kind of material to non-specialist audiences, has succeeded in the task he has set himself; the book will amply repay sustained and diligent reading by even a totally unmathematical reader."

Sir Anthony J. Leggett, *Nobel Laureate in Physics, 2003*

The only thing this intoxicating is Salman Rushdie's Haroun and the Sea of Stories.

Dr. Richard Isaacson, *former Program Director for Gravitational Physics, Physics Division, National Science Foundation, USA*

An innovative way of trying to explain some of the most complicated concepts in physics to beginners and it contains one of the best accounts I've ever read of the (almost Damscene) conversion of a newcomer to the pleasure of a night's observing. As Nietzsche said: 'What would be the joy of a star but for those who behold it?'

David Reid, *BBC Sky at Night*

Vishveshwara's is among the successful presentations of a most sophisticated, important, and beautiful theory of twentieth-century physics—Einstein's general relativity and its most fascinating corollary, the existence of black holes. A book to inform, enrich, and entertain every science-educated reader. Summing Up: Highly recommended. Lower-division undergraduates through professionals.

V. V. Raman, CHOICE

The author is a major specialist in the field of relativity, astrophysics and gravitation, and is currently working in Bangalore, India. According to me, this book deserves a very large audience: it is very different from all the popular science books written on the subject and as such will be appreciated even by the non-physicists. The physicists will probably learn new things, while the specialists in astrophysics and gravitation will certainly enjoy this new and fresh insight in their field.

Fabrice Louche, *Physicalia Magazine*

The author blends fiction, fantasy, physics and philosophy to tell the story of gravitation theory...and the astrophysics of black holes. He not only succeeds at doing this, he entertains readers with delightful digressions and illustrates key concepts with wonderful cartoons, some purportedly scribbled on paper napkins...

Michelle Press, *Scientific American*

Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand.

Albert Einstein

Imagination was given to man to compensate him for what he is not; a sense of humour to console him for what he is.

Francis Bacon

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Prologue

Ah, time flies, time flees, time flows. *Time is the culprit*, said the Master who taught us that all things are relative including time. How long has it been since I addressed you? Several years indeed! And some of you are new. At that time, long back, I recounted my discussions with my dear friend George, Professor George Gallagher, the astrophysicist at the University, that is, regarding black holes and described the fantasies induced by my magical bath tub. In fact, all that was presented in a book form with the title, *Einstein's Enigma or Black Holes in My Bubble Bath*. Some of you might have even read it.

What have I been up to during these years? Well, I have been travelling quite a bit. I have wandered all over Europe. I even journeyed for a brief period to the fabled East. To be free like a bird on the wing, a steed on the run, a fish in the blue waters of the ocean! It is exhilarating, it is euphoric. I imbibed many cultures in all the places I visited, learnt their ways of life, and tasted a variety of culinary delights. In the meantime, George too has been away as visiting professor at several universities abroad. Knowing him, he too must have lived life to the hilt enjoying it in every possible way while working assiduously on his research and teaching. I have missed him dearly indeed.

All this will change soon. I am back and so is George. As a matter of fact, I have made an appointment to meet him this evening. We shall be getting together at the lovely little Italian restaurant run by our friend Bruno. Earlier, I have described how we used to meet at this charming place, enjoy good food and drink, and most of all discuss all about black holes. I just can't wait, you know. I am sure history will repeat itself. I feel it in my guts.

On my way to Bruno's, I meet my friends Fernando and Maria along with their daughter Felicia. As usual, they are relaxing in their lounge chairs, sipping red wine, on the sidewalk outside their grocery store. During these years of my absence, Felicia has blossomed into a beautiful young lady from a plump little kid that she was.

‘Welcome back, *Señor Alfie*’, Fernando gets up and shakes my hand warmly for a long time. ‘We missed you, you know. Ah, before I forget, here is the spare key you gave us. Maria and I took good care of your apartment, no? Kept it spic and span, tiptop’.

‘Oh, thank you so much, *muchas gracias*’. I am genuinely grateful.

‘But there is something funny with your bathtub you know’. Fernando says hesitantly. ‘When I scrub it, I feel—how do I put it—I give bath to someone living. *Hombre*, it gives me creeps. What goes, *Señor Alfie*?’ Fernando looks at me searchingly.

I keep quiet. I can’t possibly tell him the most well-kept secret shared between me and my bathtub, can I?

‘Well, off to Bruno’s for a good meal?’ enquires Fernando. ‘I hear that Professor is back too. Why don’t you and him join us for food sometime? Maria will make some *tapas*, very tasty, *mucho rico*. And I bring excellent wine from my cousin Alejandro who makes it himself. Give my best to Professor’.

I say goodbye to the three of them and move on. As I said, I can’t wait. I am much too excited. Yes, there will be great food and drink again at Bruno’s. More than that, it will be wonderful to meet Bruno himself. And, needless to add, to reconnect with George and find out all the fantastic things that must be happening with him. And maybe we will discuss something else as we did about black holes before, who knows?

All right, I shall let you know how it goes this evening. Till then, as I wish you always, may peace be with you.

Chapter 1

Reconnecting

At Bruno's

The Italian restaurant *Benvenuto*, or simply Bruno's as we call it, seemed to have had a facelift in my absence. It looked freshly painted with a number of flowerpots decoratively placed to make the façade most inviting. As I entered the place, I could see that the furniture had been rearranged to make room for more people without cramping the space. All said and done, the interior had not lost its charm and elegance.

Of course, the most important event I was looking forward to was meeting George. What a delight it was to see George beaming at me and waving his hand in welcome. As always, he was seated at our favourite table waiting for me. George was unusually relaxed. He is normally in a highly excited state. As I approached our table, he gave me a warm smile, looking at me steadily as though he wanted to inspect my appearance in every detail.

'Alfie, you have not changed a bit,' said George. 'I mean it unlike some people who say that for the sake of formality.'

'I know you mean it George. And you haven't changed either,' I said returning his steadfast gaze. '*Age cannot wither you, nor custom stale your infinite variety*,' I paraphrased Shakespeare's quotation from *Antony and Cleopatra*.

'What are you talking about?' George was mystified.

'Well, that was Shakespeare's remark about Cleopatra,' I answered.

'Oh, Cleopatra, whose face launched hundred ships. You compare me to her!' George was amused.

'George, it was Helen of Troy whose face launched thousand—not hundred—ships. It was my poetic way of saying that you haven't changed in all these years.'

'Cleopatra, Helen of Troy, who cares? Beauty queens, if you have seen one, you have seen them all!'

'But, George, neither of us has seen a single beauty queen in all our lives,' I remonstrated.

Fortunately, this inane exchange came to an end as we saw Bruno emerging out of the kitchen and making his way towards our table, a big smile playing upon his face. How wonderful to see our good old friend Bruno Beltrametti—not just the owner of the restaurant, but chef, headwaiter, entertainer, and philosopher all rolled into one.

‘Don’t tell me that I haven’t changed,’ Bruno addressed us. ‘We all change; we just don’t want to admit it to ourselves, that is all.’

‘Who said you haven’t changed, Bruno? You have grown younger, pal,’ laughed George.

‘All right, you win. You always have the last word, don’t you?’ smiled Bruno. ‘You know, honestly this place is not the same without you two. I am so glad you are back. Let us celebrate, food and drink on the house. What would you like?’

‘You decide, Bruno,’ said George taking the lead.

‘Vegetarian food for me,’ I added. ‘I have become a vegetarian.’

‘Since when?’ George raised his eyebrows.

‘Since a couple of years,’ I answered. ‘It is good for health—and for conscience too.’

‘This man is impossible, suddenly changing over to vegetarianism,’ groaned George. ‘All right, let me be a vegetarian too for today, Bruno.’

‘Why not, I will make some delicious ravioli. Normally, we fill it with crab or lobster meat. But for you vegetarians it will be assorted cheese spiced with herbs. They will be simmered in special creamy mushroom sauce, my own creation. And you can have excellent Frascati wine to go with it,’ Bruno went back to the kitchen. Soon enough, a waiter brought two plates of toasted cheese for us to munch on and a bottle of chilled white wine without label to go with it.

‘You must have had some gorgeous time, Alfie, judging from the post cards you were sending me from all over the world,’ remarked George after having nibbled a bit of the toasted cheese and taken a couple of sips of the wine. ‘I couldn’t reply since you never mentioned your address.’

‘I didn’t know my own address either, George, since I was wandering without planning my next step, you know. As you say, it was fantastic, especially visiting the haunts and habitats of the greats like Galileo, Newton, and the ancient Greeks too.’

‘You must tell me all about it sometime, Alfie. I can’t say I didn’t have a nice time either visiting a couple of universities, balancing work and pleasure. I was not weighed down by responsibilities since my three students you met have graduated and are well-placed. I am yet to take some hapless kids to do their doctoral research.’

‘You must have had plenty of free time, then.’

‘Yes and no. I filled my spare time with writing a book on the Universe.’

‘The Universe!’ I exclaimed. ‘That is wonderful, George. How is it coming?’

‘I shall tell you in a minute. First, let us have something to eat,’ said George spotting the waiter coming out of the kitchen.

The waiter brought our steaming hot ravioli in sauce, accompanied by side dishes of garnished vegetables. We started eating slowly, enjoying every morsel punctuated by sips of the delicate wine. Food is the soul of happiness, isn't it?

'Ah, the book on the Universe,' George speared a piece of ravioli with his fork and waved it in the air excitedly. 'You know, Alfie, the study of the Universe is a continuously evolving process. I don't mean the evolution of the Universe. Of course, that happens too. But, the entire cosmic journey has progressed along a meandering path from its early beginnings to the modern era. It is the blossoming of human knowledge, human beliefs, human mind, and the science created by the human intellect. Even the early myths were an attempt to explain what was observed in the sky. I want to describe this exciting adventure starting with the ancient times and ending with the most recent findings. Do I have to add that the quest is one without end?'

George seemed to be a little bit tired not so much by having spoken about his book at length as by the cosmic journey he was envisaging. He sat back and took a long pull at his wine.

'That sounds fantastic, George.' I too was excited. 'How far have you progressed with the work?'

George silently bent down, picked up his briefcase, and pulled out a bound volume of typed manuscript.

'Here, I am handing over to you the preliminary draft of the book. No, no, don't open it now. Go home and read it at your leisure and let me have your feedback. We can meet regularly and discuss the contents, style, and presentation. It will help me with further drafts and the final version. What do you say?'

'That is great, George, really great,' I said with feeling. 'What is the title of the book?'

'I haven't decided it yet, Alfie,' answered George. 'You could help me with that too.'

'Aha, a book in search of a title,' I remarked. 'Like Luigi Pirandello's play, *Six Characters in Search of an Author*! The way it happens in the play, maybe the book will also evolve as we keep changing the possible titles.'

'You are absolutely crazy, you know that?' George shook his head. 'Incurably mad!'

Bruno came over and placed on our table another bottle along with three small liqueur glasses.

'Here is *Limoncello* from Amalfi coast, one of my favourite *digestivos*,' announced Bruno as he poured the chilled yellow liqueur. 'By the way, I couldn't help overhearing a bit of your conversation as I moved around, you know. Not eavesdropping for sure. What is this Universe book? Can I understand it?'

Before George could respond, I answered Bruno's query. 'You bet, Bruno. You guys must have forgotten what I told you long ago. The great Rutherford once told the equally great Bohr that a good theory should be understandable even by a barmaid. Since unfortunately I don't see any barmaids around, I must say that a good book should be understandable by a restaurant owner, that too an intelligent one like you, Bruno.'

‘Barmaids indeed,’ Bruno threw back his head and guffawed. ‘Cheers, here is to the new book!’ He gulped down his drink and filled his glass again.

George was enjoying every one of his little sips, eyes close, head tilted back a little, smiling in contentment. Bruno and I joined him in silence.

‘By the way, you noticed changes we have made around here’ Bruno swept his hand to indicate the interior of the restaurant. ‘There is going to be a major one, you know. I am hiring a young chef to help me out. He is very good at all sorts of cooking. So, there will be different types of food from different countries once a week. Do come and taste and tell me your opinion. I must now get back to work. Goodbye, my friends, *addio, amici miei!*’

Bruno got up and so did we. We thanked him profusely for the excellent dinner and the exquisite wines. He waved away our thanks as he usually does.

‘Don’t wait till you have read a lot, Alfie,’ said George. ‘I would like to discuss each section of the book as you go along. It will be a great help. Do meet me soon. Bye now.’

‘It will be an immense pleasure, George,’ I told him sincerely. ‘I shall call you soon and meet you. Till then, keep well.’

As we parted, I remembered our meeting of long ago when George had promised to tell me all about black holes. Afterwards, regular sessions of discussion had followed that were most rewarding. Now it was going to be the entire Universe no less. I walked home slowly and happily with the stars smiling in the clear sky above.

A Brief Biography of My Bathtub

I stopped short at the blind alley that is situated close to the street on which I live. My memory flooded back to the eventful day when I had inherited my precious bathtub. I told some of you about it in detail, didn’t I? Let me briefly recapitulate what had happened then.

In the short, dark stretch of the alley, there were some derelict buildings as well as a couple of warehouses. But that night, I saw to my surprise one of the small buildings sporting the sign, *Al’s All-in-One Store* with dim light shining inside. Among several other signs advertising an assortment of items, there was a large one on which was written in bold letters: *Bathtubs for Half Price!* With some trepidation, I had entered the store. I can never forget what had happened next. Allow me to recount my experience in some detail.

As I gazed upon the chaotic variety of merchandise scattered around, I felt a presence at my elbow. The sight that greeted me as I turned around has been indelibly etched on my mind. An elderly gentleman, presumably the storekeeper, had appeared from nowhere. I was captivated by his eyes looking steadily at me, eyes gentle and kind, but not without a mischievous twinkle in them. Time had woven a web of lines on his serene face that was framed by a halo of white, wispy hair.

He spoke softly with a thick accent, which I could not place. It was one of those accents that belonged everywhere and nowhere. 'I am Al at your service,' he said with a warm, friendly smile. 'So, you have come to collect your bathtub, *ja?* *Wunderbar*, this way please, *mein lieber Herr*.' He gestured with his head, his long, unruly hair waving in the air. I had entered the store with no intention of buying anything, let alone a bathtub. But, as though mesmerized, I had followed Al.

It was a large gallery that held a number of bathtubs of different shapes, sizes, and colours. Al pointed to three of them claiming that they were of great historical value. The first one, which was truly magnificent, had belonged to some ancient Egyptian queen according to Al. Perhaps to Nefertiti or maybe Cleopatra, he said. Moreover, its design and decoration reflected the cosmic order believed by the ancient Egyptians. The Egyptian myth envisaged the sky goddess Nut, decked with shining stars, arching over her reclining husband Seb, the Earth god. And their son Shu, who controlled the winds, knelt between them in the sky. During the day, the Sun, the god of gods Amon-Ra, sailed in his divine barge along Nut's body. Each night he died and entered Amenti, the nether world, to be broken up into myriad stars. At dawn, he was reborn to repeat the perpetual cycle of birth and death.

The bathtub, enormous and shaped like the Sun's barge, was made of black marble. Semiprecious stones of different kinds, like turquoise and lapis lazuli, as well as flakes of gold and silver, were inlaid into the dark background creating a continuous panorama of the sky, the Sun, and the sparkling stars. It was indeed breathtaking.

Next, Al showed me his favourite bathtub. Simple and elegant, it had been carved out of pure, white marble and was elliptical in shape. Engraved on one side was a spiral and on the other the picture of a pole balanced on a conical peg.

'The owner of the bathtub discovered the spiral you see, *mein lieber Herr*,' explained Al. He claimed that, if he were to be given a long enough lever and a place to hover around in space, he could lift the entire Earth.' And then he announced jubilantly, 'His name was Archimedes!'

'From this very bathtub here,' Al continued after pausing dramatically, 'Archimedes ran stark naked, shouting *Eureka*. Imagine our scientists following his example in their haste to announce their results! What a sight it would be!' Al roared with laughter tears in his eyes. What a contrast it was between his soft speech and this bellowing laughter that echoed from wall to wall of the store!

The third bathtub Al showed me was essentially a crude rectangular box made of mere sandstone, chipped here and there. Unadorned, it looked more like a coffin than a bathtub. Jean Paul Marat, one of the leaders of the French Revolution who suffered from some terrible skin ailment he had contracted while hiding in the sewers of Paris, apparently soaked himself in lukewarm medicated water that filled this bathtub. A woman named Charlotte Corday had stabbed him to death during one of his soak sessions. The bathtub had proved indeed to be Marat's coffin so to speak.

'I am told that, if you look carefully, you can still find faint bloodstains in the bathtub,' said Al. 'Gives you the creeps,' Al seemed to shiver at the thought.

Al took out his pipe from his pocket, filled it with tobacco from the pouch he had extracted from another pocket, and lighted it. As he puffed in contentment, he spoke about the benefits of taking a bath, but confessed, 'Personally, I hate baths myself. That follows in the tradition of the great Kepler who bathed only once in his lifetime, that too at the nagging of his wife. It nearly killed him. So, I try to avoid taking a bath although I extol its virtues.' He added, his eyes shining, 'As you very well know, sir, there is nothing nobler than to preach what one does not practice.'

Al bent down to tie his shoelace. His shoes were scuffed and he wore no socks beneath his rumpled trousers. Straightening up, he smoothed the sweatshirt he was wearing. As he escorted me along, he said, 'Pardon me, the small black box over there is not a bathtub. It is my violin case.' Al roared with laughter again.

Finally, we reached our destination. Exclaiming, 'Ah, now for your bathtub!' he pulled off with a flourish the tattered cloth that covered the bathtub. I could not believe my eyes. This bathtub, as he called it, was nothing more than a kitchen sink! It was beyond my comprehension how anyone but an infant could get into it.

Al was amused by the incredulous expression on my face. 'Half price, half size,' he laughed and then assured me, 'Take my word for it. You will find no difficulty getting into your bathtub that will adjust itself to your dimensions. Dimensions are relative you know.'

Al fell silent for a moment and spoke slowly with a seriousness he had not displayed so far.

I remember every word of Al that followed as if I heard them a moment ago: *What is more important is the fact that the bathtub is a magical one. It is filled with myth, math, science, philosophy, art, literature, and above all dreams, not to mention your bath water.*

Al told me that the heavy bathtub would be delivered home along with instructions to install it in five easy steps. 'Oh, I almost forgot. Along with the bathtub, you get a free sample of our special bubble-bath additive.' He produced a plastic bag filled with perfectly spherical black beads. They were black in a strange manner, reflecting no light at all as if they totally absorbed light, but quite pretty in a peculiar way.

'Rest assured that your newly acquired possession will give wondrous moments you could never have imagined. Goodbye now,' said Al as he walked me to the door and held it open for me. As I watched him, I wondered whether I had met him before. No, that was impossible. Did he resemble someone whose description I had read somewhere? Or someone in a photograph I had seen? My mind seemed to have become fuzzy and I was confused. I caught myself meandering through the maze of my memories as I realized that Al was regarding me with a mysterious, knowing smile. As I was about to leave, he said gently, 'We shall meet again, my friend.'

As I started walking home, I turned back. The alley was now plunged in absolute darkness. There was no light in the shop and I could see no signs either. Had I been dreaming? The shop, the shopkeeper, and everything that had befallen me, was it all my imagination? The whole episode was a bit scary.

As I trudged up to my apartment, tired and confused, I once again wondered whether I had imagined the whole episode involving Al and his store. But there it

was at my doorstep, in all its three-dimensional reality, my bathtub neatly packed. Surprisingly enough, it was quite light as I carried it inside and installed it easily. I could not wait to take my first bath in my bathtub or kitchen sink, or whatever it was. I filled it with hot water, stirred in half a spoonful of the bubble-bath mixture and eased myself in. Surprisingly, I could comfortably fit into the bathtub: either it had expanded or I had shrunk. As Al had said, dimensions were relative. Maybe the mass of the bathtub was also relative since it had proved to be quite light.

Again, as I recall what followed, every moment of my new experience is summoned up from my memory. The bubble bath was incredibly soothing. The vapours rising from the bathwater seemed to steep into my mind blending awareness, thoughts, and imagination into a flowing stream. I was surrounded by countless bubbles, multicoloured spheres that glistened and trembled, each carrying within it a dark speck that appeared to grow a little as it absorbed the vapour in its vicinity and the light that fell on it. Slowly, words I had heard that evening while talking to George came to my mind: black holes swallowing up matter and energy and growing in mass and size. Was this happening in my own bathtub? Were black holes swarming in my bubble bath?

The bubbles were swirling all around me massaging my body, gently tugging at me. As I luxuriated in the fantastic bubble bath, my eyes grew heavy and I drifted into a supremely blissful slumber.

That is ancient history. But, the past leads to the future passing through the present, does it not? Well, once again today, returning from Bruno's I climb up the stairs to my apartment. I cannot wait to start reading the draft of George's book about the Universe. I sit back comfortably in my old but cosy chair, switch on the lamp next to me, open the manuscript, and begin my own cosmic journey.

Chapter 2

Ancient Times

As George had told me, the book began with astronomy of antiquity. The ancient astronomers from all over the world—the Greeks, Indians, Arabs, and Chinese—had been avid stargazers. Night after night, they could see the fixed patterns of the stars in the night-sky: the *Constellations* as we know them. And the astronomers associated the groups of stars with their own myths and beliefs, stories and legends. Beasts, heroes, heroines, gods and demons resided in those star patterns. Whereas the stories helped identify the star-groups, the cultures that gave birth to those stories were perpetuated through those very stars. Take for instance *Orion*, one of the most prominent constellations in the sky, named after the great celestial hunter of Greek mythology. His story involved the battle between him and a giant scorpion that eventually became the constellation *Scorpio*. Indians have a fascinating story for the same group of stars as well. One of their demigods, *Prajapathi*, took the shape of a stag and chased his own daughter *Rohini*, who had assumed the form of a lovely, young doe. The gods, outraged by *Prajapathi*'s incestuous lust, complained to *Lord Shiva* who, assuming the form of a great hunter, shot down *Prajapathi* with an arrow from his bow and rescued *Rohini*. A remarkable story, is it not? The constellation, in both Greek and Indian cultures, is associated with a hunter. Is there some deep inter-cultural relationship at work here, I wondered. Incidentally, *Lord Shiva*, as *Maha Vyadha* or the Great Hunter, is identified with *Sirius*, the brightest star in the sky. In some accounts, the hunter, who kills *Prajapathi*, is called *Lubdhaka*. And *Rohini* happens to be the star *Aldebaran*, as it is known in the west. Furthermore, the three stars in *Orion*'s belt are identified with *Shiva*'s arrow.

As I read the fascinating account of the constellations, I remembered my recent wanderings in the lands far away. I could vividly visualize the ancient monuments of Greece that bore glowing testimony to a glorious era. I remembered the magnificent amphitheatres where the Greek plays had been performed a long time ago, plays by the great playwrights like *Aeschylus*, *Sophocles*, *Euripides*, and *Aristophanes*. In India, among other things, I visited many beautiful temples, some of them decorated with intricate carvings of breathtaking beauty. And there were others that were famous for imposing sculptures of immense proportions. In the

middle-east, I had gazed upon the endless stretches of desert sands, at once awesome and frightening.

I felt tired. The evening had been exciting. I closed the book, marking the page I had just finished with the sheet of paper on which I usually make my own notes. I got up and stretched, thinking of going to bed. Then I suddenly remembered my bathtub. Of course, I needed a good, hot bath to melt away my fatigue. I walked over to my bathroom and started filling my bathtub. But what about the fabulous bubble-bath mixture? Had I exhausted my supply? I didn't remember. I looked inside the cupboard where I had stashed away the sachets containing that magical ingredient. To my surprise, there were still quite a few of them left. But the mixture looked quite different from what I had used earlier. It did not consist of black beads as before, but was in the form of luminous little disks. Without thinking about this difference in appearance, I opened one of the sachets and was about to add a spoonful of the content to the bathwater. I stopped short. Had I heard a faint, eerie sound emanating from the bathtub? How could it be? I was startled.

I heard it again, a low gurgle followed by what seemed like the sound of clearing the throat. Good heavens, I had completely forgotten that my bathtub could speak!

'Hmm, we had completely forgotten that both of us can speak, had we?' There was again the low sound of resonant laughter. 'How could you, boss?'

I felt really ashamed of myself.

'Oh, well, let it pass,' resumed my bathtub. 'All these years I have been waiting for you, boss. Why did you have to ask your friend down the street to wash me regularly? He scrubbed me so hard! Fortunately, we bathtubs do not bleed. But then, he seemed to be afraid of me. That is funny.'

I remembered what Fernando had told me. Whenever he touched my bathtub, he used to feel that it seemed to be human in some uncanny manner. Maybe he had been a bit frightened by the experience, who knows?

'That was perceptive of him to think of me as human, I must admit grudgingly. Anyway, I am so glad that you are back. I am delighted that you still remember me. I would be the happiest—well, whatever I happen to be—if you recall what I used to be in my previous life.'

I was not sure about what my bathtub was referring to. What did it mean by the phrases, *whatever I happen to be* and *my previous life*?

'Surely you have not forgotten, boss!' There was a hint of reproach in my bathtub's voice. 'I was a kitchen sink in my Master's house. That house was known by one of the most famous addresses: One Hundred and Twelve, Mercer Street, Princeton, New Jersey, United States of America, no need perhaps to add the World and the Universe too. Don't forget what you were told about me: *What is more important is the fact that the bathtub is a magical one. It is filled with myth, math, science, philosophy, art, literature, and above all dreams.* How did I acquire all those things, boss? Well, I absorbed all that from the discussions and dialogues the Master used to hold with his visitors, even from his musings and his unexpressed thoughts, didn't I?'

Oh, yes, whatever my bathtub had told me long ago came back to me in vivid detail.

‘Ah, that is better. By the way, boss, why do you keep referring to me as *my* bathtub? Sounds very possessive, you know. Why don’t you call me KSBT—Kitchen Sink Bath Tub? Or how about combining the letters into *KhaSBaTh*? It refers to bath and, moreover, the word means *confidential talk* in Hindi, the Indian language that you have learnt a little bit. Confidential talk, hush-hush, *gupchup*, that is what we do all the time, don’t we? How about that?’

Crazy, but wonderful, the name *Khasbath*, I thought.

‘Well, I don’t want to hold up the great pleasure you are about to have. But, fear not, we shall have a long chat one of these days.’

My bathtub, sorry *Khasbath* I mean, fell silent. I stirred a spoonful of the bubble bath mixture into the bathwater and gently lowered myself in. I could feel the water lifting me up. Well, I knew that the Archimedes Principle was at work: *The upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces.* Needless to add, the body in question belonged to me and the fluid was my bathwater. Among the profusion of the bubbles swarming around me, I could now see not black specks as earlier, but scintillating little sparks tinged with different colours. On close observation, I realized many of them formed definite patterns. I could not concentrate long, as I felt intensely drowsy. My eyes slowly closed and I drifted away into a strange state of mind that seemed to hover on the verge of total nothingness.

The Celestial Theatre

I slowly opened my eyes. I could see countless stars shining away wherever I looked. Those stars differed from one another in their brightness. If one looked carefully, they seemed to be tinged with varying colours as well. As I knew already, many of the stars appeared to form definite patterns. Ah, the constellations that convey amazing stories, I thought. Stories! I loved those stories. But where there are stories, we need a good storyteller, don’t we?

Out of pure, empty space, the figure of a man materialized. First just the outline became visible. And then all aspects of his person filled in with complete clarity. I knew from my past experience that this would happen time and again, whenever a new character appeared on the scene.

He wore a snow-white robe held by an ivory clasp at one of his shoulders. From his apparel, I could conclude that he was probably from ancient Greece, perhaps a scholar from that bygone era. His black beard, streaked here and there with a few strands of silvery grey, was well trimmed and his eyes gleamed with good humour.

He stood in a studied pose holding a book in one hand with the other extended as though he was ready to speak ceremoniously.

‘My dear ladies and gentlemen, you who have gathered here in such large numbers,’ the Greek addressed an imaginary audience in a booming, theatrical voice, surveying the non-existent crowd. Realizing that there was hardly any audience at all, except for a lone listener, he cleared his throat and directed his words towards me. I watched him with fascination. From time to time, he would forget that he had only a single listener and revert to speaking to the large, imaginary gathering.

‘Ah, there you are, my learned guest, you who have come from afar to listen to me and watch our little theatrical performance,’ he began. ‘Please allow me to introduce myself with all modesty in spite of my considerable reputation as a playwright. My name is Aristophanes, a redundant piece of information since that name, I believe, is known far and wide.’ Aristophanes paused dramatically for effect and added, ‘You may call me *AR* for short. Saves time and energy!’

Aristophanes the great Greek playwright! I knew about him well and had read a couple of his plays. He lived around fifth and fourth century BC and was famous as the Father of Comedy and the Prince of Ancient Comedy.

‘As you perhaps already know, I hail from ancient Greece that was the source of all knowledge—history, philosophy, science, art, music—the list is endless.’ Holding up his hand next to his mouth as though guarding his words from spreading out, he said quite loudly, ‘A hyperbole, an exaggeration, sir, if you ask my opinion. Ah, you are puzzled by my gesture, are you not? Well, it is known as a stage whisper and I employed it for your benefit since I am an adept at stagecraft. In other words, I am a playwright or a writer of plays and I produce my plays on stage for people to watch and enjoy.’

He looked at his captive audience of one steadily.

‘Perhaps our honoured guest knows that I wrote a play entitled *The Frogs*. It was about both playwrights and playwongs, so to speak, quite hilarious if I may say so myself in all modesty.’

I had of course read the play *The Frogs* by Aristophanes, which was indeed hilarious. I also knew who the targeted ‘playwong’ was—it was Euripides!

‘Enough of ancient literary history,’ said Aristophanes after a momentary pause. ‘Now up with the curtain and on with the show.’ He swept his hand across the entire firmament. As he did so, a multitude of figures gradually appeared against the constellations in the background. Naturally, there were not only men and women, but also beasts, demons, and inanimate objects.

‘Well, my honoured guest, many constellations tell heroic tales involving the figures you see outlined against the star patterns,’ Aristophanes went on. ‘For instance, focus your esteemed attention on the wondrous pattern over there with three brilliant stars in the middle that can never be missed among their myriad companions. That star pattern is called the constellation *Orion*.

‘How so the name Orion? Answer me not for I shall enlighten you regarding the origin of the name of the constellation and the tale that goes with it. *Tale* and not a *tail*, mind you, although in fact a tail does figure in the tale, as you will discover soon.’ Aristophanes drew himself up to his full height preparing for his narration. After a momentary pause he went on.

‘There is but little charm in telling a story just with words. After all, I am a playwright, am I not? Should I not present to you some dramatic display worthy of your erudite appreciation? Yes, we shall proceed to do so without further delay,’ commented Aristophanes. ‘Tonight, we shall stage one of those dramas enacted night after night on the heavenly vault. In order to supplement my narration that I have created for this special occasion, I have summoned my able minstrels, namely the chorus of my play *The Frogs*, who, with their mellifluous voices, will sing for us from time to time.’

As Aristophanes gestured with his hand, a chorus of frogs of different ages and sizes materialized. They were dressed in togas somewhat similar to the robe worn by Aristophanes. Together they bowed to me formally, but then grinned, giggled, and winked at me most unceremoniously, while some made croaking noises that were far from mellifluous as had been promised by Aristophanes.

Woes of Orion

‘Now for the dramatic presentation of Orion’s tale!’ announced Aristophanes with a flourish. And the chorus of frogs made sounds, or noises, that were supposed to simulate the blare of trumpets and the beat of drums. As Aristophanes recounted the story, the characters involved, who had positioned themselves against the constellation, enacted their roles accordingly, punctuated by the choral rendering of the frogs. I began to enjoy this novel show immensely.

‘Orion was the great celestial hunter with enormous strength,’ began Aristophanes as concentrated starlight focused on the figure of Orion who struck a heroic pose. ‘Regard him, if you please, holding aloft his enormous club in one hand and a lion’s skin in the other as his shield.’ Aristophanes added in a stage whisper, ‘A lion’s skin for a shield? What could it protect him from except perhaps pebbles pelted by a child?’

Then the frogs sang in unison.

Chorus:

Brekekekex ko-ax ko-ax

Brekekekex ko-ax ko-ax

Oh, oh, Orion, hunter in the sky

You squashed a mighty dragon? Could you squat a fly?

You own a club, eh? A night club you run?

Are you a bouncer? That must be fun!
Holding up a lion's skin, a lion that hardly bites
Cut it up into pieces, man, and wear them as tights
Oh, oh, Orion, hunter in the sky.
Brekekekex ko-ax ko-ax
Brekekekex ko-ax ko-ax

‘Irreverent, nasty little creatures, these frogs,’ Aristophanes shook his head suppressing his smile. ‘The refrain—*Brekekekex ko-ax ko-ax*—is supposed to mimic the croaking of the frogs. I included it in my play *The Frogs*.’

The frogs giggled, winked, hopped around and finally settled down again.

‘You must have heard the saying that brawn and brains do not go together,’ Aristophanes continued his story. ‘Well, that is precisely what Orion managed to prove. He boasted that he was so strong that he could kill—destroy, exterminate, annihilate—all the animals on the Earth. To whom did he boast, you may venture to ask and I shall oblige you with the answer to your unexpressed query. To Artemis of all people, I mean of all gods and goddesses. A goddess Artemis certainly was, is, and will be, and that too a goddess protecting animals! She was alarmed, if you permit an understatement, and conveyed her anxiety in proper alarmed language to her colleague in the Greek pantheon, Gaea, the Earth goddess, who too was alarmed beyond measure. What would happen if Orion in his eternal folly—for follies tend to be eternal—carried out his threat in a moment of madness? There would be no animals, insects and such left on the Earth anymore.’

Chorus
Brekekekex ko-ax ko-ax
Brekekekex ko-ax ko-ax
Oh, oh, Orion, aren't you full of brawn?
Where is your brain, man, gone with the dawn?
Why boast your head off to Artemis?
The goddess of beasts, that arty-miss
You can kill off all animals, did you say?
Wiping them off the Earth a child's play?
Do you want to live or do you want to die?
Oh, oh, Orion, hunter in the sky.
Brekekekex ko-ax ko-ax
Brekekekex ko-ax ko-ax

‘To continue. In order to avoid such a calamity, Gaea sent an enormous scorpion with the specific intention of having Orion eliminated once and for all. Once and for all? How many times can one eliminate another, I ask you. Do not trouble yourself to answer, for it was but a rhetorical question. Be that as it may, the celestial hunter and his equally celestial antagonist were engaged in mortal combat. Although Orion was able to wound the scorpion with a terrible blow from his mighty club, the struggle was short lived. Despite all the strenuous efforts of Orion, the scorpion got better of him, whipped up its tail, and killed him with its deathly sting.’



After a momentary pause to let the story sink in, Aristophanes added parenthetically, ‘Ah, I told you early enough that a *tail* figures in the *tale*, did I not?’

Chorus

Brekekekex ko-ax ko-ax

Brekekekex ko-ax ko-ax

Brethren of the Chorus, you see what I see?

A steel-armoured scorpion larger than a tree!

Six sturdy legs, all multiple-jointed

Enormous pincers knife-sharp pointed

The hunter and the arachnid, watch their mortal fight

There is no room here for any cowardly flight

Club comes down, pincers snap

One false move—a dire mishap

Even the great gods shudder with fright

Although safe in their Empyrean height

Oh, dear, Orion trips and slips

His body is now in the pincers’ grips

The tail lashes out and stings his hips

Dead as a Dodo, splattered like a fly,

Oh, oh, Orion, hunter in the sky.

Brekekekex ko-ax ko-ax

Brekekekex ko-ax ko-ax

‘Ah, so we come to the end of our story,’ announced Aristophanes. ‘But how can we conclude our play on a sad note? Would not the audience clamour for their money back? No, sir, it would not do. Here then comes *Ophiuchus*, the heavenly healer, stepping forth holding a serpent in his arms. Ah, that erudite serpent happened to be the mentor of Ophiuchus. The slithery scholar had taught Ophiuchus the ancient secrets of healing. From the satchel that hung by his side, Ophiuchus

now took out a vial containing the extract of some magical herbs and applied it to the two antagonists—one dead and the other wounded. The two sprang up full of life at once, bowed all around, and withdrew.

‘All this time, the immortal gods had been watching the mortal combat with utmost amusement, for the misery of others is their inexhaustible source of entertainment. In their infinite wisdom which we mortals cannot fathom, those gods placed the two celestial combatants, Orion and Scorpio, on the opposite ends of the sky dome as constellations, so that those two would never be seen together. That is the end of our story. My chorus and I are indeed greatly honoured by your kind attention and are indebted to you till eternity yawns and turns over in her sleep.’

I applauded vigorously as Aristophanes and the frogs bowed low repeatedly.

Aristophanes swept his hand across the celestial characters who had taken part in the drama. They had gone back to their respective constellations and were about to fade away. They too bowed in unison. The constellations had slightly moved from their original locations. But the stars making them up had maintained their relative positions as before.

‘Aha, my distinguished guest has noticed that the star patterns have moved while we were staging our play,’ commented Aristophanes. ‘Oh, yes, stars rise and set just like the Sun and the Moon. So they have moved, but their relative positions are unaltered. In other words, the constellations have remained the same. I shall not attempt to describe these celestial phenomena any further, for I am but a mere storyteller. But, explanations shall be given, rest assured, my honoured visitor, not by me but by another eminent Greek.’

Wisdom of the West

As Aristophanes spoke, another figure had slowly materialized next to him. He too was dressed very much like Aristophanes. All ancient Greeks seemed to be similarly clothed for that matter. Tall and well built, he had dark curly hair. His keen, observant eyes focussed sharply on me.

‘Be pleased to meet Aristarchus of Samos, one of the greatest astronomers, or the studier of stars, our country has produced,’ proclaimed Aristophanes. ‘A man younger than me by some hundred and odd years, he will relate to you the mysteries of the stars. I take leave of you, but fear not, we shall meet again. Farewell for now!’

With those words, Aristophanes slowly faded away in the same manner as he had appeared.

Now it was the turn of Aristarchus to hold forth on the starry stage. He smiled and held out his hands in a gesture of welcome.

‘I greet you in the name of all the glitter, glory, and grandeur of the celestial sphere and its denizens, my friend from far off land and far off future,’ said Aristarchus warmly and bowed.

I bowed in return instinctively.

‘As you have been informed by my playwright predecessor, my name is Aristarchus, an avid stargazer of ancient times,’ Aristarchus began. ‘You may call me *AR* for short,’ he added with a smile.

I was amused. Here was another *AR* of antiquity.

‘Did I say the *celestial sphere*? I must explain what is meant by that term, must I not?’ said Aristarchus. ‘When you look up at the night sky, you feel that a dark inverted bowl, carved out of some black crystalline material, is fixed above you. Permanently stuck inside the bowl in definite patterns, or constellations, are the glittering stars. As the bowl turns about the pole, with the polestar or *Polaris* close by, the stars go round in their courses. Obviously, constellations too rise and set, since that is what the stars do. But, the relative positions of the stars making up the constellation are fixed. This is what you noticed at the end of the theatrical production of Aristophanes. We, who dwell in the northern part of the Earth, see only the hemisphere above us. And those who inhabit the southern regions of the globe see the other half of the celestial sphere with its own constellations. Perhaps, my friend, someday you will make your way to the southern hemisphere of our Earth and enjoy those unseen star-patterns.’

Yes, that would be great, I felt.

‘Many Greeks before me had studied the night sky very carefully and thought about things happening up there,’ said Aristarchus looking heavenwards. ‘For instance, more than three hundred years before I was born, there was this great man by the name of Thales of Miletus. He watched the sky all the time. Even when walking on the streets. While doing so, it seems he fell into an open well.’

‘He did not want to be rescued even then,’ Aristarchus went on. ‘That would have disturbed his watching the sky. He knew a lot including how the Sun seemed to move in a circle around the Earth, how long it took for the Sun to go round this way. Thales thought that all things around us were basically made up of water.’

‘Aha, that is because he fell into a well with water in it,’ I thought irreverently.

‘Could be, could be,’ Aristarchus laughed. ‘But, seriously, that was an important step Thales had taken as you can very well imagine. In the centuries that followed, people have wondered whether all things are made up basically of some common ingredients. Again, my friend, you will learn all about it in good time. As for me, I shall tell you, as we go on, about some of the other great Greeks who studied the sky. But now the time has come to talk about the Sun and the Moon, the dearest companions of the Earth.’

Aristarchus paused before continuing.

‘I have no doubt that you know whatever I am going to tell you, since astronomy has advanced enormously since our times,’ reflected Aristarchus. ‘Yet, I am confident that you will agree with me that it is important to understand the evolution of any subject over the past centuries. By simple observations, one can find out that the Moon circles the Earth in twenty-nine days, always presenting the same face to us on the Earth. Why? Is the Moon ashamed of its other side? No, because Moon’s period of rotation happens to be exactly equal to its orbital period. Round it off to thirty days, and you have the month as a measure of time. Then again, the Sun takes a year

comprising three hundred and thirty-five days to go around the Earth. As the Moon shines by reflecting Sun's light, we see different phases of the Moon, do we not?"

Aristarchus went on to describe the different phases of the Moon in detail. I knew it all, of course. But, it was so nice hearing it from this venerable astronomer of centuries ago.

Aristarchus fell silent. He must have been thinking of the past.

'The philosopher Protagoras wrote, *Man is the measure of all things*. What did he mean by that? He meant that there is no truth but that which individuals deem to be the truth. He got into trouble because of such a radical idea, what a pity! Time and again, people have to overcome the prejudices of those who fail to accept anything new. Yes, man is the measure of all things. But man is also the *measurer* of all things, is he not? So, long ago, I wondered how far the Moon and the Sun were from the Earth. Wondering is not enough I said to myself, we must find this out by actual measurement. And I did manage to devise a simple method to measure the distances of our two neighbours relative to the size of our own Earth.'

I knew that the so-called *simple methods* are invariably brilliant ones too. I had no doubt that this was the case with the measurements of Aristarchus.

'Well, what was my result? My standard of measurement was the size of our own Earth. And, I found out that the Moon's distance is ten times the size of the Earth and the Sun's distance about some two hundred times.'

Aristarchus stroked his beard for a while and went on.

'I am told that other stargazers, in ages after mine, have made similar measurements by different and more sophisticated methods. And they have found the distances of the Moon and the Sun to be respectively about thirty and twelve thousand times the size of the Earth. Ah, that is progress.'

'But the one who plants the seed must be given due credit for the fruits that has resulted,' I felt.

Aristarchus seemed quite pleased with my unspoken words.

'That is not all, my companion in curiosity,' continued Aristarchus. 'How big are the Sun and the Moon compared to the Earth? I wondered again. To repeat what I told you earlier, wondering is not enough, I said to myself, we must find out. And I did manage to devise a method, again simple enough, to measure the relative sizes of our two neighbours. What did I find? I discovered that our dear Earth is about three times larger than its follower, the Moon. And the Sun is seven times larger than the Earth.'

This must have been the first time such a measurement had been attempted and, I was sure, that the method must have been ingenious as well.

'As in the previous case, others who came after me have discovered that my estimate of the Moon's size is not bad at all. Our Earth is about four times larger than the Moon. But the Sun, on the other hand, is actually a little more than a hundred times the size of the Earth. The Sun is quite large compared to our Earth. I am confident that you agree with me.'

Oh yes, I agreed readily.

Aristarchus fell silent again for a while, musing about his findings no doubt. Then he spoke up, his eyes shining. 'Yes indeed, even seven times the size of the

Earth, as I believed, was quite large for the Sun, if you ask my opinion. That set me thinking. Of any two bodies, the heavier one always tends to be sluggish and stays at the same place, while the lighter one could run around more easily. Then the Sun must be at the centre with the Earth going around it. And not the other way round as everyone thought. Does it not make sense to you?’

‘Oh, yes, it does, it does,’ I wanted to say.

‘I wish my friends were like you. But, nobody took me seriously,’ Aristarchus seemed to be a little sad. ‘Everyone continued to believe that the Earth was at the centre. Only after two thousand years my idea was proved to be correct.’

‘By the way, we know that the Sun is far enough from us. But, I knew that the stars were much, much farther. Our story does not end there. In fact, it is just the beginning,’ Aristarchus pointed his finger at the sky. ‘Look at the night sky. Apart from the Sun and the Moon, there are five other heavenly bodies that are very special.’

Five objects brightened up to show their locations. Unlike the stars, they did not twinkle.

‘They move against the backdrop of the fixed stars,’ explained Aristarchus. ‘They are the *wanderers* or the *planets* as they are called. They rise and set like all other objects in the sky. Furthermore, they too appear to go around the Earth at different speeds completing their full circles in different periods of time.’

The planets started moving majestically against the backdrop of the stars in the night sky.

‘As you know, those planets bear the names Mercury, Venus, Mars, Jupiter, and Saturn. Apart from these planets, strange heavenly bodies with tails visit us from time to time, the *comets* as they are called.’

Aristarchus thought for a moment and then went on. ‘In addition to rising and setting, the heavenly bodies—the planets, the Sun and the Moon—go round the Earth, do they not? They follow their own *orbits*. The great thinker Plato said that the path of each of these bodies, or its orbit, must be perfect. Why? That is because they are heavenly entities and do not belong to the imperfect Earth. A circle is the perfect curve, each point on it being at the same distance from the centre. Therefore, the orbits of these celestial objects had to be circles. Then again, being perfect, each of the heavenly bodies was supposed to move with constant speed around the Earth, never faster never slower. That is what Plato said and, of course, everyone believed it without doubt.’

Aristarchus nodded and stroked his beard a few times.

‘But, you may ask how these vagabonds of the skies—for that matter the Sun and the Moon as well—are supported in their eternal journey,’ continued Aristarchus. ‘Ah, that is a good question, my learned friend, even though you did not ask me. Yes, those celestial travellers cannot just hang in empty space, can they? So, what is the answer to your unspoken query? The answer came from the great Master, the Master of Masters, Pythagoras, who lived about two hundred years before my time and was, like me, from Samos, my beloved hometown. I am sure you have come across the work of Pythagoras some time or the other. He studied so much, asked so many questions, found out so many answers! Pythagoras was fond

of numbers and asserted that everything we know is based on numbers. He was deeply interested in music and related it to numbers.'

Aristarchus pondered for a moment or two before proceeding.

'Coming back to the planets, according to Pythagoras the answer to the question regarding their support was that each one of them was fixed in a crystal sphere.'

Aristarchus moved his hand in a circle and opened his fist. As if by magic, a beautiful piece of material in a perfect geometric form lay in his palm, scintillating with the reflections of the surrounding stars.

'Here is an example of such a crystal,' demonstrated Aristarchus. 'Once again, just as the circle is the perfect curve, the sphere has the perfect surface with all points on it being at the same distance from the centre. But the crystal sphere in which a planet is fixed is much more beautiful than the crystal I have here, so exquisite that it is transparent and you cannot see it at all! And the spheres turn carrying the Sun, the Moon, and the planets along. That is not all. I told you that Pythagoras, the Master, knew all about music too, did I not? Yes, he said that as the crystal spheres turned, they made beautiful music. Each sphere produced a different pleasing sound. These different sounds did not clash with one another. They did not fight but were at peace. This was *celestial harmony*, the *music of the spheres*.'

'Yes, the music of the spheres imbued with celestial harmony was indeed divine. Just as you could not see the transparent crystal spheres, you could not hear the music made by them either. You had to be very, very special for that. Only the Master was that special. Only the Master could hear the music of the spheres, that is what people said,' explained Aristarchus. And added in a whisper, 'The Master never denied what people believed!'

That must have been quite disappointing to the ordinary inhabitants of ancient Greece I surmised.

'How do we know that Pythagoras was right, although no one doubted his word?' asked Aristarchus. 'Let me tell you how. There was this fantastic scholar who was born some ninety years before me. He thought of practically everything—how objects fall, how fire rises, how wind blows, how plants grow, and so on. He thought deeply and extensively and that is how he discovered so many things. His name was Aristotle. Well, we could say he was the greatest *AR* according to people for a long, long time.'

Oh, here comes yet another *AR* I thought. How is it that so many names began with those letters!

'This wise man too agreed with Pythagoras that the Universe is made up of these crystal spheres carrying the planets,' said Aristarchus. 'What about the stars then, you may ask. Yes, it was agreed that they too were stuck in an immense crystal sphere that was beyond all the others and they too turned.'

Aristarchus was silent for a while before continuing.

'Yes, they were both great men no doubt, Pythagoras and Aristotle,' reflected Aristarchus meditatively. 'But should we take their word for everything without examining their ideas carefully? As I told you earlier, I wondered about the possibility of the bulky Sun relaxing at the centre. Perhaps, the Earth itself turned about an axis so that all other bodies we see in the sky seemed to travel as they do,

rising and setting. Again, as I said before, it was a long, long wait, my friend, before all this became clear.’

All of a sudden, an ancient Greek similar in looks to Aristarchus streaked totally naked shouting some word in Greek repeatedly.

‘There goes the craziest *AR* in Greece!’ exclaimed Aristarchus hitting his forehead with his open palm. ‘That Archimedes is running stark naked straight from his bathtub shouting *Eureka* again and again. The word means *I have found it*. What has he found out? Maybe that the bathwater is too hot!’ He laughed heartily before adding, ‘Actually, Archimedes is a brilliant scientist. Still, I hope he covers himself up before he gets into trouble with the Greek police.’

After this momentary interlude of mirth, Aristarchus fell silent as he seemed to be absorbed in his own thoughts. I too waited quietly turning around in my mind all that I had heard from him.

Wisdom of the East

‘Bho, maha yavana khagola vigyani, vandanam!’

I was startled by these incomprehensible words of an unknown tongue intoned by a soft voice in an almost musical cadence. Aristarchus too looked up sharply in surprise. Both of us realized that a strange figure had appeared while we were absorbed in our own thoughts. He was wearing a pure white length of cloth, fastened around his waist and folded in pleats reaching to his knees covering each leg separately. Another length of equally white cloth covered his torso loosely. The colour of his body—a lustrous shade of dark brown—stood out in contrast to his spotless white clothes. His chest and shoulders were powerfully built. Long wavy hair, dark as night without stars, cascaded down to his shoulders. He smiled at us rather with his eyes than with his lips.

I knew that there was an unseen automatic translation mechanism that converted all languages into my own. Probably it was having a problem converting an exotic language simultaneously into two languages, namely my own and ancient Greek. Ah, I intuitively realized that the problem had been fixed. Instantly, the words we had missed were repeated again.

‘O, great Greek astronomer, my salutations to you,’ the stranger said politely. He spoke like a poet in a flowery style. ‘Yes, I speak the most ancient tongue, namely *Sanskrit*, the unparalleled divine language of my glorious country *Bharathavarsh* or India as it has come to be called in modern times.’

As the stranger spoke, an ethereal backdrop of a magnificent temple with beautiful carvings on its façade appeared symbolising his culture. I fondly remembered the fantastic temples I had seen during my visit to that fabulous country.

‘With your permission, O my esteemed friends, kindly allow me to inform you of my name and calling,’ said the stranger with folded hands, his torso slightly bent forward in an attitude of respect. ‘I too am an astronomer, a devout stargazer like

you, my great Greek companion. I answer to the humble name of Aryabhata.’ Then he added with a smile, ‘AR for short!’

Oh, no, no, not another AR, I thought. At this rate, Astronomy will have to be called ARstronomy! Well, I was eager to hear what this new AR had to say.

‘O my Greek brother of the celestial lore, during my lifetime on this Earth, seven to eight hundred years after your departure from your earthly abode, I too pondered the mysteries inherent to the motion of the stars and the planets,’ said Aryabhata. ‘And, just as you speculated that the Sun, being ponderous, rested at the centre, while our Earth, light and lively as it is, circumambulated the former, I too came to the conclusion that the phenomenon of the rising and the setting of the celestial objects was only an appearance created by the rotation of the Earth itself, which we inhabit and hence have made our seat of observation of the heavenly activities.’

It took some initial effort on my part to follow the long, winding structure of Aryabhata’s sentences. But soon, I was enjoying the style of his speech.

‘I recorded all my findings in verse, in the form of poetry,’ Aryabhata went on. ‘After all, the firmament is filled with poetry, is it not? Stars and planets are the letters, their patterns are the words, and together they sing the eternal song that follows the rhythm of their movement. I wrote in Sanskrit, but the verse in translation reads thus:

*As from a sailing boat one sees
The backward glide of the line of trees
So do the heavens appear to be churning,
Whereas, in truth, it is the Earth that is turning.’*

‘Oh, that is beautiful, what a lovely analogy!’ exclaimed Aristarchus as he clapped his hands in delight. ‘And above all, it is a brilliant idea that explains how we see the motion of the celestial bodies because of our own rotation.’

Aryabhata bowed low with folded hands in great humility acknowledging the admiration expressed by Aristarchus.

‘Just as in your case, illustrious seeker of Truth from the West, no one cared for my novel idea,’ sighed Aryabhata. ‘Even some of the great scholars who came after me criticized me bitterly.’

‘Oh yes, my friend and brother, your people have given this world so much knowledge,’ continued Aryabhata. ‘So have we, we from the land of the sacred river *Ganga*, from times immemorial. Your Master, Pythagoras, offered so much learning. He unravelled the mysteries of numbers. It is well known through the ages that he discovered a most profound truth about certain type of *tricon*, the triangle. It does not diminish his greatness, if I were to state the fact that our people had known this truth termed as the *Pythagorean Theorem* earlier. Even before your Master graced our Earth, two of our own scholars, *Apastambha* and *Bhaudayana*, made use of the theorem repeatedly in their tract entitled *Sulvasutra*, or the *Rules of the String*, which was used in the construction of altars for our sacred rituals. Ah, then again, the numbers, those glorious entities that gods themselves love! Forget not, O scholar from the West, *we* were the ones who presented to the world of

learning the supreme concept of *shunya* or *zero* that wholly transformed the mode of counting.'

Aristarchus nodded, acknowledging this fact.

'Zero used to be represented by a *bindu*, a mere point. It used to get lost among other numbers. It so happens that I, the humblest among the humble, introduced the small circle as the symbol for zero,' added Aryabhata in a low voice with shy hesitancy.

'Your people I am told, O seeker of Truth, knew only the numbers up to ten thousand, one followed by four zeroes,' continued Aryabhata. 'On the other hand, our ancestors had envisaged numbers up to one followed by fifty-three zeroes, each of the important numbers among them bearing a particular name, which even the great Buddha, who had enlightened this world before your Master appeared on it, knew well. Only the invention of zero could have brought to fore such large numbers, all of which have yet to be used, but will be used one day, in the realm of the stars.'

Aryabhata paused before adding, 'And we did so much in developing other branches of mathematics, *rekhaganitha* or geometry and *beejaganitha* or algebra.

Aristarchus seemed to be quite impressed with Aryabhata's narration of the ancient Indian contributions and bowed his head honouring the greatness of all this achievement.

'Just as those who preceded me had discovered marvellous truths, so did many who came after me,' said Aryabhata. 'And those wonderful findings flowed westwards just as the sunlight, emanating first in the east, travels towards the west. But, you will agree with me, my friend, if I proclaim that light is light and it dispels darkness wherever it might have originated from, east or west.'

'I agree with you absolutely, my illustrious neighbour,' said a deep, resonant voice, again surprising me as well as the two astronomers engaged in their erudite dialogue.

The newcomer who had appeared on the scene was powerfully built like Aryabhata. But unlike the latter, he wore a loose white robe, a turban covering his head. His tanned skin was leathery having apparently withstood rough weather. He had a dark beard and his perfect white teeth flashed like lightning within a dark cloud whenever he spoke. The backdrop for him was a single tent in the midst of a desert, its golden sands stretching far and wide reaching the horizon in all directions.

'*Aghayoone Mohtaram*, O Revered Sirs, I too am a keen observer of the stars,' said the stranger bowing deeply. 'I am from Persia and my name is Omar Khayyam. Kindly call me Omar, which is quite endearing.'

No *AR* this time, I sighed. What a relief!

'Allow me to point out something you have inadvertently missed, my friend,' said Omar smiling at me with amusement. 'My name Omar ends with *AR*, does it not? In our country we read and write from right to left. So whereas the *AR* appears at the end of my name according to you, it is at the beginning by our convention. So, I too am an *AR* as every stargazer ought to be.'

All three of us, including the distinguished astronomers from ancient Greece and India, were delighted by this strange revelation.

‘As I was saying, my esteemed friends, knowledge flowed from Hindustan, or India as it is called nowadays, to the west by way of our country, or *Arabia* as our region is popularly known. Yes, it was just as in the case of silk and spices, but immeasurably more precious than all such commodities,’ said Omar. Looking straight at Aristarchus he added, ‘So much knowledge you and your brethren had gathered over the ages but, alas, to be ignored by many of your own countrymen who had no appreciation for it. On the other hand, we kept it safely with us, did we not? We translated it into our own language, enriched it, and then transmitted it back to the west when the time came.’

Aristarchus bowed, as before, in acknowledgement of this fact.

‘Yes, we preserved knowledge gathered from both east and west, like wine in their casks improving with age,’ remarked Omar. ‘But we added our own ingredients to improve it. Our people held the profession of stargazing in highest esteem. The greatest Arabian astronomer, Mohammad ibn Jābir ibn Sinān Abu-‘Abdallāh al-Battāni, or al-Battāni for short, declared that the science of the stars comes immediately after religion, as it is the noblest and the most perfect of all the sciences, adorning the mind and sharpening the intellect, and that it tends to recognize God’s oneness and the highest divine wisdom and power. We, the Arabs, charted the stars and followed the movements of the planets. We gave names to many of the stars in the sky, names that have remained in vogue even up to the modern times long after our own days.’

Omar Khayyam regarded meditatively the lone tent in the background planted in the endless desert sand, swaying in the wind. Once again, I was reminded of the breathtaking spectacle of the fiery deserts I had seen in my recent wanderings.

‘I was but a humble tent maker once. But then, I wanted to stitch the tent of science and turned my eyes towards the stars. As many of my brethren did, I too was deeply interested in the reckoning of time and worked on improving the methods of keeping count of the days and hours in a year. I drank deep from the wells of nature and was richly rewarded for it.’

‘Omar Khayyam is a modest man. In his time, he was hailed as the King of the Wise,’ proclaimed Aryabhata.

Omar Khayyam spoke again. ‘Amongst the many phenomena we studied, we the Arabs and our neighbours from Hindustan, eclipses were of paramount interest.’

‘Yes, we assiduously studied eclipses—those most fascinating celestial occurrences, which turn out to be the most frightening experience for some uninitiated people,’ concurred Aryabhata. ‘Every culture has some story, some myth that tries to explain the event. But we know the true cause of the eclipse, do we not? When the Earth’s shadow falls on the Moon, that celestial body is eclipsed, while the eclipse of the Sun occurs as a result of the Moon blocking its light from reaching the Earth.’

‘Myths, stories, they are interesting no doubt, perhaps even more than reality. But let us not forget poetry,’ mused Omar Khayyam as his eyes became distant and dreamy. ‘Ah, I came to be known to the world as a poet and not as one who pursued

the noble science of the stars. In my *Rubaiyat*, I sang of man and God, of fate and destiny, of learning and wisdom, and, above all, of wine, the symbol of love for the Divine. I did not write my science in poetry unlike my dear friend and esteemed neighbour here. But the poetry of the stars always filled my mind. After all, just as our friend from Hindustan described, there is sublime poetry written on the firmament by the stars and the planets.'

Oblivious of the presence of his listeners, Omar Khayyam recited to himself some lines he had improvised spontaneously.

*Ah, my love, raise your glass of wine
To capture the ruby-red shine
Of the Sun, turning into a dying ember
As darkness descends like peaceful slumber
Bonding forever your heart with mine.*

Then again, Omar Khayyam sang another verse he had composed perhaps inspired by this rare confluence of three different streams of ancient cultures. We listened in rapturous fascination.

*Here on the endless sands of time I lie
Watching the black velvet of the sky
Would I not give my entire soul
To gaze upon night's inverted bowl
As the celestial fireflies traverse by.*

A hush had fallen on us listeners as the soft sounds of Khayyam's recitation filled the space around us. Even the stars seemed to be listening in silence.

All of a sudden, seven men, who resembled Omar Khayyam in their features, appeared on the scene. Like Khayyam, they wore long robes and turbans, but of different colours and textures. While whirling vigorously, they started circling around Khayyam at different speeds. The one closest to Khayyam, the man who was smallest in size among them, wore a robe that glowed softly. He whirled and circled in such a way as to face Khayyam all the time. The second one's clothes were dazzlingly bright. Other robes were tinged with different colours. For instance, the dress of the last but one among the men, who was also the largest among them, was painted with bands of different colours. And the last one had a circular piece of cloth stitched to his waist that rose up and formed a ring when he spun around.

'They are holy men, *dervishes* as they are called,' explained Omar Khayyam. 'They represent the Moon, the Sun, and the other planets. They are from the future and, consequently, their robes indicate the aspects of the celestial bodies that were destined to be discovered much later than my own time.'

As I watched this fantastic spectacle, all the characters in front of me slowly receded, presumably towards their own countries, growing smaller and smaller in appearance and finally disappeared altogether.

I gazed at the stars and the star patterns. The planets that were travelling across the night sky were not aimless wanderers after all. Were they not moving in circles, the most perfect paths they could follow as Aristarchus had described?

I gazed at the stars with concentration and listened intently. Did I see the faint glimmer of those lovely crystal spheres? Did I hear the faint harmony wafting from them? I wondered.

‘It is all simply beautiful,’ I whispered to myself. ‘And beautifully simple too!’

The Luminous Loops

I heard the sound of someone clearing his throat and saying, ‘Pardon me. To tell you the truth, it is not really all that simple, I mean the motion of those crafty planets.’

The sound had preceded its source, which slowly materialized, namely another person with white beard who wore an orange striped robe and a red skull cap.

‘Ah, I happen to be in the same profession as Aristarchus, studying the stars I mean,’ announced the newcomer. ‘He lived some four hundred and odd years before me. I must tell you my name, must I not, before proceeding any further? It is Claudius Ptolemaeus, or Ptolemy of Alexandria as I am commonly known. As I was saying, the motion of the planets is not all that simple, as you have been led to believe. Watch!’

One of the planets that was moving smoothly seemed to hesitate, slow down, come to a momentary halt, proceed backwards, and then turn around, and finally move forward as before. Yes, it did move in a complicated manner making loops along its orbit. This was true of the other planets as well. I was really bewildered and shook my head in disbelief.

‘Oh, yes, it *is* baffling, I must say,’ admitted Ptolemy. ‘How does one explain this most peculiar behaviour of the planets, their *retrograde motion* as it is called? How does one reproduce their motion using purely circles? Why only circles? As Aristarchus told you, the venerable philosopher Plato had declared that all heavenly motions must be circular with constant speed. Why? Because, the circle is the perfect figure in geometry and therefore in nature. So then, the peculiar paths of the heavenly planets have to be mimicked by means of circles and nothing but circles. We have a down-to-earth problem on hand, do we not? That means we are obliged to go down to the Earth.’

Amusement Park

Slowly, gently, Ptolemy and I descended to the Earth. I could see beneath me a scene of confused activity, which became progressively clear as we approached the ground. There was a big crowd made up of many families. Parents were carrying

little children, while older ones ran around excitedly with their senior siblings laughing and chasing them.

‘Well, what do you know, we have landed in an amusement park,’ exclaimed Ptolemy. ‘It is wonderful to see so many happy people at one place, is it not?’

It was indeed a happy place with many events taking place all around us.

There was a little crowd gathered around a man in pink-striped clothes and a long cap. He was throwing three different coloured balls into the air continuously and catching them in turn.

Ah, that was the juggler, wonderfully skilful at his act.

‘Yes, indeed,’ agreed Ptolemy and added with a sly smile, ‘In our profession, some of us juggle facts to suit the hypothesis. Ah, are you confused? Forget what I said, it is of no importance.’

A young girl was selling colourful trinkets made of glass. As a child, I used to love such trinkets, especially the marbles like the ones she had. Although the marbles were perfectly spherical and smooth, one could see varying textures within them.

We heard squeals of laughter coming from an adjoining enclosure. There was a tightly stretched trampoline made of some highly elastic material on which some children were jumping up and down. Whenever they went up high enough they screamed and yelled with pleasure. In a corner sat a merry toddler in the middle of the dimple his weight had created in the trampoline. He would throw a ball making it roll down the dimple straight towards the centre. Or if the child flicked the ball side-wards, it would circle round first and then spiral down to the middle.

‘Look, look, there is the balloon man,’ Ptolemy pointed excitedly. The ancient Greek seemed to be enjoying himself amidst the modern amusements.

A few yards from the trampoline stood a man with a bag full of balloons with dots of many different colours printed on them. As he inflated the balloons, the coloured dots moved away from one another. It was a pretty sight.

There were many other interesting attractions. But, Ptolemy and I moved on. Looming before us was a huge, upright, slowly revolving wheel—the Ferris wheel. Seats were dangling all along its rim. Passengers in each seat, mostly a couple or two children, were safely strapped in. As the big wheel went up higher and higher, the children squealed with excitement.

‘Wonderful, we can now illustrate how the planets move along their paths in the sky,’ said Ptolemy rubbing his hands with glee. ‘Take for instance one of the points on the rim of the big wheel going round in a perfect circle. It is like one of the planets going round the Earth, Earth being thought of as located near the centre of the wheel. At least that is what one believed to begin with. Let us get an idea of how the planet might have felt moving in such a path. Let us get on to the wheel then.’

We jumped on to one of the seats at the ground level while the wheel turned. I had not taken a ride in an amusement park in ages. This was so exciting! Slowly, we rose. Up, up, and up we went towards the sky. ‘Wheeeee!’ shouted the children around us in exhilaration.

‘Smooth sailing, is it not?’ asked Ptolemy. ‘This is how a planet was supposed to be moving. But wait, let me show you how it actually travels in its loopy path.’

Till now, our seat had been just hanging down from the rim of the big wheel. Now all of a sudden, it started rotating fast around the pivot from which it was suspended. However, the pivot itself continued to revolve as before slowly with the big wheel.

‘Ooh, this is wild,’ I stifled a scream reliving my childhood experience—excited, frightened, and rapturous—all at the same time. ‘Everything has turned topsy, turvy now; ah, it is all right again; oh, no, upside-down again. . .’ I could not even look at Ptolemy who was also probably in the same state as I was for all I knew.

After a while, the seat stopped rotating and I heaved a sigh of relief. Is this how the planets felt while travelling around the Earth, I wondered.

‘Thanks to the heavenly decree, planets, being inanimate, do not feel anything,’ remarked Ptolemy. And then he added with a shrug, ‘Although some thinkers believed that they are in fact endowed with life.’

We got off our seats when we reached the ground, but the wheel moved on.

‘Now, let us see how the planet’s motion looks like to an observer on the Earth,’ said Ptolemy. Pointing at the top of the wheel, he added, ‘Concentrate on the blue light placed on the empty seat over there.’

As if by magic, a bright blue lamp had appeared on one of the seats that happened to be empty. At once, the arm by which the seat was hanging began rotating. To my amazement, the light seemed to be moving not in a perfect circle but in a path made up of loops just like the planet I had observed in the sky. In fact, I could see this clearly since a blue streak was being temporarily left behind in the lamp’s wake.

Fantastic, I thought.

‘Yes indeed,’ affirmed Ptolemy. ‘By adjusting the size and the speed of the big wheel, or the *deferent* as it is called, and that of the smaller circle, namely the *epicycle*, the motion of any of the planets can be reproduced.’

This was indeed an extraordinarily ingenious mechanism that had been invented to mimic planetary motion!

‘Now you know how the loopy paths of the planets can be recreated using epicycles,’ said Ptolemy. A smile of satisfaction spread over his face as he regarded the giant wheel turning in the background.

‘Well, my time has come,’ announced Ptolemy after a while. ‘I must bid you farewell, for you are destined to learn more about the planets and the stars. It will be a long journey, my friend, but believe me, an extraordinarily exciting one.’

Gradually, light faded and so did Ptolemy, smiling and waving goodbye. I was once again surrounded by countless stars glittering in the night sky.

I opened my eyes that were still heavy with the dreamy visions that I had seen. The bath water had become lukewarm. Most of the bubbles had evaporated too. The remaining ones disappeared as did the scintillating specks they harboured, just as stars melt away with the first light of dawn.

The whole experience, which I had not had in a long time, was inducing in me a feeling of intense exhilaration. But all good things have to come to an end, as the saying goes. Well, I slowly got up, dried myself, went to bed and soon fell into a dreamless sleep.

Chapter 3

The Founders and the Foundations

I was to meet George in his office. As always, it was a pleasure to walk across the university campus. The Sun was playing gently upon the trees and shrubs of the lovely little park where George and I had some wonderful moments discussing the works of great scientists like Isaac Newton a few years back. The central part of the campus, *The Quad*, was quiet with very few students hanging around, since most of them were attending their classes. In the evenings, this place would be transformed, buzzing with activities that ranged from throwing Frisbees to playing impromptu music and staging skits. I made my way to the old physics building where George has his office. I knocked on the heavy wooden door, turned the polished brass knob, and entered.

George's office had hardly changed since my last visit despite the passage of a few years in time. His huge ancient wooden desk where he worked, two chairs in front meant for visitors but piled up with journals, the adjoining table overflowing with typed and photocopied articles, notes and what not, mostly 'what not'—*organized disorder* as George called it—it was all there. As usual, some equations had been scribbled on the blackboard, but George was not staring at them. I remembered clearly, as if it were just yesterday, what George had told me about staring at equations: *You have to give the third degree to mathematical equations, you know. Stare long and hard at them. Sooner or later, they will break down and confess their secrets to you.* But now, George was seated at one of the comfortable chairs arranged around a small coffee table, which was always kept comparatively tidy. He seemed quite relaxed, thumbing through one of the massive volumes lying on the table. Next to those volumes was also the manuscript of George's book on the Universe. George motioned me to the chair next to his.

'How come you are not giving the third degree to the equations today?' I smiled shaking hands with George.

'Of course, I did, Alfie,' chuckled George. 'They have already confessed. That's why they look so subdued and sad.'

‘Let me tell you something, George. Maybe you know it already. Writers have attributed to the English philosopher Francis Bacon of the sixteenth and seventeenth century the idea of having Nature on the rack and torturing her to reveal her secrets.’

‘Aha, what do you know? Great minds run in the same channel!’

‘On the other hand, I heard an Indian scholar quoting from an ancient text of his country that Nature is like a shy maiden. If you try to look at her closely, she may hide and disappear altogether.’

‘That is lovely, Alfie,’ nodded George. ‘Profound and true in many ways too.’

‘All right, so much for philosophy,’ I said. ‘I wanted to say something about the manuscript of your book on the Universe. No attempt at flattery, George, but it is enormously interesting. I just finished reading about the constellations, and the ancient astronomers both from the east and the west. Engrossing! I wish you had written more about those times, it is all so interesting.’

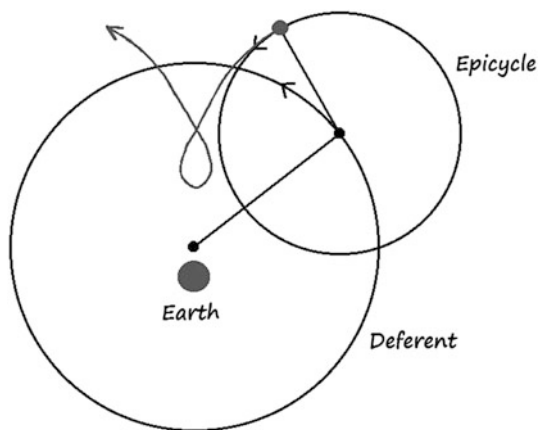
‘Well, when you have to compress the history of the Universe spanning some thirteen billion years into a mere two hundred and odd pages, you have to economize on the contents, Alfie. So, we have to move on to the next era.’

George indicated the volumes lying on the table. He held out the one he had been leafing through with obvious reverence. It bore the title *De revolutionibus celestium orbium*.

‘Here is the book that changed man’s worldview completely,’ announced George. ‘If I remember right, we had discussed the Copernican revolution in some detail long ago when we talked about black holes, hadn’t we Alfie?’

‘Right you are,’ I acknowledged.

‘Before Copernicus appeared on the scene, perhaps the last word regarding the geocentric model of the solar system had been written by Ptolemy. He described his epicycles in his book *Almagest*. Ingenious explanation for retrograde motion of the planets, but much too complicated. You must have read it all in the manuscript I gave you. Here is the relevant drawing anyway.’



‘Yes, indeed,’ I said. I almost told him how exciting it was actually to visualize the epicycles through the Ferris wheel in the amusement park. That too guided by Ptolemy no less, who had invented the epicycles. Luckily I checked myself in time. Nevertheless, I explained to George how the Ferris wheel could reproduce the retrograde motion of planets.

‘That is absolutely fantastic, Alfie,’ George was quite impressed. ‘I must include this analogy in the manuscript. Did you make it up?’

‘Well, I wish I had thought of it, George,’ I admitted. ‘You can find it in Arthur Koestler’s book, *Sleepwalkers*.’

‘Long ago, I told you about the remark that had been made by my illustrious namesake, who was probably my ancestor too,’ I reminded George.

‘Your illustrious namesake and ancestor? Who was that?’ George was puzzled.

‘You know that my name Alfie stands for Alfonso L. Sabio. My illustrious namesake was Alfonso el Sabio, Alfonso the Wise, the thirteenth-century King of Castile and Leon in Spain. When he was shown Ptolemy’s complex model of the planetary system replete with epicycles and all, he had commented: *Had I been present at the Creation, I would have recommended something simpler to the Lord Almighty!*’

George laughed long and loud. ‘King Alfonso was immensely wise and perfectly right, although I very much doubt that he was your ancestor. Probably, Lord Almighty read his mind and must have said: *Let Copernicus be, and all was light!* The Sun at the centre illuminated all the planets.’

‘At the same time, Copernicus had achieved great simplicity, hadn’t he?’ I added. ‘I always remember the beautiful saying in Latin. *Simplex sigillum veri*: The simple is the seal of the true; *Pulchritudo splendor veritatis*: Beauty is the splendour of truth.’

‘Oh, yes, that is what Copernicus had discovered. Simplicity, beauty, and truth. Let me say a few words about Copernicus and his *De Revolutionibus*, which is considered to be one of the most unreadable books of all time. You can read the details in the manuscript I have given you.’

I noticed something very characteristic of George. He would never say, *my book on the Universe*, but only *the manuscript I have given you*. It was not false modesty, but genuine lack of pride and possessiveness.

‘As you know, Copernicus belonged to the Church, he held the position of a Canon with quite a bit of administrative duties,’ George went on. ‘During his education at Padua, Bologna, and Ferrara, he had studied a number of subjects including astronomy, medicine, and law.’

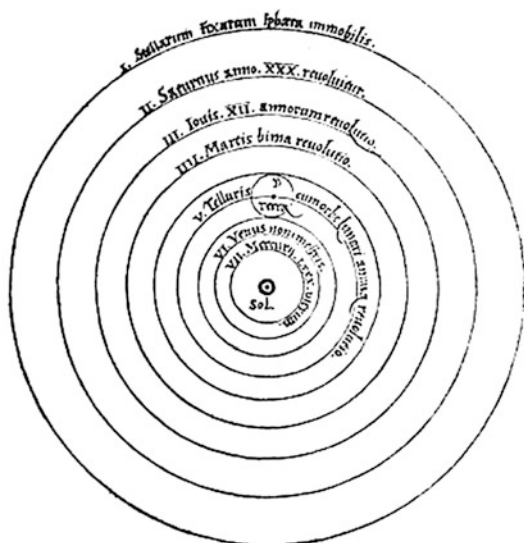
‘Oh, Padua,’ I recalled. ‘You know, George, I visited that lovely city during my wanderings. The Senate Hall of the University is a veritable place of intellectual pilgrimage. They have covered the walls with plaques bearing the names of the distinguished scholars who had studied at the University: Copernicus, William Harvey, who discovered blood-circulation, so on and so forth. Also, they have preserved the podium from which Galileo gave his lectures.’

‘Please Alfie, stop making me jealous of you, telling me all these fantastic adventures of yours,’ remonstrated George. ‘Well, coming back to Copernicus, he

had to do quite a bit of administration as the Canon at the Cathedral in the city of Frauenburg or Frombork, its original Polish name. He had to manage finances, which he wrote about. In addition, he had to take care of the protection of the city from the marauding bands of Teutonic Knights, a rapacious and unruly bunch. Isolating himself in the tower adjoining the Cathedral, he worked away on his astronomical observations using the instruments of his own make. And, of course, he formulated his heliocentric model.’

NICOLAI COPERNICI

net, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quinto loco Venus nono mense reducitur. Sextum deniq; locum Mercurius tenet, octuaginta dierum spacio circū currens, in medio uero omnium residet Sol. Quis enim in hoc



pulcherrimo templo lampadem hanc in alio uel meliori loco poneret, quàm unde totum simul possit illuminare: Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegistus uisibilem Deum, Sophoclis Electra intuentē omnia. Ita profecto tanquam in folio re gali Sol residens circum agentem gubernat Astrorum familiam. Tellus quoq; minime fraudatur lunari ministerio, sed ut Aristoteles de animalibus ait, maximā Luna cū terra cognationē habet. Concipit interea à Sole terra, & impregnatur annuo partu. Inuenimus igitur sub hac

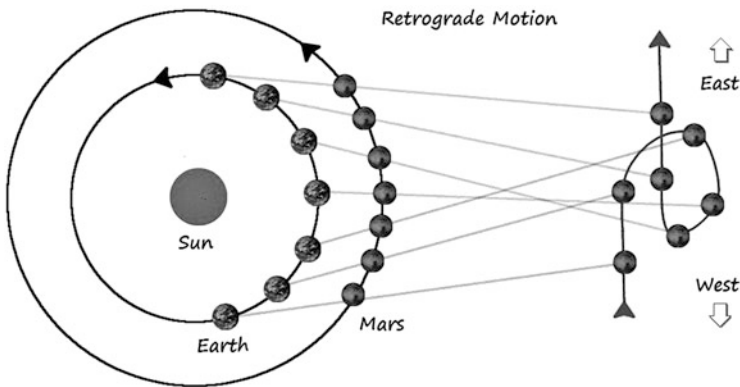
‘Well, we know that Ptolemy invented his ingenious epicycles to account for the apparent retrograde motions of the planets. How did the heliocentric model solve that problem?’

‘Ah, that is simplicity itself. Let me explain. Consider the Earth and the planet Mars, for instance. Being farther away from the Sun, Mars revolves at a slower speed than the Earth. As I move along sitting on the Earth, I do not feel my own motion, do I? Let us say that at some point of time I see Mars ahead of me. As I

overtake that planet, I find that it is now following me. This is possible only if that planet turned round from being in front of me and went behind me, reversing its motion. A leader has now become a follower! Obviously, the planet must have followed a loop in its course. Of course, this is all apparent motion. The number of loops contained in the orbit of a planet depends on the speed of the planet relative to the Earth. Absolutely simple, isn't it?"

I fully agreed. 'Even in politics, one has to make a u-turn to change from being a leader to becoming a follower and *vice versa*,' I added.

'Indeed, but fortunately planets don't have any political ambitions,' laughed George. 'Well, you can convince yourself that what I told you is true in the case of the inner planets too, Mercury and Venus, which revolve faster than the Earth. Let me show you the diagram that illustrates retrograde motion of a planet as seen from the Earth. It is within the frame work of the heliocentric model.'



George contemplated the tome in front of him, *De Revolutionibus*.

'After all these centuries since Copernicus, we take his heliocentric model for granted. We are so used to it,' reflected George. 'But tell me, do we really see or feel the Earth and the planets going around the Sun? To give up the age old, universally accepted geocentric model takes courage. To think of the ponderous Earth spinning and moving around the Sun takes imagination. It was a phenomenal leap from appearance to reality!'

'Yes, that reminds me of how Galileo described it in his book, *Dialogues on the Two Chief World Systems, Ptolemaic and Copernican*. Salviati, one of the three characters engaged in the dialogues, who represents Galileo, says,

There is no limit to my astonishment when I reflect that Aristarchus and Copernicus were able to make reason conquer sense, that in defiance to the latter, the former became the mistress of their belief.'

'Beautiful, Alfie, simply beautiful,' said George with feeling. 'Let me quote for you another wonderful passage from one of the most distinguished astronomers of our own times, Sir Fred Hoyle, from his essay on the life and work of Copernicus.'

George read out from his manuscript.

‘...*The rest of the story is quickly told. The book appeared in March 1543, but a copy did not reach Copernicus until May. He was then on his deathbed, and his actual death occurred within hours of the book’s arrival.*

To the citizens of Frauenberg it must have seemed as if an infirm old man of some past distinction had passed from their midst. They were not to know that drums were already rolling with the noise of distant thunder. His fellow-canons, as they laid him in his grave, were not to know that Copernicus had detonated an overwhelming explosion of human knowledge, an explosion still with us in our own day, and whose eventual outcome we cannot yet foresee.’

It was indeed a profound and lyrical tribute to Copernicus, quite moving at the same time. ‘George, what does Hoyle mean by his statement, *an explosion still with us in our own day, and whose eventual outcome we cannot yet foresee?*’ I enquired.

‘Alfie, Copernicus had shown that the Earth is not special within the solar system, hadn’t he? As we shall see, our solar system is nothing exceptional within the Milky Way. Then again, our Milky Way is just an ordinary member belonging to the realm of the galaxies. And all galaxies are equal. This is known as the *Copernican Principle* based on which cosmological models are built. On the other hand, we have seen only a part of the Universe as it has been in the past. Is this Principle then really valid all over space and at all times? We do not know. And that is the *eventual outcome we cannot yet foresee.*’

As it happens often enough, George sat back and closed his eyes. Perhaps he was far away in the past or far away in the future. I waited patiently, as before, for him to return to the present.

‘We meet Kepler then,’ said George opening his eyes slowly. ‘You know, while Copernicus actually became a Canon in the Church, Kepler too wanted to study theology and become a Lutheran minister. But because of his limited financial means, he was forced to learn and teach astronomy for a living. Then he switched to astronomy altogether. Religion’s loss was astronomy’s gain. And what a gain!’

‘Well, I have read Kepler’s life in some detail,’ I said. ‘Such a dismal beginning to such a magnificent career! Abject poverty, a big family run by an uncaring mother who was often absent from home chasing a drunken mercenary of a husband who beat her on the rare occasions he visited the family. Then again, Kepler was an unimaginable hypochondriac who suffered from all sorts of maladies—both real and imagined. Poor man, it seems he tried everything he could think of to cure himself. That is not all. He was a perpetual exile, moving from place to place, holding petty jobs that paid pittance.’

‘Amidst all this, the man goes ahead and discovers his celebrated three laws of planetary motion,’ remarked George. ‘It was a tremendous job, beginning with the accurate observations of Tycho Brahe, his master. Well, Brahe is considered to be one of the greatest observational astronomers of all time. He made extremely accurate and meticulous recordings of the sky. Also, Tycho recorded the occurrence of a *nova*, appearance of a new star—actually the flaring up of a star—in the constellation Cassiopeia. So, the celestial realm was not immutable after all as Aristotle had proclaimed. By the way, the *nova* was actually a *supernova*, the

stupendous explosion of a star, the remnant of which has been named *Cas A*. We shall talk about supernovae when we come to the stars and their evolution.'

'Oh yes, you had told me about Tycho's *nova* and the remnant *Cas A*.' I couldn't help smiling to myself as I remembered my bathtub experience after discussing these matters once upon a time.

'Why are you smiling so mysteriously like that, Alfie?' George was puzzled and maybe a bit annoyed. 'I often suspect you are leading a secret life on the side and hiding something from me, you know. All right, let us pursue Kepler further. Kepler had to sift through Tycho's detailed and complex data, fit them into a theoretical model, trace the orbit of the planet Mars, and finally generalize his findings into his three laws. An account of this arduous task has been given with great appreciation by—guess who—none other than Albert Einstein himself in his collection of essays, *Ideas and Opinions*. We shall come back to it later.'

'I never realized that Kepler's laws involved so much hard work, George,' I admitted.

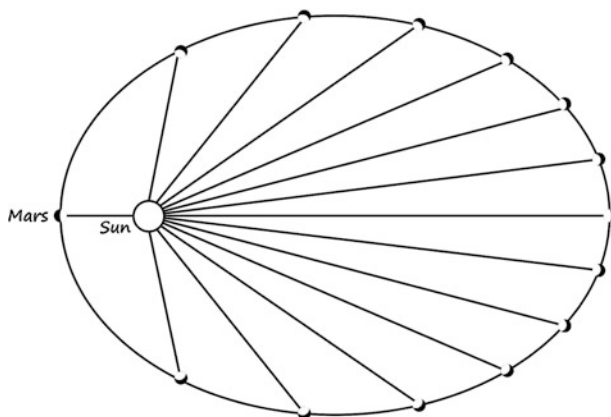
'Well, it did. First of all, Kepler found out that the planetary orbits were ellipses, not circles. I guess you know your ellipse well enough.'

'Let us see. It is like an elongated circle with two foci instead of a single centre. Draw a straight line from one of the foci to any point on the periphery of the ellipse. Then connect that point to the other focus by another straight line. The total length of these straight line segments remains a constant. In fact, that is how one can draw the ellipse in the first place. On a sheet of paper, stick in two pins to mark the foci. Place a loop of string around them. If you keep the string taut with a pencil and draw, what you get is an ellipse. Now. . .'

'Enough,' George held up his hand. 'I am convinced that you know enough of an ellipse. With his first law that made the planetary orbit an ellipse with the Sun placed at one of the foci, Kepler had removed the epicycles even Copernicus had to use in his model.'

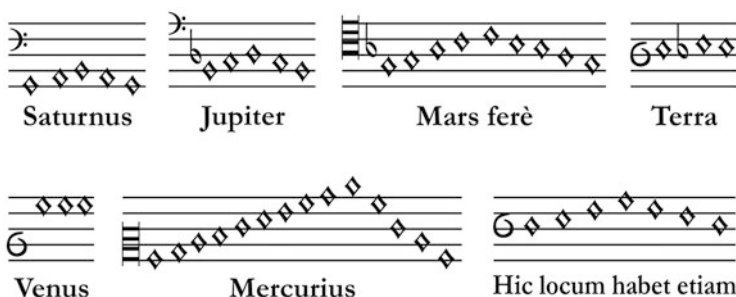
'I thought those little wheels on wheels of Ptolemy had been banished by Copernicus.'

'No, Alfie, they had remained as vestiges of the Platonic ideal of having only circles as the perfect paths of the planets going round at constant speeds. Of course, the orbit can be a circle in some special case when the two foci coincide. Now, the second law tells you that the area swept in equal time intervals by a straight line joining the Sun at the focus to the planet moving along the ellipse is the same. As you can easily see that this dictates the varying speed of the planet as it goes around the Sun: fastest near the *perihelion* or the point closest to the Sun and slowest at the farthest point or the *aphelion*. Got it?'



‘Got it,’ I affirmed obediently.

‘Kepler set down all his findings in his book, *Astronomia Nova*. Now for his third law, the law that relates the period of the planet to its distance from the Sun,’ announced George. ‘Let me make it precise. You know what the *period* is: it is the time taken by the planet to make one complete revolution around the Sun. Now, the largest diameter of the elliptical orbit is called the *major axis* and half of that the *semimajor axis*. Actually, this is the average distance of the planet from the Sun. It is also half the length of the string you used in drawing the ellipse in the first place. Now, Kepler’s third law states that the square of the period is proportional to the cube of the semimajor axis. Simple, isn’t it? The larger the orbit, the longer the period or slower the planetary motion. Do you know how Kepler arrived at his third law? Kepler firmly believed in the celestial harmony of planetary motion. He tried to assign a different musical note to each of the planetary orbits. In this process he arrived at his third law. Kepler wrote another book *Harmonices Mundi* or *The Harmony of the Worlds* in which he recorded his new discovery along with the musical notes.’



‘Well, well, well, what do you know,’ I exclaimed. ‘Pythagoras and Aristotle were right after all. The music of the spheres does exist! Anyway, Kepler had indirectly proved the heliocentric model with all this, hadn’t he?’

‘True, but there is more to it than that,’ said George. ‘Think, three laws, just three of them, govern the motion of the planets, comets, Moons—our own as well as those of other planets—and man-made satellites. Until Kepler came upon the scene, only measurements had been made and models had been built to account for the planetary motions. But now, mathematical laws had been introduced for the first time. The age of general laws describing nature had dawned. Isn’t that great? And it was Kepler who had taken the first step in that direction. As a matter of fact, Immanuel Kant, the philosopher, hailed Kepler as *the most acute thinker ever born!* Well, we shall return to Kant later on when we talk about the galaxies. Finally, let me quote the last statement of Einstein from his essay on Kepler that I mentioned earlier: *Kepler’s marvellous achievement is a particularly fine example of the truth that knowledge cannot spring from experience alone but only from the comparison of the inventions of the intellect with observed facts.* Ah, that is the ultimate harmony: blending together of experience, observation, knowledge, and intellect—the very foundation of science.’

After a long pause, George took a deep breath. ‘Are you ready? We are now going to meet that fantastic man, the great scientist, Galileo Galilei!’

‘Not just a great scientist, George, but an accomplished musician, a fine writer, and a gifted artist,’ I added.

‘He was all that?’ George seemed to be surprised. ‘I only know his magnificent scientific accomplishments.’

‘Well, his father Vincenzo was a musician. Not only did Galileo learn music from his father, but he is supposed to have excelled him, especially in playing the harpsichord,’ I elaborated. ‘Then again, his writings are testimony to the elegance of his style, composition, and eloquence. I have read that his work, in terms of richness of human content and power of style, set an example showing the path for future Italian prose. And only an artist of high calibre could have made the sketches of astronomical objects as he did. Don’t you agree that his drawing of the Moon is so realistic that it rivals the modern photographs?’

‘Maybe I should read more about Galileo,’ said George. ‘But for the moment, let me just enumerate his profound discoveries. Incidentally, we discussed these things when we were talking about black holes, didn’t we? But, it doesn’t hurt to recapitulate. First of all, he was a staunch adherent of the ideas put forward by Copernicus. Galileo’s findings went a long way in supporting the heliocentric model, you know. His little telescope did wonders. With it he could open up whole new vistas into the celestial realm. He showed that there were mountains on the Moon. Amazingly enough, he estimated their heights by his ingenious method. He observed the spots on the Sun and showed that their motion revealed Sun’s rotation. Simply incredible!’

‘So, there was nothing heavenly about the Sun and the Moon, they were just ordinary denizens of the sky like our own Earth,’ I remarked.

‘You are right,’ George gave a slight nod. ‘And Galileo’s discovery of the four Moons of Jupiter! That was an extremely important step to show that the Earth was not the only centre of revolution as those who held on to the geocentric model

believed, Alfie. All celestial bodies were similar in nature, there was nothing special about the Earth. Then, why shouldn't the Earth itself be going around the Sun? In short, all this work of Galileo did so much to firm up the foundations of the Copernican model. Not only that! He pioneered the method of combining experiment and observation with theoretical explanation. No wonder then that Einstein hailed him as the father of modern science.'

'So, with the heliocentric model firmly established, man lost his central position in the cosmos,' I added.

'Oh, yes, as the Earth moved, the crystal spheres holding the planets were shattered as well as the *primum mobile* that was host to the stars. The *Empyrean*, the abode of gods or God beyond the *primum mobile*, too vanished.'

'Is it surprising then that the Church frowned upon Copernicus and felt that Galileo's *Dialogues* was sacrilegious—worse still, dangerous! Perhaps, they found it absolutely necessary to bring him to trial. And make him recant under the threat of torture for their own safety,' I observed. 'Galileo spent his last days practically under house arrest. It was so tragic!'

'Yet, despite his growing blindness, he managed to write his pioneering work *Discourses Concerning Two New Sciences* that embodied his experiments performed over more than three decades,' George pointed out.

'Ah, many of those experiments were carried out using his inclined planes, weren't they, George?'

'Oh yes, as I tell my students, those inclined planes diluted gravity allowing Galileo to carry out his experiments with ease.'

George regarded me with a smile.

'I clearly remembered what you had told me during our discussions of years ago like the one we are having now, Alfie. I have included it in the manuscript and your name will appear in the acknowledgement for that as well as for so many other things you have told me.'

'What are you referring to, George?' I was curious to know what he had in mind. At the same time, I was touched by his comment about my conveying some facts to him.

'The lovely and profound quotation from the French philosopher, Henri Bergson: *Newtonian physics descended from heaven to Earth along the inclined plane of Galileo!*'

After a momentary pause, George announced as he always does when opening a new chapter, 'That means we are ready for Sir Isaac Newton!'

George rose from his chair. 'We need some additional energy to tackle that colossus, don't we? Well, down the corridor they have installed a new coffee machine. Not bad at all, you can even get a nice cup of cappuccino. And you can pick up some good cookies from another vending machine too.'

After we returned from our energising expedition, we sat back to talk about Newton's monumental work.

‘Alfie, I am sure you remember the famous saying of Isaac Newton’s about the seashore,’ began George.

‘Of course, George, I know the exact words of that quotation,’ I replied and repeated those words. ‘*I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore, and diverting myself now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.*’

‘Exactly! I have always envied your photographic memory, Alfie,’ acknowledged George. ‘But to us, ordinary mortals, Newton’s work itself seems like an ocean. How can we measure its extent with our little teacups or fathom its depth with our puny rulers? Well, for the moment, let me just summarize Newton’s unparalleled achievements focusing especially on gravitation.’

I nodded and waited in anticipation.

‘Let me just go over some of the pioneering discoveries Newton made,’ continued George. ‘You know that the University of Cambridge was closed because of plague for two years.’

‘Of course, I do,’ I replied and repeated the well-known fact. ‘It was during the years 1665 and 1666, *anni mirabilis*, miracle years of Isaac Newton.’

‘You are right,’ acknowledged George. ‘In those two years, Newton established firmly the foundations of mechanics, optics, calculus—or fluxions in his terminology—and the crowning glory—gravitation. He compared the fall of the apple, the acceleration due to gravity on the Earth that is, with the orbital acceleration of the Moon going round our planet Earth. Both of them were produced by the gravitational force exerted by the Earth, weren’t they? Newton realized that if the gravitational pull was assumed to decrease inversely as the square of the distance from the centre of the Earth, these two accelerations could be explained simultaneously.’

‘Ah, the apple and the Moon together gave birth to gravitation!’ I remarked.

‘Now, he generalized it: The gravitational pull between any two objects was proportional to the product of the masses of those two bodies and decreased inversely proportional to the square of the distance between them, the *inverse square law of gravitation*. That was a stroke of genius. And the age of Universal Laws that were valid everywhere and at all times had dawned. A simple formula describing the gravitational force, Alfie, but it contained within it the entire solar system. Newton could now explain not only the fabulous observations of Galileo, but also account for Kepler’s glorious laws of planetary motion. It was now clear why the Moon, the planets, and the comets moved the way they did.’

George took a deep breath.

‘That was not all. Our Earth spins like a top, doesn’t it? But a top does not always spin with its axis fixed in one direction, does it?’

‘No, sir, the top not only spins about an axis, but the axis itself goes round in a circle.’

‘In other words, the top undergoes *precession*, and so does the Earth,’ George said. ‘So, the Earth’s axis goes round a circle.’

I thought about George’s statement for a moment.

‘That means *Polaris*, the Pole Star, won’t remain fixed at one place on the celestial sphere then, since it does not exactly coincide with the pole.’ This was news to me.

‘Right you are. The period of precession of Earth’s axis is some twenty-six thousand years. Even the ancient Greeks knew this. Sorry, Alfie, you are far behind them. In any case, no one knew why this happened. But now, Newton could explain this precession on the basis of the gravitational attraction of the Sun and the Moon on our Earth.’

‘Ah, the Greeks, I don’t mind following them, but I am not sure I can follow Newton’s mathematical explanations,’ I responded.

‘Well, I don’t think there are many who are able to do that, experts included,’ assured George. ‘Well, let us move on. Newton turned his attention to the shape of the Earth. Gravity pulls the material contents of the Earth inwards. On the other hand, the effect of its rotation is to throw the material outwards. This effect is zero at the poles and is maximum at the equator. So, what is the net result?’

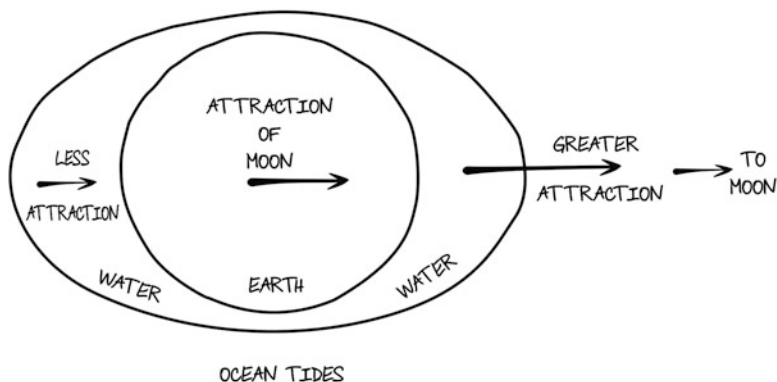
‘The Earth, like some people, develops an equatorial bulge,’ I grinned, glancing at George’s incipient paunch.

‘Alfie, you don’t have to rub it in,’ George wagged an admonishing finger with mock seriousness. ‘Like gravity, I do try to pull my tummy in. But the bulge is not due to rotation, it is because of good food, as you know very well. Oh well, coming down to Earth, it has the shape of an oblate spheroid. Newton could derive the ratio of the distance from the centre to the pole and the equatorial radius, which agreed with observation.’

‘What next?’ My question was not an expression of impatience, rather it stemmed out of curiosity. And George knew it.

‘And, to top it all, Newton could clear the mystery that surrounded the occurrence of tides. The true cause underlying it had eluded even Galileo. He had offered a clever but erroneous explanation of the phenomenon, you know. According to him, high tide occurred when the direction of Earth’s rotation was along its orbital motion and, conversely, low tide happened when the two directions were opposite to each other. That meant that each of the two tides appeared only once in twenty-four hours. What an irony, Alfie! Galileo must have known this was not true at all. After all, he must have witnessed tides all the time in Venice. Maybe, sometimes cleverness triumphs over correctness! Newton showed that the tides were caused by the differential attraction experienced by the ocean as it is attracted by the Moon. Let me explain this in a little more detail. On the side facing the Moon, the water bulges out since the gravitational pull is higher nearer to the Moon than at the surface of the Earth. On the opposite side, there is again a bulge. The water tries to move away as the force of gravity is less on the outer regions than near the Earth. So, Alfie, we have now two bulges in the ocean, one facing the Moon and the other on the opposite side of the Earth. At these two regions where there is a bulge, there

is high tide. In between, low tide occurs. As the Earth turns, those areas on the ocean facing the Moon or situated on the opposite side experience a high tide. As those areas move away, they will have a low tide. The end result is that each of the two tides—high and low—occurs twice in twenty-four hours. As before, Newton was the first one to explain all this on the basis of his law of gravitation.’



George paused dramatically before announcing, ‘All this and much more were immortalised in the form of the greatest book of science ever written.’

George held up for a moment another large book lying on the table as though it were sacred scripture before handing it over to me. I too opened it with reverence and looked at the title: *Philosophiae Naturalis Principia Mathematica*, Mathematical Principles of Natural Philosophy or simply the *Principia*. As I turned the pages quickly, I could see the formidable contents, both the written material and the accompanying complicated diagrams.

‘The three books of the *Principia* are the treasure trove of Nature!’ proclaimed George. ‘The first book deals with motion and gravitation—all occurring in empty space. The second book considers these motions in a resisting medium such as air or water. And now, look at the title of the third book.’

I could see the title of the third book printed in large letters, *System of the World!*

‘It is not an empty boast, Alfie,’ remarked George. ‘The contents of the third book more than justify the title. Newton incorporates into the body of his *System of the World* practically everything he had discovered in the realm of mechanics and gravitation. That amounts to everything that was known in his day about heaven and Earth. What more is there to say?’

We both sat in comfortable silence for a while relishing our discussion of Newton’s unprecedented accomplishments revealing the workings of Nature. If I thought that it was the end of the matter, I was mistaken.

‘You know, Alfie, one of the fantastic applications of Newtonian physics in the planetary realm happened to take place long after his death,’ George picked up the thread of his thoughts. ‘This was the discovery of the planet Neptune. Earlier, the German-English astronomer, William Herschel, had discovered the planet Uranus in the late eighteenth century. We shall be talking about Herschel, his discovery of

Uranus, and his two amazing relatives—his sister Caroline and son John—when we reach the Milky Way in our discussions. Eventually, the orbit of Uranus was calculated on the basis of detailed observations, taking into account the gravitational pull exerted on it by Jupiter and Saturn. Still, the observed orbit differed from the predicted one slightly. What transpired thereafter is quite tortuous, but interesting. You could read it all in the manuscript, Alfie. Two mathematicians, John Couch Adams in England and Urbain Jean Joseph Le Verrier in France, predicted independently the existence of a planet hitherto unobserved, responsible for the orbital vagaries of Uranus. Furthermore, they pin-pointed its exact position, enabling the astronomers to observe it. And, lo and behold, there it was, the blue planet Neptune, the god of the seas. In all this, let us not forget that it was a triumph for Newton’s laws of motion and gravitation. Those four laws had formed the foundation for the detailed computations.’

George completed the list of the planets. ‘After Neptune, the last of the planets, Pluto, was discovered. Now, they have relegated its position to that of a *Dwarf Planet*.’

‘Why is that, George?’ I knew about Pluto becoming a Dwarf Planet, but not the exact reason for this actions of the astronomers.

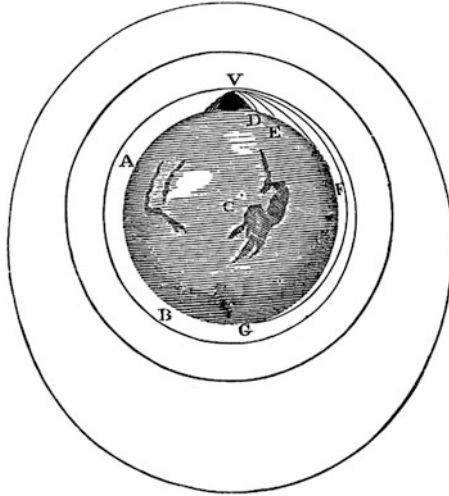
‘Well, there are a couple of logical reasons for that,’ explained George. ‘All the other planets from Mercury to Neptune have their orbits more or less in a plane around the Sun. The theory is that they all evolved from a flat rotating gas cloud. The central region condensed to become the Sun. The outer part first broke into rings, which in turn shrank, and the rings were transformed into the planets. On the contrary, Pluto’s orbit around the Sun is not at all confined to the plane of the other orbits. That celestial object seems to have been captured into the solar system from outside. Recently, more such small celestial objects beyond Pluto have been discovered once again with orbits like Pluto’s. And for all you know, more and more of those will be detected. So, for these reasons Pluto and the other similar members of the solar system have been christened the Dwarf Planets.’

‘In a way, all this belongs to the continuation of the past history of the planets,’ observed George before posing the question, ‘Coming back to Newton, where does he stand in our modern times?’

‘I know, I know, Newton is very much with us in our classrooms,’ I replied.

‘Confined to our classrooms? You must be joking, Alfie,’ protested George. ‘What about our present-day space age? Every other day, satellites are sent up to orbit the Earth, aren’t they? How is this done? Newton tells you how. Take a look at this diagram from *System of the World* of the *Principia*.’

George opened to a particular page he had marked with a flag and showed me a picture.



‘Let me read the relevant parts of the text for you,’ said George. ‘Here we go: . . .VD, VE, VF the curved lines which a body would describe, if projected in an horizontal direction from the top of an high mountain successively with more and more velocity; the body projected with a less velocity describes the lesser arc, and with greater velocity the greater arc, and augmenting the velocity, it goes farther and farther; if the velocity was still more and more augmented, it would reach at last quite beyond the circumference of the Earth, and return to the mountain from which it was projected. . . its velocity, when it returns to the mountain, will be no less than when it was at first; and, retaining the same velocity, it will describe the same curve over and over.’

George looked up to make sure I was paying attention to his reading. And I was hanging on every word of his.

‘Here is more,’ continued George. ‘But if we imagine bodies to be projected in the directions of lines parallel to the horizon from greater heights, those bodies, according to their different velocity, and the different force of gravity in different heights, will describe arcs either concentric with the Earth, or variously eccentric, and go on revolving through the heavens in those orbits just as the planets do in their orbits. There, Newton has launched an artificial satellite around the Earth or, for that matter, around any other planet!’

I sat silent, simply amazed at what I had just heard.

‘Does Newton physics end there, Alfie? No way!’ George was quite animated. ‘What about the paths of the rockets that are launched? What about the orbits of the spacecraft that are being sent routinely to the Moon and even to the other planets? All these require extraordinarily complicated calculations done on sophisticated computers. But what underlies all this? Three laws of motion and one law of gravitation! Can you beat that? Yes, yes, yes, Newton lives on!’

With that, George closed the *Principia* ever so gently as though it was a sensitive, living organism.

I realized that George was quite exhausted with all the explanations he had been giving and with his own emotional involvement with the subject. That was obvious. So, I took over to give him some respite.

‘Newton was a strange and complex personality, wasn’t he, George?’ I commented. ‘He was a highly religious person and left behind a large body of religious writings. Then again, after his career as a scientist, he became the Master of the Mint and brought about some important reforms in coinage. Furthermore, he dabbled in alchemy quite a bit trying to find the Philosophers Stone that could transmute base metals into gold, didn’t he?’

‘Yes indeed, but he didn’t have to. He had dug up immeasurable quantities of gold from the depths of Nature as no one had done before,’ reflected George.

‘One last thing before we close our session,’ continued George. ‘Let me read a quotation from the manuscript telling us what Einstein, the only scientist who stands alongside Newton, had to say about the latter: *Nature was to him an open book, whose letters he could read without effort. The conceptions which he used to reduce the material of experience to order seemed to flow spontaneously from experience itself, from the beautiful experiments which he ranged in order like playthings and describes with an affectionate wealth of detail. In one person, he combined the experimenter, the theorist, the mechanic and, not least, the artist in exposition. He stands before us strong, certain, and alone; his joy in creation and his minute precision are evident in every word and every figure.*’

That was indeed an unparalleled compliment paid by one great scientist to another one of the past. Both George and I sat in silence. I was sure that he was thinking about those two remarkable men, as I did. After a moment or two, George spoke up.

‘You know, Alfie, we spent a lot of time today talking about what seems to be ancient history. But, believe me, those were the days when the very foundations of modern science were being laid. Without those firm foundations, how could we have ever built the superstructures of astronomy and cosmology? Take Tycho Brahe for instance. He made his extraordinarily accurate observations without any optical aids. That accuracy is what we aim for even today—the limits of exact data for building up correct models. Only because of Tycho’s exceptionally accurate observations, Kepler was able to hit upon his elliptical orbit for Mars, a radical departure from the circular ideal. What about Galileo? He not only opened up uncharted vistas in astronomy with his little telescope, but combined observation with theory, a blend that is the very basis of modern science. Of course, beneath it all was the revolutionary leap Copernicus had taken from appearance to reality, the unprecedented event in human history. And, finally, Newton! The age of Universal Laws had dawned with him. Yes, Alfie, whatever we are going to say about the Universe, we have to first understand and remember whatever those fabulous founders had achieved.’

There was no need for me to say anything. George knew that I could grasp the importance of the work of the pioneers in the exploration of the cosmos.

George rose and stretched. I too got up.

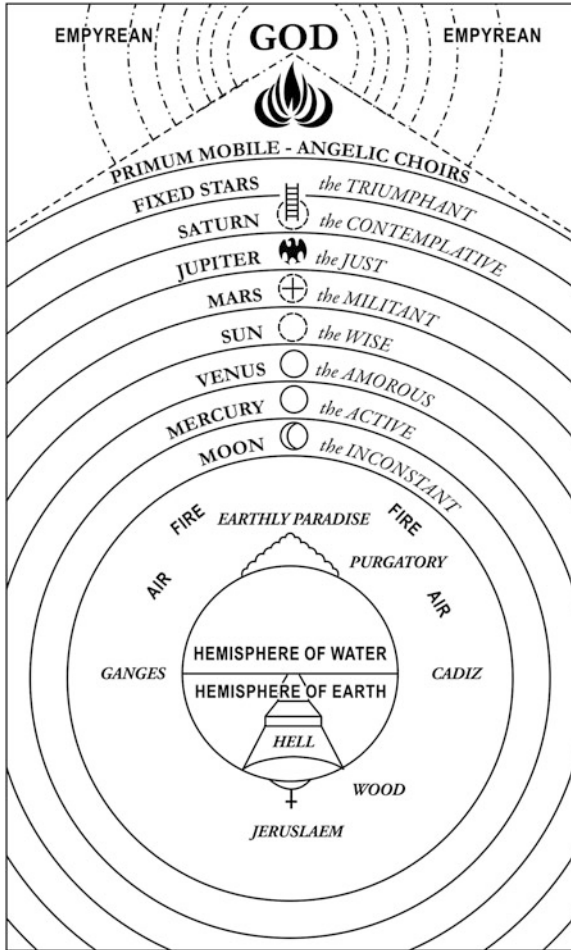
‘It has been a long day, Alfie, but wonderful as always. We shall meet soon. Until then, take care, my friend.’

I strolled slowly across the university campus enjoying the serenity of that place of learning. As I reached home, I could feel the after-effect of my inspiring discussions with George that lingered on.

Chapter 4

Casanova Calls

When I returned home after meeting George, I opened his book on the Universe. This appears to have become a compulsive but most enjoyable habit of mine. I wanted to read up whatever we had discussed: essentially about the foundations that had been laid by those great men of science, namely Copernicus, the duo Tycho Brahe and Kepler, Galileo, and finally Isaac Newton. I vividly recalled the words George had spoken about them in his animated way towards the end of our discussion. I vaguely remembered an old Chinese saying that went something like this: *You hear and learn; you see and understand; you read and remember.* I had learnt by listening to George; I hope I had understood by looking at the material George had shown me; and now, I wanted to remember it all by going over George's book. Needless to add, it is so exciting to learn from George's excellent book that not only explains in a clear and simple manner the ideas, concepts, and the detailed mechanisms of science, but also sketches the lives and backgrounds of the pioneers. I must tell you the surprising fact that I had discovered in the writing of the celebrated thirteenth-century Italian poet Dante Alighieri. Years ago, I had unearthed some verses from his *L'Inferno* or *Hell* that closely resembled ideas inherent to black-hole physics. Now in George's book I found reference to Dante's concept of geocentric Universe along with a nice illustration that showed hell at the centre of the Earth surrounded by the planetary spheres and *primum mobile*.



That is not all. Dante must have been quite progressive in advocating the exploration of new intellectual pathways, which was achieved centuries later by Copernicus and others. Let me quote Dante: *For what fruit would he bear who should demonstrate once again some theorem of Euclid; who should strive to expound a new felicity, which Aristotle has already expounded; who should undertake again the apology of old age, which Cicero has pleaded? Naught at all, but rather would such wearisome superfluity provoke disgust.* Isn't this true of all discoveries in science?

After I finish reading George's book and making suitable notes, I always have this urge—well, you know what that is—to have a soothing bath before going to bed. I filled my bathtub with comfortably hot water and took out from the cupboard one of the sachets containing the bubble-bath mixture. When I was about to add a spoonful of the mix, my bathtub started to vibrate. I knew at once what was coming and was quite happy about it.

‘This is Khasbath speaking,’ announced the bathtub in its peculiar gurgling, throaty voice. Or should I say sound rather than voice? It doesn’t matter, does it?

‘Khasbath! I like the name you gave me, Boss,’ said the bathtub.

What, I gave the name? He—sorry, it—had christened itself like Napoleon crowning himself the Emperor.

‘Thanks for comparing me to Napoleon, boss. But, I am not sure I like the controversy regarding who named whom. Let that rest in peace. So, you had your dose of astronomical adventure guided by the Professor. How do I know? Well, remember I can read your mind like, like. . . no, I can’t say like my palm, can I?’ My bathtub—sorry again, Khasbath I mean—gave its characteristic vibrant laughter. ‘I believe you remember very well that is how, by reading minds, I learnt so much when I was a kitchen sink in my Master’s home. All, right, go ahead and add the bubble bath mixture. Relax and reflect; ruminant and ratiocinate: aha, you like the sound of those words, don’t you? I do. And I shall learn more reading your mind.’

Khasbath fell silent. I added the bubble bath mixture to the bath water. Immediately, the bubbles, accompanied by the sparkling specks, appeared all over, massaging me, warming me. It was a joy to behold them. On closer scrutiny, I could detect here and there extremely minute spheres circling around some of the shining specks. I couldn’t help imagining that I was indeed observing, right within my bathtub, miniature planetary systems held in thrall by their presiding stars. As I tried to focus on those tiny orbs in revolution, my eyes became heavy and I drifted into the usual indescribable state that transcended all earthly experience.

I felt myself floating totally weightless. And I was able to navigate freely like a swimmer in water that offered no resistance. But I was now suspended amidst countless stars that greeted me wherever my eyes happened to turn. Then it happened—the familiar and unearthly occurrence of an ethereal figure rising out of pure space, perhaps made up of starlight and nothing else, yet assuming almost material existence. At the same time, I could hear the melodious sound of haunting music wafting from afar.

‘I ardently hope that you remember me, *signore*.’ Oh Yes, I had heard that deep voice long ago. I had seen this distinguished personage attired fashionably in harmoniously coordinated shades of grey and black. I had seen his countenance—his hollow cheeks, lips pressed together, ends slightly curled up in a sardonic smile, and his innucent eyes that gazed at you steadily as if vivisecting every detail of your innermost thoughts. How could I ever forget this fantastic personality from the past?

‘Ah, what an honour to be remembered by *signore*! Yes, it is none other than Giovanni Jacopo Casanova, sometimes referred to as also Giacomo Girolamo Casanova, forever your servant.’ He made a deep formal bow. Casanova closed his eyes listening to the beautiful music in the background. ‘You hear that sublime music that always accompanies me? As you perhaps know, it was composed by my dear friend, Wolfgang Amadeus Mozart, who had been baptised as Johannes Chrysostomus Wolfgangus Theophilus Mozart, a mouthful of a name in my humble opinion. Poor boy, he tried to take lessons from me in the fine art of winning over delectable damsels, which ignorant individuals condemn as seduction. This, he

claimed, was in preparation for composing his opera *Don Giovanni*. Don Giovanni, he and I share not only a common name, but also our common interest.'

Of course, I was aware of the strange interaction that had taken place between Casanova and Mozart.

After a moment or two of quiet thought, Casanova continued, 'And I am sure that you remember the unusual reason for my appearing in the celestial realm: my illustrious name that happens to be the combination of *Cas A*, the remnant of an exploded star and its original appearance that was recorded as a *nova* by that King of Astronomers, Tycho Brahe. Those two terms add up to my name *CasAnova*, do they not? As I remarked at the time of our first meeting, fate has a perverse sense of humour to think of me as the embodiment of an exploded star. Although in my own time I did shine like a star, I never exploded in any manner whatsoever.'

I could vividly recall how Casanova had escorted me to show and describe some of the constellations as well as to visit some famous astronomers of the past.

'That was a glorious journey, was it not, *signore*?' I was not surprised that Casanova had read my thought. It did not feel that it was an invasion of privacy at all. 'We made bridges out of pure space and flew across time. We wandered all over the Universe and visited some great scientists of yesteryears. In addition, although I did not guide you at that juncture, you had the rare good fortune of being able to listen to the greatest poet our country has produced, namely Dante Alighieri, the creator of the immortal poem *Divine Comedy*, who recited to you from *Inferno* those verses that resembled the ideas embodied in the subject you were pursuing at that time. In your recent studies, you have come across Dante's notion of the structure of the Universe, have you not? Where does Dante place the hell in the scheme of things, *signore*? At the centre of the Earth, does he not? Well, perhaps that was true in Dante's days. But, in my considered opinion, in your own time hell has moved to the surface of the Earth!'



Casanova covered his mouth with his lace handkerchief and permitted himself a long, controlled laugh before announcing, 'Now, the time has come again for new adventures, new explorations, and new flights of fancy. Prepare yourself, *signore*, for such an experience as no one in this world has ever had.'

Chapter 5

The Canon and His Cosmos

Casanova and I drifted along and came to an old city with a massive wall going around it.

‘We have reached the town of Frombork in Poland or Frauenberg as it is also called,’ announced Casanova. ‘That wall, the fortification, was built to protect the people of the town, as also the Cathedral standing on the hill, from the marauding Teutonic Knights. This is like a pious place of pilgrimage for those who possess keen interest in astronomy, nay in human thought itself, *signore*. For this is where the great Copernicus worked as a Canon of the Church.’

I could easily discern Casanova’s intense reverence for Copernicus, which I too felt.

‘As you very well know, Copernicus was well trained in astronomy, medicine, law, and financial matters. As the Canon of Frombork, he took care of the administration of the Church as well, which included the fortification we see.’

We had reached the base of a tall tower that was part of the fortification. We lifted off and rose gently to an open window at the top of the tower and sailed through it. We were now in a large room with high roof, rather dark and minimally furnished. Next to the window through which we had entered, stood a heavy wooden desk piled up with sheets of paper, diagrams and numbers written all over them. In the background stood strange instruments of different shapes and sizes. I wondered what they were.

On the other side of the room was a high chair occupied by an elderly man of serious countenance, dressed in a black robe. He was listening to one of the three persons sitting opposite to him. The speaker seemed to be quite a rich man, judging from his clothes, but looked quite ill.

‘O, Nicolaus Copernicus, I have come from afar seeking your help. You, only you, can save me from the dread disease I am suffering from,’ wailed the man. ‘Your fame as a Doctor has spread all over Europe. You have healed the rich and the poor alike, saved many lives from the epidemic that swept across our province. O, Nicolaus Copernicus, be generous and . . .’

‘Enough,’ Copernicus held up his hand stopping the speaker from going on any further. ‘I must inform you that I feel a strong revulsion towards any familiarity and towards frivolous, pointless conversation. Please be kind enough to state the symptoms of your malady and I shall try my best to help you.’

The poor man went about dolefully relating all the problems he had with his health, while Copernicus listened with concentration that appeared to be his inherent trait. Only when his visitor had stopped telling him the list of his woes did he speak up.

‘I shall give you a prescription for an Imperial Pill, a universal remedy, which may be taken any time and has curative effect on every disease.’ said Copernicus and repeated aloud the prescription he jotted down on a sheet of paper. ‘Take two ounces of Armenian clay, a half ounce of cinnamon, two drachmas of tormentil root, dittany, red sandalwood, a drachma of ivory and iron shavings, two scruples of ash and rust, one drachma each of lemon peel and pearls; add one scruple each of pulverized emerald, red hyacinth and sapphire; one drachma of bone from a deer’s heart; sea locusts, powdered horn of a unicorn, red coral, gold and silver foil—all one scruple each; then add half a pound of sugar, or the quantity which one usually buys for one Hungarian ducat’s worth. And prepare the pills out of those ingredients.’

As the visitor rose to leave expressing his gratitude profusely, Copernicus said softly, ‘God willing, it will help you!’ and added under his breath as if he was talking to himself, ‘Those who inherit diseases are rarely cured of them, and will be wise to endure their suffering in patience.’ He then jotted down his prescription on the margin of the open book in front of him.

‘Did you notice that book, *signore?*’ whispered Casanova with amusement. ‘It is a copy of the venerable Euclid’s Geometry!’

I looked and Casanova was right. I was amazed.

Having attended to his patient seeking medical help who left the room walking backwards with great reverence, Copernicus turned his attention to the other two visitors. One of them was an elderly person who looked distinguished in his elegant flowing robe made of expensive material. Presumably, he was a high official of the state. The other visitor was young and energetic; he wore crisp, well-fitting clothes that set off his hard muscles. The former spoke with utmost respect.

‘Canon of Frombork, my humble greetings to you,’ he began and went on to describe how the affairs of the Church were being conducted as Copernicus nodded his approval from time to time.

‘How about our financial position? I had outlined some necessary measures to reform the coinage of the country. Have they been implemented?’ asked Copernicus.

‘Our finances are good and the coinage has been improved along the lines you had suggested, Canon,’ replied the official.

‘Very well then, we must take utmost care when dealing with the finances of the state since it is my considered opinion, nay, a principle in fact, that bad or debased money will drive out the good,’ commented Copernicus. After a moment of thought, he took out a thick volume and handed it over to the official. ‘This work

of mine dealing with certain aspects of economy and finance should interest you and, hopefully, its reading would prove beneficial in your work.'

As the official respectfully accepted the book, I was able to read the title, *Monete cudende ratio*.

'That means *On the Minting of Coin*,' Casanova informed me and added with a smile, 'I realize that you did not know that the great stargazer, the author of the monumental *De Revolutionibus*, also wrote learned treatises on economics. Very few do.'

Again, my astonishment knew no bounds.

Copernicus now turned to the younger of the two visitors and addressed him, 'Yes, Commander, what have you to report?'

'Canon of Frombork, my humble salutations,' the Commander of the army bowed low. 'I am happy to report that all is well with the defence of Frombork. The fortification is in good repair and our soldiers are ever vigilant.' He proceeded to give the details regarding the army and its various activities aimed at the defence of the country in general and Frombork in particular. 'Most importantly, we do not have to fear an invasion from the Teutonic Knights any longer ever since their shameful defeat culminating in their Grand Master rendering homage to our King, all thanks to your advice, Canon.'

Copernicus waved away the compliment paid by the Commander. He nodded with dignity signifying that the audience was over. The two visitors left after bowing repeatedly to Copernicus, which he acknowledged by raising his hand. Copernicus remained motionless in deep thought for a moment or two and then walked over to the desk by the window taking unhurried steps. He sighed deeply as he sat down and regarded the pile of papers in front of him. He pulled out from beneath the pile a large book and opened it. At the top of the front page was written the title of the yet to be finished tome—*De Revolutionibus Orbium Coelestium*.

'Ah, the book of books, *On the Revolutions of the Celestial Orbs*,' exclaimed Casanova in a low voice.

'At last back to the study of stars, the only and the greatest pleasure I have in *remotissimo angulo terrae*, in this remotest corner of the Earth.'

Copernicus slowly raised his eyes and looked at us, his unexpected visitors, and smiled—a rare event indeed, which lighted up the gloomy room. He spoke in a serious but sincere fashion. I could feel that here was a modest man who was oblivious of his own importance.

'It will be a great pleasure to express my thoughts and ideas in regard to the stars, observing which and learning from them is the noblest human endeavour,' said Copernicus. He regarded us with interest. 'I do not mind imparting precious knowledge to the two of you truth seekers, which I would not pour it into the muddy waters of the human mind in general. Also, I believe that mathematics is for mathematicians.'

'Yes, I made many careful observations of the stars and planets,' continued Copernicus. 'I believe you have already noticed the observational tools here which I fabricated myself.' Copernicus pointed at the strange instruments I had seen and

wondered about. 'For instance, I made a *triquetrum* in order to check the positions of the stars.'

The triquetrum or the 'cross-bow' was twelve feet high consisting of three wooden bars and dominated the other instruments.

'Let us not get into the details of my observations. I must admit that the Greeks, my predecessors, possessed more accurate instruments, especially Ptolemy who made sufficiently precise measurements on which my calculations have been predominantly based. Most important to me are the ideas that dictate the structure of our world, our Universe. I shall explain them to you as best as I can.'

Copernicus paused to collect his thoughts and then proceeded to describe his cosmic structure comprising the Earth and the other celestial bodies.

Casanova whispered as before, 'Most of the time, Copernicus will be repeating in his own style what he has written in that big, scholarly book of his *Revolutionibus*. Just as well, since the book is considered to be one of the most unreadable tomes ever written, as you already know. Sometimes, he may repeat long passages. It is always good to know how such great men not only thought, but also wrote. I am sure *signore* agrees with me.' He added, 'I have a feeling that he will be relating only the descriptive parts that are comprehensible to ordinary mortals like us.'

'First of all, we must think of what place the Earth occupies in the Universe,' began Copernicus. 'Without this knowledge no certain computations can be made for the phenomena occurring in the heavens. To be sure, the great majority of writers agree that the Earth is at rest in the centre of the Universe, so that they consider unbelievable and even ridiculous to suppose that this is not so. Still, when one weighs the matter carefully, it will be seen that this question is not settled yet, and for that reason is by no means to be considered unimportant. Now the Earth is the place from which we observe the revolution of the heavens and where it is displayed to our eyes. Therefore, if the Earth should possess any motion, this would be noticeable in everything that is situated outside of it, but in the opposite direction, just as if everything were travelling past the Earth. And of this nature is, above all, the daily revolution. For this motion seems to embrace the whole world, in fact everything that is outside of the Earth, with the single exception of the Earth itself. But if one should admit that the heavens possess none of this motion, but that the Earth rotates from west to east and if one should consider this seriously with respect to the seeming rising and setting of the Sun, of the Moon and the stars, then one would find that this is actually true.'

That is what the remarkable Indian astronomer, Aryabhata, had conjectured centuries before Copernicus. The motion of everything in the sky that happens daily is due to the turning of the Earth. And he had described it through his lovely verse offering the analogy of how the trees seem to move backwards while we are going forward in a boat.

'Now, is the Universe finite or infinite?' Copernicus asked rhetorically. 'We shall leave that question to the quarrels of wise men. For us remains the certainty that the Earth is finite and is bounded by a spherical surface. Why should we hesitate to grant it a motion, natural and corresponding to its form, rather than

assume that the whole Universe, whose boundary is not known and cannot be known, moves?’

Copernicus paused several moments and asked emphatically, ‘Why are we not willing to acknowledge that the *appearance* of a daily revolution belongs to the heavens, its *actuality* to the Earth?’

‘*Appearance and actuality!*’ Casanova nodded his head a couple of times. ‘Think, *signore*, the great man himself asserts the difference, the difference that was to be emphasised again by another great astronomer, my revered compatriot, Galileo Galilei.’

‘Since nothing stands in the way of the mobility of the Earth, I believe we must now investigate whether it also has several motions, so that it can be considered one of the planets,’ said Copernicus seriously. ‘Let us think then of the annual motion of the planets. That the Earth is not the centre of all the revolutions is proved by the irregular motions of the planets, and their varying distances from the Earth, which cannot be explained as concentric circles with the Earth at the centre.’

‘Now, on the other hand, let us admit the motionlessness of the Sun and transfer the annual revolution from the Sun to the Earth,’ proposed Copernicus. ‘Then one can see that the distances to the planets from the Earth do vary.’

That was a simple, but most important, argument. If the Earth stood still and the planets were going in circles around it, obviously the distance from the Earth to any of the planets had to remain constant. On the other hand, if the Earth too were moving in a circle around the Sun, as well as the planet at a different speed compared to the Earth, then the planet’s separation from the Earth had to be varying. Simple ideas are often profound!

‘Having the Sun immobile at the centre with the Earth revolving around it will also account for the halting and backward motion of the planets,’ announced Copernicus. ‘Those peculiar motions are not those of the planets at all but they appear to do so because of the motion of the Earth.’

I clearly remembered how George had explained the retrograde motion of the planets on the basis of the Copernican heliocentric model of the solar system.

Copernicus now spoke up. From the tone of his voice it was apparent that he was making a most significant statement that must have appeared in his monumental book. It was the summing up of his heliocentric Universe. ‘I say that the Sun remains forever immobile. Whatever apparent movement belongs to it can be verified as due to the mobility of the Earth. Planets move in circular paths of sufficiently manifest dimensions compared to the distance between the Sun and the Earth. But the Universe is such that these distances, as compared to the distance to the fixed stars, are imperceptible.’

Copernicus rose from his high chair with great dignity. I felt that he was about to quote something of utmost importance from his own magnificent work. In a commanding voice that echoed from every wall of the august chamber in which he had discovered the true nature of the cosmos, he proclaimed:

In the middle of all sits the Sun enthroned. In this beautiful temple could we place this luminary in any better position from which he can illuminate the whole at once? The Sun sits as upon a royal throne ruling his children, the planets, which circle round him.

Majestically Copernicus closed his book, *De Revolutionibus*.

‘This work has lain concealed in my abode for thirty-six long years,’ said Copernicus solemnly. ‘The moment has finally come for it to see the light of day.’

Copernicus seemed to have forgotten our presence altogether in his deep contemplation. He walked to the open window and gazed out at the night sky filled with glittering stars. Ever so slowly, the night sky seemed to seep into the room and engulf Copernicus, who gradually merged with the starry background.

‘We have come a long way, have we not *signore*?’ reflected Casanova. ‘Once upon a time, demons and dragons, heroes and hydras inhabited the constellations. Then came the crystal spheres of Aristotle only to be replaced by Ptolemy’s complex epicycles. And now, at long last, Copernicus has established his own cosmos with the Sun enthroned at the centre and his children, the planets, circling him in loving obedience. What a glorious revelation, truth shining forth like the central fire!’

Casanova bowed his head as though he was paying his homage to Copernicus. Then, raising his head, he said, ‘Let us move on, *signore*, to visit two celebrated astronomers who, at the moment, happen to be engaged in deep discussion of high matters.’

Chapter 6

Hven and the Heavens

The Dwarf and the Giant

We were now in a spacious room, the walls decorated with several paintings and heavy curtains hanging by the windows and doors. At a large wooden table, sat the two astronomers, Casanova had just mentioned. They were absorbed in animated discussion. The older one on the right was dressed in the finest clothes fashioned out of silk and velvet. An intricately designed medallion hung from a golden chain that he wore around his neck. Curled up at his feet lay a dog yawning from time to time, bored as it was with the conversation going on over its head. In striking contrast to the older astronomer, the younger one on the left wore modest clothes crumpled with constant use. He had a pale look as though suffering from some illness or the other constantly. Nevertheless, his eyes were bright and penetrating, reflecting an exceptionally keen intellect.

All of a sudden, I was gripped with a strong feeling of *déjà vu*. Had I not visited this place earlier and listened to the two men in conversation before me? I felt that even the description of the scene that arose in my mind was the same as what I had written earlier.

I realized that Casanova was regarding me with an amused smile. ‘Yes, *signore*, mind is a strange entity that often does not distinguish between the past, present, and future. The greatest scientist to grace this world after Isaac Newton, who appeared in your own time, was right when he said that time is a persisting illusion. In the present context, let me acknowledge your innermost feeling that we have been here in the past. And, most likely, you will hear and witness exactly the same things as before. But such summoning up of memories of the past should prove most instructive, not to mention its high entertainment value.’ I was reassured by his words and concentrated on what was happening in front of me.

In the background one could see a variety of astronomical instruments somewhat similar to the ones that Copernicus had possessed. Casanova, who seemed to be familiar with astronomical instruments, pointed them out to me: *quadrants* ranging

from a radius of 16 inches to seven feet, *sextants*, complicated spherical devices like *astrolabes*, and several other aids used for astronomical measurements.

While I was gazing upon all this with great fascination, I was suddenly drawn to an extraordinary sight. Seated beneath the table was a dwarf chattering away to himself. At that moment he too noticed us and came over.



‘Oh, ho, ho, what on Earth do we have here?’ exclaimed the dwarf making strange faces. ‘Visitors from the future! Hey doggie boy, look, we are honoured by the visit of two distinguished guests.’

The dog yawned, opening its mouth wide, and most offensively thrust out its long red tongue. The dwarf kicked at it muttering, ‘Stupid mutt,’ and the dog yelped in protest.

‘Oh, yes, your honours, welcome to Uraniborg, the Palace of Astronomy, situated on the island of Hven outside Copenhagen, dedicated to Urania, the Muse of Astronomy,’ the dwarf bowed so low that his cap fell off. ‘Ah, forgive me, I forgot to introduce myself, your honours. I am Jeppe, the pet dwarf of the nobleman you see before you on the right, the King of Observers, Tycho Brahe.’ Jeppe pretended to hold up an imaginary trumpet and made a strange noise apparently to mimic its blaring heraldic sound. I was reminded of similar sounds made by the chorus of frogs that had accompanied Aristophanes long ago.

‘Tell me, how many astronomers keep pet dwarfs, eh, eh?’ questioned Jeppe. ‘None, your honours, none! But, my Lordship does, you know why? Because he takes my advice on the affairs of Hven, which he happens to administer. You know why, let me repeat the question. Because I am blessed with prescience, knowledge of things before they happen, and I can foretell the future.’ Jeppe held his open palm against his mouth and said in a conspiratorial, but loud, whisper, ‘At least that is what the man believes!’ Jeppe rolled on the floor laughing uncontrollably.

Getting up quickly, Jeppe continued. 'Please allow me to relate to you of an occasion on which my master sought my highly valued advice. And to give him due credit, he followed my advice too. On the said occasion, when the peasants of Hven had been insubordinate, I counselled that they be assembled and offered all the beer they could consume instead of punishing them. And it worked, it worked! Alcoholic amelioration of administrative ailments I call it.' He winked at me and added insolently, 'I ardently hope that your vocabulary is good enough to understand what I just said.'

Jeppe drew himself up with pride as tall as he could, after having established his importance to his employer. I watched him with fascination not unmixed with a bit of uncomfortable feeling, while Casanova looked on, his customary amused smile curling up the corners of his lips. I then looked away from Jeppe and focussed my attention on Tycho Brahe and his magnificent attire. My attention was diverted by something strange about his nose, which had a dull sheen to it.

'I perceive that your honour has noticed my Lordship's nose,' observed Jeppe with ill-concealed glee. 'It glows strangely, for it has been constructed out of gold, silver, and bee-wax—an admixture of two noble metals with the ignoble produce of a lowly insect, I must say. My employer designed it himself with great ingenuity. Whatever happened to the original nose made of flesh and blood, you may ask. Ask away, your honour, and I shall oblige you with the correct answer. The God-given olfactory organ was severely damaged in a duel my master fought with his third cousin. A duel fought over the amorous attentions of a dainty damsel perhaps or to put it rather crudely a fight over a woman?'

'Alas, no such romantic happening,' Jeppe sighed. 'Swords were crossed on account of an argument that broke out at the dinner table as to who knew more mathematics, my master or his third cousin. Can there be anything more absurd, I ask you. Allow me to hasten to add that your honour need not strain his brains for an answer, because the question was purely rhetorical, which means, I am told by linguistic experts, a question to which the answer is obvious and therefore need not be given. In short, a query tantamount to waste of time!'

Jeppe was out of breath now, having chattered away with hardly a pause. He held up his forefinger to his lips and hushed me saying, 'Why is your honour talking so much? What did you say? It is I who has been chattering away? No, your honour, I only echo the words and thoughts of others. Be that as it may, let us turn our attention to my Lordship, a great man, though between you and me, no man is great to his own dwarf.'

After catching his breath and collecting his thoughts, Jeppe spoke on again. 'Ah, I have told you so much about my master who is a nobleman. What do we mean by a nobleman, your honour? A man whose parents, parents' parents, parents' parents' parents and so on were all high and mighty, rich and famous, and, mark my words, often lazy and useless. Of course, not so with my Lordship, although he came from a noble family. But forget him for a moment and take a good look at the younger man sitting next to him.'

Jeppe waited for a while apparently to allow me time enough to study the man on the left. 'He is another accomplished astronomer as well, who answers to the name

of Johannes Kepler. He came originally from Germany and became master Tycho Brahe's assistant, but never worked here at Uranisborg, but only later on in Prague. But as you know, space and time can get smeared out in this world of imagination, of fantasy, of make-believe. So you see them together here at Hven. Once, our master, the great Dane—no, no, I don't mean the Great Dane, a type of dog, heaven forbid or should I say Hven forbid—used to call Johannes a mad dog. An irony involving dogs, eh, your honour? Anyway, now the master realizes his assistant's worth.'

'Please allow me to tell you briefly about Kepler's background,' Jeppe continued. 'He too must have come from a noble family, did you say? My, my, your honour has a warped sense of humour I must admit. What a contrast between the families of the two men! Please do not take my word for whatever I say, no scandalmonger I am, no, sir, never. Kepler himself has bared it all in his chronicles. His father was, according to his beloved son, vicious, inflexible, quarrelsome, a wanderer, and beat his wife to boot—perhaps with his boot too—quite often. He fought in different armies for money as also for his own sadistic pleasure, visiting his home rarely, maybe whenever he felt like beating his wife and children. Well, young Kepler's mother often followed her husband abandoning her children, maybe for her own masochistic pleasure of getting beaten up. Hush, listen but not a word spoken loud, the mother had a reputation of being a wicked witch. Maybe it matters not, since she is long dead and gone. But you never know, since vindictive ghosts may exist after all. Kepler's mother's aunt was also believed to be a witch and was burnt by people out of fear—looks like witchcraft was a hereditary hobby. To cut the story short—ah, I love shortness naturally—Kepler was brought up in a poor, chaotic household. All his life he suffered from a variety of ailments, some real but most of them imaginary. Yes, sir, he has written them down too. At the age of four I nearly died of smallpox, he says, my hands were badly crippled; later on, he goes on, I suffered continually from skin ailments, severe sores, scabs, a worm in the finger, whatever that means, so on and on and on. Let us forget all these complaints. One more thing about Kepler, which I almost forgot. In all his life he took a bath only once, that too at the continuous nagging of his wife, and almost died as a result. What did you say, your honour, he is a *stinker*? No, no, no, he is a *thinker*, not a stinker.' Jeppe guffawed loudly and then added with unusual seriousness, 'Yes, he is a brilliant thinker, one of the greatest, who has transformed astronomy. He wanted to be a priest, but had to teach astronomy and mathematics to make a living. How fortunate for those two subjects! Tycho Brahe is the King of Observers and Johannes Kepler is a King among Thinkers.'

Jeppe seemed to grow old. He mumbled to himself, forgetting our presence. 'Ah, playing the fool to make others laugh renders you sad, does it not, my dear Jeppe? Well, sadness and joy cancel each other out leaving nothing behind, I suppose. Maybe they are the two faces of the same coin. Maybe, maybe, there is something for you to think about, my dear Jeppe.'

Jeppe shook himself out of his reverie. His face had assumed a serene expression. He spoke now in a serious tone. 'There they are, two erudite men discussing the heavens. Listen to them and you shall reap the treasures of vast learning.'

With that Jeppe withdrew to the background, only temporarily as it turned out, leaving the two astronomers in focus

‘Observing the *nova*, the new or the guest star as we know it, was the greatest event of my life, which led me to dedicate myself to the divine pursuit of observing the heavens and recording the positions of the celestial objects,’ Tycho was saying.

‘I still remember vividly the momentous occurrence on the eleventh day of November in the year fifteen hundred and seventy-two,’ Tycho continued his reminiscence. ‘It was evening, after sunset, when according to my habit, I was contemplating the stars in the clear sky, I noticed that a new and unusual star, surpassing all the other stars in brilliancy, was shining almost directly above my head; and since I had almost from boyhood known all the stars of the heavens perfectly, there is no great difficulty in attaining that knowledge, it was quite evident to me that there had never been any star in that place in the sky, namely in the constellation Cassiopeia, even the smallest, to say nothing of a star conspicuously bright as this.’

‘I was so astonished at this sight that I was not ashamed to doubt the trustworthiness of my own eyes,’ continued Tycho. ‘But when I observed that others too, on having the place pointed out to them, could see that there really was a star there, I had no further doubts. A miracle indeed, perhaps the greatest of all that have occurred in the whole range of nature since the beginning of the world!’

‘So far so good,’ I was startled a bit, when suddenly Jeppe intervened. ‘My master has been describing his spotting a new star, a revelation that truly belongs to the realm of astronomy. But humans, in their folly, think that there is more to it than meets the eye, you know. They believe that stars and planets control their lives, their destiny, and foretell things to come, events to befall. This so-called science, known as *Astrology*, is as bogus as my so-called prescience. Hush, not a word more about this! Your honour should not talk lightly of these high matters. Like most astronomers of his time, my master believed in astrology and so did Kepler, to some extent, or maybe they pretended to believe, who knows?’

Casanova, who was listening to Jeppe’s monologue with an indulgent smile, commented, ‘Well, let us give credit where it is due. Tycho happened to say: *Astrologers do not bind the will of man to the stars but grant that there is something in man that has been raised above the stars*. As for Kepler, he clearly claimed: *Astrology is the step-daughter of astronomy, a dreadful superstition, sortilegous monkey-play*. Still, even in your modern age, *signore*, there are some astronomers, I am sure, who harbour such superstitions. Well, so be it. But let us listen to what the new star was supposed to have prophesied.’

Tycho went on to describe the astrological implications of his *nova*. ‘The star was at first like Venus and Jupiter, giving pleasing effects; but as it then became like Mars, there will next come a period of wars, seditions, captivity and death of princes, and destruction of cities, together with dryness and fiery meteors in the air, pestilence, and venomous snakes. Lastly, the star became like Saturn, and there will finally come a time of want, death, imprisonment and all sorts of things.’

‘None of which came to pass of course,’ sneered Jeppe. ‘But that is not the end of the story—as we are about to learn.’

‘I assume that you are aware of all the inane speculations and the absurd furore that followed in the wake of the *nova*,’ continued Tycho.

‘As I was only a year old at the time, I am afraid I cannot be expected to have learnt about it first hand,’ smiled Kepler. ‘Nevertheless, I heard about it later on.’

‘But the crucial question was whether the *nova* belonged to the realm of the stars. This would have contradicted Aristotle’s idea that the celestial region is eternal and immutable. I am sure you know about his dictum.’

‘Naturally,’ answered Kepler. ‘Aristotle held that only the region below the Moon was subject to changes as it is composed of inferior matter obeying different laws of nature as opposed to the superior quality of the material that makes up the region above it, which is regulated by totally different laws.’

‘Yes, indeed,’ concurred Tycho. ‘Did the *nova* then belong to the sub-lunar world of changeable earthly elements? Was it perhaps a comet condensed from ethereal vapours or from fumes of human sin as some imagined? I put an end to all those foolish conjectures, did I not?’ Tycho paused to savour the memory of his triumph and continued. ‘I had to make repeated measurements of the position of the *nova*, its distance from the celestial pole, to show that it was indeed a star and not an inhabitant of the sub-lunar region, thereby contradicting the cherished ideas of Aristotle. But what was this strange new star composed of? I believe it was formed out of celestial matter, but of less perfect variety than that of normal stars and thus gradually dissolved away.’

Tycho stroked his beard as he mused about the days of his glory.

‘I wrote down all my findings in my book *De Stella Nova*, or *On the New Star*,’ recounted Tycho. ‘A masterpiece many said afterwards. Deciding whether to write that book or not was a struggle for me, for many a nobleman of my acquaintance felt strongly that writing a book was an occupation beneath my rank. Nobility has its own norms and manners, does it not?’

A serious look came over Kepler’s countenance as he remarked, ‘Am I not aware of that fact! I know of the occasion on which you accompanied one of the Royal Councillors to supper. Although you drank a bit over-generously and felt pressure on your bladder, you had less concern for your health than for your manners, and remained seated at the table. By the time you returned home, you could no longer pass water.’

Jeppe suddenly jumped up and screeched, ‘From Urania to uremia, from Urania to uremia!’ and cackled loudly. Kepler, wanting desperately to get out of this awkward situation, hastened to change the subject.

‘Three years after you left for your Heavenly Abode, I too was fortunate enough to discover a *nova*. Its location was in the constellation *Ophiuchus* who holds in his arms the serpent, depicted by the constellation *Serpens*.’

I remembered how Aristophanes had concluded his dramatic presentation of the Orion story with Ophiuchus healing both Orion and the scorpion as also the fact that the serpent was supposed to have been the mentor of Ophiuchus.

‘I was also able to demonstrate that the *nova* belonged to the region of the stars and not to the vicinity of the Earth,’ Kepler went on to say. ‘Again, one more blow to Aristotle’s philosophy.’

‘That is not all,’ Tycho said excitedly. ‘Five years after the appearance of the *nova* in 1572, I observed a comet and proved that it was far above the Moon and had started its journey way beyond the planet Venus. Aristotle, like many before him, had claimed that each planet was fixed in a rotating crystal sphere, had he not? If so, the comet in its journey ought to have shattered the crystal spheres. Did we here the tinkling sound of the falling shards of crystal?’ Tycho laughed at his own comment. ‘Oh no, and why not? Because the crystal spheres do not exist at all. Often, those who watch the sky never think of the implications of what they observe. That is why I rebuked them in my book on the new star with the words, *O crassa indgenia, O caecos coeli spectores—O thick wits, O blind watchers of the sky!*’

‘Aristotle thought that the Sun and the planets circled around the Earth imbedded in their crystal spheres, and Ptolemy gave a fine but complicated model of this Earth-centred Universe. But we know that the planets go around the Sun, do we not?’ added Kepler.

‘Yes, what about the Earth?’ asked Tycho. ‘According to your Copernicus, the Earth goes around the Sun too. I think not, for the Earth is a hulking, lazy body unfit for motion. Look at my beautiful model of the Universe in which the planets move around the Sun, but the Sun, along with the planets, revolves around the Earth.’

Kepler remained silent. He knew that Copernicus was right. Yet, one had to admit that Tycho’s model was the same as that of Copernicus but as viewed by an Earth-bound observer. It just complicated matters unnecessarily.

‘I wanted you to prove my model,’ continued Tycho. ‘That is why I set you on to my observations on Mars from which I expected you to deduce its orbit.’

Kepler’s eyes became remote and thoughtful as he recalled the past. His voice was tinged with gratitude as he spoke.

‘I consider it an effect of Divine Providence that I arrived in Prague when the time was ripe for studying Mars and you asked me to take up the problem. Because for us to discover the secret knowledge of astronomy, it is absolutely necessary to use Mars. Otherwise, that knowledge would remain eternally hidden.’

‘You anticipated that you would complete the calculation of the orbit of Mars in eight days,’ Tycho pointed out. ‘How long did it take in the end?’

‘More like eight years,’ Kepler smiled. ‘Vanquishing Mars, the god of war no less, was an immense task. But what a revelation to discover that the orbit was an ellipse and not a circle as had been believed since antiquity! And Mars did not move with uniform velocity either. He speeded up near the Sun and ambled slothfully far away from the Sun when the latter’s influence on him diminished.’

‘Did you ever think of the physical causes that control the planetary motion?’ enquired Tycho.

‘Indeed I did,’ Kepler responded. ‘My goal after all was to show that the celestial machine is not so much a divine organism but rather a clockwork as much as all the variety of motions are carried out by means of a single, very simple magnetic force of the body, just as in a clock all the motions arise from a very simple weight. The Sun is the fountain of strength, a great magnetic body, whose rotation also turns the magnetic emanations that propel the planets in space.’

‘On the other hand, some believed that the angels, who serve God, push the planets around,’ Tycho pointed out.

‘I feel that the subtle reflections of some people in regard to the blessed angels do not concern us. We are discussing natural matters of much lower rank.’

‘Well, I wish I had lived long enough to see the fruits of your labour, which was, after all, based on my observations.’

‘So do I, for the reason that, a few years after you were freed from your earthly shackles, the Italian astronomer and philosopher Galileo Galilei introduced his glazed optical tube, or telescope as it has come to be known, to astronomy. He made astounding discoveries with its aid. Incidentally, he too sighted the two different guest stars we had observed. I cannot imagine what marvels you might have revealed with the use of the optical tube.’

‘Did you ever employ that instrument for your own observations of the heavens, Johannes?’

‘I wrote to Galilei entreating him to send me an optical tube, but he sent me only his book. The Duke of Bavaria lent me one for just five weeks and took it back promptly thereafter.’ Kepler’s regret of having missed the use of the telescope was evident.

‘I understand that Galilei, because of his observations with his optical tube and moreover because of his staunch adherence to the Sun-centred Universe of Copernicus, ran into conflict with the Church, and had to recant his beliefs under the threat of torture. Most unfortunate indeed! Of course, all this must have happened after my time.’

Kepler was passionate: ‘That was truly tragic. While in theology it is authority that carries the most weight, in philosophy it is reason. The Holy Office, namely the Church, nowadays is holy which, though allowing the Earth’s smallness, denies its motion. To me, however, the truth is more holy still, and with all due respect to the Doctors of the Church, I prove philosophically not only that the Earth is round, not only that it is contemptibly small, but also that it is carried among the stars.’

Tycho closed his eyes in thought. ‘We all strive to find the truth underlying what we see. How far we succeed it may not be given to us to decide and often not even to know.’

Kepler fell silent for a moment and recalled with a touch of sadness. ‘During the last night of your life, you kept whispering again and again: *Let me not seem to have died in vain.*’ And then he added with emphasis, ‘There was no need for such thoughts. You were and will always be the King among Astronomers, Master.’ The two men fell silent, each engrossed in his own thoughts.

After a short while, Kepler slowly rose to his feet and came around the table at which he was conversing with Tycho Brahe. At the same time, the whole scene, including Tycho and Jeppe, receded back and faded away.

Vanquishing the God of War

Kepler smiled as he approached us. Ah, here is a man who is friendly, kind, and loveable, I thought. He spoke now in a simple style, distinctly different from the one he had been using in his discussions with Tycho Brahe. Obviously, most of the time, the two astronomers had been quoting from their own writings as in the case of Copernicus.

‘Yes, it took me a long time in arriving at the true nature of the path taken by the planet Mars around the Sun,’ reminisced Kepler. ‘I had to match my own calculations to the remarkably accurate observational data of my master, the revered Tycho Brahe. First of all, I firmly believed in the Copernican model in which the planets went around the Sun that stood still at the centre. The first step was to take into account the motion of our own Earth around the Sun before tracing the orbit followed by the planet Mars. It happened to be quite a tricky task indeed!’

‘An ingenious piece of work in itself,’ Casanova commented.

‘Well, my next assumption was that all planets, including our own Earth, described similar curves as they circled the Sun. What geometric figure would that be? As you must have heard time and again, everyone before had believed that this path *had* to be a circle, the perfect, the most beautiful curve of all. And, in addition, the planetary motion was supposed to be uniform with constant velocity. I too tried my hand at a circular path for Mars. Things did not work out if one made it move with unwavering speed in a circle centred round the Sun. So, I moved the Sun away from the centre and made Mars run faster and slower in its course. Ah, it seemed to work! Trial and error, trial and error, I spent five long years on this arduous exercise. Finally, theory seemed to fit the observations, my calculations running to some thousand pages no less. Except for a miniscule discrepancy of eight minutes of arc! As you must know very well, one goes a full circle by going around by three hundred and sixty degrees and a degree is divided into sixty arc minutes. So you can imagine how small the discrepancy happened to be. But could I just ignore this mismatch, when I knew so well how exacting and precise my master’s observations were? Heaven forbid! I had no choice but to abandon the sacred circle as the chosen path for the celestial body. And I tried to make it an oval in shape. But then, what kind of oval? Another two years of relentless struggle and I had the trajectory that beautifully agreed with the observation. I could even derive the equation for this curve, but failed to realize what it was. Another year passed. Then it dawned upon me. It was an *ellipse*! I said to myself: *Ah, what a foolish bird I have been!* And I could derive the law that ordained the varying speed of Mars.’

‘The god of war marched in an elliptical path around Helios, running fast as he basked in the brilliance of the great god when he was in his vicinity, but sauntered slowly far away from him,’ paraphrased Casanova. ‘Kepler had discovered his first two laws of planetary motion for Mars in particular, but would be applicable to all the planets.’

Kepler smiled. He had recounted very briefly the heroic struggle he had put up in vanquishing the god of war. But he seemed to take no pride at all in his spectacular

achievement. ‘The elliptical orbit followed by Mars was almost identical to a circle, the difference being hardly perceptible. That was just a detail. What mattered was the fact that I had abandoned the ideal of uniform circular motion! But then, why should we consider only the circle to be beautiful? Any curve Nature chooses to use is beautiful. A drop of rain is spherical and it is beautiful. So are snowflakes, made up of water as well, that take myriad forms, which I had examined carefully. So is the beehive with its orderly compartments whose shape and structure I had studied in detail. Yes, after eight long years of incessant thought and toil, I had discovered, by appealing to the precise observations of my master Tycho Brahe and carrying out painstaking calculations of my own, that the orbit of Mars—and that of any other planet for that matter—is not a circle, but an *ellipse*! I recorded in great detail my long journey with all its twists and turns, false starts and dead ends, and the final result in my book, *Astronomia Nova* or *New Astronomy*.’

‘Another great book to appear after the two volumes by Copernicus and Tycho Brahe,’ remarked Casanova.

‘All my life I happened to ponder upon the mystery of the Universe,’ mused Kepler. Perhaps he had forgotten our presence. ‘Why is the Universe constructed the way it is? Why are there only six planets, including our beloved Earth, with five gaps in between? Why are they arranged at particular distances from the Sun? At one time, I had arrived at some conclusions in this respect making use of the five Platonic Solids and even recorded my ideas and findings in my first book, *Mysterium Cosmographicum* or *The Cosmic Mystery*. I imagined that I had at last unravelled the mystery of the Universe. I even wrote in the preface to the reader: *I saw one symmetric solid after the other fit in so precisely between the appropriate orbits that if a peasant were to ask you on what kind of hooks the heavens are fastened so they do not fall down, it will be easy for thee to answer him. Farewell*. But I soon found it otherwise. All this before I found out the two laws that govern the motion of the planets. Perhaps the ultimate mystery of the Universe will never be understood—a thought that never occurred to me, a sentiment that I never expressed. In any event, I did try to find the inherent harmony pervading the cosmos, did I not? The planets moved slower and slower as their distances increased from the Sun. I thought that I could hear the music made by them—fast and slow. In my book *Harmonice Mundi*, *Harmony of the Worlds*, I even wrote down the musical notes created by each of the planets as I had imagined. Beneath it all is the harmony of the worlds, the music of the spheres, the mysterious melody of the Universe. Yet, it is music that can be heard not by the ear but by the mind and mind alone.’

‘And underlying that harmony of the worlds was the third law of planetary motion, which Kepler went on to discover and write down in his book,’ added Casanova.

Kepler seemed to be trying to listen to some remote imaginary strains of heavenly harmony. Then he looked up and nodded at us acknowledging our presence.

‘I hope—and may I presume—that everything we have discussed is not only clear but interesting as well,’ said Kepler eagerly. ‘But, fact would be far more

interesting when blended with a bit of fantasy, would it not? Indeed I cannot take leave of you without relating to you my *Somnium* or my *Dream*. It is based on true astronomy enshrined within the framework of Copernican cosmos, but presented in a fanciful way.'

'Let us listen with undivided attention, *signore*,' exhorted Casanova. 'The story we are going to hear is the very first example of what you call science fiction nowadays.'

'Our hero of the *Somnium*, Duracotus by name, hails from Iceland, situated in the northern-most part of the Earth,' Kepler related the story. 'His mother, Fioxhilda, is a wise woman tutored by a demon who lives on the Moon, which she calls Levania. After his five-year apprenticeship at Hven under the August tutelage of the celebrated Tycho Brahe, Duracotus is privileged to learn some of his mother's secrets. Demons inhabit both Levania and Volva, namely the Earth, but they cannot cross the gap between the two worlds as light is lethal to them and they would perish in the dazzling brilliance of the Sun. However, during an eclipse the Earth's shadow would make a bridge of darkness between the two celestial objects, along which the demons can travel back and forth. When these facts are revealed to him, our hero wants to make a journey to Levania. His mother summons the demons from that world, who administer to him a dozing draught to make the journey painless and take him up to the point where the pull of the Earth just balances that of the Moon. When the demons let go of him at that point where no external force exists, his limbs curl up like those of a spider since the body itself attracts its minor parts, namely the limbs, because the body itself is the whole. To cut the story short, Duracotus does manage to find his way on to Levania and behold the inhabitants. They are not human: some are serpent-like, while others are equipped with fins so they can swim in the swamps of Levania.'

After just a momentary pause, Kepler announced, 'Well, I awoke suddenly to find my head covered with a cushion and my body tangled in a rug. That was the end of my tale. After all, it was just a *Somnium*, a *Dream*, was it not?'

Kepler shook with laughter, which too was filled with warmth and simple, pure joy. And we laughed with him.

Kepler looked up at the sky. Was he searching for the planets that were forever obeying his laws? Was he contemplating his own life, his own work, and his own imminent exit from this Earth, a planet that followed his dictum like its companions? His countenance was now suffused with absolute serenity tinged with slight sadness. Then he spoke in a barely audible whisper:

*I measured the sky, now the shadows I measure
Skybound was the mind, Earthbound the body rests.*

Faint sounds of several instruments seemed to be coming from far away, from different directions creating an exquisite, indescribable melody. That music grew louder, played on for a short while, and then faded away. So did Kepler merging into the background of the night sky as was the case with his venerated predecessor Copernicus.

‘Kepler’s last words were his epitaph, which he wrote himself,’ said Casanova. ‘He had firmly believed in the Copernican scheme of the cosmos. He had based his work on the heliocentric model for the solar system thereby providing an indirect proof of that framework. Now, *signore*, let us go and meet an absolutely fascinating astronomer, a towering philosopher, who hailed from my own country.’

Chapter 7

The Starry Messenger

New Vision, New Worlds

‘Ah, welcome, welcome,’ greeted the man effusively. ‘What took you so long? I have been waiting for you, my friends. Well, I know where you have been. You met Tycho and my friend Johannes, didn’t you? What a pair they make, what contrast! The nobleman with the false nose and the commoner assistant with imaginary ailments.’ He threw back his head and roared with laughter and then added seriously, ‘No, I should not make fun of them. Tycho is a fantastic observer and Johannes is an excellent philosopher. And most of all, before visiting them, you met our great teacher, Copernicus himself. How I wish I had that privilege! I envy you. By the time I was born our teacher was gone for twenty-one years. Oh, well, allow me to introduce myself before I forget my manners, which I often do. I am Galileo Galilei. Son of the accomplished musician, Vincenzo Galilei, I am a philosopher, experimenter, mathematician, and, most of all, a stargazer.’

I was transfixed by the sight of the one and only Galileo, whom I could easily recognize from his portraits. He had a large head with a receding hairline that made for a high forehead. He sported a full beard, which made his head look even larger. He had an intensely expressive face: his eyes, brows, and lips displayed his changing moods in forceful concerted movements. His eyes would glitter mischievously, widen with wonder; his brows would arch questioningly, knit together in a frown; his lips would widen with a smile, curl up in a sneer.

As I looked around, I realized that I was on the top of a tall building overlooking the town below. It was a strange lovely town, covered by a network of canals in place of streets, bridges arching over them. People moved around in gondolas, many of which were quite picturesquely decorated. Some even played guitars and sang as they enjoyed the ride in those gondolas. Far away, there was the sea with ships sailing in and out of the harbour. Of course, this was Venice of bygone days, not the modern version I had visited recently.

‘Let me show you my glazed optic tube, my spyglass, or telescope as it has come to be commonly called,’ said Galileo taking out a long tube. He detached from its ends two lenses. ‘Ah, look at these lenses,’ pointed out Galileo. ‘They are plane on one side. But on the other side, one of them is *convex*, it bulges out. The other one is *concave*, it is hollow—just the opposite of the former. I am sure you know these things. I have shaped these pieces of glass by meticulously polishing them. It takes quite a bit of accurate work, you know. Let us attach them to the tube, one at each end. There, we have our optic tube ready. We look through it with the eye held close to the concave lens—like this. Ah, what wonders we see then! You will discover for yourself since I have arranged a spyglass specially for you.’

Of course, I was familiar with the Galilean telescope. I had used it even as a kid. But, it was such a rare pleasure and privilege to have it demonstrated by Galileo no less.

Galileo turned the telescopes towards the town below and beckoned, inviting me to take a look. As was to be expected, people who were far below now appeared so close, that I felt I could actually touch them.

‘I set up my optic tube on the top of the highest building I could locate in this city of Venice, just as I have done right now’ related Galileo. ‘Many important people mounted up the stairs, some of them huffing and puffing because of their great age or bulk, in order to see the ships that were so far off that it was two hours before they were seen without my spyglass, steering full-sail into the harbour. The effect of my instrument was such that it made an object fifty miles away appear as large as if it were only five.’

Galileo waited until I had fully enjoyed the sight of the town below.

‘Looking at people and objects at a distance was only a pastime. But, between you and me, the foolish people—they happened to be important ones as many fools are—were so impressed that they gave me a permanent job carrying a generous remuneration,’ laughed Galileo. ‘But then, the greatest event of my life happened: I turned my optic tube heavenwards!’

As he spoke his last words in all seriousness, Galileo turned the telescopes slowly upwards. At the same time, night descended, the sky darkened, stars and planets shone brightly.

‘You will see for yourself the wonders I observed through my spyglass,’ said Galileo. ‘I recorded my findings in a short book with the title *Sidereus Nuncius* or *The Starry Messenger*. I wrote my book in Latin as the custom was in those days. In any case, take a look at the sky above through your optic tube.’

Peering through my telescope, I was overwhelmed by the incredible sight of countless stars, although this was to be expected.

‘Oh, yes, I too was astonished when I looked at the night sky through my spyglass,’ confided Galileo. ‘You will see a fantastic number of stars. Most of them cannot be seen without the aid of an optic tube. They are unbelievably numerous, are they not? Some of them are crowded together in an amazing manner.’

‘Now look at the Milky Way,’ Galileo indicated the faint band of light that festooned the night sky. ‘You will hear quaint tales related to the Milky Way later on, my young friend. Its mysterious appearance had tormented philosophers through the ages, but now my spyglass could resolve all wordy disputes by revealing its true

nature. When I turned my optic tube towards the Milky Way, it dissolved into a mass of innumerable stars planted together in clusters. For, the Milky Way is nothing but collections of innumerable stars grouped together. Upon whatever part the optic tube is turned, a vast crowd of stars is immediately presented to view. Many of them are rather large and quite bright, but the number of smaller ones is quite beyond determination.'

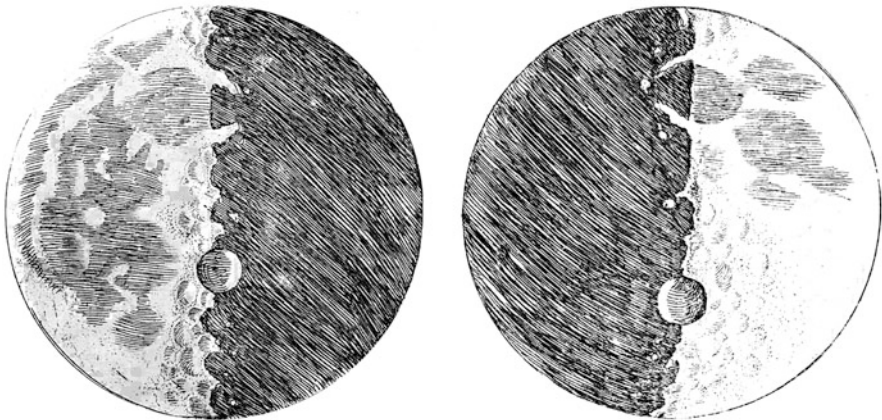
'Now, how about our nearest neighbour?' asked Galileo pointing to the Moon that shone with a pearly glow in the sky. 'It is most beautiful and it is pleasing to the eye to look upon the lunar body, is it not?'

'Take a closer look at the Moon,' urged Galileo. 'Almost the entire face of the Moon glows bright. But there is an uneven darker region that seems like a cloud covering part of it. This had been noticed for ages.'

Oh yes, I had noticed this since my younger days as I gazed upon the Moon on many occasions.

'Yes, I turned my optic tube towards our heavenly neighbour,' said Galileo, his head held high with pride. 'And what do you think I observed? Observed for the very first time, observed as never before! The entire face of the Moon is covered with spots. They look even more interesting when only a part of the Moon is illuminated by the Sun. I made a drawing of what I saw. Let me show it to you.'

Galileo brought out the sketch of the Moon that he had made after observing it through his telescope, showing all the spots or patches he had mentioned.



'What a beautiful drawing, *signore!*' exclaimed Casanova. 'Even your modern-day telescopes reveal almost exactly the same picture of the Moon, do they not?'

By now, the real Moon above us resembled exactly Galileo's drawing, partially illuminated by the Sun, with a jagged line separating the bright and the dark sections. As I looked through my telescope, Galileo continued his description.

'Spots, spots everywhere,' exclaimed Galileo. 'They are no ordinary spots. Look, they are bright on the side facing the Sun and, moreover, they cast shadows on the other side, do they not? As I said, those spots are no ordinary ones, my friend. They form, in fact, chains of mountains and depths of valleys just as it happens on the Earth.'

I felt that I could actually see those mountains and valleys. This was a totally different view of the Moon.

‘Now, for something beautiful,’ announced Galileo. His excitement was infectious. ‘The bright and dark parts of the Moon are exactly like day and night on the Earth with a dividing line between them. Look, look, a point lying in the dark area, some distance away from the dividing line, has brightened up. Why? Because, the first rays of the Sun, grazing the surface of the Moon, have lit up a mountain peak while the surrounding region is still in the dark. See, more peaks are brightening up, while the surrounding regions too are getting bathed in sunlight. What a lovely sight! All this happens right here on the Earth too.’

This was indeed amazing. One could feel the thrill of watching something happening far, far away.

‘Yes, yes, it was all wonderful to watch,’ recounted Galileo. ‘But, you know, by measuring the distance of the lighted peak from the dividing line and from the known size of the Moon, I could estimate the height of the mountain. It was quite simple.’

‘Simple but ingenious,’ added Casanova. ‘Like the measurements of Aristarchus, whom you met long ago.’

‘Oh, what a surprise! I found out that some mountains on the Moon are loftier than those on the Earth.’

‘Not quite I am afraid,’ put in Casanova in a low voice. ‘That is because, in those days, they did not know the exact heights of the mountains on the Earth as you do now.’

‘What does it all mean?’ mused Galileo stroking his beard. ‘It means that the Moon, with all its mountains and valleys, is just like our Earth. For ages, philosophers had claimed that the Moon, like all heavenly bodies, is perfectly spherical and absolutely smooth. But, I had demonstrated that this was not true. But, foolish people, would they give up their idiotic ideas? Some said the Moon was indeed smooth as it should be. All the mountains, peaks, and valleys were *within* the smooth surface. Like the marbles you saw in the amusement park.’

I remembered the amusement park, where I had spent not only some joyful time, but also had learnt about epicycles that too guided by Ptolemy himself.

‘Humans are a strange lot,’ reflected Galileo shaking his head. ‘They do not give up their prejudices easily. In any case, the important fact is that the Earth and the Moon are alike. Both of them happen to be just two similar celestial bodies.’

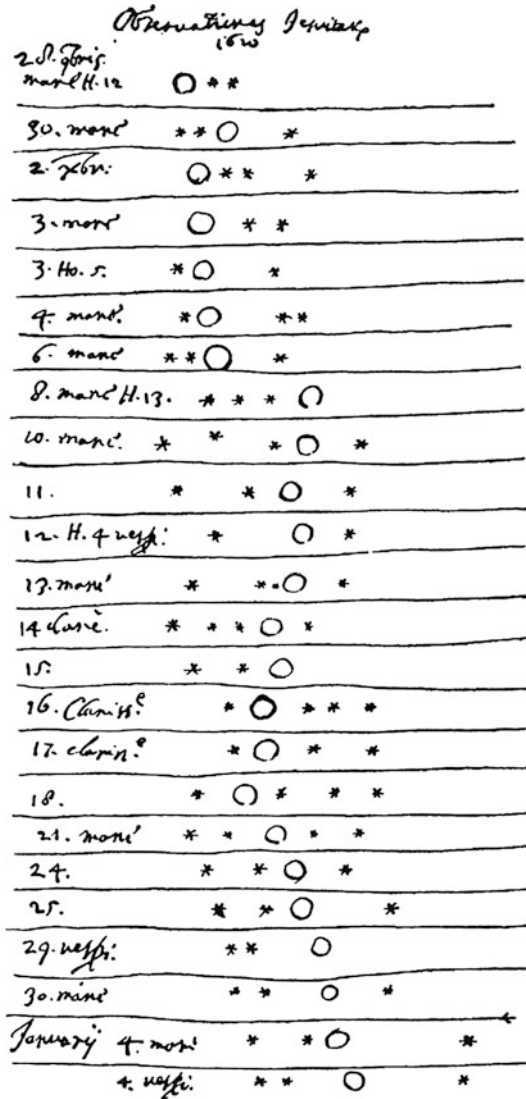
Galileo paused to give time for me to digest all the details about the Moon he had demonstrated and the conclusions that had followed.

‘Now, my dear friend, let me tell you about another observation I made. I feel it deserves to be considered the most important in my work. I am talking about the discovery of the four Moons of the planet Jupiter,’ announced Galileo. ‘Ah, those Moons, they looked like little stars through my spyglass. But were they fixed like ordinary stars? Oh, no, they moved along a straight line that passed through Jupiter. There happened to be four of them in all. Three of them were quite bright, but the fourth one was very faint indeed. Different ones appeared sometimes on one side of the planet and sometimes on the other. Then again, sometimes, they disappeared altogether. Do you see what I mean?’

I was delighted to watch the hide-and-seek the little stars, or the Moons, were playing around Jupiter.

‘Here, let me show you the diagram I made marking their positions.’

Galileo pulled out a sheet from his pocket and spread it out. It showed a series of very simple sketches of the planet Jupiter drawn as a circle and the positions of what he had taken to be regular stars marked by little crosses.



‘From these meagre notes, I concluded that what I had observed were not stars, but Moons circling around Jupiter just as our nearest neighbour goes around our Earth.’

Galileo inclined his head and looked intently at me, holding my attention.

‘Needless to add, it was I who discovered those Moons of Jupiter for the first time in all human history,’ proclaimed Galileo.

Galileo was proud of his discoveries. Justly so, I felt.

‘In essence, just as our Earth circles the Sun, while the Moon does the same as it goes round the Earth, we have exactly the same situation in the case of the planet Jupiter and its four Moons. Again, therefore, there is nothing special about the Earth. It is not the only centre of revolution, it is not the centre of everything, as had been considered all along. Why couldn’t the Earth itself go round the Sun then, as Copernicus taught us? He was absolutely right, no doubt about it.’

‘To complete the story, those Moons Galileo had discovered are collectively known as the *Galilean Satellites* as they should be,’ said Casanova and added, ‘They bear the names, *Io*, *Europa*, *Callisto*, and *Ganymede*. In mythology, the last one was the cup-bearer of Jupiter, while the other three were his sweethearts.’

‘Is the Earth at the centre or the Sun? Is Ptolemy correct or Copernicus? That was the question,’ Galileo extended his open palms and raised and lowered them alternately as though he was weighing two imaginary objects held in his hands. ‘Why not put this question to a planet and ask whether it went around the Earth or the Sun? How about the brightest of them all, namely Venus, the planet named after the goddess of love? So, I focussed my spyglass on Venus. And what did I discover? Ah, the phases of that lovely lady!’

Galileo nodded his head a few times vigorously and went on.

‘I do realize that you know all about the phases of our Moon. Oh, fortunate one, you learnt about that phenomenon from that towering astronomer of ancient Greece Aristarchus himself. He was the first one to think of the Sun being the centre of the Universe, was he not? There is no limit to my astonishment when I reflect that Aristarchus and Copernicus were able to make *reason* so conquer *senses*, that in defiance to the latter, the former became the mistress of their belief.’

‘That transition from *appearance* to *reality*, so well articulated by our distinguished host just now, was a giant leap in human thought, *signore*,’ said Casanova emphatically. ‘All your science has striven since then to establish reality gleaned out of appearance, however elusive, however contrary to common sense it might have looked at first on the surface. But let us listen to my illustrious compatriot’s further observations.’

‘Suppose the Earth is at the centre and Venus and the Sun go around it,’ continued Galileo. ‘Then Venus would always be nearer to the Earth than the Sun. One can easily show that the planet would appear to have a crescent shape alone as viewed from the Earth. On the other hand, let us go along with Copernicus and assume that Venus and the Earth, in that order, circle the Sun. So, Venus is sometimes between the Earth and the Sun and sometimes on the farther side of the Sun. In this case, it would exhibit a complete set of phases as observed from the Earth, but quite different from those of the Moon though. Look through your optic tubes and see for yourself which of the two possibilities happen in reality.’

I eagerly glued my eyes to the telescope in front of me. Oh, yes indeed, the bright beautiful planet went through all the phases but unlike what I had seen in the case of the Moon, as Galileo had described. I was not surprised. Galileo seemed to know it all.

Galileo's eyes shone with joy as he declared, 'Yes indeed, Venus displayed the entire range of phases. The love goddess showed her full face in all its glory, whereas sometimes she displayed only part of it tauntingly, and finally hid it shyly in complete darkness. Was this not positive proof of the Copernican model? Yes, indeed! Oh, yes, yes!'

Galileo waited, relishing his past momentous observation and the conclusion that followed, before going on.

'Let me recount two more discoveries I made with my optic tube,' Galileo went on. 'I now turned my most powerful telescope—I had made several of them you see—towards the farthest planet of all, namely Saturn. I could see its disk all right. But, on closer examination, I was startled to see what I saw. And what *did* I see? The planet Saturn was not just one entity, but was composed of three parts, which almost touched one another and never moved nor changed with respect to each other. The middle one was three times the size of the one on each side.'

As Galileo spoke, Jupiter had made way for Saturn and I could make out the central disk as well as the adjoining members of the planet.

Galileo pondered for a moment, running his hand along his telescope, and continued, 'I was puzzled to say the least. The two attendants of Saturn were quite unlike the satellites of Jupiter. They showed no relative motion at all. Two years later, I was even more astonished to discover that the planet was single. The other two parts were gone. What was to be said of this strange transformation? What had happened to the two attendants? Had they suddenly vanished or fled? Had Saturn perhaps devoured his own children? Or were the appearances indeed illusion or fraud, with which the glasses had so long deceived me, as well as many others to whom I had shown them? I did not know what to say in a case so surprising, so unlooked for, and so novel. But, marvel of marvels, the two attendants appeared again now in the guise of arms or handles attached to the main component!'

Galileo shook his head frowning in bafflement.

'Poor Galileo,' laughed Casanova softly. 'What he had observed were the rings of Saturn. His optic tube was not powerful enough to show the details. When viewed edge-on, those rings had become invisible.'

It took a little while for Galileo to regain his composure after experiencing once more his lack of understanding of Saturn's mysterious behaviour. He shook his head again and again before continuing with his exposition.

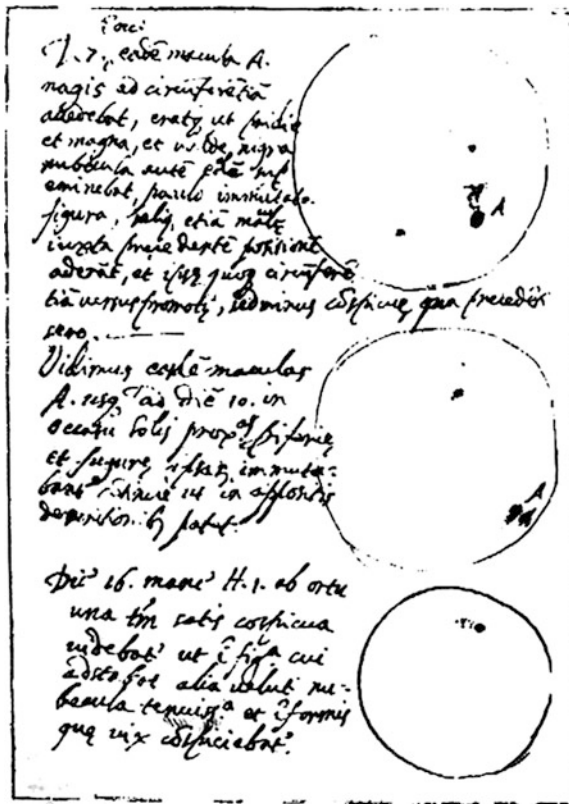
At that moment, light started seeping into the night sky as though it was dawn now. The Sun seemed to be hastening to appear in the sky, realizing that its presence was needed for Galileo's next demonstration.

'The Sun, the blazing source of light, a perfect heavenly body, venerated by people of all ages as a supreme god!' exclaimed Galileo. 'But is the Sun perfect? Tell me, my friend from the future. No, there are blemishes, spots on that god's face as I discovered. But let us not look upon that face through the spyglass. For, there is no doubt that we shall go blind. Let us, instead, direct the spyglass as if we were

going to observe that body. Having focused and steadied the optic tube, expose a flat white sheet of paper placed about a foot from the concave lens close to which you normally place your eye. Now look, a circular image of the Sun's disk has fallen upon the paper, with all the spots showing exactly as they appear on that heavenly body.'

Oh yes, I could see on the sheet of paper the face of the Sun marked with a few dark spots.

'As you can see, these spots are carried across the disk of the Sun from day to day. By following their movement, I could determine that the Sun takes between three to four weeks to spin once on its axis.'



Galileo sat down on a chair next to the telescope, mopped his brow with the back of his hand, and heaved a sigh. The excitement of reliving the moments of his phenomenal discoveries had exhausted him. He closed his eyes and sat motionless, while I watched him with utmost respect. To my immense astonishment, ever so slowly, he seemed to grow older. His hair and beard turned grey, wrinkles appeared on his face that clearly showed signs of extreme weariness.

Crime and Punishment

‘I was convinced beyond doubt that Copernicus was right,’ Galileo said gathering his strength. His voice was still firm and his mind was clear. ‘Yes, the Sun was the centre of the Universe and the Earth went around it. How could anyone doubt this fact when I had proved it by my own observations? I was determined to spread the truth about our Sun and his family of planets and spread it I did.’

Galileo’s voice turned sombre as he recalled the past events. ‘But the Church did not take this kindly. How could the Earth—and man with it, man who had been created in the image of God—be banished from its central position? More importantly, how would people react if they came to know the falsity of all the teachings of the Holy Scripture that they had come to believe for ages? Let me not go into the details of the painful dealings with the Church I had to carry out in the initial stages of my struggle. I was ordered to abandon the doctrine of Copernicus and, in the words of the Church’s decree, *not to hold, teach or defend it in any way, orally or in writing.*’ Galileo’s eyes gleamed as he announced, ‘Yet, I wrote my book discussing the Copernican system as opposed to that of Ptolemy, *Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican.* I wrote the book in Italian, our common language, so that everyone, including the vegetable vendors and boatmen, could read it and understand the true nature of our Universe. That was a point against me since all scholarly books were supposed to be written in the ancient language, Latin, which the common man could not read or write so that knowledge remained the property of a chosen few, especially those belonging to the Church. Well, I presented my arguments as a discussion among three people, Sagredo, Salviati, and Simplicio. Of these three, Sagredo is an intelligent questioner eager to learn.’ Galileo’s face lit up as he described the second member of the trio. ‘Salviati, who champions Copernicus, is brilliant, profound, and possesses a sharp wit and tongue, which he uses to advantage in argument. Well, I do not feel ashamed to say that I had my own self in mind when I created this character.’ A malicious glee appeared on Galileo’s face now. ‘And Simplicio, as his very name indicates, is a blundering simpleton, who firmly believes in Aristotle and repeats that ancient scholar’s ideas time and again, advocating the Ptolemaic system of the Universe. Salviati, needless to add, demolishes Simplicio and holds up Copernicus for all the eyes of the world to behold.’

Galileo’s face darkened as he brooded over the events that had followed his writing the *Dialogue*. ‘At first the Church did not mind what I had written. The book was duly published. But then the tide turned. It was thought that I had deliberately lampooned the Church through the character of Simplicio. The Pope, the highest authority in the Church, was infuriated. Then came the shattering blow. I was summoned to Rome, the highest seat of the Church, to be tried. This was the worst thing that could have happened to me or to any other man.’

Galileo bowed his head in silence. By now he had aged completely.

Then the scene shifted.

‘We are in Rome, *signore*.’ Casanova said in a hushed voice. His expression had turned sad and serious. ‘We are standing in the Piazza della Minerva. Behind us stands the Church of Santa Maria built in the thirteenth century on the ruins of a Roman temple dedicated to Minerva. Look over there on the right. That building is the Convent of Santa Maria Sopra Minerva, the seat of the inquisition, its victims relentlessly pursued by the Dominican order. It is here, at the moment, Galileo faces the inquisition, standing trial for his heretical views and their propagation in violation of the order issued by the Church.’

Casanova shook his head. ‘Minerva, the goddess of wisdom! What an irony, *signore*, wisdom seems to have been thrown to the winds by those who are in power.’

I was reminded of the last lines of Robert Frost’s poem *Stars*:

*And yet with neither love nor hate,
Those stars like some snow-white
Minerva’s snow-white marble eyes
Without the gift of sight.*

Had Minerva, the goddess of wisdom, turned a blind eye on the proceedings taking place within the temple dedicated to her? I felt the atmosphere in the piazza oppressive and threatening.

‘Let us go in, *signore*, to witness the end of the tragic event of the past, an event that cannot be reversed,’ Casanova spoke his words gently and led me into the Convent.

The interior of the Convent was gloomy. A number of people had thronged around. Seated on high carved chairs were men with stern faces dressed in impressive robes. In front of them stood Galileo. He appeared to be almost on the verge of collapse, far from what he had been—the exuberant stargazer, robust and happy, who had described his observations and explained the system of the Universe.

‘The entire Congregation of the Holy Office, the highest authority of the Church, has gathered here,’ informed Casanova in a barely audible whisper. ‘They have just passed their judgement on Galileo.’

Galileo bowed low before the Congregation and knelt down with great difficulty. I could hear his feeble voice that shook as he made his forced confession and caught a few of his last words.

‘I Galileo, son of the late Vincenzo Galilei of Florence, aged seventy, kneeling before you, do swear that I have always believed, and now believe, and with God’s help will in the future believe all that is held and taught by the Holy Church. The Holy Office intimated to me that I must altogether abandon the false opinion that the Sun is the centre of the world and is immovable, and that the Earth is not the centre of the world and moves, and that I must not hold, defend or teach in any way whatsoever, either verbally or in writing, the said false doctrine, which is contrary to Holy Scripture. . . Therefore, with sincere heart and unfeigned faith I do abjure, curse and detest the said errors, which are contrary to Holy Church. I swear that in future I will never again say or assert verbally or in writing, anything, which might again give ground for suspicion against me. . .’

Galileo's voice trailed off as the scene slowly faded away.

'They say that even then, as he rose from his kneeling position, Galileo had mumbled inaudibly, *Eppur si muove—And yet...it moves,*' remarked Casanova. 'That is absurd, to say the least. By the time he faced the Congregation of the Holy Office, Galileo was already a broken man. He had been shown the implements of torture in order to intimidate him. If those hounds of inquisition had even suspected that he had uttered those words repudiating his own abjuration, they would have torn him to pieces. For the rest of his life, Galileo became practically a prisoner confined to his home in Arcetri. Let us move on to that last abode of the unparalleled scientist who had changed Man's view of the Universe as none had done before him.'

Twilight Days

We were inside a room of modest proportions with very few pieces of furniture. Seated at a rough-hewn table, was Galileo. On the table rested his favourite telescope, the very first one he had fabricated, which he had turned heavenwards.

Galileo was silent. He seemed to be far away, somewhere in the past surrounded by his memories. Those memories were probably not happy ones as his frown betrayed. Presently, he started to mumble to himself, his musings often accompanied by exaggerated gestures. Strangely enough, most of his words seemed to have been written by him long before.

With a wistful smile, Galileo picked up his telescope and caressed it lovingly.

'Ah, my spyglass, my glazed optic tube,' he addressed it affectionately. 'My friend Kepler thought that you were more precious than any sceptre. You revealed so many wonders, so many new phenomena. But my colleagues stirred up against me as if I had placed these things in the sky with my own hands in order to upset Nature and overturn the sciences. But you, Kepler, you confirmed everything I wrote, without rejecting an iota of it. I indeed congratulate myself on having an associate in the study of Truth, who is a friend of Truth. For it is a misery that so few exist who pursue the Truth and do not pervert philosophical reason.'

Galileo's lips twisted into a sardonic smile. 'Even after my demonstrating Jupiter's Moons with my optic tube, none of the philosophers and scholars conceded their existence. They claimed that, seven being a sacred number, there could only be seven objects in the sky: Sun, Moon, Mercury, Venus, Mars, Jupiter, and Saturn. Cesare Cremonini, teacher of philosophy at Padua refused even to look through my optic tube. So did my dear colleague Julius Libri!'

Galileo's expression turned into one of intense glee, almost verging on the malicious, as he recalled his own past reaction to this foolishness. 'Soon after, Libri died and I could not help commenting: Libri did not choose to see my celestial trifles while he was on Earth; perhaps he will do so now *en route* to heaven!'

Galileo exploded with uproarious laughter slapping his thigh, but fell quickly into his melancholy mood again.

‘Ah, Kepler, most of my colleagues are incapable of identifying either Jupiter or Mars, and hardly even the Moon. What is to be done? Let us laugh at the stupidity of the crowd, my Kepler. Why are you not here? I wish I had more time to laugh with you. How you would shout with laughter, my dearest Kepler, if you were to hear what the chief philosophers of Pisa said against me to the grand duke. . . . But the night has come and I can no longer converse with you.’

Galileo closed his eyes in weary loneliness. ‘I believe that good philosophers fly alone, like eagles, and not in flocks like starlings. It is true that because eagles are rare birds: They are little seen and less heard, while birds that fly like starlings fill the sky with shrieks and cries, and wherever they settle befoul the Earth beneath them.’ After a pause he added, ‘The crowd of fools who know nothing is infinite. Those who know very little of philosophy are numerous. Few indeed are they who really know some part of it. And only One knows it all.’

‘Ah, the Universe!’ exclaimed Galileo with awe after a momentary pause. ‘To investigate the constituents of the Universe is one of the greatest and noblest problems in nature. But has anyone so far proved whether the Universe is finite and has a shape, or whether it is infinite and unbounded? O, foolish man, does your imagination first comprehend some magnitude for the Universe, which you then judge to be too vast? If it does, do you like imagining that your comprehension extends beyond the Divine Power? Would you like to imagine for yourself things greater than God can accomplish? And if it does not comprehend this, then why do you pass judgement upon things you do not understand?’

Galileo wiped away the glistening beads of perspiration that had appeared on his brows with the back of his hand.

‘No son of Adam had seen further than I since the beginning of the world,’ Galileo closed his eyes and heaved a deep sigh. ‘This Universe which I with my astonishing observations and clear demonstrations had enlarged a hundred-, nay, a thousand-fold beyond the limits commonly seen by wise men of all centuries past, is now for me so diminished and reduced, it has shrunk to the meagre confines of my body.’

I was startled as Galileo raised his head, opened his eyes and stared vacantly into space. He had grown very old indeed, his hair and beard had turned white, and his face was covered with a network of wrinkles. ‘Alas, Galileo has become infirm with age and his eyes have lost their power of vision,’ said Casanova in an almost inaudible whisper. ‘He has become totally blind, *signore*.’

Galileo sat motionless as he brooded over his own condition.

‘Bereft of my powers by my great age and even more by my unfortunate blindness and the failure of my memory and other senses, I spend my fruitless days which are so long because of my continuous inactivity and yet so brief compared with all the months and years that have passed. And I am left with no other comfort than the memory of the sweet former friendships. I shall therefore remain silent, and so pass what remains to me of my laborious life, satisfying myself in the pleasure I shall feel from the discoveries of other pilgrim minds.’

Galileo’s countenance turned serene and peaceful with his acceptance of his fate combined with the conscious realization of his achievements.

‘I must not forget my book *Two New Sciences* which I believe is superior to everything else of mine hitherto published, for it contains results which I consider the most important of all my studies.’

‘Galileo wrote that book during his last years,’ said Casanova. ‘It was based on a number of experiments he had performed over many years and the conclusions he had drawn from them. A monumental work indeed!’

After a moment of absolute stillness, Galileo’s final words reverberated in majesty.

‘There will be opened a gateway and a road to a large and excellent science into which minds more piercing than mine shall penetrate to recesses still deeper.’

Galileo then bowed his head, his clasped hands resting against his forehead. ‘I render infinite thanks to you, God, for being so kind as to make me alone the first observer of marvels kept hidden in obscurity for all previous centuries. *Grazie, grazie, Dio...*’

The rest of his prayer was said in silence.

I felt sad, so sad as I had never felt before.

‘Yes, *signore*, Galileo had a difficult life. We did not learn about all the tragic twists and turns it took,’ said Casanova. ‘But let us not forget, he is one of the greatest men of science ever. His book, *The Starry Messenger*, heralded a new age in astronomy. But Galileo himself ought to be hailed as the Starry Messenger. There are many other things he discovered, some of which you will learn about later on. They happen to be so important to the modern science of your own times. Galileo will always be remembered by those who wonder and think about the stars, the planets, and the entire Universe.’

I could not agree more with Casanova.

‘You heard what Galileo said at the end,’ Casanova recalled. ‘*There will be opened a gateway and a road to a large and excellent science into which minds more piercing than mine shall penetrate to recesses still deeper.* Yes, a man with a great mind most piercing came into this world the same year Galileo passed on from it. You are fortunate enough to learn about him and his work soon enough.’

Casanova smiled. Not his usual mocking smile, but a smile of warm friendship. The melodious music of Mozart had started playing in the background again.

‘As always, it has been an immense pleasure to spend these precious moments with you, *signore*,’ said Casanova. ‘Once again, let me make it clear that I am not going to bid you *addio*, my final farewell. Please allow me to say just this, *arrivederci per il momento, e che la pace sia con voi*: goodbye for the moment and may peace be with you.’

As Casanova slowly melted away, so did the soft soulful music. At the same time, I was engulfed in thick yellow fumes.

Chapter 8

The Fall and the Firmament

The Golden Goal

When the fumes cleared, I realized that I was in the strangest room I had ever seen. There was a variety of appliances made of glass and metal. A young man was stirring some material in a large vessel that was being heated and from which the clouds of yellow fumes, that had engulfed me, were still rising up. He was pale and seemed to be somewhat weak. Although he was in his shirtsleeves, he was profusely perspiring.



There was a knock on the door and, without waiting for a response from the young man, an older gentleman entered. He was quite handsome and appeared to be aware of the fact. He was splendidly dressed in a maroon velvet coat with silver buttons, embroidered vest, frilled shirt, and a cravat of white lace. Most striking was his auburn coloured hair cascading down to his shoulders in a profusion of curls—obviously an expensive custom-made wig.

‘What a strange place!’ exclaimed the gentleman in his deep resonant voice looking around with curiosity. ‘Ah, there you are. I do not know how you can stand all this smoke and smell,’ said he spotting the young man at the fire.

The latter extinguished the fire, wiped his hands on a cloth lying nearby, and hastened towards the visitor, while putting on his coarse jacket which he had tossed on a nearby chair.

‘Mr Edmond Halley, what a pleasure to meet you again after such a long time, sir,’ the young man beamed. ‘I hope you remember me. I am Humphrey Newton, assistant to the great man with the same last name, but let me hasten to add, no relation of his as some jump to the mistaken conclusion.’

‘Of course, I remember you well, Humphrey,’ Halley assured him. ‘What is going on here? I could not find you in the library, so I ventured here.’

‘You must have heard about Mr Isaac Newton’s alchemical experiments in search of the Philosophers Stone that can turn base metals like lead into pure gold,’ answered Humphrey. ‘As you can see, he has set up several pieces of equipment for this purpose. Please allow me to show them to you. Here are two furnaces made of iron and copper to heat different substances; *alembics*, vessels for mixing, heating, and distilling; *solem*, a distillation tube; and a *tribikos* or funnel.’

‘Oh yes, these are used in scientific experiments also,’ said Halley. ‘The science of chemistry that involves the study of the properties of various substances—solids, liquids, and gases—has gained much from alchemy. But tell me, what are those ingredients you are handling?’

‘Seven metals mainly—gold, silver, iron, tin, mercury, lead, and copper. Sulphur is also used for processing, which gives out horrible yellow fumes. Mercury, the *prima material*, the first member of all substances, is considered to be the soul of alchemy. But, it too gives out noxious vapours.’ Humphrey motioned towards a tray that contained the ingredients he had mentioned: glittering gold and silver, shining red copper, a dull piece of lead, and a crucible of bright mercury. He added in a whisper, ‘Between you and me, Mr Halley, I think this vapour causes some kind of nervous reaction in Mr Isaac Newton leading to irritability, which is not beneficial to him.’ He lowered his voice even further and mumbled almost inaudibly, ‘Or for that matter to others around him, I am afraid.’

‘I understand your concern for Mr Newton, Humphrey. I am sure these experiments are not pleasant for you either,’ sympathized Halley. ‘But do you have any idea why the eminent thinker is indulging in alchemy? I am sure it is not for material gains, since I know he is not interested in amassing money.’

‘No, not for any material benefits is he pursuing the path of alchemy, which many have followed in vain since time immemorial,’ agreed Humphrey. ‘This is what I understand from the snatches of his conversations with others who are interested in this esoteric pursuit including the well-known scientist Mr Robert Boyle. In order to be a true devotee of this ancient art, one has to find, read, and assimilate all the ancient writings, because the ancients were the wisest people and were the repository of all knowledge and wisdom. The primary prerequisite for practising alchemy is that the alchemist be pure in soul through religion, or metaphorically speaking, he has to transmute himself into pure gold. Mr. Newton

thinks, I believe, that he is ideally suited for the role as he satisfies all the requirements including the possession of the highest degree of intellect that enables him to avoid the pitfalls of the others.’ Humphrey lowered his voice again to a whisper. ‘All alchemists assume pseudonyms or code names in their interactions with one another. Do you know the pseudonym Mr Newton has chosen for himself? It is *Jeova Sanctus Unus*, One Holy God, based upon an anagram of the Latinised version of his own name *Isaacus Neutonus!*’

I knew very well that Isaac Newton, one of the greatest scientists of all time in fact, was a very complicated person. And I was now glimpsing one of his unusual sides. Yes, this was altogether a different world I had stumbled into.

‘Let me show you something most interesting that Mr Newton has produced during the course of his experimentations,’ said Humphrey, opening one of the boxes that had been stacked in a corner. Inside, on dark blue velvet lining, lay a beautiful crystal harbouring within it a scintillating star-like structure.

‘What is it?’ enquired Halley with astonishment.

‘A *Star Regulus* or *Regulus of Mars*,’ exulted Humphrey. ‘It is the crystalline configuration of the metal antimony produced by processing it with iron, copper, tin, and lead. Please look carefully at its structure, which may be visualised as rays of light radiating outwards. But I overheard Mr Newton thinking aloud: *The components seem like lines of force acting inwards towards the centre like gravity in fact.* Those were his very words, Mr Halley.’

Halley shook his head in amazement. ‘Humphrey, mysterious are the ways in which genius works! Imagine how the profound intellect of Mr Newton might have linked the *Star Regulus* to the idea of a *central force* that gravity seems to be. And it is precisely in connection with that force, which Mr Newton has so magnificently explained and employed in describing the motion of the heavenly bodies, have I come to see him as you might very well have surmised. Let us adjourn to the library, Humphrey, if you please.’

The Magnum Opus

Slowly, the scene shifted to Isaac Newton’s library.

The furnishings indicated a preference for the red colour; even the books on the shelves had been bound in red leather.

‘Look at the red colour everywhere,’ Humphrey made a sweeping gesture with his hand. ‘I am told that the red colour too contributes to the nervous irritability of my master just as the mercury vapour does. Returning to alchemy, no less than one hundred and thirty-nine books among Mr Newton’s collection are on that subject, while only thirty-one pertain to the science of chemistry.’

‘I can see that,’ commented Halley who was casually turning the pages of some of the books. ‘You showed me the lovely *Star Regulus*, which seems to symbolise the *central force* or a force that acts towards a centre. Well, the most important visit I made to Mr Newton’s lodgings here in Cambridge sometime ago was to explore

the role of such a force in the context of planetary motion. When I asked him about it, Newton readily said, why, of course it is an ellipse. How do you know that, I enquired. I have proved it and I shall show it to you says he rummaging through his papers, but could not find it. I was astounded by the piles of paper containing an enormous amount of work he had done. With great difficulty, I persuaded him to write up his findings so the world could learn the secrets of Nature, which he had revealed for himself alone till then. The rest is history as the saying goes. He has now thrown himself—body, mind, and soul—into the glorious task of composing his masterpiece, a book of science such as the one that has never been written before nor, perhaps, will ever be written in the future. The monumental volume will bear the title, *Philosophiæ Naturalis Principia Mathematica—Mathematical Principles of Natural Philosophy*—or *Principia* for short. I have come to see how his work is progressing and discuss the book’s publication, the responsibility of which I have shouldered in its entirety.’ Halley added with a smile, ‘That includes bearing the costs of publishing as well.’

‘You will have to wait a little, I am afraid, Mr Halley,’ said Humphrey tilting his head towards a room at the back of the library. ‘Mr Newton is in his study, which he hardly leaves, thinking all hours.’

‘Is he taking care of himself properly?’ asked Halley anxiously.

‘So intent, so serious upon his studies is he, that he eats very sparingly, nay, oft times he has forgot to eat at all, so that, going into his chamber, I have found his meal untouched, of which, when I have reminded him, he would reply—*Have I!* and then making to the table would eat a bit or two standing. As you know, he keeps neither dog nor cat in his chamber, which makes well for the old woman his bed maker, she faring much the better for it, for in the morning she has found both dinner and supper scarcely tasted of, which the old woman has very pleasantly and mumpingly gone away with.’ Humphrey permitted himself a subdued laughter taking care not to disturb Isaac Newton in his study.

‘Does he sleep well at least?’ enquired Halley.

‘He very rarely goes to bed till two or three of the clock, sometimes not until five or six, lying about four or five hours.’

‘With all this strain, I hope his health has not suffered.’

‘Fortunately, his health has remained satisfactory. I once expressed my concern and can you imagine what he says to me—*Do not trouble yourself, Humphrey. If I die, rest assured that I shall leave you a legacy.* What an extraordinary notion!’ Humphrey shook his head.

Halley suppressed his mirth at this remark and decided to wait for Newton to take a break from his work.

All of a sudden, the door to the study flew open and Newton emerged from his study. His countenance indicated a vast penetrating mind. His wig with flowing hair, which he must have worn earlier to receive some visitor and had forgotten to take off, was askew displaying here and there his real hair that had become grey as a result of his severe studies. Though not tall in stature, yet he seemed to be strong, sinewy, and well built. His eyes were very full and protuberant, which had rendered him near-sighted in youth, but was the reason of his seeing so well in age.

Newton, absorbed as he was in his own thoughts, seemed to be totally unaware of our presence in his library. He strode towards one of the book cases, briefly consulted a volume, and jotted down a few lines in a thick note book he was carrying. Then, as abruptly as he had emerged from his study, he hastened back and disappeared.

‘Well, Humphrey, while Newton is busy in his study, let me attend to the pleasant task of discussing Mr Newton’s prodigious work with our honoured visitor here who has been following our conversation keenly and watching with great interest all that you have shown me. It is best I undertake the job in the vast expanse of space inhabited by stars and planets. I shall return soon, Humphrey. Farewell till then.’

Halley smiled at me and inclined his head in silent invitation to follow him.

Newton’s lodgings slowly dissolved giving way to the night sky.

A Matter of Gravity

I was happy to return to the infinite space sprinkled with distant stars, the Earth glowing far below. I was floating now in the august company of Edmund Halley.

‘Wonderful feeling, is it not?’ remarked Halley. ‘Ah, the exhilaration of weightlessness with no gravity pulling you down! On the other hand, as you very well know, sir, Newton’s greatest discovery was related to the nature of gravity, which is so important a force in Nature.’

Halley relaxed for a while enjoying this feeling of total freedom only the far reaches of space could offer.

‘I know that you have learnt all about Newtonian physics in the course of your deep discussions with a most learned friend, philosopher, and guide of yours,’ began Halley. ‘Nevertheless, please allow me the privilege of discussing some important aspects of Newton’s monumental work, his book of books, *Principia*, a modern copy of which you have acquainted yourself with.’

Halley reflected for a moment drumming his finger on his chin. ‘Before we come to *Principia*, let us begin our discussions with Isaac Newton at Cambridge, shall we?’ Halley resumed. ‘Newton, owing to the lack of sufficient funds when he joined Trinity College at Cambridge, was obliged to become a Sizar, a student who paid his way through his studies by doing odd jobs by waiting on his tutor. What a lowly position for one who was destined to be a towering genius, my dear sir! Well, by great good fortune, he became a Fellow when vacancies opened up. Do you know how such an opportunity arose? A Senior Fellow had been sent away from the college on account of insanity and two others because they had unceremoniously fallen down the stairs after a long bout with the bottle! Grape and gravity make a dangerous combination, do they not?’

Halley threw back his head and laughed heartily. I could not help but join in.

Halley pulled out a pure white lace handkerchief from his jacket pocket and wiped away the tears caused by his mirth. He would repeat this performance in a rehearsed manner whenever he laughed.

‘In his youth, Newton did his best work not within the confines of the University, but outside in the free atmosphere of his home, the Woolsthorpe Manor,’ Halley went on. ‘That was during the two years around sixteen hundred and sixty-six that have come to be known as *Anni mirabilis*, the Miracle Years of Isaac Newton, when Cambridge was closed because of the plague. Perhaps it is a splendid idea to shut down universities for a while from time to time to allow the scholars to think in peace so that new ideas may blossom forth, maybe some of them permanently!’

Halley permitted himself another blast of laughter before continuing, ‘Newton was to reflect upon the work he did during those years. Listen, dear sir, to what he had to say:

All this was in the two plague years of 1665 and 1666, for in those days I was in the prime of my age for invention, and minded mathematics and philosophy more than at any time since.

‘*All this!* Those two simple words represent a staggering amount of work. In those two years, mere two years, Newton had laid the foundations of his mechanics, optics, fluxions, and the supreme pinnacle—gravitation.’

Ah, the genesis of Newton’s universal law of gravitation inspired by the sight of a falling apple! I remembered what I had read about that event as described and commented upon by a host of people like Voltaire, De Morgan, Brewster, and Newton’s young friend and his first biographer, Dr. Stukeley, to name a few.

‘Yes indeed, the falling apple has become a fine symbol of earthly gravity, has it not?’ Halley read my thought. ‘But, let us not imagine that the law of gravitation flashed in the mind of Newton as a result of divine inspiration. On the other hand, the discovery was initiated by comparing the gravitational pull on all objects on the Earth like the apple with the gravitational attraction exerted on the Moon by its parent planet, the Earth. Once again, here is what Newton had to say in a note he wrote years later:

I thereby compared the force required to keep the Moon in her orb with the force of gravity at the surface of the Earth, and found them answer pretty nearly.’

Halley held one of his hands up, the forefinger pointing heavenwards and the other down with the forefinger indicating the Earth. ‘Yes sir, the Moon in the sky conspired with the apple on the Earth to lead Newton to the law of gravitation. He realized that if gravity decreased inversely as the square of the distance, then he could explain how he *found them answer pretty nearly*. Again, it took him nearly twenty years to prove that a spherical body like our Earth acts as though all its mass is concentrated at its centre only under the influence of an inverse square law. Ah, then came Newton’s stroke of genius—the Universal Law of Gravitation as we know it today, a sweeping generalization of a particular observation.

Halley held out his two hands. A magnificent copy of the first edition of *Principia*, bound in thick leather, appeared on his open palms turned upwards. He opened the volume respectfully and extended it for my inspection.

I quickly leafed through the book, although I was quite familiar with it. Once again, I was overwhelmed by the contents. It was a veritable forest of definitions, propositions, theorems, corollaries, problems, and scholiums. Page after page was covered with complicated geometric figures—lines, triangles, rectangles, polygons, circles, ellipses, and other curves. I was reminded of Galileo's famous statement:

Philosophy is written in that great book which ever lies before our eyes—I mean the Universe—but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. The book is written in the mathematical language, and the symbols are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through dark labyrinth.

Halley, who was watching me, remarked, 'Rather humbling, is it not?'

I nodded quietly. I felt that it must be an immensely difficult book to read, let alone understand.

'Indeed, it is not at all an easy task to navigate through that tome,' agreed Halley. 'Newton himself told a friend: *to avoid being bated by little smatterers in mathematics he designedly made his Principia abstruse, but yet so as to be understood by able mathematicians*. But then, even the ablest mathematicians found the *Principia* difficult to understand.'

Halley paused and offered, 'Let us take a closer look at this living scientific monument. We can only have a glimpse of the treasures it contains.'

Halley opened the book and revealed the title page. The full title of the work stood out boldly at the top: *Philosophiae Naturalis Principia Mathematica*, Mathematical Principles of Natural Philosophy.

As a prologue to the book, there was something I could never have expected.

Halley smiled, a smile that exuded his joy, his pride, and his contentment.

'Yes, sir, I had the honour of contributing that *Ode to Isaac Newton*, which stands at the very beginning of the volume. After extolling Newton's achievements in my own poetic terms, I concluded my Ode with my tribute to that man of unique genius:

Nearer the gods no mortal may approach.

That in fact sums up my humble feeling about one whose contribution to human knowledge happens to be literally beyond measure.'

Halley fell silent. Perhaps he was thinking of how to proceed further in his description of *Principia*. It was a great pleasure and privilege just to watch a brilliant man like him immersed in silent contemplation.

'I fully realize that you have already learnt about the main results contained in the book, sir,' Halley went on. 'I shall just read out some salient parts of the book that should interest you in a broad sense. I shall complement those quotations, if I may, with my own observations, which, I piously hope, will not do injustice to the thoughts and ideas of the venerable author.'

Halley turned the pages of the book before him, selecting sentences, and reading them in his sonorous voice. He interspersed his recitation with his comments and reflections. The whole experience proved to be a most inspiring one, to say the least.

‘Right at the beginning, Newton puts forward an idea, which is extremely important. It is an idea that is taken for granted and used routinely. Here it is in Newton’s own words:

Wherefore the reader is not to imagine . . . that I attribute forces, in a true and physical sense, to certain centres, which are only mathematical points, when at any time I happen to speak of centres as attracting, or as endowed with attractive powers.

What does the sentence have to say? Forget how huge the celestial bodies like the Sun and the Moon are. Forget their structures. Assume they are just points. Assume they are characterized by, but not physically endowed with, mass and power of attraction. Then Newton will show you how those objects move. He will do it entirely from his laws of motion and his law of gravitation. This is exactly what people do when they study the motion of any object, from the minute spec to the largest celestial body. And Newton started it all. ‘Simple but profound, sir.’ Halley shook his head in admiration. He seemed to be carried away by these basic ideas that had shaped science for centuries since Newton.

‘Here is another idea, a rather an important one that again occurs right at the beginning. Newton discusses motion and rest, the two states of all bodies in nature.

But motion and rest, as commonly conceived, are only relatively distinguished; nor are those bodies always truly at rest, which commonly are taken to be so.

In other words, states of rest and uniform motion are relative. This is Newtonian relativity initiated by his celebrated predecessor, Galileo Galilei. They both knew that one cannot tell who is at rest and who is moving with constant velocity by performing any mechanical experiments.’

I knew that those ideas of Galileo and Newton formed the starting point for Einstein’s revolutionary theory of relativity, which was to emerge far in the future. It was astonishing to listen to Newton’s very words in this matter.

‘The *Principia* is divided into three Books, as you are aware. And we are now starting on the First Book,’ Halley announced ceremonially. ‘You already know the astonishing results Newton derived from his three laws of motion and a single law of gravitation, especially in relation to our planetary system. In essence, Newton now held the entire Universe in his palm. Did he stop there? No, sir, no!’

What else did he do? Like Halley, I was getting excited too.

‘We know that the Sun is very heavy compared to the planets. We can therefore assume that the Sun is at rest while each planet goes around it. This has come to be known as the *one-body problem*. Now, if you consider two objects of comparable masses, say the Earth and the Moon, you then have to take into account the motion of both objects. This is the *two-body problem*. Newton solves this too. Did he stop there?’

No! I answered Halley’s rhetorical question under my breath.

‘Let us march on. Take then the Earth-Moon system with the Sun interfering in their affairs,’ smiled Halley. ‘This is the famous—or infamous, according to your personal perception—the *three-body problem*, as it has come to be known.’

Sounds like a human situation to me, I thought.

‘Equally or still more complicated than that,’ Halley’s smile widened. ‘At least the human problem can be solved once in a while. The physical problem cannot be solved exactly at all. The influence of the Earth and the Sun on the Moon is so complicated that Newton complained that his head *never ached but with my studies on the Moon!* All the same, Newton made a good beginning in handling the problem with suitable approximations. This is more or less the essence of the First Book. All in all, it is a magnificent treatise on mechanics as applied to the Solar System, each result a pioneering discovery.’

From what I had learnt already, the First Book by itself was sufficient to establish the *Principia* as a great work. But I knew that there was much more to come. Halley paused in preparation for further exposition of the *Principia*.

‘Now we come to the Second Book,’ Halley began. ‘In the First Book, Newton had considered all motion to be taking place in empty space. Now he treats motion in a resisting medium such as air or water. For instance, he considers motion of objects under gravity, including pendulums when there is air resistance. I must add that Newton deals with the flow of fluids as well in his Second Book. In all this he keeps in mind experimental results, his own as well as those of others. All this is typical Newton. But allow me to point out to you two of the astonishing subjects he deals with. First is his mathematical treatment of wave motion.’

Wave motion—I knew very well that it was one of the most important phenomena in all of physics as well as in our daily life.

‘You are absolutely right, sir, in your recognizing the inestimable importance of waves! Newton derives certain fundamental results for the first time, thus leading the way for further discoveries.’

What results? I wondered.

‘Ah, what he does now is simply amazing. He wants to find out the shape of an object that meets with the least resistance from the medium saying that it *may be of use in the building of ships*. I am sure that this problem has proved to be unavoidable not only in building sailing ships but also in designing their flying counterparts that have become a reality in your own time.’

Which meant that Newton was far ahead of his time!

‘Very much so! And he proves that fact again and again. That, dear sir, is the briefest glimpse of the Second Book. We shall desist from going any further into it, not because it is uninteresting or unimportant, but simply because it is not directly relevant to our story of gravitation.’

Halley appeared to be totally relaxed and in a mood of profound anticipation. I could feel that something extraordinary was in the offing. After a while, he opened the *Principia* to reveal the first page of the Third Book.

System of the World, the title of the Book was printed in large letters. Halley read out what Newton had written in the beginning:

In the preceding books I have laid down the principles of philosophy; principles not philosophical but mathematical . . . It remains that, from the same principles, I now demonstrate the frame of the System of the World.

That sounds like too fantastic a claim to make—it was the same feeling I had experienced earlier when I had seen the title of the Third Book.

‘With another man, in another book, it could very well have been a resounding hollow boast. But not with Newton,’ Halley averred echoing George’s words. ‘Those lines always sound to me like—how shall I put it—like the heraldic proclamation of a triumphal march. And what follows is truly magnificent beyond measure.’

I wondered what exactly Newton meant by the caption the *System of the World*.

‘Just that,’ Halley’s two words were the response to my unspoken query. ‘Newton explains practically everything that was known about the heavens at our time. I know that you have learnt this from a distinguished scholar. And much more. On what basis? Just his three laws of motion and one law of gravitation. Incredible!’

The Third Book ran to some two hundred and odd pages that would reveal the clockwork of the cosmos.

‘First of all, Newton describes and accounts for the motions of the Moons of Jupiter and Saturn as well as our own constant companion,’ continued Halley. ‘And, of course, he deals with the orbital motion of the planets around the Sun. All this within the framework of his gravitational theory.’

That was the central theme of his whole work, I supposed.

‘To begin with, yes. But, now, Newton performs an incredible feat, invading completely uncharted territories. This is exactly according to the guiding principle Newton sets down right in his *Preface*. Let me show it to you.’

Halley thumbed back to Newton’s *Preface*.

For the whole burden of philosophy seems to consist in this—from phenomena of motion to investigate the forces of nature, and then from these forces to demonstrate the other phenomena.

This was indeed a revelation. ‘That seems to sum up the entire purpose of science!’ I could not help exclaiming aloud.

‘How right you are, sir, how perceptive!’ remarked Halley. ‘So, Newton sets out to demonstrate what he calls *the other phenomena* now. For instance, he not only derives the shape of the Earth taking into consideration its self-gravity as well as its rotation, he extends it to other planets too. As a matter of fact, the shape of rotating fluids happens to be a fundamental problem by itself. Many mathematicians must have worked on it since Newton’s time, I am sure.’

Halley leafed through *Principia* for a moment and found what he was looking for.

‘Ah, here we are. Listen to what he writes later on in the *Principia*:

Bodies projected in our air suffers no resistance but from the air. Withdraw the air and the resistance ceases; for in this void a bit of fine down and a piece of solid gold descend with equal velocity.

Why, that is exactly what the astronauts verified on the Moon by dropping a feather and a hammer! This was incredible.

‘Precisely, as the travellers into the vast outer space of your modern days demonstrated it so dramatically. I wonder what Newton would have said about it. Maybe nothing, since it would have come as no surprise to him.’

I fully agreed with Halley’s conjecture.

‘Now another phenomenon again of fundamental importance, namely the occurrence of tides. I certainly realize that you are already quite familiar with how tides are generated as explained by Newton on the basis of the differential gravitational attraction exerted by the Moon on the oceans. Until Newton gave his explanation, the tides had remained a mystery. Even the great Galileo had not been able to resolve it. He had put forward an ingenious but completely erroneous theory in this regard.’

‘So far we have been considering Newton’s work related to our Earth, have we not?’ said Halley. ‘Now let us fly back from the Earth to the sky once again.’ Halley held out his hands apart to indicate the vast space around us.

‘You remember how it all began, sir, I mean the creation of the *Principia*?’

How could I ever forget it? It all began with Halley’s meeting with Newton in order to consult him about a *comet*. Did it not?

‘I am overjoyed that you recognize that fact, sir. Ah, comets, comets!’ exclaimed Halley. ‘It was but natural for Newton to study the comets amongst other celestial objects. He worked out their orbits and considered the detailed observational data of some of them. In this context, he took note of the comet I happened to observe with a period of 575 years. It was the same comet that had appeared at the time when Julius Caesar was assassinated!’

I remembered Calpurnia’s warning to Caesar in Shakespeare’s play:

*When beggars die there are no comets seen
The heavens themselves blaze forth the death of princes.’*

‘Well, that used to be one of the beliefs, apart from all kinds of other superstitions about comets,’ Halley remarked.

At that moment a comet came drifting from afar with its tail blazing. It was an extraordinarily beautiful sight indeed.

‘Ah, here sails in the comet that happens to be my favourite one,’ said Halley joyfully. ‘It makes its round once in 76 years. I observed it with great care and interest, did I not?’

Yes indeed, it was none other than the most well-known comet of all—*Comet Halley*!

Halley acknowledged the compliment with a slight bow and remarked, ‘You know sir, having a celestial object named after you bestows upon you, in a sense, a sort of immortality. It is nothing to be proud of. As a matter of fact, it makes you feel humble.’

I remembered what Mark Twain had said in 1909:

I came in with Halley’s Comet in 1835. It is coming again next year, and I expect to go out with it. It will be the greatest disappointment of my life if I don’t go out with Halley’s Comet. The Almighty has said, no doubt: ‘Now here are these two unaccountable freaks; they came in together, they must go out together’

And his wish had been fulfilled.

Yes, even to this day, we look forward to the appearance of Comet Halley with great anticipation.

‘Newton went on to theorize about the nature of the comets and the origin of their tails,’ Halley waited for my musings to be over before continuing. ‘He had some ideas that you may find a bit outlandish after all the observations and theories that have evolved since our time. For instance, Newton conjectured that some comets may fall into the stars, including the Sun, and fuel them. You have learnt about the *novae* that were observed by Tycho Brahe and Kepler, have you not? Newton thought that comets falling into the stars were the cause of those *novae*. But, stranger still you may find Newton’s notion that cometary matter, dissipated and scattered throughout the heavens, rejuvenates the Earth and the planets. Whether correct or not, Newton’s writings on comets make quite interesting reading even to you in your modern day, I am sure.’

Halley patted the big book with affection. ‘Well, sir, I think we have had a good glimpse of the *Principia*. Do you agree?’

All that I had learnt, was just a glimpse of the book? It was unbelievable.

‘Yes, it contains a great deal of other things we have not discussed. After all, the *Principia* provided the foundation for the work of the brilliant mathematicians who came after us.’

As a matter of fact, I knew the tributes that had been paid to the *Principia* by mathematicians like Laplace, Lagrange, Euler, and so on. For instance, Laplace wrote: *This admirable work contains the seeds of all the great discoveries that have since been made about the system of the world.*

‘Now, I just want to read to you, sir, parts of the General Scholium, which concludes the Third Book. It is a lofty testament to gravity,’ Halley remarked. ‘Here are some of Newton’s thoughts.

Hitherto we have explained the phenomenon of the heavens and our sea by the power of gravity, but have not yet assigned the cause of this power . . . I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypotheses.’

Yes, I had read about Newton’s famous statement: *Hypotheses non fingo—I frame no hypotheses!*

‘I must add that Newton is very emphatic here, as he was in his correspondence, about his firm refusal to hypothesise about final causes. This was indeed a radical departure from the age-old tradition. In essence, Newton was asserting that he demonstrated *how* gravity worked and not *why*.’

Isn’t that true of all science? One will never reach the final cause, which keeps receding with every step one takes forward?

‘You are perfectly right, sir,’ endorsed Halley. ‘To continue with the General Scholium, a single sentence summarizes the central theme of Newton’s entire work:

It is enough that gravity does really exist, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and our sea.’

Well, that was a superb summing up. I was quite impressed by this statement.

Halley joined his hands together as though in prayer, closed his eyes, and pondered for a moment. Opening his eyes slowly, he said, ‘There is one topic we must touch upon without which our discussion of the *Principia* would be incomplete.’

What might that be? I waited for Halley to go on.

‘God!’ announced Halley. ‘As you may know, Newton was a very devout Christian and extolled God and his creation in his General Scholium. Here, allow me to show you. After describing the Solar System, Newton writes:

This most beautiful system of the Sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being.’

That sentence seemed to echo in spirit what Copernicus had written about placing the Sun at the centre of the planetary system.

‘Yes indeed. Now here is something about God that seems to be an offshoot from his Second Book on motion in a resisting medium. It gives you an impression of almost childlike innocence and simplicity.

He is omnipresent not virtually but substantially; for virtue cannot subsist without substance. In him are all things contained and moved; yet neither affects other: God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God.’

That was absolutely charming. As Halley had pointed out, there was childlike innocence in that statement.

‘Finally, Newton concludes his thoughts about God with his view on the purpose of scientific exploration.

And thus much concerning God; to discourse of whom from the appearances of things, does certainly belong to Natural Philosophy.’

Halley closed the *Principia* slowly, gently, with utmost care.

Halley seemed to be in a mood of peaceful contentment, having described some important ideas enshrined in the *Principia*, especially through Newton’s own words. He was most likely thinking back on all the interactions he had with that great man. I had read in sufficient detail Halley’s own remarkable life and work. He had contributed so much to science in so many different ways, including charting the southern stars, so much so that he had been hailed as *the southern Tycho*. He had mapped the magnetic field of the Earth at various places as an aid to navigation. In fact, Halley had proved to be a skilled navigator and had been made captain of a ship several times. There was even evidence that he had served his country as a discreet spy, but his indiscretion in his amorous adventures had won him a rather dubious reputation.

I looked up and saw Halley watching me from the corner of his eye and smiling at my thoughts.

‘Coming back to Newton, one cannot underestimate his marvellous investigations in areas other than those that are covered in the *Principia*,’ resumed Halley. ‘His experiments and hypotheses concerning the nature of light made new pathways

in many directions. He was the first one to reveal the component colours of white light using a prism. He wrote it all in his other magnificent book *Opticks*, that too in English unlike his *Principia* which was in Latin, so that the book was accessible to everyone. The study of spectra, following Newton's discovery, was destined to encompass so many different fields including astronomy. Yes, astronomy which he enriched with his invention of reflecting telescope that employed a concave mirror instead of a lens thereby reducing dispersion of light and increasing the clarity of image. Well, there is no end to the list of Newton's achievements, is there, sir?

Halley raised his head and looked deep into space as his gaze became distant and dreamy. In his open palm, which he held forth, appeared a glass prism. A single shaft of light shot out from somewhere in the encompassing space, perhaps from a distant star, passed through the prism splitting into brilliant colours. Slowly the glass prism turned into a single drop of water and the multi-coloured light spreading out from it arched into a rainbow around Halley. He bowed deep as he repeated softly as if to himself the last words from his Ode to Isaac Newton:

Nearer the gods no mortal may approach!

Halley then dissolved slowly into space that hosted myriad glittering stars, while the rainbow surrounding him lingered on for a long time.

Ever so slowly, I opened my eyes. My bathwater was still covered with glittering star-like specks surrounded by what looked like miniature planetary systems. They gradually dissolved away, leaving behind just the bathwater.

It took some time for me to come out of the trancelike state I was in. I climbed out of my bathtub like a sleepwalker. Like a sleepwalker, I flopped on my bed and was in no time fast asleep.

Chapter 9

Lives of the Stars

George and I had agreed to meet once again in the University. This time it was not to be in his office, which George calls dusty, musty, and rusty! We decided to get together in the loveliest spot you could think of, namely the University Park. Being located on the outer edge of the sprawling campus, it is far from the madding crowd of stressed out students and frustrated faculty. Beautifully landscaped, yet retaining the natural charm of spontaneous growth, the park is a work of art harmoniously blending a variety of colours through its plants, shrubs, and trees. It was late afternoon and the gentle sunlight seeping through the foliage of the trees added to the beauty of the surroundings.

When I entered the park, I could see George already relaxing on one of the comfortable benches. Now that his students have graduated and his teaching duties are still to begin, he can afford to take life a bit easy. George looked up, smiled, and waved to me.

‘Well, Alfie, how have you been?’ enquired George. ‘Knowing you, you must have been assiduously going through the manuscript. What do you think of it?’

‘You want my honest opinion?’

‘Yes, free, frank, and fearless.’

‘All right, here we go,’ I grinned. ‘I love it, George. It is so vivid in its details, still so imaginative in recounting the lives of the great scientists. I felt as though I was really meeting all those fantastic people face to face.’

Of course, I didn’t divulge the secret source of my experience. But there was no denying the fact that my extraordinary flights of mind were being triggered as much by George’s book as by my precious. . . Well, better leave it at that, I thought.

I could see that George was quite pleased by my opinion, which was indeed absolutely honest.

‘All right, you had your private meetings with the pioneers and your flight among the planets,’ smiled George. ‘The time has come to reach for the stars, then.’

‘Yes, indeed,’ I agreed. ‘We discussed the birth, existence, and death of the stars when you told me all about the black holes a few years ago. You called it *The Stellar BED*. You remember?’

‘You forget nothing, do you, Alfie?’ George remarked. ‘That was a nice acronym, wasn’t it, BED for Birth, Existence, Death? Well, doesn’t hurt to recapitulate our earlier discussion. As Francis Bacon said, repetition maketh a perfect man.’

‘George, Francis Bacon never said that,’ I laughed. ‘His famous saying is, *Reading maketh a full man; conference a ready man; and writing an exact man.*’

‘What, Bacon never said anything about repetition and perfect man?’ George feigned surprise. He has these impish moments from time to time. ‘Well, he should have, don’t you think? Even great minds have their blind spots, can’t be helped.’

‘Some humorist added another line of his own to Bacon’s quotation though,’ I said. ‘*Bacon maketh a fat man!*’

‘That is a good one,’ laughed George. ‘Anyway, let us remind ourselves of stellar evolution.’

George leaned back against the bench. He seemed to be scanning the flowers of varied brilliant hues in front of us.

‘I wonder how those flowers would look like were they to be transformed into stars. Or if we could see the stars in all their gorgeous colours as we see the flowers. We can only imagine that,’ mused George. ‘But, before we talk about stellar colours, let us begin with their formation. Let us make the constellation Orion our reference point, shall we? I don’t have to ask you whether you know that constellation, do I?’

‘Of course, I know Orion,’ I nodded. ‘Orion is one of the handful of constellations I can identify in the night-sky.’

‘Very well, then. Beneath the stars that form Orion’s belt, you can see a fuzzy patch. That happens to be *The Great Orion Nebula*. It is a huge cloud of gas.’

I had seen the picture of Orion Nebula, a composite image of photographs taken using different colour filters. It was spectacular and looked like blazing tongues of brilliantly coloured flames leaping out, mostly red tinged with yellows and greens.

‘There are lots of such gas clouds you can see in the sky,’ continued George. ‘And those gas clouds are the breeding grounds of stars or the nurseries of new stars. In time, the gases in the nebulae may clump together here and there. Inevitably gravity pulls the gas within such a clump inwards. What happens then? The clump starts condensing and grows increasingly dense and hot. Finally, when the temperature zooms up to some millions of degrees, nuclear reactions are triggered off that produce immense amounts of energy.’ George paused before adding dramatically, ‘And, lo and behold, a star is born!’

‘You took hardly a few seconds to describe this fantastic process, George. But in reality, how long does such star formation take?’

‘You mean the gestation period of stellar pregnancy? Let us see. Well, for the gas cloud to shrink from a diameter of trillions of kilometres to the present size of the Sun, it would take, say, about ten million years. Give another twenty million years and the star will stabilise.’

‘George, you talk as if millions of years are mere minutes,’ I laughed. ‘I think it is all a professional show-off for you guys studying the stars. Am I right?’

‘Can’t fool you, can we?’ George laughed too. ‘In any event, I am sure you are familiar with the big numbers we use. A million is one followed by six zeroes, a

billion nine zeroes, a trillion twelve zeroes and so on. They used to be called astronomical figures. Now they belong to finance too with all the deficit budgets, national debts, and what not, the what-not includes scams too.'

'Of course, I know all those numbers. And don't tell me what a light-year is. It is the distance travelled by light in one year which amounts to about ten trillion kilometres.'

'My, my, am I impressed, Alfie,' George widened his eyes in mock admiration. 'Yes, the light-year will come in handy as we go on. You reminded me of the Stellar BED, didn't you? Birth B is over. Now we come to E for existence. E also stands for equilibrium the essence of existence. Nice alliteration, if you hadn't noticed.'

'I did notice, George,' I gave my assurance. 'Especially, since you had made exactly the same remark some years ago when we discussed your BED.'

'Not *my* BED, my boy. Any way, we exist because we maintain our equilibrium. And that equilibrium arises only if we keep our balance among opposing forces. Stars are no exception. What are these opposing forces in the case of a star? On the one hand, it is the outward pressure created by the heat, which is in turn generated by the nuclear reactions going on within the core of the star. On the other hand, we have the inward pull of gravity. The two are exactly balanced, so that the star stays in equilibrium shining away. A star like our Sun remains in equilibrium for about ten billion years. Our Sun is a middle-aged guy having spent almost half of his life span.'

'Ah, youth has dreams, age memories, and midlife only crises!' I wanted to be dramatic too.

'That is splendid, Alfie,' George nodded with genuine appreciation. 'I know, no need to ask who said that. You will say that modesty prevents you from telling me. I think I shall include your saying in the manuscript, with proper acknowledgement of course. Now, coming back to the Sun, there will be no middle-age crisis though. A happy stable life for the next five billion years. The crisis will occur only towards the end of those ten billion years since its birth, as we shall see.'

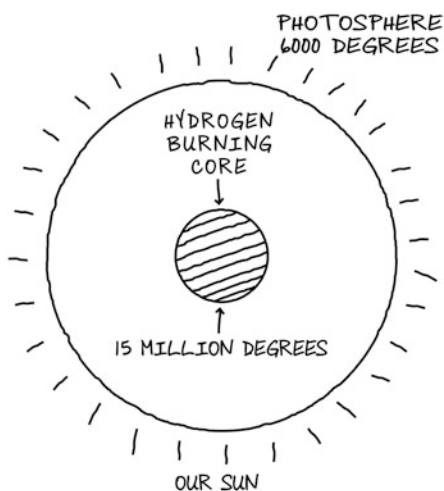
'You mentioned the two opposing forces. The pull of gravity I know. But what kind of nuclear reactions are we talking about?'

'Well, before we go into the question of nuclear reactions, let us take a look at the structure of the Sun and what goes on in the interior,' said George. 'First of all, the Sun is a huge ball of fire, a sphere of burning gas. It is 75 percent hydrogen, about 24 percent helium, and a small quantity of other elements. What we see of the Sun is the light from the surface, which is at a temperature of about 6,000 degrees. Most of the mass of the Sun is concentrated around the centre, nearly 90 percent within the inner half of its radius. The temperature at the centre is some 15 million degrees. Horribly hot, wouldn't you say?'

The hottest temperature I had experienced was around forty degree Celsius when I was travelling in India. But, fifteen million degrees? I couldn't even imagine what that meant.

'The temperature is so high that the electrons are ripped off from the atoms,' continued George. 'They fly around madly leaving the nuclei shamelessly naked. The nuclei themselves streak around at a frenetic pace and come close to one another. The density and pressure are extraordinarily high. But this mixture

agitating violently still behaves like a gas, you know. This is the nuclear furnace where the solar energy is generated by nuclear reactions. So, that brings us to the question of nuclear reactions, which you are eager to know about. To begin with we have these hydrogen atoms at the Sun's core stripped of their electrons. This we saw just now. At a temperature of millions of degrees in the stellar core, the hydrogen nuclei—or equivalently the protons—and the free electrons would be flying around at breakneck speeds colliding incessantly. This enables them to interact with one another. Now the stage is set for nuclear transformations. Four hydrogen nuclei undergo a chain of reactions, combining to form the final product, namely a helium nucleus. Now, a helium nucleus is made up of two protons and two neutrons. A neutron, as you know, is an elementary particle just like the proton. Except that it is neutral carrying no charge and it is a wee bit heavier than the proton.'



'Yes, I do know something about elements and their composition, as also elementary particles like protons, neutrons, and electrons,' I told George.

'Very well, then. Now here is the extraordinary fact that underlies this nuclear fusion or the thermonuclear reaction in which hydrogen is converted into helium. When you add the individual masses of the four hydrogen nuclei we started with, the sum exceeds the mass of a helium nucleus, the final product, by a minute quantity. This mass difference is converted into energy in the form of heat and radiation during nuclear fusion. The conversion is in accordance with Einstein's famous formula $E=mc^2$, which says that energy released is equal to the mass difference times the square of the speed of light.'

'A formula, which even a child can recite nowadays, like a nursery rhyme,' I said and added, 'But, very few understand it.'

'Let us get an idea of the immense amount of energy generated in the interior of the Sun,' George went on. 'The energy produced in a single thermonuclear reaction, when four hydrogen atoms combine to form a helium atom is minute. But the Sun is

huge containing an enormous amount of hydrogen. Each second at the Sun's core, 564 million tons of hydrogen are converted into 560 million tons of helium.'

'That means every second 4 million tons of mass are transformed into energy. And you have to multiply this stupendous amount by the square of the speed of light to get the actual amount of energy released. How much would that be, George?'

'Let us see. You know what a *watt* is?'

'Come on, George, everyone who pays electricity bills knows that. It is the unit of power, the energy generated or consumed per second, named after James Watt, the inventor of steam engine. Maybe a tautology, but a hundred watt light bulb obviously uses up a power of hundred watts.'

'Good. Each second, the Sun generates some 400 trillion-trillion watts of power. Remember a trillion is one followed by 12 zeroes, so the energy released within the solar core measured in watts is 4 followed by 26 zeroes. Now the total amount of electrical power being used in the whole world is about 10 trillion watts. In other words, the energy the Sun produces in one second is equivalent to what mankind would use in 40 trillion seconds or in a million years!'

'Don't tell me that we are bathed every second in this immense amount of energy coming from the Sun.' The magnitude of energy production in the Sun was incredible.

'Wait a minute,' George held up his hand. 'We are talking about what goes on within the core of the Sun. The vast amount of energy we talked about is created in the form of high energy X-rays or *gamma rays* as they are called. This radiation travelling towards the surface is continually scattered by the matter in the Sun's interior. As a result, it keeps losing energy as it travels and becomes more or less the visible radiation streaming out of the Sun.'

'Now, don't forget that this radiation goes out in all directions,' George continued. 'Only a fraction of it falls on our Earth making sure we enjoy a comfortable life. So, to answer your original question, we are not bathed every second in a horrendous deluge of destructive amounts of energy.'

'All right, so the mass of hot gas in the Sun remains a spherical globe of fire instead of simply spreading out as the self-gravity of the gas pulls it towards the centre. There is perfect balance between this inward pull of gravity and the outward pressure of gas. And the Sun continues to exist retaining its size and shape.' I summed up the equilibrium the essence of existence—E of *The Stellar BED*—on behalf of George.

George nodded his approval of my performance several times smiling with satisfaction.

'So much for Birth and Existence of a star like our Sun,' resumed George. 'Now we come to Death. Well, it won't be a sudden death like, say, cardiac arrest or something like that, you know. It will be somewhat long-drawn affair with complications.'

'George, please try not to be so morbid about death,' I protested. 'After all, we are talking about stars that have had their days of glory or should we say nights of grandeur?'

‘Alfie, my boy, life and death are the two faces of the same coin. We have to take them philosophically, you know,’ said George solemnly.

I thought for a moment. Sometimes memories come up slowly.

‘Ah, I remember now, George,’ I exclaimed. My data bank had yielded the information I was looking for. ‘During my wanderings in Europe, I visited Frederiksborg Castle in Denmark. To my great surprise, I came across the coat of arms Niels Bohr had designed and adopted when he was conferred the prestigious Order of the Elephant, normally given to royalty and heads of states. Those men are supposed to be as wise as elephants, which was of course true in the case of Bohr. The coat of arms featured a *taijitu* the symbol of *yin* and *yang* along with the motto in Latin, *contraria sunt complementa*—opposites are complementary. According to Bohr, *There are trivial truths and the great truths. The opposite of a trivial truth is plainly false. The opposite of a great truth is also true.* Bohr believed that life and death are also complementary like many other things. There is wholeness only when they are put together.’

‘There you are, Alfie. And a fascinating facet of Niels Bohr,’ George seemed to be moved by what I had recounted. He thought about it before getting back to the final stages of our Sun and any other similar star.

‘All right then, let us get back to the Sun,’ George said and picked up Sun’s evolution again. ‘So, in the Sun’s core the heat production through nuclear reactions keeps going on. In other words, the hydrogen keeps burning as the process is commonly described. As we have already noted, the nuclear furnace at the heart of the Sun continues for ten billion years. Of which five billion years are already gone. Sun shines on. In another five billion years, the situation takes a rather dramatic turn. It is a complicated story from now on. Let me give you a brief, simplified account of the somewhat complex events that follow.’

George paused, probably trying to compress ten billion years of Sun’s life into a few minutes of exposition. I knew that this was not at all difficult for him especially since he had done it already for his book.

‘Now, in ten billion years most of the hydrogen at the Sun’s core would have been converted into helium,’ George went on. ‘So what happens? There is no longer enough heat production to balance the gravity of the core mass. The core shrinks under its own weight and gets heated up. And this heat is transmitted to the shell surrounding the core. The shell is of course made up of hydrogen too, which starts burning. The outer part of the Sun in turn gets heated up and bloats up. And as you know an expanding gas cools down. So, the surface temperature drops because of this expansion. The Sun, grown gigantic by now, glows red. In short, the Sun has turned into a *red giant*.’

‘Everything in the world of astronomy is gigantic,’ I observed. ‘But, how gigantic is gigantic in the case of a red giant?’

‘Well, the Sun’s radius in its reincarnation as a red giant would have shot up to some two hundred times its original value, you know. Big enough, wouldn’t you say?’

I thought about it for a moment. ‘What happens to the planets then?’ I wondered.

‘Ah, the Sun, now turned into an immense ball of fire, will gobble up the planets Mercury and Venus. Like a mythological monster swallowing up some unfortunate victims!’

‘You know what your remark reminds me of, George?’ I said. ‘Not a mythological monster, but the story of the so-called Cannibal Count Ugolino of the thirteenth-century Italy. He is said to have eaten his own sons, starved as they were all in prison. Dante writes about it in his *Inferno*. And Rodin sculpted the episode into his *Gates of Hell*. Actually, the whole story is supposed to be apocryphal.’

‘Ghastly, Alfie! I am often amazed by the amount of weird information stored in your brain. With all that stuff churning in your head, how can you even sleep?’ George shook his head.

‘More to the point, think of what Copernicus said,’ I ignored George’s comment about my brain. ‘Didn’t he say that the Sun sits upon his royal throne, while his children, the planets, circle him? Once again here is an example of the Sun, transformed into a red giant eating up his own offspring, Mercury and Venus. Well, what about our beloved Earth?’

‘Destiny reserves no better fate for the Earth either. If it is not gobbled up, it will still be scorched to a cinder. Obviously, all life would be extinguished. The Earth is now a dead planet enveloped by thick clouds rising out of the boiling oceans.’

‘Enough of red giant’s wanton havoc! What is going on with the Sun’s core in the meantime?’

‘Ah, the Sun’s core. The nuclear reactions within the Sun’s core have come to a halt. But the hydrogen in the outer envelope keeps burning. And the region where this happens keeps growing outwards. Helium, the ash of the hydrogen burning, so to speak, goes on getting deposited on the core. Now, the core, which is under tremendous gravitational compression, heats up enormously from 15 million degrees to some 100 million degrees.’

‘The story is getting hotter and hotter,’ I remarked.

‘You said it. At this temperature even helium is ignited. As a result, some amounts of carbon and oxygen are produced through nuclear reactions.’

‘How long does this process take?’

‘Oh, in a star like our Sun this *helium flash*, as it is called, lasts just a few seconds. In heavier stars it can be longer.’

‘It looks like the star is trying to prolong its own life, undergoing a lot of turmoil.’

‘That is what happens with the onset of old age and the approaching death, Alfie. We humans try to postpone the end with medication and what not. But no such luck for the stars. During the death-throws of the star like our Sun, it sheds its outer layers which expand away in glowing colours. The expanding shell is called a *planetary nebula*.’

I had seen photographs of planetary nebulae. They present a lovely picture glowing with variegated colours of reds, yellows, and greens.

‘Again my question, what has happened to the inner core in the meanwhile?’

‘The core has contracted to the size of the Earth, that is about a hundred times smaller than its original radius or a million times smaller in volume.’

‘That means it has become extraordinarily dense.’

‘Absolutely. The density is now around a million grams per cubic centimetre. Or tens of tons per cubic inch. Can you imagine it? Do you have any idea how dense that is? Well, a chunk of matter the size of a sugar cube, if brought to the Earth, would be as heavy as an elephant.’

‘Amazing! The Sun had once become a red giant. But now, is this a totally new phase of our nearest star?’

‘Exactly. The Sun has now become a *white dwarf*. It is white because the surface shines bright as it has been heated up when the core contracts. But it slowly cools down and shines no more. We can call it a *black dwarf*. The Sun has entered its eternal resting place now. That means. . .’

‘The letter D in BED that stands for the death of the star has been reached!’ I completed the sentence for George.

‘Let me get something clear,’ I said after a moment. Sun’s metamorphoses were so interesting. ‘There is no longer any heat production within the Sun’s core that has turned into a white dwarf. Am I right?’

‘Correct. All nuclear processes have come to an end.’

‘Then how does the white dwarf hold up against its own gravity?’

‘Aha, if some student of mine had asked such a question in class, I would have said that it was an excellent question. And now I say that unto you,’ commended George. Needless to add, I felt most gratified.

‘The interior of a white dwarf is where two revolutions join hands, Alfie.’ George is fond of making these mysterious remarks. He claims that he is following my example in this regard! Absurd, I would say.

‘George, I know of the Copernican revolution. We talked quite a bit about that,’ I said. ‘What do you mean by *two* revolutions?’

‘Oh, the two modern revolutions, Alfie, that happened at the beginning of the twentieth century,’ George clarified. ‘Quantum physics and relativity! We pause before plunging into the strange world of these two theories.’

George paused for a long while, a satisfied smile on his lips. He needs occasional rest, having used up sufficient energy what with all his detailed explanations. I too needed a bit of time to digest everything I had heard.

‘All right, first the quantum, relativity comes later,’ began George slowly. ‘Quantum physics, as I am sure you know very well, describes the subatomic world populated by elementary particles such as protons, neutrons, electrons, and photons, and even the photons that make up electromagnetic radiation. This area of physics was created by brilliant minds—Max Planck, Albert Einstein, and several others. To begin at the beginning, let us talk about the blackbody radiation and Max Planck or the birth of quantum physics. As you will see, Alfie, the spectrum of the blackbody radiation is extremely important for stars and even for cosmology.’

Radiation everyone knows. But what is this *blackbody radiation*, I wondered.

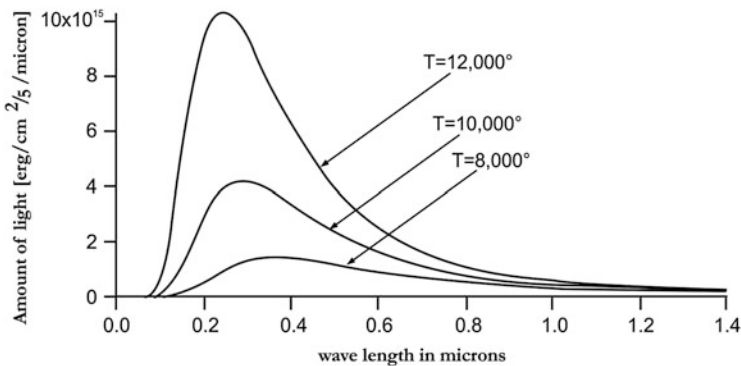
‘Let me answer your unasked question,’ smiled George. ‘Blackbody radiation is nothing but radiation that is in thermodynamic equilibrium. Let me elaborate.’

Suppose you consider an enclosure painted pitch black so that the walls absorb and re-emit the radiation that falls on it. Now heat this enclosure to some sufficiently high temperature so that radiation is generated within it. Now after a while, the emission, absorption, and re-emission processes keep going on and the radiation comes to a thermodynamic equilibrium. If this radiation is made to escape through a tiny hole without affecting the equilibrium, then the radiation coming out would be *blackbody radiation*. This is the ideal situation. But in lots of cases in nature, one encounters approximate forms of blackbody radiation, as in the case of stars for instance. Have I made myself clear enough or is it all just a black box?'

'Clear as always,' I responded.

'All right then. Let us see how this radiation's brightness, or intensity, behaves as we change the temperature. First, take the simple case of an iron rod. Keep heating it. As the temperature rises, it will glow with increasing intensity and its colour will go from dull red to blindingly brilliant blue-white. Similar behaviour occurs in the case of blackbody radiation. If you take its spectrum, the peak of intensity moves from longer wavelengths to shorter ones as the temperature is increased. Or equivalently, the intensity maximum shifts from a lower frequency to a higher one when the temperature is raised. Correspondingly, the overall colour changes from, say, red to blue. Let me show you the curves displaying the spectra of blackbody radiation for different temperatures.'

George opened the manuscript of his book, which he had brought with him, and showed me the plots.



'You see, these curves illustrate the colours of the stars also. Red giants, whose temperatures are lower than 5,000 degrees, appear orange or red, because that is the wavelength where the spectrum peaks. Our own Sun glows yellow at 6,000 degrees and so on. All this is fine. But how do you account for the blackbody spectral curves theoretically? This was a puzzle that classical physics could not solve. Physicists could explain those curves at either high or low wavelengths, but not the full curves. Max Planck did the job with his neat little trick and so was born quantum theory!'

I could see that George was quite excited, as he had thrown open the portals to the strange new world of the quantum.

‘What was Planck’s revolutionary idea?’ George posed his rhetorical question. ‘Well, let me give you an analogy. Think of radiation as, say, milk. For centuries it was considered to be like milk, a continuous fluid, which you could extract in any amount you wished, however small. This worked well at large scales of classical physics. But now, Planck said, no, radiation had to be exchanged in discrete units, or packets of energy or the *quanta*, at the subatomic scales. This was like demanding that milk be bought and sold only in small bags of a fixed amount. *Planck’s Law* simply states that the amount of energy carried by each *quantum* is proportional to the frequency of the radiation, the constant of proportionality bearing the name, what else, *Planck’s constant*. And, lo and behold, he could reproduce the blackbody curves with this extraordinarily simple equation. With this, quantum hypothesis came into its own explaining many other phenomena in quick succession. Niels Bohr gave his atomic model. Erwin Schrödinger derived his famous equation ushering in the probabilistic interpretation of physical phenomena. A system could be in more than one state with different probabilities. I am sure you have heard of the *Schrödinger cat* that could be both dead and alive simultaneously—two probable states.’

‘Oh yes, some time ago, I saw a quaint poster that depicted a cat as a bandit with the caption: *Schrödinger’s cat, wanted dead AND alive!*’

‘I wish you had pinched that poster, Alfie,’ laughed George. ‘Well, to continue, our hero Einstein came on the scene. Sitting in his patent office, he was to publish three groundbreaking papers one after another: Brownian motion, which demonstrated the real existence of atoms and molecules; photoelectric effect; and of course the theory of relativity. Planck had assumed that energy of radiation could be exchanged only in discrete packets, namely the quanta, as in the case of milk. Now, Einstein had shown that radiation *existed* in those discrete units. It was like showing that milk was not only bought and sold in packets of minimum units, but it existed in those units within the barrels to begin with.’

‘That is a nice analogy, George,’ I said.

‘To give due credit, Alfie, I read it in Einstein’s biography written by his Czech colleague Philipp Frank. Yes it is a lovely analogy,’ admitted George. ‘Now, the quantum story gets weirder and weirder. Werner Heisenberg put forward his *Uncertainty Principle*. You could not pinpoint both the location and the momentum of an elementary particle—they were sort of fuzzily smeared out. Finally, we come to the brilliant Austrian physicist Wolfgang Pauli’s *Exclusion Principle*. And it is this Exclusion Principle that is responsible for the pressure that holds up the white dwarf against the inward pull of gravitation.’

George paused before continuing his white-dwarf story.

‘All right then,’ George nodded and continued. ‘As we have seen already, the matter in the white dwarf is in a highly compressed state. The electrons are no longer held by individual nuclei, but move freely and behave like a gas—*electron gas* as it is called. This gas obeys the exclusion principle that generates the required pressure. Let me explain very briefly. A subatomic particle like an electron is supposed to be in a *quantum state* described by a set of *quantum numbers* that indicate its various attributes like energy, angular momentum, and so on.’

‘It is like assigning to a person numbers that give his height, weight, age etc. Isn’t it?’ I pointed out.

‘Nice comparison, Alfie, but the quantum numbers can take only certain values unlike the quantities you mentioned,’ clarified George and continued. ‘The exclusion principle essentially means that no two identical particles, like electrons, can occupy the same state with the same quantum numbers. So, two electrons having opposite spins can occupy the same state. Since their spin quantum numbers are of opposite signs.’

‘You mean an electron spins like tops? An atom with electrons both orbiting and spinning would be like a miniature solar system then.’ This was interesting.

‘No, Alfie, you cannot visualize subatomic particles like macroscopic objects such as the planets,’ corrected George. ‘We just say electrons are endowed with spin quantum number half. We say plus and minus half correspond to opposite spins. Two electrons with opposite spins can occupy the same quantum state. Any other electron in the electron gas has to occupy another state. This kind of repulsion, so to speak, gives rise to the pressure acting within the electron gas.’

‘So, it is like a bus that allows only two passengers, that too of opposite genders, to sit together in each seat,’ I visualized the situation. ‘If a seat is occupied, another passenger would be kept away.’

‘Crazy, this seems to be a special day for analogies,’ George shook his head. ‘By the way, Pauli’s exclusion principle applies only to spin-half particles that are called *fermions* named after the celebrated Italian physicist, Enrico Fermi. Particles like protons and neutrons are also fermions.’

‘Are there particles that have spins other than half and are therefore not fermions?’

‘Yes, indeed. They have integers for their spin quantum numbers, like photons that have spin one. There are other elementary particles, *mesons*, some of which have integral spin quantum numbers. They are not subject to the exclusion principle. These are called *bosons*, in honour of the distinguished Indian physicist, Satyendra Nath Bose. Any number of bosons can congregate in the same quantum state together.’

‘Like a cocktail party you mean. Don’t groan, George,’ I grinned.

‘This is getting out of hand,’ said George suppressing his smile. ‘In any case, we now know how the pressure in the electron gas is created that can oppose gravity and keep the white dwarf stable.’

‘So, all is well with the white dwarfs,’ I said. ‘I suppose that all stars would rest in peace as white dwarfs once they have used up their nuclear fuel. Am I right?’

‘Well, that was the general belief among the astronomers,’ answered George. ‘But then, the most unexpected event happened. Subrahmanyan Chandrasekhar, the Indian astrophysicist who was to win great fame eventually in his lifetime, showed that only stars up to about 1.4 solar masses could become white dwarfs. This is known as the *Chandrasekhar limit*.’

‘Ah, Chandrasekhar!’ I exclaimed and went on to convey what I had learnt while studying Indian culture. ‘*Chandrasekhar* is one of the names of Lord Shiva, the

Indian God. *Chandra* means the Moon and *Sekhar* means the wearer. Shiva wears the crescent Moon above his forehead as an ornament.'

'What a wonderful name for an astronomer, Alfie!' George's eyes gleamed on hearing what I had told him. 'And to think that Chandrasekhar was called Chandra by his friends many of whom probably didn't even know that the word meant the Moon!'

I too felt happy with the piece of information I had passed on to George.

'Well, coming back to the white dwarf, Chandra worked on it during his stay at the University of Cambridge in the 1930s at the rather early age of about nineteen. And it is in his work that the two revolutions, quantum physics and relativity happened to meet. We have already discussed the quantum effect of producing pressure in the electron gas. Let me say a few words about Einstein's *special theory of relativity*, as it is called, without straying too far from the white dwarf.'

I remembered George explaining to me in great detail both the special theory of relativity and the general theory of relativity of Einstein some years ago. But it did no harm to receive a brief recapitulation from George again.

'Long before Einstein's time, Galileo and Newton had realized that observers moving with constant velocities with respect to each other could not decide who was at rest and who was in motion by any mechanical experiment. It is like playing billiards either in the comfort of your basement or in the luxury of an ocean liner. This was known as *Galilean* or *Newtonian* relativity. Here was a most important tacit assumption: both observers measured the same time—time was absolute. Now, with the advent of electromagnetism, this changed drastically. I don't want to go into the complicated story. Let us just say that a new kind of relativity was required and Einstein did the job. Now, even time became relative, its measure changing among the *inertial observers*, observers moving with constant velocities relative to one another. This special theory of relativity introduced strange effects like length contraction, time dilation, mass changing as a function of velocity, and so on. And of course, from his relativity theory Einstein was able to show the equivalence of mass and energy. We talked about all this once upon a time, do you remember?'

'I do, I do,' I said emphatically.

'Relativistic effects become important and perceivable whenever one encounters enormous speeds comparable to that of light. In our ordinary macroscopic world, we do not normally come across such speeds. On the other hand, the electrons within the white dwarf fly around with speeds that are indeed comparable to that of light. So, Chandra realized that relativistic effects have to be taken into account in describing the behaviour of the electron gas mathematically. Essentially, he derived the formula that related the pressure of the electron gas to its density. From this he could study how the radius of a white dwarf varied as a function of its mass. For low masses, the radius increased with mass. On the other hand, it started decreasing with increase of mass eventually reducing to zero. This meant that there could be no white dwarf beyond this limit of about one and a half solar mass, the Chandrasekhar limit. That was indeed a fantastic and most important piece of work.'

‘All right, George. Stellar core of mass below the Chandrasekhar limit enjoys eternal life as a white or a black dwarf after the death of the parent star.’ I could see how important Chandrasekhar limit must have been for stellar evolution. ‘Then what happens to a massive star that may end up with a core heavier than Chandrasekhar limit?’ This was a natural question following our discussion so far.

‘Fine, let us drop the curtain on the white-dwarf drama for the time being,’ said George. ‘That means the time has come for us to talk of heavier stars, their evolution, and their ultimate fate.’

‘I guess a star of high mass behaves quite differently from the one comparable to our Sun.’

‘Exactly, both during its evolution and in its final fate,’ affirmed George. ‘Because of the higher mass, the gravitational compression acting towards the centre is much more than in a lighter star like our Sun. Consequently, higher temperatures are generated in the core and more power is released. Correspondingly, the gas pressure in the interior of the heavy star is also greater, which counteracts the stronger gravitational force.’

‘We know that the Sun’s life span is about 10 billion years. Now, the heavier star has a lot more mass to burn than the Sun. So, it must live longer than our Sun. Am I right?’

‘Sorry, Alfie, you are wrong there,’ George shook his head. ‘As I just told you, tremendous temperatures are generated within the heavy stars. That means the energy generation takes place at enormous rates. What happens as a result? These fat cats burn themselves up pretty fast, even though they have a lot of mass to begin with.’

‘Ah, just like humans!’

‘All right then. Let us compare the life of the Sun with that of a heavier star,’ George went on to give an illustration. ‘Suppose we scale down our Sun’s life-span to one year. On this time scale, a star seven times more massive than the Sun lasts for about a day. And, the one that has eighteen solar masses survives for just nine hours! Well, many of such stars may shed part of their mass and live longer.’

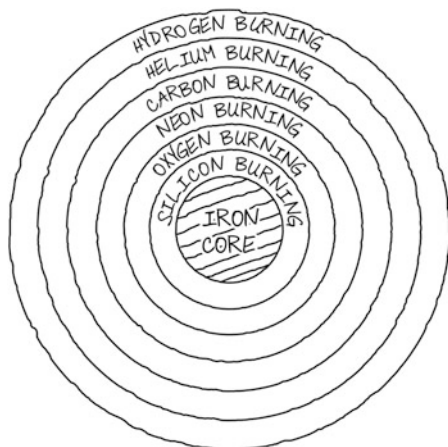
‘Aha, there is a case for going on a diet,’ I laughed glancing at George’s paunch.

‘There you go again, Alfie,’ George wagged his finger. ‘You once quoted Philip James Bailey’s saying—*It matters not how long we live but how*. So, eat, drink, make merry, and get fat. Happiness may prolong your life, how do you know?’

‘All right, George, you win,’ I conceded. ‘How about the nuclear reactions taking place within the cores of massive stars? Because of the high temperatures now, they must be quite different from those that occur within the Sun. Say I am right!’

‘I say you are right!’ confirmed George with a smile. ‘Once again, let me give you just a glimpse of what happens within the massive star. As a result of the high temperatures, nuclear burning does not stop at helium produced from hydrogen. Helium, the ash of hydrogen burning as it is called, is further converted into carbon. This way, a whole sequence of elements is cooked in the interiors of heavy stars: neon, oxygen, silicon and so forth and finally ending up with iron. Then there can be no more nuclear reactions. You know why? Because, in iron we have hit the most

stable configuration. What is the end result of all this toil and trouble taking place within the stellar cauldron? An onion-like structure with an iron core surrounded by shells containing ashes left behind by the successive thermonuclear transformations.'



CORE OF A HIGH MASS STAR

'I love French-fried onion rings, especially those cooked inside the massive stars,' I said making George groan as usual. 'What about the core? I suppose it is condensed even more than the white dwarf. If so, I repeat the question I asked in the case of a white dwarf. What counteracts gravity?'

'*Similia similibus curantur, like cures the like*, the homeopathic dictum of Samuel Hahnemann, the originator of that system of medicine. Aha, you thought I didn't know any Latin, didn't you?' chuckled George. 'To paraphrase that dictum, similar questions have similar answers, my dear disciple. Now nuclear reactions have come to an end. There is no longer any heat generation, no gas pressure to balance gravity, just as it happened in the case of the white dwarf. The whole situation is quite ironical you know.'

'What is ironical? Is that a pun on iron, the final product of stellar evolution?' I asked.

'No puns, I mean gravity's role in all this,' answered George. 'It was gravity that gave birth to the star and it was gravity that regulated its life. But look at what happens now. That same force turns into an agent of utter devastation. Iron nuclei are crushed and torn apart by the gravitational compression. Not only that. The electrons are forced back into the nuclei turning all protons into neutrons. The stellar core is now composed of just neutrons. It has turned into a vast sea of neutrons, or the *neutron gas*.'

'In other words, this neutron gas has taken the place of electron gas that inhabited the white dwarf.'

'Yes, the neutron gas now behaves exactly like the electron gas.'

'We are back to quantum effects then?'

‘Indeed. Like electrons, neutrons are also fermions, spinning particles that obey Pauli’s exclusion principle. And the resultant pressure of the neutron gas due to this quantum effect counteracts gravity. We have now a *neutron star* composed of nothing but the neutron gas.’

I had heard of neutron stars of course. Now, I knew what they were.

‘My next question. The white dwarf is the size of the Earth you said. How large is a neutron star, George?’

‘How small you mean,’ George corrected me. ‘The radius of a neutron star is typically around a mere ten kilometres. You could cover the distance from the centre to the surface easily. Of course, if you attempted such an adventure, you would be crushed out of existence by the compression of the matter.’

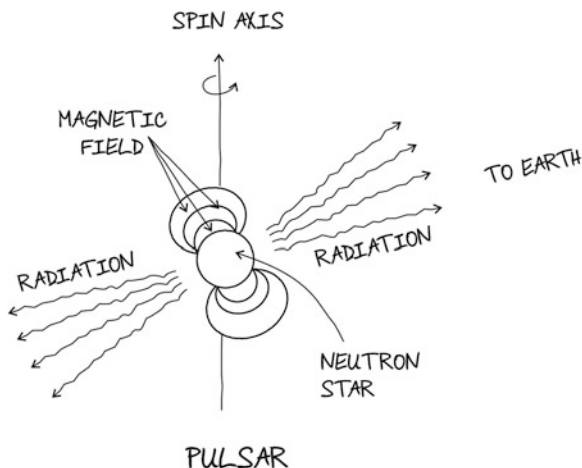
‘Let us see. Matter of the order of a solar mass is now packed into a sphere of ten kilometre radius! That means the density of a neutron star must be awfully high.’

‘You bet. Since the stellar core is made up of closely packed neutrons, it is of nuclear density, which is phenomenal. About one hundred trillion grams per cubic centimetre. Can you imagine that! Suppose you manage to bring a spoonful of neutron star matter to the Earth. It would weigh as much as the entire humanity put together. Present population of course.’

Illustrative analogies are meant to help understand unusual phenomena. But, in the present case, it was impossible to imagine such high densities. Well, that is what happens in astrophysics I thought. Having learnt a bit about white dwarfs a little earlier, more questions arose in my mind. I continued my enquiry.

‘George, you told me that a white dwarf shines merely because of the heat it has retained from its shrinking. When it cools completely and becomes a black dwarf, it no longer shines and becomes invisible,’ I recapitulated. ‘What about a neutron star? Does it shine? Does it become visible so that it can be detected observationally?’

‘Very relevant question as usual, Alfie. Well, the scenario we have now is rather different from the one we had in the case of the white dwarf,’ George went on to explain. ‘When the core collapses giving birth to the neutron star, the surface of this monstrously heavy new-born baby is at a temperature of about a million degrees. At such high temperatures, the surface would correspondingly emit high energy radiation like X-rays. Eventually, the neutron star will cool down and cease to glow. Obviously the neutron star would be invisible in this state. Nevertheless, there is something extraordinary that can happen. Neutron stars often possess a pair of beacons of radiation, radiation composed of different wavelengths. This could possibly include visible light too. As the star spins, we would observe a flash of radiation each time we come in the line of the radiation beam. It is like what happens in the case of a lighthouse. So the neutron star keeps sending pulses of radiation at constant intervals. Such neutron stars are called *pulsars*. Neutron stars spin so steadily, that the pulses sent out by pulsars are extremely regular. The regularity of the pulses is comparable to the accuracy of atomic clocks, you know. Because of this, when the pulsars were first detected, astronomers wondered whether some extra terrestrial beings might be sending these signals. So half jokingly the new objects were christened *LGM* or *Little Green Men*.’



George smiled to himself. He must have remembered something amusing from the past.

‘You know, Alfie, I happened to attend this one-day conference convened to discuss the mystery behind the pulsars,’ George reminisced. ‘One of the experts said that if indeed extra-terrestrials were sending the pulses, it proved that life existed beyond Earth. But it could not be intelligent life, the expert said, if they were wasting so much energy, especially targeting the Earth inhabited by another stupid civilization!’ George laughed remembering the past incident.

‘That is quaint, George,’ I joined George in his mirth. ‘At least some scientists do have a sense of humour I must admit. Still, a question remains. You said there is no energy generation going on inside the neutron star.’

‘That’s right.’

‘Then how are these beams of radiation produced?’

‘That is a million-dollar question, Alfie,’ remarked George. ‘Neutron stars happen to come with very strong magnetic fields attached to them. Charged particles moving in these magnetic fields are supposed to produce the radiation beams emanating from the magnetic poles. Nobody knows the exact details of such a mechanism. If I found out the answer, I would be rich and famous. I wouldn’t be sitting here doling out my hard earned knowledge, you know.’

‘All right, ignorance is bliss as the saying goes,’ I said. ‘To sum up what you have told me then, stars lighter than the Chandrasekhar limit end up as white dwarfs. And all those that are heavier rest in peace as neutron stars.’

‘Patience, Alfie, patience, let us not jump ahead too fast,’ cautioned George. ‘Even neutron stars, like white dwarfs, have a mass limit. This was demonstrated by Robert Oppenheimer and his co-workers in the thirties. They even thought of what would happen to stellar cores heavier than such a limit.’

‘You mean the same Robert Oppenheimer who headed the Manhattan Project that produced the atom bomb?’ I was quite surprised.

‘Yes, Alfie, the very same Oppenheimer,’ confirmed George. ‘As you correctly pointed out, he is well known for his leading role in producing the most lethal weapon of mass destruction. Only experts in theoretical physics know and appreciate his work on neutron stars and gravitational collapse.’

George fell silent. After collecting his thoughts, he resumed the discussion. ‘Oppenheimer, in collaboration with George Volkoff, was the first one to work out the mass limit for neutron stars. This was a major advance in line with the Chandrasekhar limit to the mass of white dwarfs. Our knowledge of nuclear interactions has steadily increased since those times and a lot has been done in this field. But even then, Alfie, our knowledge is not really complete especially in the case of the immense compressions that exist in the core of a neutron star. In any case, the neutron star mass limit may be taken to be, say, about three solar masses.’

‘All this is theoretical. So far, so good,’ I commented. ‘But, how about observational values for the neutron stars?’

‘You are right. One must always keep in mind what is actually observed in nature,’ George nodded. ‘It so happens that many neutron stars, or pulsars, have been observed with masses of about the Chandrasekhar limit, which is about one and a half solar masses as we have seen. But, pulsars of around two solar masses have also been observed. But we can take as extreme theoretical limit of, say, five solar masses for neutron stars. After all, Alfie, we have to be absolutely certain of the identity in a line-up.’

‘All right, what happens to stellar cores that exceed this limit?’

‘Aha, we are now getting to the most interesting part of our story, Alfie,’ George said jubilantly. ‘There is no known force in nature that can withstand the overwhelming gravitational attraction within such a heavy core. Gravitational collapse is now inevitable. The collapse is catastrophic, continuous, and relentless. And, Alfie, what is the final result? It is the formation of a *black hole*. The bizarre end product of a super-massive star that has exhausted its nuclear fuel, the grand finale to the symphony of stellar evolution!’

Ah, black holes! Everyone is enamoured by black holes. After all, gravitation is an irresistible force of attraction, is it not?

‘Well, let us get back to Oppenheimer for a moment,’ said George. ‘In 1939, Oppenheimer, along with H. Snyder, studied the continuous collapse of a heavy star and showed how it ends up as a black hole.’

‘This process was obviously a logical sequel to the neutron star mass limit, I suppose. Was there anything fundamentally different from the formalism that had been used for white dwarfs?’

‘That was a telepathic question, Alfie.’ George regarded me for a moment. ‘How did you know that I was going to tell you precisely what you wanted to know? Well, I explained how Chandrasekhar had used Einstein’s *special theory of relativity* in his calculation, didn’t I? Now, Oppenheimer and his co-workers had to use the *general theory of relativity*.’

Well, I knew it. Something new this way comes!

‘In 1905, Einstein gave his revolutionary special theory of relativity that dealt with inertial observers moving with constant velocities with respect to one another,’

George elaborated. ‘That theory fused space and time into spacetime among other things. Einstein now wanted to extend the theory and the spacetime formalism to include accelerated observers. Acceleration naturally incorporates gravitation, doesn’t it? *If God had been satisfied with inertial systems, he would not have created gravitation*, Einstein declared. For ten years, he grappled with gravity, working incessantly, meandering in unfamiliar mathematical grounds, following false leads and then returning to the right path, on and on. During the course of this strenuous stretch of work, he wrote to one of his colleagues: *I am now working exclusively on the gravitation problem. . . Compared to this problem, the original theory of relativity is child’s play*. And at the end of it all, in 1915, he presented to the world his magnificent general theory of relativity. It was a geometrical theory of gravitation, a total departure from Newtonian gravity, Alfie.’

George paused to catch his breath.

‘From the first fundamental ideas to its final completion, the theory was an unprecedented stroke of genius, Alfie,’ George said emphatically. ‘J. J. Thompson characterized general relativity as, *One of the greatest—perhaps the greatest—achievements in the history of human thought*. It was not an achievement just in physics, Alfie, not even science as a whole, but *in the history of human thought*. According to Dirac, had Einstein not given special theory of relativity, sooner or later, someone or the other would have formulated it. On the other hand, if Einstein had not created general relativity, no one would have accomplished such a feat. In that case, there would have been no black holes, no gravitational waves, no proper description of the Universe as a whole!’

To tell you the truth, I had never seen George so carried away as now when he was talking about the general theory of relativity.

‘I can go on with my panegyric to GTR. But, returning to Oppenheimer, his collaborative work on both the neutron-star mass limit and gravitational collapse leading to the formation of a black hole involved general relativity. This was indeed a major step forward in astrophysics. Unfortunately, his work was all but forgotten till the nineteen sixties. Then there was a surge of tremendous activity in the field of gravitational collapse with enormous amount of studies, both theoretical and observational, on neutron stars or pulsars, and black holes.’

‘You explained how, when a star collapsed to a white dwarf, the outer shell was thrown out gently as a planetary nebula. What happens to the stellar matter when the core is catastrophically reduced to a neutron star or a black hole?’ I enquired.

‘I think you know the answer, Alfie, since these things get lot of publicity nowadays,’ said George. ‘The outer envelope of the star explodes violently. The energy released is enormous, some hundred million times the luminosity of the Sun. Or equivalently, the energy released in a supernova explosion amounts to all the solar energy emitted in a million years! The exploded star shines as bright as the stars of an entire galaxy put together. This is what we call a *supernova*. Remember elements up to iron are cooked within a star? Now heavier elements are formed in the brief, intense heat generated in a supernova. But that is not the end. New stars can be formed out of the debris of a supernova, which now contains all the elements that exist in nature. As a matter of fact, our Sun is made up of such recycled stellar

matter and so are the planets. That is how our Earth happens to contain all the elements needed for life. Therefore, Alfie, you and I are parts of the same star that exploded way back in the past. Think about it!’

I didn’t have to think about it. It was indeed a spectacular fact.

‘My usual question, George, what about the observational situation regarding the supernovae?’ I continued my enquiry.

‘First of all take our own Milky Way,’ George went on to answer my question. ‘Way back in the year 1054, Yang Wei-Te, the Chinese astronomer, observed a new *guest star*, as it was called, appearing in the morning sky. It could be seen even in broad daylight for weeks on end. Now, the remnant of that event, which was in fact a supernova explosion, has been identified as the Crab Nebula in the constellation Taurus.’

‘I have seen the photograph of the Crab Nebula. A network of glowing multicoloured filaments enveloping a diffuse cloud of gas. It is beautiful.’

‘Many celestial objects are absolutely beautiful, Alfie!’ acknowledged George. ‘The Crab Nebula contains a pulsar, the Crab Pulsar, which is the relic of the star that exploded. We have already talked about how Tycho Brahe sighted a supernova in the constellation Cassiopeia in 1572. Again in 1604, Kepler also observed a supernova in the constellation Ophiuchus. In either case, no neutron star resulted during the stellar explosion. Both of these celestial events were noticed by Galileo also. Since then no supernova has been observed in our Milky Way. There is a saying that a supernova is seen in our galaxy only when there is a great astronomer around. The implication is obvious.’ George added in a stage whisper, ‘Alfie, never mention this to our astronomer colleagues. They will get terribly upset.’

‘My lips are sealed, George,’ I laughed. ‘But, George, I do read quite often in the newspapers about some supernova or the other being detected. What about them?’

‘Ah, several supernovae are observed each year in other galaxies, not our own Milky Way.’ George thought for a moment. ‘A bit more about supernovae, Alfie. Supernovae resulting from catastrophic gravitational collapse are classified as Type II supernovae. There is another type of stellar explosion that involves the white dwarf. Let me explain. Suppose a white dwarf is paired with another normal star. The two stars form a binary system going around each other. Take for example, Sirius the brightest star in the sky. It is actually a binary star system. The bright star has a faint companion, which is a white dwarf. If some amount of matter is dumped on the white dwarf by its companion, the former can flare up. This is now termed as *nova* in modern astronomy. On the other hand, matter can be accreted in large quantities by a white dwarf from its companion. When the white dwarf’s mass reaches the Chandrasekhar limit, it explodes. The end-result is not a *nova*, but actually a *supernova*. This is classified as Type Ia supernova. Incidentally, the *new star* that was observed by Tycho Brahe, or *nova* as he called it, happened to be a type Ia supernova. Such supernovae have the same brightness, since the conditions needed for their occurrence are also the same. As we shall see later on, they come in handy in measuring distances to far off galaxies. And, believe it or not, this has led to one of the most recent and extremely important discoveries in cosmology. The little white dwarf measuring the vast expanses of the Universe as a whole, amazing

isn't it? Well, before we come to our own times, there are many aspects of our Universe we have to cover, Alfie.'

George knit his brows as though he had forgotten something he wanted to tell me. And then his face brightened up.

'Alfie, let us get back to the black holes for a moment, shall we?' George resumed. 'Once considered to be invisible and hence undetectable, black holes seem to be everywhere. Many of them of several solar masses have been detected in binaries. But the surprising fact is that most of the galaxies seem to harbour giant black holes at their centres. Our very own Milky Way boasts of a black hole weighing some three million solar masses. There seem to be galaxies loaded with black holes of billions of solar masses.'

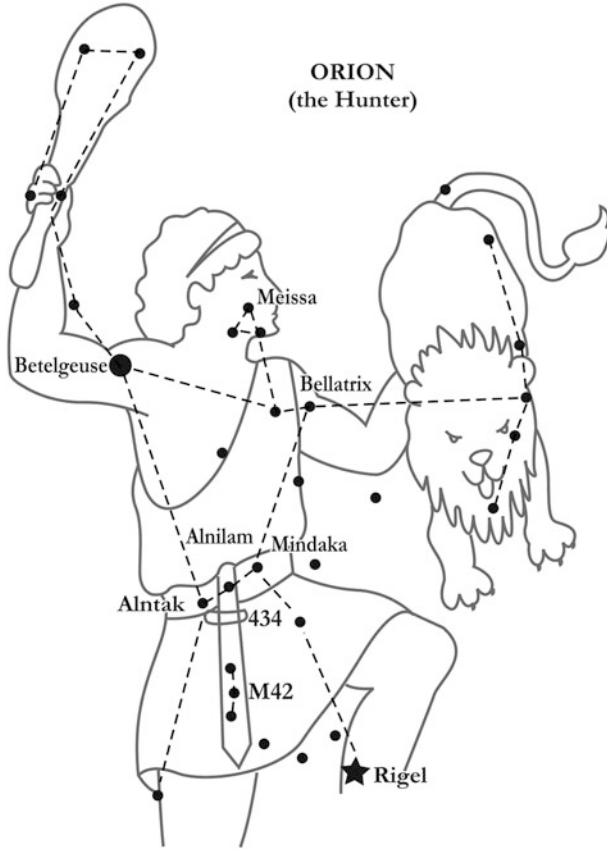
'Oh yes, one reads about them in news papers all the time. Do they lead a quiet life like us ordinary citizens or do they get violent like some others we come across once in a while?'

'I thought you led a pretty wild life, not a quiet one, Alfie,' smiled George. 'Fortunately, the one that our Milky Way holds in its bosom is a tame one. But matter can pour in copiously into a black hole from a normal companion star forming an *accretion disk* around it that can lead to spectacular effects. This happens in the case of stellar black holes too. But, the galactic giants! There you can have fireworks of cosmic proportions. Huge amounts of matter can be thrown out from around the black holes with energies comparable to billions of supernova explosions. Centres of such activity are called *Active Galactic Nuclei* or *AGNs*. That is not all. Even objects known as *quasars* are supposed to be energised by such galactic black holes. They are so distant that you do not see the parent galaxy, only the brilliant baby. Obviously, these big black holes can be of prime importance for cosmology.'

Both George and I had been so absorbed in our discussion that we had been oblivious of our own surrounding,

'Good heavens, Alfie, did you notice how long we have been talking? It is getting dark already!' George exclaimed.

Indeed, it was dusk and the stars were appearing here and there hesitatingly to make sure that the Sun was gone and they had the night sky for themselves. As we walked across the campus, George looked up at the sky and pointed at the most familiar constellation that happened to adorn the zenith: Orion the Celestial Hunter!



‘Beautiful, beautiful,’ murmured George. ‘Look at the shoulder of the Hunter’s arm holding up the club, Alfie. Can you see the bright reddish star there? It is *Betelgeuse* a red super-giant similar to red giant. But it has resulted from the evolution of a star more massive than the Sun. Near his ankle is the hot blue-white star *Rigel*. One can spend hours looking at all those stars that make up the constellation, wondering about them. You know, Alfie, practically every culture has some story or the other associated with Orion. Ancient Egyptians, Romans, Indians, the Chinese, the Bororo Indians of Brazil, the Maori of New Zealand, on and on, they all had their own legends of Orion. It is amazing that one can write the cultural history of the world through constellations. Ah here we are, where our paths diverge, you on your way home and I trudging up to my office. Let us meet soon, Alfie. How about Bruno’s for an exotic meal he promised?’

‘Great, let us do that, George,’ I responded enthusiastically.

‘Take care, my boy,’ George waved and was on his way towards his physics building.

As usual, I sauntered across the campus enjoying its ambience under the scintillating starry canopy.

Chapter 10

The First Rung of the Cosmic Ladder

I spent the day in total relaxation doing nothing. Doing nothing? Is that possible? Perhaps not. I did go over George's manuscript, studying whatever we had discussed in our recent session—basically about stellar evolution and its three end-points. I found it absolutely fascinating. This was in a way to prepare myself for my next meeting with George. I was eagerly looking forward to the joyful event that would take place in the evening. Well, between you and me, let me confess that there was the added attraction of having a good time at Bruno's, that haven for rare culinary delights.

As I entered Bruno's, the first sight that greeted me was of George carefully reading his manuscript, scribbling some notes on the margins. Being a perfectionist, he would be trying to improve it till the last. Once, he had told me that a talk, like a baby in a mother's belly, keeps developing till the moment of delivery. It is the same with a book, I suppose, it keeps improving till the moment of its delivery to the publisher.

Instinctively, George looked up and broke into his customary spontaneous smile, to which only the most hard-boiled misanthrope would not respond. And, believe me, I am no misanthrope.

At that moment, a lovely piece of music started playing in the background. It was Joaquín Rodrigo's *Concierto de Aranjuez*, which is considered to be one of the pinnacles of Spanish music and of the guitar concerto repertoire. Soon enough, Bruno arrived followed by a young man.

'Ah, my two most special guests!' Bruno welcomed us with his customary exuberance. 'Let me introduce our new chef. I told you about him last time, didn't I? He has travelled all over the world and has learnt to cook food of many lands, *squisito!* I shouldn't forget to tell you his name. He is Jose Ramirez, but goes by different names in different places: Yusuf Reza in the Middle East, Jomo Ramyatta in Africa, simple Ram in India and Thailand, so on. For us he is just Joe.'

Joe, who looked more like a Flamenco dancer from Andalusia rather than a chef, bobbed his head up and down with each of his name mentioned, flashing his sparkling white teeth.

Bruno extended his hand towards us and continued his introduction, 'Joe, these are our most important guests who come here all the time, George the big Professor at University and our dear friend, Alfie the Wise.'

Joe bowed ceremoniously and said in perfect English, 'I am greatly honoured indeed!'

'Today Joe makes Spanish food for you,' announced Bruno.

'Oh, Spanish cuisine, my favourite!' exclaimed George. 'What is on the menu?'

'What menu?' Bruno raised his eyebrows. 'Look around, you are the only two guests. We make some special dishes for you.'

The young chef Joe took over as his eyes glittered with delight. 'We can start with *Albóndigas*, meatballs in garlic sauce, one of the delicious *tapas*. Then we move on to the main course—*arroz negro*, squid cooked with rice in its own ink, absolutely divine. Finally, we would end the meal with the dessert—*Mantecados*, traditional Spanish crumble cakes served with whipped cream, an unparalleled delicacy. Does such a dinner appeal to you?'

'Sounds great,' I said. 'Except that I happen to be a strict vegetarian.'

'Oh Alfie,' George groaned. 'Heaven help me, as a matter of principle I have to join this cruel man. Yes, make mine a vegetarian meal too.'

'No problem,' Joe assured us. 'We shall replace meatballs with breaded potato balls. The main course will be *pimiento rellenos*, big red bell peppers stuffed with slightly spiced rice, chopped nuts and mushrooms, covered with cheese and baked in tomato sauce. We shall retain the dessert.'

'Sounds great. Vegetarians of the world, Unite. You have nothing to lose but your cholesterols!' George shook his raised fist.

'Food will be wonderful, doubt not,' nodded Bruno. 'How about some wine to go with the meal? It is pure vegetarian, you know,' he grinned.

'What do you have in mind?' George raised an eyebrow.

'Two major types of Spanish wine are Rioja and Ribera del Duero,' answered Bruno. 'People fight which is best, you know. We will serve both, you decide.'

Bruno and Joe withdrew to the kitchen to prepare the special meal for us.

'Knowing you, Alfie, you must be going over the manuscript religiously to absorb all that we have been discussing and more,' began George. I was waiting for this. 'We have talked a lot about planets and stars, especially stars—their types, their evolution, and their end-states. They are the little ingredients that make up the Universe, aren't they? We are now ready to look at the larger picture.'

Our progress towards the large-scale structure of the Universe had been gradual and meticulous. Unless you have the foundations firmly established, how can you build the super-structure? I was sure that the journey forward would retain this character.

'Ideas regarding the large scale structure of the Universe dates way back to antiquity, Alfie,' continued George. 'As a matter of fact, around 300 BC, Zeno of Citium proposed a finite cosmos of stars in an infinite void, the *Stoic model*, although they had no idea of the real nature of the stars at that time. Then came the *Epicurean model* due to Epicurus of Samos, an infinite cosmos consisting of uniform material of unlimited quantity, with worlds scattered and spread all over. All matter was composed of atoms, regulated by natural laws.'

‘You mean they were already thinking of atoms, natural laws, and all that?’ I queried.

‘Not in the modern way, they were all philosophical ideas,’ said George. ‘Nevertheless, these ideas were revived by Isaac Newton. He first believed in the Stoic model of the cosmos. But then, his young friend, the clergyman Richard Bentley, pointed out that such a model would be unstable since the finite spherical distribution of stars within a void would collapse under its own self-gravity. Newton then switched to the Epicurean model with an infinite number of stars, all attracting one another. This was an equilibrium configuration all right. However, Newton realized that this was like an infinite number of needles standing on their pointed tips, a totally unstable situation. Still, the Universe was very much a reality, wasn’t it? So, Newton asserted that this showed the existence and omnipotence of Divine Providence without which the Universe could not exist!’

‘God to the rescue, what do you know?’ I said. ‘George, I have heard that long ago, when physicists were confronted with what looked like innumerable types of elementary particles, they classified them all under the categorical name *Gokons* that stood for *God-Only-Knows-ons!* Is this true?’

‘Absolutely! I had completely forgotten about it,’ George laughed long and hard.

George leaned back in his chair as he caught sight of the waiter approaching our table. The waiter placed before us a carafe of wine and two glasses.

‘Is this Rioja or Ribera?’ George enquired.

‘I wouldn’t know, sir,’ the waiter smiled. ‘Even if I did know, boss would have asked me not to inform you. He wants you to decide which one is better. Next carafe will contain the other type.’ He went back letting us fill our glasses ourselves as we prefer to do.

We poured the wine into our glasses and took a sip slowly. It was simply exquisite, whichever R it might have been.

‘Let us get back to the Universe, Alfie,’ George resumed. ‘The first step that leads to its large-scale structure happens to be our own Milky Way, the mysterious wispy band that stretches from horizon to horizon across the night-sky. As with the constellations, different cultures had different mythological stories associated with it. You can read about them at your leisure as you always do.’

‘And Galileo’s little telescope resolved the stars and groups of stars in the Milky Way as we saw some time ago,’ I said.

‘That is right. But then, it was William Herschel who really launched upon its observational study for the first time, you know.’

‘Ah yes, you did mention Herschel in passing when we talked about Uranus, didn’t you, George?’

‘True, his discovery of Uranus was a major event in itself. On the universal scale his findings and ideas regarding the Milky Way are very important, Alfie. Let me briefly tell you about the man first.’

George took a sip of his wine, closed his eyes, and silently enjoyed its taste. I followed his example, but with eyes wide open.

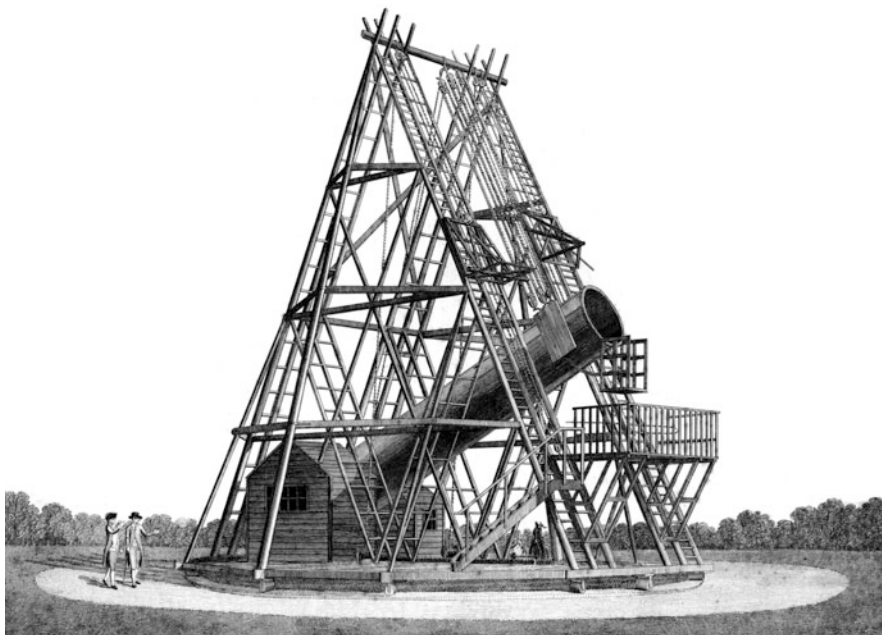
‘William Herschel was a talented musician,’ began George after his sip of wine.

‘Wait a minute,’ I interrupted. ‘I thought he was an astronomer.’

‘Of course, he became a celebrated astronomer in due course. But he began his career as a musician,’ explained George. ‘Herschel was born in Hanover, Germany, in the year 1738. At the age of fifteen, he joined his father who was a musician, an oboe player, in the Hanoverian Military Band. The young Herschel was an accomplished player of not only the oboe, but also the violin and the organ. Quite remarkable, isn’t it? Four years later, he visited England with the Hanoverian Guards regiment. Probably, that country was quite attractive to him. So he chose to settle in England a year later. Herschel became quite well-known for his prodigious musical output, Alfie. He had to his credit no less than twenty-four symphonies, seven violin concertos, and two organ concertos!’

‘That is quite impressive, George,’ I was indeed astonished at this unexpected side of Herschel.

‘Indeed, but his astronomical record was even more striking, you see. Attracted by the stars, Herschel began his celestial journey as an amateur astronomer, constructing his own telescope of twelve-inch aperture. It was one of the finest at that time. Building telescopes became his passion. He fabricated progressively larger ones, completing his big forty-eight inch instrument by the age fifty. Imagine that!’



‘I know that many amateur astronomers make their own telescopes as a hobby. But Herschel’s case seems quite different,’ I observed.

‘You are right, Alfie,’ George agreed. ‘Herschel started making his large telescope for his progressive exploration of the sky, not just as a hobby. Well, let us first

consider Herschel's discovery of Uranus. As you know, Uranus was the first planet to be discovered using a telescope. Even with the aid of a telescope, Uranus happened to be a very faint object in the sky. But Herschel's ability to spot a new celestial entity, however dim, was similar to Tycho's. Remember what Tycho wrote in the context of his discovery of a *new star*? Let me read from the manuscript. Here it is, the relevant part of Tycho's statement: *It was evening, after sunset, when according to my habit, I was contemplating the stars in the clear sky, I noticed that a new and unusual star. . .; and since I had almost from boyhood known all the stars of the heavens perfectly, there is no great difficulty in attaining that knowledge, it was quite evident to me that there had never been any star in that place in the sky, namely in the constellation Cassiopeia., even the smallest. . .*'

Ah, I had heard those very words from the mouth of that astronomer himself, hadn't I? I couldn't possibly tell George about it, could I? George went on without noticing my momentary mood of distraction.

'Likewise, Herschel compared the acquisition of his rare gift to his musical training: *Seeing in some respects is an art that must be learnt. To make a person see with such power as I am able to is nearly the same as if I were asked to make him play one of Handel's fugues upon the organ. Many a night have I been to see, and it would be strange if one did not acquire a certain dexterity by such constant practice.*

'Well, Herschel realized with great pleasure that he had discovered a new object, perhaps a comet! This was in the year 1781. But then, to his even greater joy, he could show that it was indeed a planet and not a comet. In his later career, Herschel discovered two Moons of Saturn—Mimas and Enceladus, as well as two Moons of Uranus—Titania and Oberon. Incidentally, Herschel's sister Caroline was also an astronomer who succeeded in discovering her own comets. And William's son John, born in 1792 went on to become a distinguished astronomer in his own right. So you see, Alfie, it was a remarkable Herschel astronomical family!'

'Stars streamed through their veins so to speak,' I commented.

'Most people know only Herschel's discovery of Uranus and none of his other important findings,' pointed out George. 'Let me recount briefly some of Herschel's brilliant contributions to astronomy, Alfie. First let us recognize an exceptional fact, namely William and Caroline Herschel were the first astronomers in history to do a systematic survey of the night sky. William, using the much larger telescopes, discovered that many of the stars that he had previously observed as single stars were in fact double or binary stars. By observing them over a period of time, he realized that they seemed to be moving around each other. This observation was very significant, Alfie. Because it showed that Kepler's laws of planetary motion and Newton's law of universal gravitation not only applied to the planets going round the Sun, but extended even to the stars far away. Those laws were truly universal, you know.'

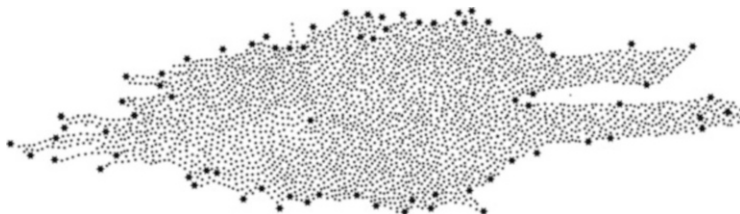
Herschel's achievements seemed to be growing in number. I was happy that I was learning so much about the great astronomer.

'What next?' I asked.

‘What next?’ George repeated my question. ‘The first of the building blocks that make up the cosmos!’

‘What might that be?’ The story seemed to be getting more and more interesting.

‘The Milky Way!’ announced George. ‘Herschel had noticed in his survey of the skies that the density of stars varied depending upon what region he was looking at. Two things could account for this varied distribution of the stars. Either the stars were closer together in the regions where they appeared to be more compact. Or the stars were actually spaced apart more or less uniformly. But, the stars seemed to be the denser in some region because that is where the Milky Way extended farther out. It was the latter explanation that William believed to be the case. After further analysis, he concluded that the shape of the Milky Way was that of a disk or a grindstone.’



‘We now know the correct shape of the Milky Way, which does not really resemble Herschel’s model,’ said George. ‘But what is important, Alfie, is that he was the first one even to come up with the idea. That is what counts. We shall soon see how another remarkable astronomer demonstrated the true shape and size of the Milky Way. For the moment let us join Herschel as he trains his large telescope at the *nebulae*, the diffuse patches that populate the night sky.’

George slowly sipped his wine a couple of times with undiluted enjoyment and, needless to add, so did I.

‘Ah, the *nebulae*! Herschel had received a copy of Charles Messier’s catalogue, *Connaissance des temps*, an almanac published in 1781, in which 103 *nebulae* had been listed. Herschel began observing these objects using his twenty-foot reflector with an aperture of about nineteen inches. Because William was using an instrument larger than anything that Messier could lay his hands upon, he was able to discover new *nebulae* that Messier had missed. And in the course of the next several years, he had added no less than some 2,500 new *nebulae* to the list! And his son John would discover more of them eventually.’

‘That is an impressively large number, George,’ I was genuinely astonished.

‘Yes indeed, Alfie. Now, Herschel tried to see whether the *nebulae* could be resolved into stars. Many could be, but others remained just diffuse clouds. One such example was the case of a planetary nebula around a white dwarf. We talked about that while discussing the end-states of stellar evolution, didn’t we? On the other hand, there could be *nebulae* that could not be resolved because of their great distances. In regard to the *nebulae*, the German philosopher Immanuel Kant had put forward a rather unusual idea.’

Once upon a time, I had read Immanuel Kant's philosophy. I recalled now his saying that had been etched on my mind.

'George, I remember what Kant wrote: *Two things inspire me to awe: the starry heavens above and the moral Universe within.*'

'That is a deep philosophical statement, Alfie,' George appreciated the quotation. 'Kant had something to say about the starry heavens above. Kant had theorized that nebulae that could not be resolved into clusters of stars had to be *Island Universes*, what we call *galaxies* today. They were being observed at great distances beyond the Milky Way and therefore could not be resolved into stars that made them up. This was a prophetic insight into the nature of the Universe, Alfie. Of course, Kant did not possess exact and extensive observational evidence for his idea in his own time. Kant also believed that the Milky Way was itself an Island Universe, like the distant nebulae. He even speculated that it was shaped like a flat circular disk. As we saw, Herschel did work out from his survey of the stars what he believed to be the shape of our Milky Way, a disk in fact. What is more, many of the nebulae he had observed lay beyond the Milky Way, the denizens of the Universe at large. Isn't that amazing?'

George fell silent for a moment or two. He quickly goes over in his mind whatever he has been relating so far before proceeding further.

'William Herschel, musician of great talent, astronomer of immense ability! He built his telescopes with finesse, used them with skill. Driven by his passion, he explored the Universe with imagination. He had the unique distinction of having set foot on the first rung of the cosmic ladder. In the next century, the realm of the nebulae would be opened up by one of the greatest astronomers of all time. But before that, the Milky Way had to be charted out completing the work Herschel had begun. Enter Harlow Shapley!'

George looked up and exclaimed, 'Ah, I see the much-awaited angelic vision of someone other than Shapley entering the scene, bringing joy to our earthly existence.'

I could not but smile at the last dramatic statement made by George. Of course, I too was happy to see the smiling waiter carrying a tray and making his way towards our table.

We watched as the waiter placed two small plates in front of us. What did Joe say about the starter? It was *Albóndigas*, meatballs in garlic sauce, one of the delicious *tapas*, but the meatballs replaced by breaded potato balls as concession to us vegetarians. I let George try the dish first. As expected, he closed his eyes as he savoured the morsel of food in his mouth slowly, gently.

'Oh, this is out of the world. Try it, Alfie, what are you waiting for?' George nodded his head a couple of times and smiled contentedly at the waiter. The latter returned his smile and went back to the kitchen. I was sure he would report George's reaction, the touchstone of culinary art, to Bruno and Joe. I too joined George in the delightful tasting of the *Albóndigas* and we ate for a while in silence, as one should, helping ourselves to the fast depleting supply of the delicious wine.

'Now for Harlow Shapley. We move in space and time, from England to the United States, and from the nineteenth century to the twentieth,' George took up the

story of the Milky Way after we had finished eating the appetizer. 'As usual, let me very briefly outline Shapley's life and work. I shall let you read the details later on when you go home.'

'Fair enough,' I agreed.

'All right, Shapley had a rather chequered career before he took up astronomy,' George resumed. 'He was brought up on a farm, worked with a newspaper as a reporter in his teens, wanted to become a journalist, but had no choice but to take up astronomy at the University of Missouri. So Shapley ended up as an astronomer. How do you like that?'

'He was an accidental astronomer then,' I commented.

'You could say that,' said George. 'So was Kepler for instance. He wanted to go into theology but stumbled into astronomy, lucky astronomy! Nowadays, there are hundreds of accidental astronomers, students who register for astronomy since they were not admitted to any other discipline. Alfie, please don't get me started on that dismal subject. Anyway, let us get back to Shapley. After obtaining a doctorate from Princeton University, Shapley joined the Mount Wilson Observatory in the year 1914. He got interested in a class of stars known as the *Cepheid Variables*.'

'What are they?' I interrupted George with my question. Sometimes my curiosity gets better of me.

'I was coming to that,' George said patiently. 'We have talked about Orion, which happens to be a most interesting constellation, haven't we? There is a rather not so interesting constellation, Cepheus the King, which lies opposite the Big Dipper on the other side of Polaris. We shall be speaking of Andromeda, daughter of Cepheus next time, when we discuss the expanse of the Universe. Well, perhaps the only interesting, and most important, aspect of Cepheus is that the constellation is host to a star called Delta Cephei. It is a variable star. Let me explain. Over a period of five days and nine hours, the star passes through a cycle of brightness with clocklike regularity. The difference between its brightest and faintest appearance is so pronounced that you can actually observe the variation with unaided eye.'

'What is the reason for this variability in brightness?'

'It is caused by the periodic change in size, Alfie. The star gets brighter as it swells up, and fainter as it shrinks. Delta Cephei was first observed in 1784. Since then many such stars with both longer and shorter periods have been discovered. These are the Cepheid variables.'

I wondered as to what these variable stars, however interesting, had to do with the Milky Way.

'Before we move on to the inter-relationships among the Cepheid variables, the Milky Way, and Harlow Shapley, let me introduce a remarkable lady,' smiled George. He had obviously read my mind. He added seriously, 'Her name was Miss Henrietta Swan Leavitt.'

George took the last sip of the wine in his glass before continuing.

'After her college education in 1893, Miss Leavitt joined the Harvard College Observatory as one of the *human computers*. That is how the women, who were employed for examining photographic plates in order to measure and catalogue the brightness of the stars, were called. They were also dubbed *Pickering's Harem*,

since they had been hired by the astronomer Edward Pickering. The work was gruelling, but the wages were low. Because Leavitt had independent means, Pickering initially did not pay her. Later, she received a royal stipend of thirty cents an hour for her work!

‘Apart from scanning photographic plates, did Leavitt do any observational work?’

‘No Alfie, in the early 1900s, women were not allowed to operate telescopes,’ George shook his head. ‘From the photographic plates, Leavitt could find a number of variables in the *Small Magellanic Cloud*, or *SMC*, an irregular dwarf galaxy which is a next-door neighbour of our Milky Way. Their periods varied from as short as one and a half days to as long as one hundred and twenty-seven days. But, here is the most important thing. The longer the period, the brighter was the star.’

I did not understand why this fact was of utmost importance immediately. I knew fully well that George was going to reveal the secret of those stars.

‘Let us now try to understand the concept of a *standard candle* and relate it to the remarkable discovery of Miss Leavitt,’ proceeded George as I had anticipated. ‘Suppose I have a lamp, Alfie, and move it away from you progressively. If I double the distance, the *apparent brightness* of the lamp, which you actually measure, decreases fourfold. Increase the distance three times, the lamp appears to have become nine-fold fainter and so on.’

‘Ah, I know that—the *inverse square law*, just like Newton’s law of gravitation!’

‘Exactly. If you know the *intrinsic brightness* or *absolute luminosity* of the lamp, you can deduce the distance of the lamp from you by measuring its apparent brightness using the inverse square law. This turned out to be true of the variable stars too. Leavitt’s detailed analysis of the photographic plates that had recorded the variable stars in SMC established a direct relationship between the intrinsic brightness of a variable star and its period of variability. So, what do we have in the end? We determine the period of brightening and dimming of a variable star by observation and hence its absolute luminosity. Therefore, we can estimate its distance from its apparent brightness, which we can again find out by direct measurement. In short, the Cepheid variables can serve as *standard candles* for determining distances on cosmic scales. That, in essence Alfie, was the stupendous discovery of Miss Henrietta Swan Leavitt!’

Yes, this was indeed a fabulous discovery, I agreed. I was certain that the detailed measurements of Henrietta Leavitt must have involved a lot of work.

‘Miss Leavitt must have been hailed as a great astronomer, an unprecedented accomplishment for a woman at that!’ That was but natural I thought.

‘Not in her lifetime, Alfie,’ George shook his head. ‘Leavitt could work only sporadically because of her health problems, including her increasing deafness. In 1921, Harlow Shapley the new director of the Harvard observatory appointed her the head of stellar photometry. But within the year she had succumbed to cancer at the early age of fifty-three.’

George fell silent. I could see that he was truly sad, thinking of the great lady who had been robbed of her deserved place among the stars by her tragic end.

‘It is true that she was a member of several scholarly academies during her career. But that is nothing compared to the honours she should have won,’ said George. ‘As an individual, she must have been a wonderful woman too. Let me quote what one of her colleagues noted in her obituary: *She had the happy faculty of appreciating all that was worthy and lovable in others, and was possessed of a nature so full of sunshine that, to her, all of life became beautiful and full of meaning.*’

George paused and went on.

‘Unaware of her death four years earlier, the Swedish mathematician Mittag-Leffler, a member of the Swedish Academy of Sciences, considered nominating her for the 1926 Nobel Prize in Physics. He learnt that it was too late. The Nobel Prize is not awarded posthumously.’

George leafed through his manuscript. ‘Let me read the letter from Mittag-Leffler to Miss Leavitt dated February 23, 1925:

Honoured Miss Leavitt, What my friend and colleague Professor von Zeipel of Uppsala has told me about your admirable discovery of the empirical law touching the connection between magnitude and period-length for the S. Cepheid-variables of the Little Magellan’s cloud, has impressed me so deeply that I feel seriously inclined to nominate you to the Nobel prize in physics for 1926, although I must confess that my knowledge of the matter is as yet rather incomplete.

‘And here are the words of Harlow Shapley, the director of the Harvard Observatory, from his March 1925 letter to Professor Mittag-Leffler:

Miss Leavitt’s work on the variable stars in the Magellanic Clouds, which led to the discovery of the relation between period and apparent magnitude, has afforded us a very powerful tool in measuring great stellar distances. To me personally it has also been of highest service, for it was my privilege to interpret the observations of Miss Leavitt, place it on a basis of absolute brightness, and extending it to the variables of the globular clusters, use it in my measures of the Milky Way. Just recently in Hubble’s measures of the distances of the spiral nebulae, he has been able to use the period-luminosity curve I founded on Miss Leavitt’s work. Much of the time she was engaged at the Harvard Observatory, her efforts had to be devoted to the heavy routine of establishing standard magnitudes upon which later we can base our studies of the galactic system. If she had been free from those necessary chores, I feel sure that Miss Leavitt’s scientific contributions would have been even more brilliant than they were.’

George sighed deeply. I could see that he was in a pensive mood having recounted the moving story of Miss Leavitt.

‘Much later, one of the asteroids and a crater on the Moon were named after her. But the greatest tribute to the groundbreaking discovery of Miss Leavitt came first through the work of Harlow Shapley who demonstrated the size and the structure of the Milky Way. And then through the exploration of the Universe as a whole by Edwin Hubble. Both of them used Miss Leavitt’s Cepheid variables in their measurements.’

After a momentary pause, George added, ‘So, Alfie, we are back to Shapley.’

Before George could continue, the waiter appeared again. He cleared our table and placed on it a fresh carafe of wine, the second of the two choices I was sure. Also, pimiento rellenos—the luscious red bell peppers glistened and quivered as steam rose from their hot interior. As before, the waiter looked on until we tasted the dish, while sipping the wine.

‘This is indescribable,’ George said. ‘How can anything taste so good?’

‘Aren’t you glad that you have become a vegetarian, George?’ I said. ‘There can be so much variety in vegetarian dishes, often with subtle difference among them.’

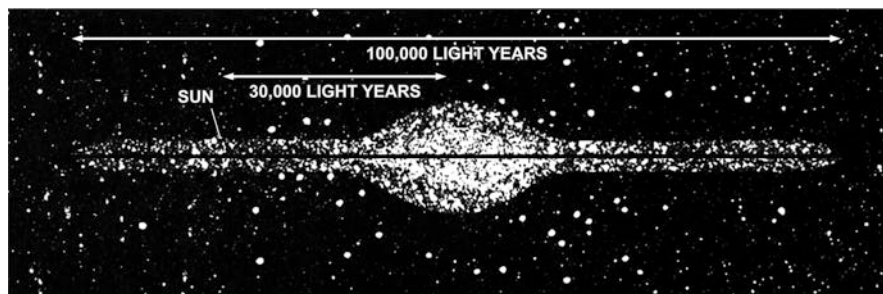
The waiter smiled, satisfied that we were satisfied, and returned to the kitchen.

After a few minutes of concentrated epicurean pleasure, George took up his exposition.

‘Shapley was now equipped with his standard candles, namely the Cepheid variables,’ George said. ‘Now, he started his work trying to establish the dimensions of the Milky Way and its shape. For this, he focused on the Cepheid variables couched within *globular clusters*. They are essentially spherical distributions of thousands to hundreds of thousands of stars.’

‘I know what they are,’ I told George. ‘While explaining Newtonian gravity in his famous *Lectures on Physics*, Feynman includes a photograph of a globular cluster and remarks: *This figure shows one of the most beautiful things in the sky—a globular star cluster. If one cannot see gravitation acting here, he has no soul!*’

‘Ah, that is Feynman for you, capturing the soul of gravitation,’ George was quite happy with what I had told him and so was I. ‘Those beautiful things came in handy for Shapley. At the time of his observations, around a hundred globular clusters were known. Shapley concentrated on studying the variable stars within those clusters. He could measure distances to sixty-nine clusters. From these measurements, he could find out their distribution pattern. And in turn, he estimated the dimensions of the Milky Way, its shape, and—what is more—the place of the Sun within this vast system of stars. The Milky Way was found to be roughly like a disk with a central bulge with a diameter of some 100,000 light years. And where is the Sun, where are we? Shapley discovered that we are not at the centre of the Milky Way, not even near enough, but around 30,000 light years from the centre, almost at the edge of our galaxy comprising some 300 to 400 billion stars! Think about it, Alfie.’



‘Copernicus had dethroned man from the centre of the solar system,’ I remarked. ‘And now, Shapley nudges him away from the centre of the Milky Way. What a pity!’

‘Exactly,’ nodded George. ‘The Milky Way had turned out to be so vast with billions of stars, that Shapley believed that it constituted the entire Universe. As we have already seen, astronomers, starting with William Herschel, had observed diffuse patches in the sky, the nebulae. Did they belong to our own Milky Way, as Shapley believed, or did they lie beyond it? That was the big question.’

‘Was the question settled? If so, in whose favour?’ This seemed like an astronomical suspense story.

‘No happy and easy ending here, Alfie,’ answered George. ‘In the wake of these two different opinions, a debate was arranged between Shapley and another established astronomer, Heber D. Curtis, who was a proponent of the Island Universe hypothesis. The great debate took place on April 26, 1920, before the National Academy of Sciences in Washington, United States.’

‘My goodness, thankfully it was not a duel.’ I remembered Jeppe’s recounting of how Tycho Brahe had lost his nose in a duel. But mum was the word! ‘So what happened?’

‘Curtis was not convincing,’ George replied. ‘The judges gave their verdict, point by point of the arguments based on observational data, in favour of Shapley. For the moment, the Milky Way was the entire Universe.’

‘We know that it is not true, don’t we?’

‘Of course, thanks to Edwin Hubble who is about to rise over the horizon in our story,’ said George. He added, ‘Next time we meet that is. You must wait till then.’

‘Let us not forget that since Shapley’s time there has been a lot of observations and theoretical modelling of the Milky Way,’ said George as a postscript. ‘For instance, we now know that the Milky Way turns about its centre. As a result, our solar system is moving round with a speed of about 220 kilometres per second. That seems quite fast, doesn’t it, Alfie? However, since our galaxy is so huge, it takes 240 million years for the solar system to go one full round. The last time the Sun was at the position it is now, dinosaurs roamed the Earth! How do you like that?’

We had finished the main course of our dinner. Our waiter, who brought our dessert *Mantecados*, traditional Spanish crumble cakes accompanied by whipped cream, was soon followed by both Bruno and Joe. They were eager to participate in our enjoyment. And they were not disappointed.

‘That was a fantastic, fabulous dinner. Let me not even try to guess how you manage to create such a wonder,’ George offered his high compliment. That went for me too. ‘I have a question and I am sure Alfie has the same query too. The two wines you served were excellent, never tasted better, you know. But which was which, Rioja or Ribera?’

Bruno and Joe exchanged glances and smiled sheepishly. ‘We don’t know,’ volunteered Bruno.

‘What, you don’t know? How can that be?’ George was perplexed and so was I.

‘You see it is like this,’ Bruno went on to explain. ‘When we poured wine into the two carafes, we forgot to keep track. We don’t know which one went where.’

George burst out laughing as did the three of us.

‘So that was an experiment with negative but very happy result,’ concluded George. ‘That means we have to repeat it with better control. Bruno, we congratulate you.’

‘What for?’ It was Bruno’s turn to look puzzled.

‘For roping in Joe,’ replied George. ‘We can’t thank you enough for the great joy of tasting an exquisite meal.’

As always, Bruno waved away our thanks, while Joe bowed ceremoniously as he had done earlier.

We lingered outside the restaurant for a while. It was a crisp, clear night, the stars shining bright against the dark inverted bowl of the sky. Arched over the sky was the Milky Way that must have been both an intriguing and inspiring sight for eons. George gazed at it silently. It was as if he were looking at it for the first time.

‘Isn’t it gorgeous, Alfie? It fills you with wonder,’ said George. ‘As with the constellation Orion, every culture had some story or the other to describe the origin of the Milky Way, *Via Lactea*, in Latin. To the Greeks, it was the starry wake left behind by the chariot of Helios, the Sun God, as the horses drawing it went out of control, when his son Phaethon drove it against the warnings of his father.’

‘I know. I have heard the Indian myth depicting the starry path,’ I added. ‘It marks the course of the sacred river *Ganga*, or Ganges as it is known in the west, as she cascaded down from heaven. Lord Shiva broke her fall, lest the impact should shatter the Earth. He held her captive playfully for a while tied up with the long strands of his hair, and finally freed her so she could descend gently on to the Earth and flow on, bestowing spiritual joy and liberation. The Milky Way is called *Akashaganga*, the River Ganga of the Heavens.’

‘That is beautiful, that too with a happy note, Alfie,’ George nodded his appreciation. ‘It is not at all like the Greek myth that ends in tragedy. Phaethon was struck down by Zeus, since Sun’s chariot, out of control, had been wreaking havoc.’

‘Alfie, we shall try to understand the expanse of the Universe the next time we get together,’ said George. ‘Why don’t we go to the University Observatory and meet our young astronomer friend Mike Brown? He can explain to us Hubble’s monumental work. We can ask Mike to show us some photographs too. What do you say?’

‘That would be real great, George.’ I was delighted at the prospect of visiting the Observatory as well as meeting Mike.

‘All right then. Oh, I almost forgot. Here, I got for you some recordings of the lovely music William Herschel created. I am sure you will enjoy it.’ George handed over a compact disc, which he had taken out of the bag he carries nowadays to hold his manuscript.

‘Take care, Alfie. We shall meet soon.’

I wished George good night and walked briskly. I was eager to read George’s book as usual. Tonight I had the added bonus of Herschel’s music.

Chapter 11

The Map of the Milky Way

As soon as I arrived home, I started reading about William Herschel and Harlow Shapley in George's book, while playing the recording of Herschel's music George had given me. The majestic sounds of the orchestra playing one of his symphonies filled my room. As I read the manuscript, I was greatly impressed by the dedication and zeal of the two astronomers in charting out the Milky Way. They had thereby initiated the exploration of the large-scale structure of the Universe. All this brought to my mind two quotations from Plato. I repeated those quotations to myself softly:

*Star gazer, my star, if only I were the sky,
I would watch you with ten thousand eyes.*

And then again,

*Alive, you shone among us like the morning star;
Now, like the evening star, your mantle lights the dead.*

After my reading was finished, I carried the record-player to my bathroom, set it on a stool, and started playing one of Herschel's violin concertos. Again, the soft strains of that soothing music spread around my little bath room.

I opened the faucets to fill my bathtub. My bathtub started vibrating gently. I found that the two streams of water from the faucets were rhythmically changing their rates of flow thereby modulating the vibrations and creating sounds that were in total harmony with the music playing in the background.

'So beautiful, boss, the music you are playing,' the bathtub spoke in an almost whisper. 'I hope my own humming does not disturb you.'

Of course, it did not. As a matter of fact, it added to the charm of Herschel's music.

'Thank you, boss,' the bathtub sounded genuinely happy. 'You are so fortunate, boss, but I don't envy you. You read so much, think so much, and you can recall so many things you have learnt like the two quotations you were just reciting to yourself. Those lines are so apt when you think of the astronomers who have illuminated this world with the knowledge of the stars.'

I could not agree more with the bathtub's last statement. But, what I had just heard was not its usual style of speech, casual and tinged with playful banter. Moreover, the statement had been crafted beautifully well.

'Like you, I am fortunate too,' continued the bathtub. I could sense its unexpressed appreciation for my unexpressed thought. 'You know why? Long ago my Master used to convey to me so much of his knowledge, so much of his thoughts. Now, you do the same in a different way. If only I could...'

The bathtub hesitated. I wanted to know what it had in its mind. Yes, *its mind*, I was convinced that it had its own mind, its own thought process, however different it might have been from ours, perhaps better than ours!

'Thanks again immensely, boss,' said the bathtub with utmost sincerity. 'What I was going to say is this. I wish I could go out with you and look at the stars, gaze upon them, decipher the multitude of their messages. But then I thought perhaps it is better the way it is. You are my eyes, boss. And I can imagine what you see from your thoughts. After all what did the Master say? *Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand.*'

I was moved by what the bathtub had said. I was indeed fortunate to have such a bathtub for a companion.

'All right, boss, let us not get sentimental about our roles to play,' said the bathtub calmly. 'Let us not postpone the pleasure of having a bubble bath. Yes, it is a pleasure for me too. I share your thoughts, your dreams, your fantasies, don't I? Pour in the mixture, let the bubbles rise and whirl, let all the imaginings in the Universe stir up your mind.'

Well, I followed the bathtub's excellent suggestion. And the brilliant specks that the bubbles had brought with them swirled around me. They glistened in varying brightness and colour. They came singly and in clusters and to my great surprise some of the clusters, containing a large number of the sparkling specks, were shaped like little globes. I closed my eyes and surrendered to the exquisite pleasure of being surrounded by not only the bubbles and miniature stars, but the lovely music that added immeasurably to my experience.

Stargazing Siblings

I thought I knew where I was. During my recent wanderings, I had in fact visited this lovely city of Bath in England. The city was first established as a spa with the Latin name, *Aquae Sulis*, the Waters of Sulis by the Romans sometime in the first century about 20 years after they had arrived in Britain. They built a temple and baths around hot springs on the hills surrounding Bath in the valley of the River Avon. I could go on describing the city, which has become a great tourist attraction. But now, the vision of the town before me looked quite different from what I had seen recently. I felt that I had been transported a couple of centuries back in time.

I could hear beautiful music emanating from the massive, ornate building in front of me. I hesitantly tiptoed inside and stood at the back of the spacious hall. There was a large gathering of people inside listening to the music in absolute silence. On an elevated platform sat the musicians of a full orchestra playing different instruments. Facing them, back to the audience, stood a tall formally dressed figure with silvery grey hair, conducting the orchestra. Waves after waves of harmonious melodies issuing forth from the various musical instruments swept over the listeners. I was sorry that I had missed the beginning of the concert. Soon the concert ended. The conductor turned round and bowed repeatedly to the thunderous applause of the audience. Then the listeners trooped out exchanging admiring comments about the music and the conductor. I too moved on in silence still feeling the power of the music I had heard.

All at once, I realized who the conductor happened to be. It was none other than William Herschel, musician, composer, and conductor. The piece the orchestra had been playing was one of the symphonies he had composed. Probably, this was a rare occasion on which he had found time to conduct an orchestra amidst his busy schedule of observing the heavens. I followed Herschel as he came out of the concert hall and headed towards his home.

The house before me was like any others I had seen on my way. But what was remarkable was the large, seven-foot long telescope that had been installed in the garden supported by sturdy scaffolding. The telescope pointed towards the sky ready to capture light from the celestial bodies. It was getting dark now, night was about to descend. Herschel came out of the house. A handsome and dignified lady accompanied him, carrying a large book apparently to keep record of their observations.

‘Caroline, it has been a long time since the new planet was first spotted. It is a pity that you were not here that night when I took a look at that planet for the first time,’ said Herschel addressing his sister.

‘I know, it was the week of my thirty-first birthday and I was away,’ recalled Caroline wistfully.

‘First I thought it was a comet,’ recalled Herschel. ‘I am so proud that you yourself have discovered no less than eight comets, Caroline. But what a strange comet this one was! An imposter with no tail trailing behind,’ Herschel laughed.

‘Oh, yes, and we traced its motion night after night and tried to fit its path into a normal orbit a comet usually takes, didn’t we, Wilhelm?’ said Caroline and added with a smile, ‘I am sorry, I forgot that I must address you by your British name William. Anyway, the crafty celestial object was determined to move along a circle.’

‘At last, we knew what it was a planet no less!’ Herschel was elated at the recollection of the past revelation.

‘A planet begging for a name,’ laughed Caroline. ‘Many astronomers wanted to name it after you, remember? You wanted to name it after King George, your benefactor. Finally, following the tradition of selecting names from mythology, the planet was christened Uranus, after the ancient Greek deity of the sky, father of Cronus or Saturn and grandfather of Zeus or Jupiter.’

‘The right choice if you ask me,’ commented Herschel modestly.

‘But, William, everyone recognizes the fact that you are the first person in human history to have discovered a new planet. Not only that. The distance to Uranus from the Sun happens to be twice that of Saturn. Every one hailed that single-handed you had doubled the size of the solar system. What an extraordinary feat!’

Herschel accepted Caroline’s praise hesitantly, embarrassed as he was by her admiration.

‘You discovered two Moons of Uranus and two years later another two that circled Saturn. But, the most intriguing fact has been the orbit of Uranus. It is not exactly like what one would have expected it to be, assuming that it is going round the Sun under the latter’s gravitational pull. No one has been able to explain its odd behaviour. So strange!’

‘Well, it is an unsolved mystery indeed, and no one has a clue as to why the planet behaves thus,’ Herschel shook his head. ‘But, I am sure sooner or later the problem will be solved.’

The scene faded as did the two astronomers, brother and sister, along with their magnificent instrument that had revealed so much of the night sky. Of course, I knew what that wonderful pair did not, namely why their planet behaved so oddly: it was due to the gravitational pull of another planet, Neptune, to be discovered much later. Another coincidence, I had earlier learnt about, struck me. It takes Uranus a little more than 83 years to complete one revolution round the Sun. And strangely enough, William Herschel, its discoverer, lived exactly that long!

Stars on Stage

While I was still musing about the scene that I had witnessed, I was abruptly woken up from my reverie by a deep voice.

‘The stars seem to go on and on forever. Is there no limit to their realm?’ the resonant voice reverberated. Now fully alert, I looked up at the extraordinary spectacle in front of me. On an elevated platform, illuminated by gaslights, stood a handsome man. He was elegantly dressed in a long velvet coat and a white frilled shirt. He wore a wig of curly locks of hair and held in his hand a silver-tipped cane of dark mahogany. Surprisingly, he bore a striking resemblance to William Herschel.

Then realization dawned on me. Why, I had been instantaneously transported to a theatre in London. And the man on the stage was an actor made up to look like the celebrated astronomer. I was in a large hall filled with people, who were relaxing comfortably on cushioned seats. Thick curtains hung from ornately decorated walls. The hall was dark except for the faint light issuing forth from the distant gaslights propped up on the stage. The single actor on the stage was acting the role of William Herschel describing the astronomical findings of the latter. People loved these shows that were at once both instructive and entertaining.

The actor made his presentation with great fervour, varying his voice, accent, and intonation according to the subject matter he was reciting and the persons he was depicting. He gestured with his hands skilfully to suit his recitation as well as to indicate the astronomical phenomena he was describing.

‘Let us begin with the renowned philosopher Galileo, an Italian who was an extraordinary observer of the heavens. Besides, he was a man given to dramatics,’ said the actor and made a slight bow as he added, ‘Not unlike your humble servant.’

‘Galileo’s spyglass, though small in size, revealed the immense Universe as never before.’ With his silver-tipped cane, the actor pointed to a model of Galileo’s telescope on which a hidden gaslight was turned on. ‘Recall, if you will, ladies and gentlemen, how he described his vision of the hazy band of light adorning the night sky: *The galaxy is, in fact, nothing but congeries of innumerable stars grouped together in clusters. Upon whatever part of it the telescope is directed, a vast crowd of stars is immediately presented to view. Many of them are rather large and quite bright, while the number of smaller ones is quite beyond calculations.* Ah, what a glorious vision derived from observation! But observation leads to imagination, intuition, and speculation. Indeed, bold and far-reaching were the speculations of the renowned German metaphysician, namely Immanuel Kant.’

The actor swept his hand gracefully towards the background as a portrait of Kant on a large canvas suspended by wires descended from above, stayed on for while, and disappeared as it was hauled up.

‘Pray allow me to convey to you, although I am aware of your erudition, ladies and gentlemen, and heaven forbid that I insult it, the gist of what he wrote in his early work *Cosmogony*. I quote: *The Universe by its immeasurable greatness and the infinite variety and the beauty that shine from it on all sides, fills us with silent wonder.* Forgive me, if I fail to be as silent as the great Kant wishes me to be, as I cannot contain my awe at the Universe he depicts. Well, what more did Kant offer that emerged from his unbounded imagination? He went beyond the Milky Way, yet not straying too far from it in his generalisation. He imagined systems of innumerable stars each system gathered together in the shape of a thin disk, similar to the Milky Way, but so far removed from our earthly moorings that individual stars within those systems are indistinguishable even with a telescope. Rather, each system would appear as a dim little patch, circular if its plane is perpendicular to the line of sight, elliptical if viewed obliquely. Such is the true aspect of the faint *nebulae* one perceives in the sky, each made up of countless stars so distant in space that they seem to cluster together indistinguishably, so limited in light that they are the most feeble candles in the heavens, yet sister galaxies to our own. Thus was born the idea that each one of them was an *Island Universe*.’

The actor paused as an enormous frame descended behind him carrying a beautiful picture of the star-studded night sky showing the Milky Way and a few faint patches depicting the nebulae.

‘Then came William Herschel,’ announced the actor with a flourish and held himself in a dramatic pose before continuing with his oration.

‘Yes, ladies and gentlemen, new vistas were destined to be opened up by none other than William Herschel who is hailed as the Prince of Astronomy and

considered by many as one of the greatest celestial observers of all time. But he made his entrance on the cosmic stage only after following his destiny along a tortuous path in this world, a story which I have the honour to relate.'

The actor proceeded to recount Herschel's varied career and his discovery of Uranus. A large-scale model of his telescope was pushed onto the stage for effect. An actress dressed as William Herschel's sister Caroline and a young boy portraying his son John joined the main actor. They would go through various movements supporting the actor's recitation.

'Not being content with all his achievements thus far, Herschel decided to address himself to some of the most difficult questions of astronomy. Night after night, his telescope swept the heaven's vault as the Earth turned, while Herschel worked relentlessly driven by his unquenchable thirst for knowledge. But think of the treasures he *unearthed* in the night sky, if you would be kind enough to permit such a paradoxical expression, ladies and gentlemen. He discovered more than some eight hundred double stars paired in conjugal bliss. He added no less than two thousand and four hundred nebulae to the mere hundred or so known previously. He was now confronted by the profound questions that dogged many: What shape is the Milky Way and where are we in relation to the Universe as a whole? In answer to these queries, Herschel unveiled his great celestial star map.'

The actor paused as Herschel's depiction of the Milky Way descended from above.

'In consonance with the ideas of Immanuel Kant, Herschel conjectured that the Milky Way in fact possesses the form of a disk—or a grindstone, if you please, which has a central bulge very much like a lens. And, pray, where are we stationed in the immensity of this stellar realm? Herschel proclaimed that the Sun and his family of planets are located somewhere in the middle of the celestial grindstone. Had not Copernicus banished man from the centre of the solar system? Now, Herschel restored man's lost honour and dignity by placing him again at the centre of our galaxy.'

The actor lowered his head as if in deep contemplation and fell silent for the moment to allow his listeners to absorb what he had recounted so far and think about the implications of the facts he had conveyed to them.

'Now, observe how the celebrated astronomer turns his attention to the empire of the nebulae, the almost imperceptible patches of illumination scattered across the sky. He is no longer stargazing, but star gauging. He notes down the time at which each nebula passes his telescope and its elevation thereby pinning down the position of the dim denizen of the night sky. His gifted sister Caroline takes down copious notes as her brother dictates the data, while his son looks on with wonder, inspired to aspire, determined to follow in the footsteps of his illustrious father. Herschel ponders and lets his imagination take wing. Perhaps each nebula, like the Milky Way was an immense aggregate of countless stars. Let us believe for a moment in Galileo's idea that faintness measures distance. Then these nebulae must be far, far away lying outside our own galaxy.'

The actor lifted his eyes heavenwards as if he were indeed gazing at one of those nebulae.

‘Let us dream with Herschel then and echo his words: *Those nebulae may well outvie our Milky Way in grandeur.*’

The actor slowly shifted his gaze towards his audience who watched him transfixed with wonder and admiration.

‘Let us return to Galileo and hark back to his words of conviction: *With the aid of the spyglass, the Milky Way has been scrutinized so directly and with such ocular certainty that all the disputes that have vexed philosophers through so many ages have been resolved, and we are at last freed from wordy debates about it.*’

The actor gave a theatrical laugh and continued.

‘Did the observations of that unparalleled stargazer Galileo and those of the Prince of Astronomy put to rest the disputes about the Milky Way, let alone the nebulae? Did they free the philosophers from wordy disputes? Time, only time, the impartial arbiter of debate and dissent, will tell. For the moment, I offer you my profound gratitude for your attention, patience, and encouragement and bid you farewell.’

The actor bowed deeply to the standing ovation of the audience. He beckoned to his two assistants who joined him and, holding hands, all the three on the stage bowed repeatedly as the curtain descended slowly.

Measurer of the Milky Way

I was quite impressed by the theatrical performance, especially the actor who had presented the facts about the Milky Way and the nebulae in such a picturesque manner. While still savouring the novelty of it all, I could instinctively feel that I was travelling both in space and time as had happened to me time and again. Once, this used to be a rather disconcerting and often disorientating experience. Not any more, in fact I had started enjoying this strange passage and looked forward to it.

I was surprised to see a man on all fours looking intently behind some bushes. I had expected to meet someone gazing up at the sky, not peering down at the ground.

The man looked up. He had a round face with chubby cheeks, above which his eyes glittered with good humour. He gestured towards the spot he had been observing with keen concentration.

‘Ants, you know, ants,’ he explained as he straightened up. ‘I have been studying how they behave, especially how they move around at different temperatures. See, I have equipped myself with excellent instruments. Here is a thermometer to measure the temperature and this is a barometer that finds out the pressure. I have discovered that the ants’ movements have nothing to do with pressure. But they do run faster in the heat. Anyway, I have studied their motion day and night very carefully. I even wrote an article entitled *On the Thermokinetics of Dolchoderine Ants*. How do you like that? But my astronomer colleagues thought it was all a joke, although those who study insects took it seriously. Oh, by the way, I do study the stars too you know—that is my main business. It’s terribly stressful sometimes, if you have to watch the

stars all night and the ants all day. Can't get enough sleep. Look over there. That is the observatory where I work. We are on the top of a mountain called Mount Wilson, you know. And the observatory is obviously called Mount Wilson Observatory, what else?'

In the background, I could see the observatory, a big white building with a shiny metallic dome.

'Yes, ants are fascinating creatures, as interesting as stars,' said this strange man. 'Dear me, I haven't introduced myself, I am so sorry,' he added apologetically. 'My name is Shapley, Harlow Shapley. Let me give you my background so you may know me better.'

Shapley went on to describe his childhood, his education, and his career as an astronomer, all of which I found incredibly fascinating. As the story unfolded, Shapley receded into the background, only his voice audible. Scenes and events from his life appeared in succession illustrating his biographical narration.

'I was born on a farm near the little town of Nashville in the state of Missouri, United States of America. My father Willis Shapley was a farmer and a county schoolteacher too, you know. I loved the animals we had on our farm—hens with little chicks following them, a couple of horses, and cows. My twin brother Horace and I went to this one-room school on the border of our farm. Well, I studied up to just fifth grade. That is not much, is it? Anyway, I studied at a business school for a while and worked as a crime reporter for a miserable little newspaper called *Daily Sun*. Humans commit all sorts of crime like stealing, killing, so on and so forth, don't they? Animals on the other hand, like the ones we had on our farm, don't do such bad things. Reporting crimes is no fun at all. But then I discovered this treasure house of a library where I could read all sorts of things—history, literature, poetry and what not. I loved poetry, didn't I? Reciting verses helped me milk the cows rhythmically!' chuckled Shapley and continued. 'I wrote a nice essay, in fact, on Elizabethan poetry. Because of that, I was admitted to the University of Missouri where I could learn a lot of things. From then on, I never stopped.'

Shapley paused, before continuing, to think fondly of the happy days of learning. 'Did I want to study the stars at the university? No, sir, I never paid attention to them while I was on the farm, nice to sleep after the day's hard work rather than stay awake looking at the night sky, wouldn't you agree? I wanted to become a newspaperman. But, horror of horrors, they were not teaching journalism that year at all—the subject I needed for working for a newspaper. So I had to choose something else. Let me look at the list of things they are teaching this year, I said to myself, and fix something. First to appear on the list was *archaeology*. Archaeology indeed, I couldn't even pronounce that word! So I decided to take up the next subject—*astronomy*! That was it. So, you see, I became an astronomer by pure accident.'

'You may call me an accidental astronomer if you like,' said Shapley with a knowing smile.

Ah, here is another one of them, I thought.

Shapley laughed heartily at his recollection, his eyes buried in his round cheeks, before continuing.

‘Well, I know you came to learn more about the Milky Way and not about me. I will be glad to tell you all about it. As a matter of fact, I spent a lot of time making its map,’ said Shapley. And with a broad smile he added, ‘I succeeded too. The important thing is to measure distances to the stars of the Milky Way in all directions. But how do you measure distances to the stars? You have learnt about Herschel’s work, haven’t you? He did his star gauging using the fact that light becomes dimmer with increasing distance. I know, I know. You are quite familiar with how exactly that happens, I mean the inverse square law and all that. Furthermore, as you have already learnt, we need *standard candles* whose intrinsic brightness or *absolute luminosity* is known. Then, by measuring their *apparent luminosity*, we can determine distances to the stars. Let me demonstrate it, quite entertaining you know.’

Shapley pulled out of his jacket pocket a whole bunch of brand new candles all of which looked exactly alike.

‘Yes, these candles are identical to one another. They give out light that is of absolutely fixed brightness, which has been measured accurately. In other words, they are our standard candles.’ Shapley lighted the candles one by one with a matchbox that he had produced out of his pocket too. Shapley snapped his fingers and we were surrounded by thousands of lighted candles. Distant ones shone fainter than the closer ones.

‘Isn’t that nice? If we measure distances to the candles in different directions, we can know how they are distributed in space. In other words, we can find out the size and the shape of the distribution of the candles. Not only that. We can also find out where we are among the lighted candles. If the farthest candles are more or less at the same distance in all directions, then we must be at the centre. On the other hand, if there are more of them on one side than the other, then we know that we are nearer to the latter edge. This is precisely what I did for the Milky Way.’

He smiled to himself as he recalled his thrilling—although painstaking—explorations of the past.

‘But how do you do this in the case of the stars?’ Shapley paused to let the question sink in. ‘Well, you need bright enough sources of light spread all over the Milky Way for a starter. For that you make use of *globular clusters*.’

All of a sudden a huge collection of stars appeared before my eyes. These stars were distributed in a spherical shape, packed densely around the centre and thinning out towards the outer periphery. They were going in orbits around their common centre at extremely slow rates. They looked like beautiful iridescent bees flying around in orderly patterns to make up the globular cluster. This was incredibly more beautiful than looking at a globular cluster in a photograph or perhaps even through a telescope.

‘Ah, there is a globular cluster for you,’ said Shapley. ‘As you know, these clusters contain anywhere from thousands to hundreds of thousands of stars—even a million—so that they glow quite bright. They are distributed all over our Milky Way.’

The candles were now replaced by globular clusters—nearly a hundred of them—and they shone with varying brightness depending upon their distances. In one direction, there were many of them, more densely packed than in the others.

‘All right, we have our globular clusters in place, the distant ones glowing fainter than the closer ones. But we need a standard candle within each, whose actual brightness is known, so we can measure their distances. Astronomers are quite clever you know, even if I say so myself. They found a standard candle that shines not steadily but changes its brightness regularly—a *variable star* as it is known. Again, I am quite aware that you know all about *Cepheid variables*. Look over there, in the nearest cluster, you can see one.’

Oh yes, I could see the star clearly, its brightness varying rhythmically. It was amazing.

‘All right, let us recapitulate the most important aspect of the Cepheid variables,’ continued Shapley. ‘The period of the variable star is directly and exactly related to its brightness. The longer the period, the brighter is the variable star. So, if we just measure the period of a variable star within any globular cluster, we would know the true brightness of that star. If we determine the star’s brightness as observed here on the Earth, or its apparent brightness, we can estimate its distance—or equivalently that of the globular cluster from us. Simple enough, right?’

Of course, it was quite simple, I thought.

‘Actually, in practice it is quite a bit of hard work,’ admitted Shapley. ‘In any event, I was able to determine the distances to the globular clusters around us and thereby measured and mapped the Milky Way. And what did I find?’

Shapley gazed at me savouring the suspense his pause had created.

‘Let me tell you very briefly,’ continued Shapley. ‘Our galaxy, the Milky Way I mean, is like a thin disk with a central bulge where lots of stars can be found. And how big is the Milky Way? What I found out was a big surprise to my friends. It is some 100,000 light years across! Pretty large, isn’t it? And, let us not forget it contains billions of stars too.’

Yes, the Milky Way is large enough. In all probability, in Shapley’s days it must have seemed unimaginably big.

‘And where are we? I mean, where is our solar system located within this huge system of stars?’ Shapley went on. ‘Are we at the centre of our galaxy? No, sir! We are at a distance of around two thirds the radius of the Milky Way from the centre! That means about 30,000 light years away from the centre of our galaxy. Copernicus, as you very well know, had shown that man is not at the centre of the solar system. And now we find that he is not at the centre of the Milky Way either. What does that mean?’

Shapley paused dramatically before answering his own question. ‘It means, my friend, that man is not a big chicken after all!’ He burst out laughing and continued to laugh for quite a while. Perhaps he was thinking of all the chickens he used to feed on his farm long ago.

Having recovered from his bout of mirth, Shapley said, ‘One last thing. The galaxy is so immense that I was convinced that it was everything there is. It was the entire Universe. Those faint luminous patches one saw in the night sky were

nothing more than gas clouds belonging to our own Milky Way. Were they Island Universes beyond our own galaxy? I could never, ever accept such a preposterous idea. But there were those who didn't agree with me. We had lot of disputes and debates over that matter. Anyway, at least we had come to know how big our galaxy was.'

Shapley seemed to be quite content with his remarkable discovery. 'I had come a long way from milking the cows to measuring the Milky Way, my friend. Ah, that was indeed the milky way to the Milky Way!' Shapley again laughed long and loud.

'Oh well, let us forget the stars for the moment. They shine on any way, don't they? Maybe it is time for me to get back to my ants.'

Shapley went down on all fours once again and seemed to forget my presence altogether as he peered at the ants running around on the ground.

I opened my eyes reluctantly. Awareness returned hesitantly. Herschel's melodious music was still playing on. How long had I been out of this world, so to speak? Dreams may seem to last for a long time even though they occur for a moment or two. Does it matter? Time is after all relative, isn't it? I stayed on happily in the comfortable warmth of the bathwater until the music came to an end.

Yes, it is wonderful to dream. Undoubtedly it is also wonderful to sleep without dreaming. And that is what happened to me when I went to bed after having enjoyed my bath.

Chapter 12

Through the Glass Brightly

George drove his old car along the tree-lined winding road up the hill. Shafts of mild sunlight of the approaching evening shone intermittently through the foliage overhead. Happy memories of our previous visit to the University Observatory flooded my mind. Soon, the memories were replaced by a sense of anticipation as I saw the tall, white, cylindrical building capped with the gleaming metallic dome looming large in front of us. I was thrilled at the sight of that remarkable place. I am always filled with amazement at the very thought of telescopes. Centuries ago, Galileo had fixed a couple of lenses, mere pieces of glass, to the two ends of a tube and turned it into the most powerful aid in his quest to discover the secrets of the night sky. Then, Newton had replaced one of those lenses by a mirror heralding a new age in astronomy. Then again, Newton's discovery that a triangular piece of glass could split white light into its component colours had revolutionized the study of the stars and galaxies. Since their days, so much progress has taken place in celestial observation, and in theoretical interpretation, that there seems to be no limit to the possible exploration of the Universe.

George and I were surprised to see Mike walking around in circles outside the observatory.

'Hey, Mike,' hailed George. 'What are you up to?'

'*Solvitur ambulando!*' Mike broke into his boyish grin.

'You crazy man, what language is it? And what does that mean?' George asked pretending to be annoyed. I know he just likes everything Mike does.

'It is a Greek proverb, George, meaning *the problem is solved by walking*,' replied Mike.

'For heaven's sake, why didn't you say so in plain English?'

'Because saying in Greek makes every statement seem profound,' laughed Mike. 'Then again, it makes for brevity since the two words of Greek have to be translated into six words of English. Furthermore, we must honour the ancient Greeks who originated the proverb. Also...'

'I have heard enough, Mike. But what is the problem you are trying to solve by ridiculously walking around in circles?'

‘Oh, that? Nothing to it, some little irritating thing about a disintegrating integrated circuit, that is all,’ Mike brushed away his problem which, I am sure, was more serious than that. ‘Welcome back, George and Alfie, you two beautiful people.’

We entered the observatory, as Mike held open the door.

‘Would you like to pay your respects to the Queen of the Firmament first?’ asked Mike.

I knew that was the name given to the large, main telescope of the observatory. My memory went back to a huge old cannon I had seen in India. It had been named *Malik-e-Maidan*, the Master of the Battlefield. A telescope resembles a cannon, doesn’t it? But of course, the night sky is not a battle field, far from it.

‘It will be an honour,’ responded George. I made a slight bow to indicate my own desire to pay the Queen my respects as Mike had put it.

There she was in all her majesty, the great telescope, turned heavenwards presumably surveying the sky through the open hatch of the observatory dome.

Mike held up his forefinger against his lips and whispered, ‘We cannot disturb her. She sleeps during the day and keeps awake all through the night. We shall come back to her when it gets dark. Let us go up to our observers’ lounge where we can relax and talk.’

We followed Mike to the lounge, a cosy compact place. Everything in the observatory had to be compact and efficiently organized because of the limited available space. Arranged around a low circular table were a few comfortable chairs with a small blackboard standing close by. This is where the astronomers met to discuss their results as well as their strategies for further observations. I could see that some writing pads, astronomical photographs, and other material had been placed tidily on the table.

‘Well, Alfie, I understand that you want to fly away from the Milky Way,’ Mike opened our discussion. ‘George tells me that you have learnt all about our home galaxy—Herschel’s preliminary studies of the Milky Way and the nebulae, and Shapley’s measurements using Miss Leavitt’s Cepheid variables. Shapley discovered the shape and the size of our Milky Way as also our own place in it, didn’t he? No wonder he thought that was it, the Milky Way was the entire Universe. Soon enough, the picture of the Universe was going to change.’

‘Yes, lo and behold, Edwin Hubble raises his head, I mean his telescope,’ George interposed.

‘Oh man, you took away my words,’ Mike gave George a big smile. ‘Yes, we are going to talk about one of the greatest observational astronomers of all time, Edwin Powell Hubble. Let me give a thumbnail sketch of his life quickly and then outline his work. I know, Alfie, you will learn all this in more detail when you go home and read George’s marvellous manuscript. Won’t you?’

‘George gave you a copy too?’ I asked. I was not really surprised. After all, Mike was a professional astronomer and was one of the closest colleagues of George.

‘Oh dear, the cat is out of the bag, two bags actually,’ George wrung his hands in mock dismay.

‘I know that you are supposed to find a title for the book, Alfie. Let me know when you do that,’ Mike gave me a wide smile. He seemed to be always happy.

Mike took out a couple of pages on which he had jotted down some notes. I assumed correctly that it was about Hubble. Mike is quite systematic about

everything he does. I am sure it is essential in his work, which requires keeping accurate record of your observations.

‘All right, back to Hubble,’ continued Mike. ‘Like Shapley, he too had quite an unusual career, but in a totally different way. He was born in 1889, four years later than Shapley. His father, John Powell Hubble, worked for an insurance company. As a young man, Hubble was quite well-known as an athlete rather than a scholar. Of course, he did earn good grades in all the subjects he studied except in spelling.’

‘Ah, I am better than Hubble at something at least,’ I commented with satisfaction.

‘We are sure you are better at some other things as well, Alfie,’ assured Mike and continued. ‘Actually, Hubble’s athletic record is quite impressive, you know. He excelled at baseball, football, basketball, and he ran track in both high school and college. In fact Hubble even led the basketball team of the University of Chicago to a major title in 1907. That is not all, he happened to be an amateur boxer too.’

‘Thank heavens, he did not choose to become a professional athlete,’ remarked George. ‘Otherwise, what would have happened to the Universe?’

‘Nothing would have happened to the Universe, George, as you very well know. It would have merrily continued its life,’ laughed Mike. ‘In any event, Hubble did choose a path that would lead him eventually to becoming an astronomer. He studied mathematics and astronomy at the University of Chicago, obtaining a bachelor’s degree in science. That was in 1910.’

‘Then on he must have pursued astronomy as his goal steadfastly,’ I guessed.

‘Hold it, Alfie, that is not what happened,’ Mike shook his head. ‘Hubble won the prestigious Rhodes Scholarship that enabled him to go to Oxford. That scholarship does not allow you to study the stars, you have to study law. So, Hubble went on to earn a master’s degree in law. He included literature and Spanish too in his curriculum. All this was done as a devoted son fulfilling the promise made to his father. Hubble must have known that his father was dying, because his father passed away in 1913, while the young Edwin was still in England. He returned home soon to take care of his family—mother, two sisters, and his younger brother.’

‘That is truly sad, Mike,’ George said.

‘Indeed it is. Hubble must have been a most dutiful son with strong family bonds,’ I added. ‘What happened next?’

‘I shall be brief with the story,’ Mike said. ‘Hubble was not keen on practicing law on his return to the United States. He taught physics, mathematics, as well as Spanish at a high school for about a year. I shouldn’t forget that he also coached the basketball team! Finally it happened. At the age of twenty-five, Hubble decided to become a professional astronomer.’

‘Hooray for astronomy!’ cheered George shaking his fist.

‘Cheers,’ Mike too smiled holding up an imaginary wineglass in celebration. ‘Through the good offices of one of his former professors, Hubble joined the graduate school at the University of Chicago. He worked at the Yerkes Observatory and received his doctorate after submitting his thesis.’

‘Ah, the Yerkes Observatory, how well I remember my visit to that venerable and beautiful institution,’ George reminisced happily. ‘I saw a group photograph featuring Hubble along with the faculty, students, and the staff. There was this

Edwin Frost too in the photograph, who served as the director of Yerkes, in spite of his blindness. Also, Chandrasekhar worked at the observatory for a number of years. Great place, Yerkes!’

‘So, with his doctoral degree in hand, there must have been nothing to stop Hubble from reaching his cherished goal of studying the stars fulltime,’ I concluded.

‘Not so fast, Alfie,’ Mike held up his hand. ‘In the year 1917, the United States found itself in war with Germany, didn’t it? Hubble submitted his PhD dissertation in a hurry and joined the army. He was sent overseas holding the rank of Major. When the war ended, he went back to the study of astronomy at Cambridge before returning home for good.’

‘What a tortuous journey!’ I exclaimed. It was a most unusual life indeed.

‘The year 1919 dawned,’ Mike announced dramatically. ‘The year in which the magnificent career of Edwin Hubble as an astronomer finally began. George Ellery Hale, the founder-director of the Mount Wilson Observatory in California offered him a position on the staff of the observatory. Hubble carried out his great work there for the rest of his life. As he did during the First World War, Hubble again served the army at the Aberdeen Proving Ground during the turbulent years of the Second World War. In recognition of his contribution to research in ballistics, he was honoured with the award of the Legion of Merit. In 1949, the giant two hundred-inch Hale Telescope of Mount Palomar became operative. Edwin Hubble was the first astronomer to use it, taking the very first photographic exposure. He continued to work at both Mount Wilson and Mount Palomar. But his days were drawing to a close. In July of the same year, he suffered a heart attack while vacationing in Colorado. His wife, Grace Hubble, tended to him with great care for the next four years. In 1953, Hubble passed away due to a blood clot in his brain. No funeral was held for him, and his wife Grace never revealed his burial site.’

We sat in silence, immersed in our own thoughts about Hubble. I looked out of the window. It was dark now, myriad glittering stars sprinkled all over the night sky. Edwin Hubble did not need a monument. Instead of a lone sentinel standing at his burial spot, there were billions of stars scattered all over the cosmos shining in his memory.

At last, Mike broke the silence.

‘On the night of October 4, 1923, the measure of our Universe changed totally, irreversibly,’ announced Mike. ‘On that night Edwin Hubble turned the giant Mount Wilson telescope towards the nebula in the constellation Andromeda.’

Mike paused savouring the suspense he was creating with his silence. Like George, he has a flair for the dramatic. And every good actor knows the power of a pause separating spoken words.

‘Ah, Princess Andromeda, the damsel in distress chained to a rock by her own parents, Queen Cassiopeia and King Cepheus of Ethiopia, as sacrifice to appease the sea-monster Cetus that was devastating their coastal regions, which Prince Perseus slew in time and rescued the Princess whom he married forthwith thereby bestowing a happy ending on the story. Whew!’ Mike drew his breath heavily after the long sentence he had spoken at one stretch. ‘All the participants in the story have been immortalized as constellations.’

Mike opened a book lying on the table and showed me the constellations he had mentioned. ‘You may borrow this book and a couple of others about Hubble, his

work, and his collaborators, Alfie. It will make for wonderful reading, complementing George's manuscript.'

'Now, back to Hubble and the nebula Andromeda,' Mike returned to the great discovery. 'Hubble exposed a photographic plate for half an hour or so, the telescope trained towards the Andromeda nebula getting a smudgy image harbouring a star within it. Comparison with photographs taken earlier revealed that the star was a Cepheid variable. Fortune favours a prepared mind, as the saying goes. As Shapley had done before him, Hubble estimated the distance to the star, hence to the nebula, using the knowledge of the star's absolute luminosity and the inverse-square law. That cosmic measurement owed its success to Miss Henrietta Leavitt. What distance did he measure between us and the nebula?'

'Tell us, tell us,' urged George feigning ignorance.

'I shall tell you, fear not,' Mike said solemnly. 'Hubble's estimate was some 900,000 light years. What did that mean? Shapley had shown that our own Milky Way stretched over a distance of 100,000 light years, hadn't he? So then, Andromeda lay far beyond the Milky Way. That meant that our Milky Way did not constitute the entire Universe. Hubble had once for all demonstrated that the Universe was vaster than ever imagined before.'

I could feel how thrilling such a revelation must have been. It was indeed a unique turning point in the history of cosmology.

'Well, Hubble continued his observations of the nebula in Andromeda as well as the one in the nearby constellation Triangulum, detecting more Cepheid variables in them. There was no turning back from his conclusion regarding the measure of the Universe.'

'Mike, why do you keep on using the term *nebula*? We know they are *galaxies* as the common terminology goes,' pointed out George.

'Aha, that is because in his entire lifetime Hubble refused to use the term *galaxy*, and referred to those luminous patches in the sky as *nebulae* and nothing but *nebulae*. I am following in his footsteps with the hope that someday I shall make some discovery of my own similar to his. By the way, the modern value for the distance to the Andromeda nebula is about two and a half million light years.'

'What did Hubble do with his revelation? Did he send it immediately to some scientific journal for publication?' That would have been the normal course of action for any scientific discovery I thought.

'No sir, he sent it off to New York Times on November 23, 1924,' Mike answered.

'Ah, that is the current trend too, to get your name in the press,' added George.

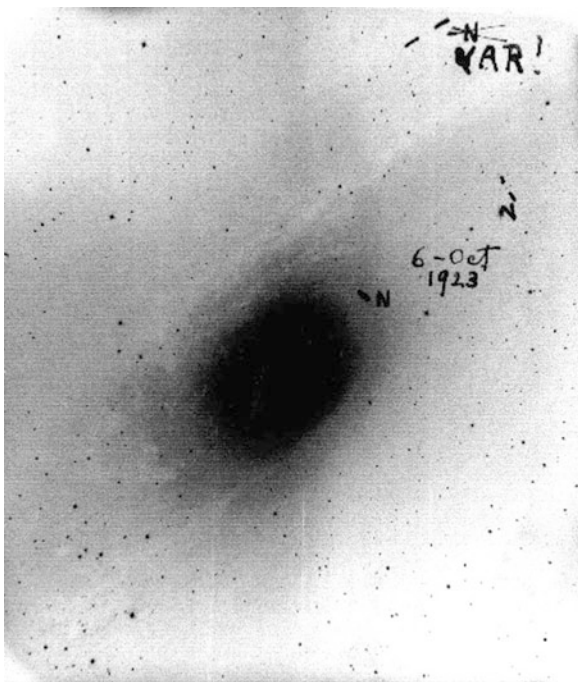
'To be fair, Hubble cabled his results in the form of a paper to his astronomer colleague Henry Norris Russell on December 31, 1924. Next day, the first day of the New Year, Russell read the paper to his fellow astronomers gathered together during the joint meeting of the American Astronomical Society and the American Association for the Advancement of Science in Washington, D. C. On that day, the astronomers came to know that the extent of the Universe had radically changed thanks to the explorations of one man. A new era in cosmology had arrived.'

Mike sat back in his chair for a while. With his account of Hubble's monumental discovery, the atmosphere in the Observatory seemed to have changed, charged with a new spirit. Perhaps it was just my imagination.

From the material stacked on the table in front of us, Mike took out an old photographic plate and opened one of the books.

‘Here is a photographic plate that was used in Hubble’s time taken out of our archival collection,’ Mike held up the plate and then pointed at the picture appearing in the book. ‘And look at the picture in this book. It is a reproduction of the photograph of Andromeda Hubble took.’

The photographic plate looked so primitive, I wondered how those astronomers of the past could extract so much groundbreaking information from it. Then there was Hubble’s photograph of nebula Andromeda, no more than a faint oblong smudge that looked more like an enlarged version of a careless thumbprint. At the top right-hand corner of the smudge, two little lines had been drawn enclosing a dot presumably to indicating the variable star. Beneath it was written, in Hubble’s own hand, the date of his marking the photograph, *6—Oct 1923*, a small arrow pointing towards the variable star. I looked at it with awe, the date and the dot that had transformed the face of the Universe. It reminded me of the meagre crosses drawn by Galileo showing the positions of the satellites of Jupiter that had centuries ago changed the face of the solar system.



Silently, Mike placed next to the open book a glossy print showing the galaxy in Andromeda that had been taken through a modern telescope. It was spectacular. An ethereal glow emanated from its bright central region like the radiance of the Princess from whom it had inherited its name. Wisps of spiral arms curled around

it as if protecting that comely maiden. Here was our neighbour that had paved the way to the realization of the awesome expanse of our Universe!

Having waited for me to take a good look at the Andromeda galaxy, Mike spread out more prints of several other galaxies. With their brilliant colours and detailed structures, they looked gorgeous.

'Look at them, aren't they a feast for the eyes?' Mike exulted. 'They have names based on the constellations they are located in, like Hercules, Ursa Minor, and so on. Or they could be descriptive of their appearance—Whirlpool, Cartwheel, Cigar, Sombrero, Tadpole etc. One of them has the nickname—Black Eye or Evil Eye, how do you like that? Then again, some of them have been named after their discoverers like Hoag's Object, Mayall's Object, and so forth. Alfie, notice they have different shapes too—*spirals*, *barred spirals*, *elliptical*, and the *irregular ones* like the Small Magellanic Cloud, our nearest neighbour in which Miss Leavitt had found her Cepheid variables. In fact, those names represent the classification proposed by Hubble himself after observing countless galaxies and determining distances to many of them.'

Hubble seemed to have made a thorough job with his nebulae, it was truly amazing. George sat silent and smiling, enjoying my initiation to this immense wonderland. Mike too remained silent for a while. He must have been reliving his own excitement of the past when he had come upon, for the first time, all the work he was describing.

'So much for the expanse of our Universe,' resumed Mike. 'What comes after expanse? It is expansion, the most unusual aspect of the cosmos! Let us go back to the early twentieth century, a decade before Hubble looked at Andromeda. At a meeting of the American Astronomical Association, which Hubble happened to attend as a doctoral student, the astronomer Vesto Slipher presented his findings suggesting that several spiral nebulae were speeding away from us at enormous speeds of almost up to 1,000 kilometres per second. Compare this with the speed of the Earth going around the Sun, which is merely about 30 kilometres per second. This was incredible and in fact few believed Slipher's observations. And none could make any sense of it. We do not know what sort of influence Slipher's findings had on Hubble. In any event, it would take another fifteen years before Hubble started his systematic study of the flight of the galaxies.'

'Well, often what you have seen or heard sometime or the other can stick in your subconscious and influence you later on,' commented George. 'It happens to all of us and could have happened to Hubble too. Sorry for interrupting you, Mike, please go on.'

'How did Slipher measure the speed with which the nebulae were zooming away from our Milky Way?' Mike posed the question and answered it. 'It was by using the well-known Doppler Effect. I am sure you know what that is, Alfie.'

'Yes, I do,' I nodded. 'We experience it all the time when a fast-moving automobile honks its horn. The pitch goes up as it comes towards us and goes down as it speeds away. I have read the amusing account of how Doppler Effect was verified by having musicians blow their trumpets while travelling on a train.'

'Right you are,' said Mike. 'The ratio of the change in the received frequency, or the pitch, and the emitted frequency of the sound wave is proportional to the ratio of

the speed of the source and the speed of sound. If the speed of the source is comparable to the speed of sound, then the change in the frequency would be detectable. And by measuring that change in frequency, one can determine the speed of the sound emitter. I hope I have made myself clear.'

'Perfectly clear, Mike,' George answered for both of us.

'Now, this is true for light or electromagnetic waves also,' continued Mike. 'In place of pitch we have colour now. The spectrum of a source is shifted towards red if it is moving away from us and towards blue if it is coming towards us. Naturally these are called *redshift* and *blueshift* respectively. Then again, as in the case of sound, the shifts would be appreciable if the speed of the source is comparable to that of light.'

'I have heard an anecdote involving the renowned physicist Albert Michelson of the Michelson-Morley Experiment fame,' I related. 'It seems he was hauled before a magistrate by a policeman for jumping a traffic signal that had turned red. Michelson pleaded innocent, claiming that the light had appeared green due to Doppler Effect as he was driving towards it. The magistrate, who knew enough physics, ruled that Michelson was indeed innocent of the charge of jumping the signal, but fined him anyway for speeding!'

'I must remember to tell this story to my class, even if it has been made up,' George clapped his hands laughing. And, of course, Mike was laughing too.

'Well coming back to cosmology, we know how Slipher had measured the velocities of a few spiral nebulae, by the redshifts of their spectra,' Mike continued. 'And a couple of other astronomers reported such recession velocities for other galaxies too. But the exploration of the enormous speeds of galaxies speeding away from us in relation to their distances was to be pursued systematically by Hubble.'

After a studied pause, Mike announced, 'At this point we introduce Milton L. Humason!'

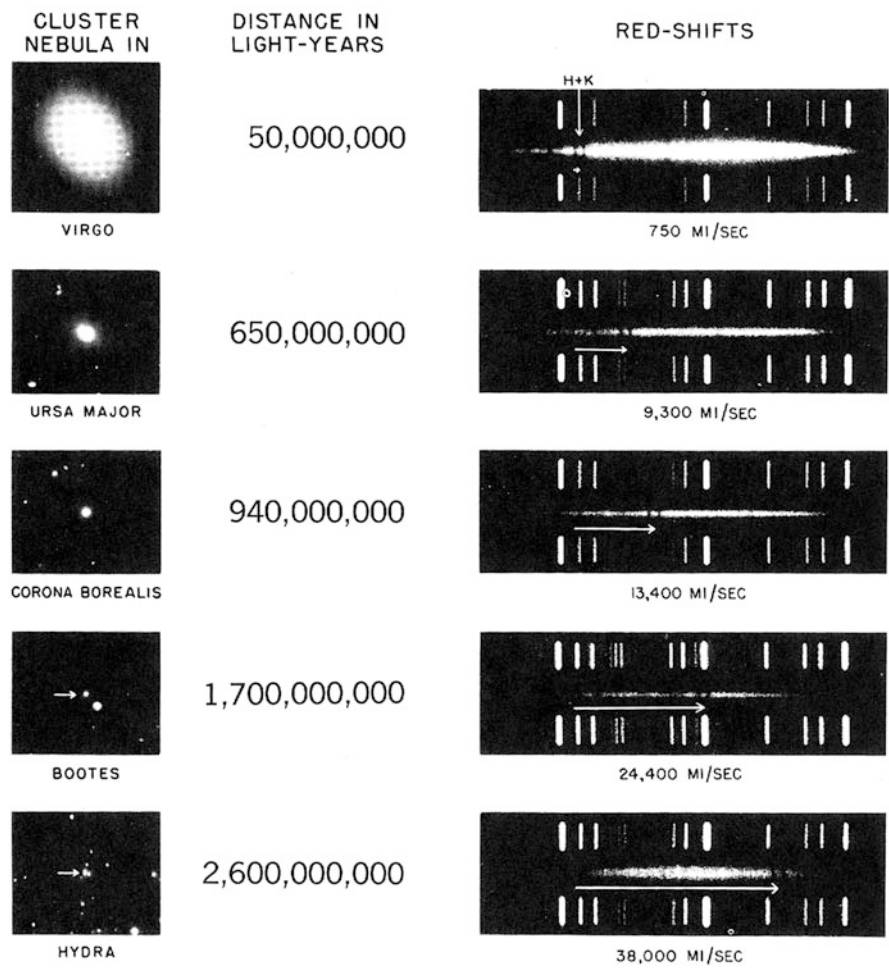
George's face lit up in anticipation of what Mike was going to say.

'Using the Mount Wilson telescope, the finest one available at the time, Hubble was to collaborate with Humason on his redshift studies of the galaxies,' Mike went on. 'Before we go into that, let us ask the question: What was the path that Humason had taken before attaining the coveted position of being Hubble's collaborator? Well, it was the winding path that led up to the top of the mountain where the observatory was being built, as Humason led his pack of mules carrying construction material! Yes sir, Humason happened to be a high-school dropout, who made a living as a mule driver. He joined the Mount Wilson observatory as a janitor, learnt the trade on the sly with the help of some professional astronomers, and came to be known as a magician of measurements. He was picked by Hubble to determine the redshifts of galaxies. Their observations together led to one of the most astounding discoveries of all time, namely the expanding Universe.'

'Alfie, we learnt about Copernicus the Canon, Kepler who wanted to be a theologian, Herschel the musician, Shapley who had hoped to become a journalist, and now we have Humason the mule driver,' George pointed out. 'The ultimate accidental astronomer indeed!'

‘Ah, the accidental astronomer, I like the term,’ smiled Mike. ‘You must read all about Humason in detail, Alfie. Although he had not been trained in astronomy and had no scent of mathematics, Humason could make the most sensitive determination of redshifts of a number of galaxies, while Hubble measured their distances. From these findings emerged the *Hubble Law*, which showed that the velocities of the galaxies were linearly proportional to their distances from our Milky Way.’

Mike opened one of the books lying on the table and showed me a picture that showed the redshifts of a few galaxies, their velocities, and their distances.



‘Take a look, Alfie,’ Mike pointed at the photograph. ‘You can see the sharp spectral lines of calcium as observed in the laboratory. Compare them with the galactic spectrum of the same element. See how fuzzy the latter is. Still, you can discern the redshift that increases with the distance. It is this kind of photographs

that led to the Hubble Law. And that Law heralded a whole new chapter in cosmology.'

I remembered what Winston Churchill had said in the totally different context of the Second World War: *This is not the end. It is not even the beginning of the end. But, it is, perhaps, the end of the beginning.* I was sure what I had heard was, perhaps, not even the end of the beginning, but just the beginning of the beginning. There was going to be a lot more to the cosmic drama.

'The cosmic journey has just begun. Alfie,' Mike echoed my thought. 'I guess you will read more about the Universe from books. And George would be telling you all about the theoretical side of cosmology and the latest developments in the field. How exciting!'

Mike looked out of the window and so did I. It was dark outside and the stars were sparkling in all their glory. I remembered the lines from Shakespeare:

*The skies are painted with unnumber'd sparks
They are all afire and everyone doth shine.*

'Ah, the time has come to wake up the Queen. Let us go.' Mike rose from his chair and we followed him.

We were back in the telescope chamber. I was again filled with awe, even though this was the second time I was looking at the telescope within a short period of time.

'Yes Alfie, I know that feeling,' said Mike quietly, reading my mind perhaps through the expression on my face. 'I see the magnificent instrument many times every day. But it never fails to inspire me with mysterious wonder. Well, the Queen has already turned her attention to one of the billions of galaxies in the sky. Take a look.'

I peered through the eyepiece of the telescope. After a little bit of adjustment I saw it—a spiral galaxy in all its vivid beauty. The central region glowed bright sending out the curling spiral arms, decked with countless brilliant specks and flaming dust clouds, seemingly reaching out to catch the stray stars that actually belonged to our own Milky Way. No doubt, the many photographs I had seen of a variety of galaxies were fantastic, but paled in comparison to the real one I was looking at now.

Reluctantly I tore myself away from the telescope. It was George's turn to take a look at the galaxy.

'I can't believe it, Mike,' said George with fascination. 'How far are those celestial marvels? Millions and billions of light years? And light has travelled all that distance, for all that time to reach us. What we are seeing right now is how those galaxies were so long ago. Incredible, incredible!'

Mike too glanced through the telescope before escorting us out of the building into the night. Free from the light pollution of the sprawling city quite a distance from the observatory, we could see the night sky filled with immeasurably more stars than we normally did. I knew Mike had his work waiting for him. We had to take leave of him.

‘Well, Mike, that was fabulous. Thanks from both of us,’ said George. ‘Are you going back to walking around to solve the problem as dictated by your Greek proverb?’

‘No, George, while we were talking, my brain went on auto-drive. And the problem got solved,’ laughed Mike. ‘Now, my wild nightlife begins.’

‘Take care, Mike, and do visit us soon. Let us live it up,’ said George holding up his thumb.

‘That goes for me too, Mike,’ I added. ‘Come down from your mountain of meditation.’

‘Thus Spake Zarathustra,’ Mike smiled. ‘Will do.’

He waved goodbye and strode back to the observatory.

We drove down the hill. After the inspiring, miniature cosmic journey, what was there to say?

I got off near George’s physics building. I loved to walk home.

‘Our next meeting at my office, Alfie,’ said George. ‘As Mike said, we have to discuss the theoretical basis of cosmology and a bit of modern stuff. All my best to you.’

Every time I look up at the sky, it appears to be new. Among the resplendent stars above, I could see in my imagination diffuse nebulae sprinkled all over. If I focused on them long enough, they resolved into their individual structures from elliptic to spiral. Then they slowly faded out. I had reached home.

Chapter 13

The Universe: Expanse and Expansion

I wish I could describe my innermost thoughts and feelings as I contemplated all that I had heard and all that I had seen at the University Observatory. Is there any limit to the incredible riches the night sky can yield? I remembered and repeated quietly what Edmund Burke, statesman, author, orator, political theorist and philosopher all rolled into one, had written: *Darkness is more productive of sublime ideas than light*. Nothing could be truer than that statement in the case of astronomy: darkness without which the stars had no visible existence and the stars without which some of the most sublime ideas could never have been inspired.

I am lucky to be a fast and voracious reader. With the greatest speed I could muster, but without making any compromise on comprehension, I went over the books in front of me—George’s manuscript as well as those Mike had leant me. By the time I finished, *night’s candles were about to be burnt out, and jocund day was preparing to stand tiptoe on the misty mountain tops*, to paraphrase Romeo.

The soothing warmth of my bathwater penetrated every part of my body. The magical bubble-bath mixture had created an enchanting surrounding. The water had shed its natural colour and appeared dark like the night sky. There were diffuse luminous patches interspersed among the brilliant little star-like spots that shone against the dark background. On closer look, I could see that they were not just patches, but collections of countless miniscule, glittering specks. In short, I was not just relaxing in my bathwater, but was immersed in my own miniature cosmos. It was me and my Universe! Surrounding me was absolute silence for a while.

‘Forgive me for interrupting your reverie, boss,’ whispered the bathtub as if waking me up gently. ‘I know, silence is golden. But words are diamonds, what boss? Did you say that *darkness is more productive of sublime ideas than light*? I hope I quoted your quotation correctly. But then, the Master could come up with all his great ideas, most of them sublime too, whether it was dark or light. Hmm, maybe those thoughts came to him in the night after all—while reading, writing, eating, drinking, sleeping, dreaming—all in the night time, when it was dark. Who knows? Maybe he happened to announce them in daylight. Maybe, maybe!’

‘Be that as it may—ah, I like that expression—be that as it may, what about you?’ the bathtub continued after a momentary pause. ‘I know you had a fantastic evening at the observatory, learning about great men, their great discoveries, looking at the great starry night directly, having a great time in short. You know something, boss? I can see through your eyes, hear through your ears, read your thoughts. I used to think I could do this only when you were near enough. But this evening, I realized I could do it even when you were far away in the observatory. My range has increased, just like the modern telescopes. What do you call it, boss—distance learning, telepathy? Matters not, as long as it works. My Universe is expanding too!’

Listening to my bathtub was as soothing as soaking in the bathwater. I did not have to think at all.

‘Aha, I talk too much and you listen too much, is that so?’ teased the bathtub. ‘But what about the thought process? Am I thinking on my own? Am I reflecting your thoughts like a mirror? Or are you thinking through me? Whatever it is, it is nice. All right, boss, let me not stand—how can I, a bathtub, stand? I mean come—between you and your sublime pleasure, cocooned as you are in your own private cosmos. Otherwise, the headlines will read: *Bathtub betrays boss!* All articles left out for the sake of alliteration. Drift away, boss, drift away!’

My mind was becoming numb. Transition to trance transcended terrestrial techniques. . . All articles left out for the sake of alliteration. . . My consciousness was dissolving away. . .

Beauty and the Beast

I was ecstatic to say the least. What a surprise to be in the presence of someone I had already met with immense pleasure. It was the great Greek playwright Aristophanes, standing in front of me with a big smile lighting up his face. And of course, the chorus of frogs were there too grinning widely, some of them winking slyly at me.

‘Welcome back, our honoured guest and dear friend, to grace our celestial theatre,’ greeted Aristophanes bowing formally. The chorus of frogs imitated him and giggled.

‘Ah, last time, we enacted for your pleasure and edification, the story of Orion, the Great Hunter of the Skies, did we not? Now, we proceed without undue delay to present our theatrical performance of the curious chronicle of Princess Andromeda, a one-line gist of which you have already heard.’

As Aristophanes narrated the story of Andromeda, the drama was played out by the starry characters in the background as had happened with the Orion tale.

‘Once upon a time, ages ago, there lived in Ethiopia King Cepheus and his Queen Cassiopeia, she of immense beauty, immeasurable by the common standards of man or beast. The King and Queen begot, as it normally happens, a daughter, Andromeda, whose beauty rivalled that of her mother. Beauty, alas, often breeds vanity and vanity acquires a loquacious tongue. Cassiopeia, in her foolish abandon, boasted that her and her daughter’s beauty surpassed that of the Nereids, the

sea-nymphs. Ah, what, may I ask, did the Nereids do? Insulted as they were, they complained bitterly to Poseidon, god of the seas. Poseidon, infuriated by the impropriety of a mere mortal, namely Queen Cassiopeia, decided to inflict dire punishment on her. Woe betide the proud, what terrible retribution awaited the vain woman? I shudder to think.'

Chorus

Brekekekex ko-ax ko-ax

Brekekekex ko-ax ko-ax

Cassiopeia, O, Cornucopia

Of lovely features that lure all creatures

Big and small, one and all

Dimples rubbed and pimples scrubbed

Washed in beer to make skin clear

Queenie, O, Queenie, why be a meanie?

Why blow your own trumpet?

Annoying the sea-nymphet?

Why slice her ego like a sickle?

And land yourself in a pickle?

Brekekekex ko ax ko-ax

Brekekekex ko-ax ko-ax

'Poseidon seething with rage summoned the terrible sea-monster Cetus and ordered him to devastate Cassiopeia's kingdom. Cetus, assuming the form of a monstrous whale, swam up and down the coast, leaving behind in his wake death and destruction. Alas, alack, what could King Cepheus do now but wring his hands in helpless despair? Well, in addition to wringing hands, he consulted an oracle who claimed, just claimed mind you, to be able to communicate with the gods themselves, extract a miniscule portion of their infinite wisdom, and convey it to the mortals. Offer your daughter as a sacrifice, the oracle advised the King, and the slaughter will cease. Torn upon the horns—ask me not the horns of what animal—of the dilemma between his love for his daughter and the welfare of the people, Cepheus magnanimously chose the latter and had Andromeda chained to the rocks in the sea, the innocent young lady mercilessly forsaken and waiting for the inevitable death in the form of Cetus to approach her.'

Chorus

Brekekekex ko-ax ko-ax

Brekekekex ko-ax ko-ax

Andy girl, O, Andy girl,

To your parents a priceless pearl

We are awfully pained to see you chained

Waves leaping, people weeping

We cannot bear it, nor repair it

Ye gods, swims in Cetus, vicious since a foetus

A fearsome whale bellowing like a gale

*See him spread destruction and dread
 O, maiden fair, dire despair!
 Brekekekex ko-ax ko-ax
 Brekekekex ko-ax ko-ax*

‘I tremble to proceed with my narration as I see in my mind’s eye the monster closing in on the doomed damsel,’ continued Aristophanes. ‘When Cetus saw the comely creature chained to the rocks, he forgot the people and the cattle he was slaughtering, and swam towards his precious prize of a free meal.’

‘Oh, what happens now?’ Aristophanes pressed the back of his hand to his forehead in despair. ‘Ye gods, would you not cast your eyes down on this calamity, on the impending wanton destruction of all the loveliness in the world, on the fearful fate of the miserable maiden? You would? I heave a sigh of relief as strong as the west wind. Lo and behold, the distant vision of Prince Perseus.’ Aristophanes paused for effect.

‘Take heart, my honoured guest, here arrives hope in the form of our Prince Valiant,’ assured Aristophanes holding out his open palms towards the single honoured guest of his, namely me. ‘What has been Perseus up to? Well, let me tell you his story so far briefly. Perseus was now returning from the expedition he had undertaken to eliminate Medusa. I am sorry, my distinguished guest, everyone seems to be bent on eliminating everyone else in our tale. But then, who was this Medusa? She was once a beauty with a face that shone like the full Moon, framed by the lustrous streaks of black clouds, namely her dark flowing hair. Nice description, eh? Again, alas, in her overweening pride, she boasted that her beauty was comparable, nay even greater, than that of Athena the Virgin Goddess of Arts, Crafts, and, oh no, of War. The last bit is incongruous with the former ones, would you not agree? Well, be that as it may, Athena, in her untrammelled indignation, transformed Medusa into the most terrible monster. Her face changed from the Moon into a bunch of its craters. Her hair deteriorated into a tangle of hissing serpents. Well, maybe she had forgotten to shampoo her hair, who knows? The end result was that so abominable was her face that anyone who was unfortunate enough to have a glimpse of it would be turned instantaneously into stone.’

The storyline seemed to be getting scarier and scarier, gorier and gorier. In spite of that, or maybe because of that, it was absolutely fascinating to listen and watch.

‘Now, our Perseus was persuaded to go and put an end to Medusa’s monstrous mayhem. To aid him in this noble endeavour, Hermes, herald and messenger to the gods, lent him his winged shoes and Athena offered him her brilliantly burnished shield. Flying merrily, Perseus sought Medusa and found her fast asleep having left no stone unturned, I mean having turned many into stones. Gazing at Medusa’s reflection in Athena’s shield, not directly at her, and edging backwards gingerly, Perseus gave a mighty whack and decapitated Medusa, stuffed the still bleeding head, hissing serpents and all, into a sack, and proceeded to fly back to Athena in order to make a pleasing present of the body-less top of the slain subject. That is when he saw what was happening down below, the horrible monster Cetus approaching the hapless Andromeda.’

Chorus

Brekekekex ko-ax ko-ax
Brekekekex ko-ax ko-ax
There is hope, there is hope
Like a mountaineer's rope
Yes, hopes are raised, Heaven be praised
Comes Perseus the Brave the situation to save
Slayer of Medusa the hideous sedusah
None would dare at her face to stare
To be turned into stone without a moan
Brekekekex ko-ax ko-ax
Brekekekex ko-ax ko-ax

‘Have you been with me all along our adventure, your eminence?’ asked Aristophanes.

I nodded vigorously and leaned forward to catch every word of the narration.

‘To return to our original story then, Perseus was distressed beyond measure, enraged beyond words to see the gorgeous girl straining against the chains, her diaphanous dress soaking wet in the seething sea, and worst of all, the inhuman whale—whales are by definition inhuman, are they not?—the menacing monstrosity swimming swiftly towards her, smacking its lips in anticipation of a sumptuous meal. Oh, maiden of incomparable loveliness, why are you in this woeful state, asked our inquisitive Prince. Well, well, well, curiosity in the face of calamity! Be that as it may, to repeat the oft-repeated phrase, our informative Princess recounted her tale of woe in a few chosen words mindful of the fast approaching doom in the form of Cetus. Ha, says our courageous youth, ha again, says he and lunges towards the advancing abomination and plunges his sword through a soft spot between the impregnable scales covering its body. Cetus, roaring in agony thrashes for a while, sinks to the bottom of the sea dead as a doornail, if not a Dodo.’

Chorus

Brekekekex ko-ax ko-ax
Brekekekex ko-ax ko-ax
Hie, Princey, hie; fly high in the sky
Hear the maiden cry? By your hand the beast must die
Ah, the Prince dives down, brows knit in a frown
Fight, oh, fight with all your might
Let the sword flash while the sharp fangs gnash
Bash up the monster's brain
Slash up his body in twain
At last the horror lies slain
Brekekekex ko-ax ko-ax
Brekekekex ko-ax ko-ax

‘Seeing with their own eyes the Prince kill Cetus and realizing that all was safe at last, the throng that had gathered on the shore to watch this free show cheered and

jumped with joy. The tearful parents freed their daughter from her chains after taking time to hug and kiss her demonstrating their unbounded regal love for her. What about our Prince the saviour? As all such stories end, he and Andromeda were joined in holy matrimony and lived happily forever. Not really forever, but they were given honoured places in the heavenly vault as constellations, to remain so as long as the stars in those celestial patterns endured.’

Chorus

Brekekekex ko-ax ko-ax

Brekekekex ko-ax ko-ax

Enter the Queen and enter the King

While all the town bells loudly ring

Kiss the Princess with immense joy

And hug to their bosoms the heroic boy

See the young ones holding hands

Watch them exchange the wedding bands

All, all, all—man, woman, and beast

Happily partake the wedding feast

In universal joy the story ends

As the curtain slowly descends

Brekekekex ko-ax ko-ax

Brekekekex ko-ax ko-ax

The frogs of the chorus were quite excited and wagged their palms up and down gesturing to me to join them in the refrain. I caught myself repeating under my breath *Bre ke kex ko-ax ko-ax* and looked self-consciously at Aristophanes. He seemed to be quite happy and beamed at me.

‘That brings us to the conclusion of the story of Andromeda who shines as a star-studded constellation in the night-sky,’ announced Aristophanes. I applauded heartily as Aristophanes and his chorus took a deep bow and melted away.

Beyond the Milky Way

The transition from one scene to another was sudden, as it often happened, leaving me breathless. When I regained my bearings, I realized that I was back at the Mount Wilson Observatory where Shapley had explained to me how he had mapped the Milky Way. My attention was drawn to the commanding presence of a man at the window—tall, handsome, and strong with powerful broad shoulders. He was studying a glass plate, covered with what looked like darkish smudges, with absolute, serene concentration. He seemed to be striking a heroic pose, even though there was no one to watch him. Let alone admire him.

From the photographs I had seen I could immediately recognize him. It was none other than Edwin Hubble himself! It seems that some people thought he looked like

a Greek god. At least his wife Grace Hubble thought so, especially when she first met him.

Hubble looked up and took out the pipe he was smoking. He gave me a warm, welcoming smile.

‘Ah, there you are, I have been waiting for you, you know’ said the famous astronomer. ‘I know you have learnt a lot about the Milky Way from my colleague Harlow Shapley. Shapley, shapely, out-of-shapely, especially in his ideas!’ he laughed. ‘Hush, not a word, old chap, that was strictly for your ears only, I would never say such things in public. Dear me, as Harlow said to you when you met him, I haven’t introduced myself to you, I am so sorry.’

‘My name is Hubble, Edwin Powell Hubble, pleased to meet you I am sure,’ he made a slight bow a bit too dramatically and put away carefully the glass plate with smudges on it. ‘That is a photographic plate on which we capture the image we see through the telescope, you know. We shall take a look at it later on, precious it is, quite. Now where were we? Yes, I told you my name, didn’t I, old fellah?’

Hubble sounded strange when he kept addressing me as *old chap* and *old fellah*. After all, I happened to be younger than he by more than a century.

‘Ah, that is a manner of speaking I picked up at Oxford, old sport,’ chuckled Hubble. ‘I use it once in a while. We shall talk about Oxford when I relate briefly how I came to be an astronomer. Of course, I am sure that you know much more of my life and work than I know of yours. But one derives great pleasure by talking about oneself, don’t you agree?’

Hubble told me the story of his life, which I found most engrossing. It was no twice-told-tale vexing the dull ear of a drowsy man, contrary to what Shakespeare had written. As it happened in the case of Shapley, scenes from Hubble’s past appeared and faded out from time to time, while his voice could be heard in the background narrating the events.

‘Let me begin with my first encounter with the stars,’ began Hubble. ‘It was in the small village of Marshfield in the state of Missouri, USA, which was my place of birth. Aha, that is the same state in which our friend Harlow Shapley had been born four years earlier some seventy miles to the west of my own place of birth. No streetlights, no pollution, clear dark skies always, mind you. So, one could see thousands of stars above you glittering away in all their grandeur. How could you not watch them and wonder at them? Ah, but it was a great pleasure to view the stars and the planets through a telescope, wasn’t it? My grandfather, Martin Jones Hubble—a hefty guy he was—had built a telescope with his own beefy hands. On my eighth birthday, I was supposed to have a party. Instead, I asked my parents for permission to stay up all night and watch the stars. My granddad and I had a whopping good time indeed. When I was a little older, we did it again and talked a lot about astronomy. We both had a great fascination for the planet Mars, you know.’

Hubble paused remembering those exciting moments of his childhood days and continued. ‘I joined Wheaton high school in this big city of Chicago. I grew up fast all right and stood six feet and two inches tall—but one full inch shorter than my father, what a pity. Apart from my studies, which included Latin and German, I was

fond of sports too. Ah, let me not boast, but in fact I happened to excel in so many of them—pole vault, shot put, standing high jump, running high jump, discus and hammer throw—you name it, I did it. All my life I have loved athletics.’

Oh, yes, I had learnt that his name had appeared in news papers praising him for setting new state records.

‘Then on to the great University of Chicago,’ continued Hubble. ‘I wanted to become an astronomer, you know. But my father, John Powell Hubble, said he wouldn’t let me go through school if I was going to become *a thing so outlandish*, as he put it. So, I studied law as per his wish. But I learnt a lot of physics and mathematics also that would help me with astronomy later on. Well, my immediate ambition was to get the highly coveted Rhodes scholarship.’

Rhodes scholarship, it is considered to be quite prestigious even to this day.

‘Rhodes scholarship is hard to get,’ continued Hubble. ‘I had to prepare for it a lot. I knew I would get it and get it I did. I went to Oxford, as I told you earlier, to the great University. I was expected to study law at Oxford as per the terms of the Rhodes. I joined Queen’s College, one of the twenty colleges of the University which was considered to be the most beautiful of them all. And I had a ripping good time there, really capital, old chap.’

I could not help but notice that Hubble’s accent and his manner of speaking had radically changed all of a sudden.

‘Aha, you noticed how my speech changed when I entered Oxford,’ smiled Hubble. ‘Be a Roman when you are in Rome they say. Oxford, Rome, it is all the same. So, I cultivated the accent and jargon characteristic of my new University. After all, I had to jaw the hours away—I mean talk the hours away—with the old chaps I came to know, right?’

I was sure that many people, especially Hubble’s American colleagues, must have thought his accent was quite artificial.

‘It was at that time that I took up my father’s habit of smoking and built up a nice collection of pipes. Watch this,’ said Hubble and lighted his pipe that had gone out. He then flipped the match into the air in such a way that it described a circle and he caught it, still burning as it came down, without burning his fingers. ‘Jolly little trick, eh?’ laughed Hubble. ‘Never failed to impress my friends whenever I did that after scoring a point in a debate.’

Hubble gazed far into space and spoke to himself what appeared to be words he had written long before. ‘*Ah, I am still dreaming away and awaiting perhaps a rude awaking, wonderful realization, or more dreams upon dreams until the end of all dreaming. The nearest approach to happiness I know is in dreaming, having nought to do with external things.*’ After a pause he added, ‘*Labour which is labour and nothing else becomes an aversion. Work, to be pleasant, must be towards some great end; an end so great that dream of it, anticipation of it overcomes all aversion to labour. So until one has an end which he identifies with his whole life, work is hardly satisfactory.*’

I knew and knew it well that Hubble’s dreams had come true beyond his expectations.

Hubble who had become silent for a brief moment continued with his recollections. 'No, my heart was not in the study of law. Some of it was awfully dry. But it had to be done and I decided to face it like a man. However, I did get around to be in touch with astronomy, my great love, through a friendly professor who was the director of the University Observatory. Of course, I took part in all sorts of athletic activities which brought me many prizes. And I was the captain of the baseball team, which was a novelty to the cricket-loving people of Oxford. I read books voraciously, some three hundred of them in my first year, five books per week that is. Impressive, eh? To jump ahead—I love to jump as you know—I completed my studies and got my degree in jurisprudence, the science or philosophy of law. Never mind all that, old chum. I must add that my one or two excursions into astronomy astonished some good science men of the University. I as a law man was supposed to know nothing about the stars up there. In any case, it was time to return home.'

A serious expression came upon Hubble's countenance. 'Many people think that I practiced law in the state of Kentucky after passing the required examination,' he said as though he was making a confession. 'Let me admit it, it is not true. To be honest with you, I might have created that impression deliberately. What I did was to translate some legal documents from Spanish, a language I knew well. That is all. Later on, I taught at a high school—Spanish, physics, and mathematics. Most of all, I was a successful basketball coach you know, quite. But, of course, my heart was set on astronomy and an astronomer I was determined to become.'

Hubble paused. I could sense that a new chapter was beginning in his life.

'Where should I go to pursue my dream? That was the question,' Hubble went on with his narration. 'The obvious choice was my old University of Chicago. So, I wrote to my professor there. I was fortunate to get attached to Yerkes Observatory of the University. I could now directly study the skies and get a good degree, Doctor of Philosophy or PhD as you know. I was most interested in those mysterious patches of light scattered all over the night sky, the *nebulae*. Did all of them belong to our own Milky Way as Shapley believed? Or did at least some of them lay outside our own galaxy as conjectured by those who talked about the Island Universes? Well, the answer to that question was to come sometime in the future. But for now, I studied the nebulae carefully and wrote up my findings under the title, *Photographic Investigations of Faint Nebulae*. I had to submit it to the University in order to get my degree, you see. I wanted to get out of astronomy for a while in a hurry. You know why? There was this war going on in Europe, came to be known as the First World War, didn't it? Along with the English and French people, our country was fighting the Germans. I wanted to fight too.'

I had read all about World War I. Every war brought with it its ravages, the death toll, and the untold misery as its aftermath. The two World Wars were the extreme examples.

'At first, I went for training in preparation for fighting in the war,' continued Hubble. 'It was a tough job all right. My knowledge of astronomy came in handy. You know how? I was able to instruct others in marching in the dark guided by the stars! Eventually, I was made a Major. We sailed to Europe finally to fight in France. The hardest thing was to see wounded men fall, and go forward without

stopping to help them. In any event, the war was ending, as the Germans were about to be defeated. I did manage to sustain some injuries. I still carry the scars. But to tell you the truth, I barely got under fire and altogether was disappointed in the matter of the war. When it was all over, I stayed on and visited Cambridge University where once Isaac Newton, the greatest of all scientists, had worked. At last I was ready to return home and join this wonderful place, the Mount Wilson Observatory, where we happen to be right now.'

What a remarkable life, I thought once again, as I had done when I had heard it for the first time. I knew that Hubble's real achievements were yet to come. Hubble watched me, striking his heroic pose. Now he had found someone to admire him, hadn't he? He must have been quite accustomed to the ardent adulation of others!

'Let me show you the telescope through which I have been observing the nebulae, the same one Shapley used for his work on the Milky Way,' said Hubble and walked briskly towards a nearby door, which he opened and waited for me to enter. I gasped, although I had seen a large modern telescope before. This one was not only large, but the history behind it was incredible. I was inside an immense dome at the centre of which stood the huge telescope. It did not have a closed tube. Instead, sturdy girders made up a cylindrical structure. At its lower end was the most important element of the telescope, namely the mirror polished to extraordinary precision. It was one hundred inches in width, I had learnt. That meant it could gather and reflect large amounts of light so that very faint objects in the sky could be seen clearly. The reflected light was brought to focus by a convex lens. Overhead, the dome could be opened whenever observations were to be made, but was kept closed at other times. Hubble led me up the long flight of steps to the observing platform.

'From here, one can directly observe the object of one's interest,' explained Hubble. 'You can also photograph it. Or you can attach a *spectrograph*, which splits the light from, say, a star into individual colours the same way Newton split white light with his prism. All this helps us in finding out a lot about the celestial object of interest. What *is* the object of our interest then? Well, it is a nebula located in the constellation Andromeda. Ah, Andromeda! There is a nice story for you, isn't there? I know you have already had the great good fortune of enjoying the myth enacted specially for you. So we can proceed with our scientific exploration of the nebula Andromeda.'

The Realm of the Nebulae

'Andromeda along with her parents and her prince charming, Perseus, have been immortalised as constellations, as you know,' said Hubble. 'I realize that Shapley has told you about Cepheid variables. The name derives from the constellation Cepheus named after Andromeda's father. Now, here comes the moment when you can see the skies through our great telescope. It is trained towards the constellation Andromeda.'

I was highly excited to look through the large telescope. I could see again the faint nebula with the wispy spiral arms emanating from the luminous main body. It was a unique opportunity to gaze upon the vision that had radically changed the measure of the Universe.

Hubble brought out with utmost care the photographic plate he had been holding when I first saw him.

‘Take a look at this,’ offered Hubble.

At the centre was the largest of the grey smudges having a granular structure, but distinctly bore the image of the nebula I had seen through the telescope. I was thrilled to look at the original photograph directly, not just a reproduction.

‘Well, it was the night of October fourth in the year nineteen hundred and twenty-three. How can I ever forget that date?’ recalled Hubble. ‘Despite poor visibility, I took a photograph of one of the spiral arms of the nebula Andromeda. I thought I could detect the presence of a nova. So, next night, which was clearer, I took another photograph and marked the plate as H335H, the one you see here.’

Yes, H335H was destined to become the most celebrated photographic plate ever!

‘I compared my photograph with those of the same nebula that had been taken earlier,’ Hubble went on. I could feel his mounting excitement. ‘It was clear that the brightness of one of the spots on the photograph had been undergoing periodic variations. It was indeed a Cepheid variable. I took out my pen and wrote in capital letters ‘VAR!’ to identify the star.’

I gazed at the star so marked. It seemed to me for a moment that it was actually going through its periodic variations in brightness. An illusion, I was aware.

‘The next step was simple,’ continued Hubble. ‘The same way Shapley had done with his Cepheid variables, I could estimate the distance to the Andromeda nebula. You know what I got? Some nine-hundred thousand—well round it off to a million—light years. How big is the Milky Way as determined by Shapley? A mere one hundred thousand light years across, was it not? Then clearly, the nebula was way outside the Milky Way.’ After a momentary pause, striking his theatrical pose again, Hubble announced, ‘One little Cepheid variable had proclaimed that our Milky Way was not the entire Universe!’

I gazed at the photographic plate with absolute fascination just as I had done with its reproduction. Once again, the image of the Andromeda nebula reminded me of Galileo’s meagre jottings of Jupiter’s Moons that had supported Copernicus and opened up new avenues in astronomy and human thought.

Hubble stroked his chin thinking back about his momentous discovery. ‘Well, I wrote a letter to Shapley informing him of my findings,’ said Hubble. ‘Poor chap, on reading my letter, it seems he said: *Here is the letter that has destroyed my Universe!*’

I too thought about the impact of Hubble’s discovery. Astronomers had hailed William Herschel on his discovery of Uranus, saying that he had doubled the size of the solar system. Now Hubble had enlarged the entire Universe ten times. He did not stop there. He went on to discover that the Universe made up of galaxies was inconceivably larger than that.

‘Take a look through the telescope and see for yourself how the Universe looks like,’ invited Hubble.

I looked through the telescope again. I could see everywhere, interspersed among the stars, fuzzy patches. Some were bright enough, but in addition there were innumerable faint ones, some of which were so faint that I had to strain my eye to see them. These patches differed in shape to some extent from one another. Apart from individual galaxies, there seemed to be groups of them here and there.

Hubble waited for me to have my fill of the galactic panorama and continued his narration.

‘Every one of those nebulae is like our own Milky Way consisting of billions of stars,’ informed Hubble. ‘The farther they are from us, the fainter they appear. You noticed that those nebulae come in different shapes. There are spiral-shaped ones like our Milky Way, while some have a bar at the centre of the spiral structure. And there are those that are elliptical.’

Once again, I had learnt that it was Hubble himself who had classified his nebulae into different categories.

‘As you saw, many nebulae are grouped together into *clusters*,’ continued Hubble. ‘Our Milky Way and the nebula in Andromeda belong to the *Local Group* of thirty or so nebulae. In the constellation Virgo, there is a rich cluster made up of some thousand or even two thousand nebulae. Yes, sir, the Universe is quite something.’

The picture of the Universe at large was getting more and more amazing to say the least.

‘Well, I realized that it would take thousands of years to photograph the entire sky with our telescope and count all the nebulae that could be observed. I didn’t have that long a time, did I?’ laughed Hubble. ‘So what to do, chum? I did the next best thing I could. I photographed one thousand two-hundred and eighty-three—oh yes, I kept count for sure—sample regions of the sky. My survey showed the total of around forty thousand nebulae. From that I could estimate that no less than a hundred million nebulae must exist within the range of our one-hundred inch giant of a telescope. And there is a two-hundred inch supergiant of a telescope sitting on Mount Palomar. And that one can see up to a billion nebulae. Yes sir, again the Universe is really something. Quite so, old chap.’

Of course, astronomers following Hubble were to show how immense the Universe actually is using more powerful telescopes and more sophisticated methods. But, Hubble had taken the first and the most important decisive step in that direction. A historic event that will never be forgotten!

‘Yes, the future was to tell us how big the Universe happens to be in reality,’ Hubble echoed my thoughts. ‘But the strangest fact related to the nebulae and therefore to the Universe was yet to emerge. Before we go into that part of our story, I must introduce to you my dearest friend and my most esteemed colleague.’ Hubble held out both his hands in a joyous welcoming gesture, ‘Ah, here comes Milt, Milton Lasalle Humason that is! Everyone loves Milt.’

The Magnificent Mule Driver

I stared down the mountain path in surprise. I could see a man on horseback winding his way up. His coarse clothing was covered in dust and his dishevelled hair blew in the wind. A big dog rode behind him, standing on its hind legs with its forepaws placed firmly on the man's shoulders. Strangest of all, the man was driving a pack of mules carrying a heavy load of lumber.



When he reached the top of the mountain where I was standing, he dismounted, as did the dog. The latter came close to me, sniffed at me, wagged its tail in friendship, yawned wide and then fell asleep curled up on the ground. The horse too nodded vigorously several times at me and bared its teeth in what appeared to be a smile as it neighed its greetings. The man called out to the mules to stop as they tried to wander off and cursed under his breath. Then he spat out tobacco juice from his mouth in a neat jet.

'Pardon me, pardon me,' he said. 'I shouldn't spit tobacco juice, let alone curse in front of visitors, isn't it so? Well, I am Milt as you were told. Mighty glad to meet you, buddy.'

Milton Humason, Milt to all his friends, was stocky in build, with a round face, twinkling eyes, and easy manner that pleased everyone. I liked him instantly.

'Ah, it is hard work, driving those mules bringing up all that timber and other material. They are needed for building telescope's supporting structure, local cottages, scientists' quarters, and all that jazz you know,' said Milt looking over my shoulders.

I looked back and I was startled to see that the fully built observatory was no longer standing there. Instead, a number of hardy men were busy on the construction work of the half-built observatory.

‘Oh, yes, we have gone back in time,’ chuckled Milt. ‘The building work is going on full speed. It will all be done soon. Oh, you are confused about me, this place, and whatnot. I can see that. Let me tell you my story, so you will get a better idea of things around here.’

Milt took a deep breath and went on to give a brief account of his life. As always, this was often accompanied by shifting scenes tracing the passage of time.

‘Well, to begin at the beginning, I was born. Don’t we all!’ guffawed Milt. ‘That happened to be at Dodge Centre in the state of Minnesota. When I was fourteen—ah, to be young again, what wouldn’t I give—I came here to Mount Wilson, a summer camp it was. What an experience! After that, who wanted to go back to school? So, I dropped out. My parents, bless their souls, allowed me to do whatever I liked. I became a bellboy at the brand new Mount Wilson Hotel. What did I do? Carry guests’ luggage, make them comfy, tend to their pack animals, wash dishes and so on, that’s what. I dunno if I liked my job, but I sure loved the mountain. So what did I wanna do? Settle down here. Yes sir, and that’s what I did.’

Milt closed his eyes with a big smile playing on his face recalling those bygone days before going on with his story.

‘Well, as you can see, I became a mule driver,’ said Milt waving his hand around to indicate his present occupation. ‘Let us fast-forward a little, shall we? I loved the observatory, naturally.’ In a stage whisper he added, ‘This is strictly between you, me and the doorpost over there. More than anything, I loved my Helen, daughter of the engineer Mr Merritt C. Dowd, didn’t I? Any better reason than that to become part of the observatory? Women have a greater pull than all the stars put together, you know.’ He winked and gave a long, belly laugh.

Milt paused again to indicate that the story was moving into another phase.

‘We got married, Helen and I, and had our Baby Bunting, named William after his grandpa,’ Milt went on. ‘So, being the man of the family, I was obliged to support it. I had to take up some regular work. So, I got a janitor’s job at the observatory. But, lucky me, one of the students taught me how to take pictures of the stars on plates, bless him. You met Mr Shapley, didn’t ya? Yes, he noticed me all right. It was all so jolly good—me and my heady Panther Juice, which some people sipped on the sly, and my passing around a deck of cards on cloudy nights when no one had noth’n to do. Wish I could give you a taste of my Panther Juice, but you look underage to me, what to do?’ Milt winked again and laughed boisterously. ‘Ah, well, I began taking photos for Mr Shapley. And more than that, I enjoyed telling visitors about Mr Shapley’s ants.’

‘Shapley acknowledged that Milt was one of the best observers we ever had,’ put in Hubble who was listening to Humason with pleasure. ‘That is one point on which I fully agreed with Shapley. Let me complete the story for Milt. From Janitor, his position was elevated to night assistant. When his abilities were recognized, Milt was appointed to the regular scientific staff. Then on, there was no stopping. He went on to become successively Assistant Astronomer, Astronomer at not only Mount Wilson, but also at Palomar Observatory that was to house the two-hundred inch telescope, the world’s largest. And the high-school-dropout-mule-driver was

to receive the honorary degree of Doctor of Philosophy from the University of Lund in Sweden, no less!’

Humason, both happy and embarrassed, was pretending to be busy dusting some old photographic plates. All three of us had now moved once again into the Observatory.

‘The most enthralling part of the story begins now,’ said Hubble. ‘The strangest and the most spectacular discovery Milt and I made together about our Universe.’

Galloping Galaxies

‘Before we discuss our discovery, I must remind you of a phenomenon you know very well, namely the Doppler Effect,’ informed Hubble. ‘In the case of sound, its pitch goes up, if the source is moving towards you. And it goes down if the emitter of the sound is travelling away from you, right old chap? For the effect to be appreciable, the source must be moving with a speed comparable to that of sound. Then again, this can happen in the case of light too. Light, or equivalently its spectrum undergoes blueshift if the source is rushing towards you, and shows redshift if the light emitter is zooming away from you. Yes sir, the speed of the source in this case has to be a good fraction of light’s phenomenal velocity. Nothing on Earth can move that fast. Then what’s the point of all this blueshift, redshift, greenshift, and all that, eh?’

I shrugged as if the Doppler shift of light was of just academic interest and was of no use for practical application, although I knew what was coming. Of course, it was wonderful to listen to Hubble’s recounting of the past.

‘Aha, I said nothing on Earth moves that fast. Did I say anything about the objects in the sky?’ Hubble wagged his finger. ‘Let us find out what is happening up there. We go back to the telescope.’

I was again overwhelmed by the gigantic telescope just as I had been when I had first seen it. I know, I had no control over this feeling.

‘Hey, Milt, come down for a minute, our friend here wants to see the spectra you have photographed,’ called out Hubble cupping his mouth with his two palms.

Humason came down panting as he descended down the ladder adjoining the telescope. He beamed at me in spite of his fatigue clearly written on his face.

‘Whew, what a life,’ groaned Humason. ‘Night after night I am perched like a monkey on the tiny platform five stories above the observatory floor. I wonder how I look like with my face illuminated by the red dark-vision lamps. More grotesque than I am, I am afraid. God, some nights it is freezing cold up there and the merciless winds make it worse.’

Involuntarily Humason cursed under his breath.

‘Sorry, sorry, I should watch my language especially in front of our young visitor here,’ Humason was apologetic. ‘Look at the telescope. It is a monster. I have to make sure it points exactly at the guide star. Sometimes the whole system stops and I have to put all my strength into my shoulder and hold the thing in place.’

Sometimes, I have to get on to the iron frame and do some contortionist acts so as to make sure the photographic plate is in place. I have to go through this circus night after night so the plate soaks in enough light. The nebulae out there are awfully faint, you know. Heaven help me.'

Humason took out of his hip pocket a small flask and took a swig of his famous Panther Juice from it to compensate for his plight.

'Milt, why don't you let me have a sip too,' said Hubble taking the flask from Humason. He tilted it up and helped himself to what seemed like a gulp rather than a sip.

'All right, Milt, we do realize the great trouble you take in photographing the nebulae. You are doing a wonderful job, old boy,' said Hubble with genuine appreciation. 'I would like to show our visitor here some of your spectra displaying the redshifts of the nebulae.'

Humason took out a photographic plate from the drawer of a nearby desk and held it up to light. I had forgotten all about the faint appearance of the galactic spectra I had seen in the books on cosmology. Naturally then, I had expected to find a band of brilliant colours or sharp luminous lines as I had seen in other contexts. But here was a diffuse, faint grey strip with a few fuzzy dark lines distributed along its length.

'Surprised, are we?' laughed Humason. 'The light captured on the plate comes from a nebula millions of light-years away from us, you know. That is why the photograph is so faint. And that is why I have to toil for nights and expose the plates for awfully long durations. Why are the lines dark? Well, they are *absorption lines*. You see, suppose white light passes through the vapour of an element which is not hot enough to emit its characteristic radiation. Then that vapour absorbs precisely those wavelengths that the element would emit if it were hot. That is how absorption lines are produced instead of emission lines. Now, the lines you see are those of the element calcium—not the emission lines, but absorption lines. Calcium is very important stuff if you ask me. Why? Because, calcium is essential to the bones. And I need strong bones to tame the mighty telescope over there, got it?'

It was obvious that Humason was an expert in the matter of spectra and in taking their photographs. He was very lucid and animated the way he described his work.

'Now, here is a photograph of calcium lines taken directly in the laboratory. Hope you will be satisfied,' Humason pulled out another plate. This was much better although it was not coloured. Against a dark background white lines stood out sharp and clear. Humason superposed the two plates with edges coinciding exactly. 'Take a look. The absorption lines on the first photograph are all shifted by the same amount in comparison to the *emission lines* captured in the laboratory. You see it? Excellent! Aha, that is the Doppler Effect for you. What does that mean? They say it means that the nebula is running away from us, quite fast too. I capture the spectrum, we measure the redshift, and my boss, Mr Hubble here, calculates the velocity corresponding to that shift using his Doppler formula. Also we know the distance to the nebula by observing the Cepheid variables it contains. Now I know you know how it is done. Now you know I know you know.' Humason gave his hearty laugh and continued. 'Mr Hubble will tell you that this nebula, in the

constellation Virgo, is at a distance of some 50 million light-years from us and happens to be flying away at a speed of around 750 miles per second. There you have it—redshift showing how a distant nebula is rushing away from us. Whew, that was a long tiring explanation.’ Humason took another swig of his Panther Juice.

‘Milt gets easily tired talking, at least that is what he claims so he can keep guzzling his Panther Juice,’ chuckled Hubble. ‘The photograph Milt is taking right now is of the nebula in the constellation called Corona Borealis, which is at a distance of, say, 940 million light-years from us. And, we expect its velocity to be about 13,400 miles per second. Far enough and fast enough, what ho? As I told you, we can detect redshift of light, if the speed of the source is comparable to that of light. And that is precisely what is happening with those nebulae up there in the sky. We hope to keep measuring even greater distances and higher speeds.’

‘That means more photographing,’ Humason groaned. ‘Tell our friend about the distance-velocity relation, boss.’

‘Ah, that is another thing—really interesting,’ Hubble’s eyes lighted up. ‘We found that the two quantities, namely the distance to a nebula and its redshift, or equivalently the velocity with which the nebula is flying away, are very simply inter-related. Double the distance, the velocity doubles too. Make the distance, say ten times larger, and the velocity becomes ten times greater too. This is known as a *linear relation*.’

Yes, it was well-known as the *Hubble Law* in his honour.

I could see a faint glimmer of pride appearing on Hubble’s countenance. That was quite natural, wasn’t it?

‘The speeds you encounter in astronomy are truly great. And the nebulae take the cake,’ Hubble said. ‘Here, I clap my hand twice. That makes it a second. In that time, the Earth has gone around the Sun by about 18 miles. Clap, clap, the entire solar system has moved by some 137 miles about the centre of our Milky Way. Clap, clap, again, and the nebula in Corona Borealis has zoomed away by 13,400 miles!’

‘Oh, well, as far as I am concerned, I have always been rather happy that my end of it—my part in the work—is, you might say, fundamental. It can never be changed, no matter what the decision is as to what it means,’ shrugged Humason. ‘Those lines are always where I measured them. And the redshifts, if you want to call them that or velocities or whatever they are going to be called eventually, will always remain the same. So, here I go to get some more lines up over there.’

Humason gave me a broad smile, waved goodbye, and made his way slowly up the ladder back to his photographic plates.

‘Yes, he will always be remembered for his spectral lines, good old Milt,’ said Hubble his eyes following fondly the receding figure of his dear friend and distinguished collaborator. ‘We make our observations all right. But it is important to know what they mean. For that, one has to build models based on mathematical theories. Long ago, Newton did that with his law of gravitation, which described everything that was known at his time. But now we have to explain why the nebulae are flying away at breakneck speeds. Newton’s theory cannot do the job. We need a new theory of gravitation for that. Fortunately, such a theory already exists.’

After a momentary pause, Hubble made his dramatic statement. ‘The nebulae are flying away from one another. And the reason is this: *the Universe itself is expanding.*’

I was startled by the announcement, although everyone in our own time knows that amazing fact. But, of course, there was a lot more for me to learn about the cosmological expansion, especially its theoretical explanation.

‘Patience, my man,’ Hubble held up his hand. ‘You will learn all about it soon, very soon. I have got work to do you know, quite pressing indeed. So I must take leave of you now. Farewell, old sport!’

With that Hubble started moving out of the Mount Wilson observatory. The observatory faded gradually. In its place, I could see an immense telescope, even larger than the one on Mount Wilson, looking out of the dome of another observatory. I realized what it was—the newly-built two hundred-inch supergiant at Palomar. Strangely enough, seated right inside the telescope at its prime focus was Hubble, who had grown much older. And then even that vision melted away and was replaced by the dark night sky filled with the stars. Strangely enough, I could see everywhere diffuse patches that had grown unusually bright. It was the realm of the nebulae.

The bathwater still resembled the dark night sky with the stars, peppered with the ubiquitous faint patches of light, the nebulae. Those nebulae started moving, gathering speed, flying away from one another, and dissolved away. The bathwater once again assumed its natural appearance.

Ah, the Universe is awesome in its vastness. Yet, it is expanding greedily to become vaster still. There is so much to know about it all. I wished I could stay on in my bathtub and enjoy the rare cosmic visions that kept floating across my mind. But wishes are wishes and reality is reality. With a sigh I got up. *To sleep*, I whispered to myself, *perchance to dream?* Sleep yes, but dream no, I thought. As soon as I hit the bed, the Universe curled up and enveloped me in the form of deep, uninterrupted sleep.

Chapter 14

Space, Time and Gravitation

As always, I knocked on George's office door and entered without waiting for George to respond. George maintains that it is a waste of energy to call out 'Enter', 'Come in,' or whatever. If the door is kept unlocked, it means that everyone is welcome to his office—students, faculty, and visitors, with the only exception of burglars. If he were really busy, then he would keep his door locked.

George was seated in one of the comfortable chairs in front of the low table, on which several books were lying, as well as a few photo-copied articles.

'Listen to this, Alfie,' said George without any pleasantries or preamble as though we were already deep into our dialogue. He was holding in his hand a somewhat large volume, its dusty grey cover needing replacement. Of course, George would never do any such thing claiming that it would destroy the venerable aura surrounding the book.

'Listen, let me read the opening passage for you from this very interesting article appearing in this book,' repeated George and read out the passage he had mentioned. *'Speculations about the Universe in which men live are as old as human thought and art; as old as the view of shining stars on a clear night. Yet it was the general relativity theory, which only thirty years ago, shifted cosmological problems from poetry or speculative philosophy into physics. We can even fix the year in which modern cosmology was born. It was in 1917 when Einstein's paper appeared in the Prussian Academy of Science under the title: Cosmological Considerations in General Relativity Theory. Beautifully put, what do you think?'*

It was indeed an elegant and meaningful passage. But, what was this article about? And who wrote it? I am sure George had noticed my puzzlement.

'Ah, sorry, Alfie, forgot to tell you the source of that opening paragraph,' George hastened to demystify me. 'The article is titled, *On the Structure of Our Universe* and is authored by Leopold Infeld, who had worked with Albert Einstein. The article is one of the several historically important essays including Einstein's own *Autobiographical Notes*. And the volume I am reading from is *Albert Einstein: Philosopher-Scientist*, edited by Paul Arthur Schilpp and brought out in 1949. We shall come back to the article soon enough.'

George smiled and added, 'Needless to add, but I shall add anyway, you are most welcome to borrow the precious volume as well as other books I shall lend thee, provided you return them safe and in good time.'

George opened his manuscript for ready reference, collected his thoughts for a few moments, and began his explanation of the fundamental tenets of modern cosmology based on the general theory of relativity.

'What does Infeld say about the importance of general relativity to cosmology?' began George. 'Let me quote him again: *the general relativity theory... shifted cosmological problems from poetry or speculative philosophy into physics*. So let us talk about the general theory of relativity first before thinking of its application to cosmology.'

'All right disciple, let us hark back to our discussion of stellar evolution,' continued George. 'We touched very briefly upon general relativity when we talked about Oppenheimer's studies on the gravitational collapse of a massive star to form a black hole, right? Hark back even further, setting the clock backwards by a few years before you launched upon your life of a vagabond. We discussed relativity theory, both special and general, exhaustively—I mean it exhausted me—in describing black-hole physics in great detail. You can read it all from the copious notes you must have kept at that time. If I remember right, and I do, you even got a book published craftily, didn't you? You can read that too.'

'There was nothing crafty about the publication, George. You gave your *imprimatur*, didn't you?' I protested and added with a grin, 'After making sure I had expurgated all your objectionable expletives.'

'What nonsense, I am incapable of uttering profanities,' asserted George and went on seriously. 'Let us get on with general relativity. We already noted how the most distinguished scientists like J. J. Thomson and Dirac extolled the virtues of the theory. And rightly so. The special theory of relativity itself had been hailed as a revolutionary theory. But general relativity, which now included gravitation within its spacetime description, was the supreme achievement of pure thought based on relentless logic with no appeal to observation. Simply put, it was a unique work of unprecedented genius.'

'There was already Newtonian gravity. Where was the need for a new theory of gravitation then?' I enquired.

'Let us not forget that Newtonian gravity too was a stroke of genius,' commented George. 'It completely transformed physics by bringing in so many factors like setting ideas within mathematical framework, bringing in the notion of force, enunciating universal laws, and so on. All along, there were astronomical observations related to planetary motion in the background. And, as we have repeatedly observed, Newton could explain everything in nature that was known at his time.'

'That is fine with Newtonian physics. But, you haven't still answered my question regarding the need for a new theory of gravitation,' I pointed out.

'All right, let me answer your question,' George said. 'First of all, Newtonian physics did not conform to the tenets of special theory of relativity. So, Einstein had to find a theory that embraced both relativity and gravitation. The starting point for

this was the fusion of space and time into a unified entity, namely the spacetime, which had been a natural outcome of Einstein's special theory of relativity.'

'I remember your telling me that it was Hermann Minkowski who blended together space and time,' I said.

'You are right. Minkowski was Einstein's mathematics teacher at the famous Federal Institute of Technology in Zurich, familiarly known as Polytechnic or simply as Poly. Apparently, being more interested in physics rather than in mathematics Einstein used to cut Minkowski's classes,' remarked George.

'And Minkowski used to refer to him as *that lazy dog Einstein!*' I added.

'Precisely,' nodded George. 'Actually, when someone asked what Einstein thought about the spacetime representation of his special relativity, he had replied: *Now that mathematicians have invaded the theory, I no longer understand it!* However, Einstein included Minkowski's name among his important mentors at the Polytechnic later on in his *Autobiographical Notes*. Anyway, Einstein wanted to include gravitation into the spacetime picture. This was a logical extension of special relativity, a theory that had nothing to do with gravitation. The cornerstone of the theory was the fact that all objects fall with the same acceleration.'

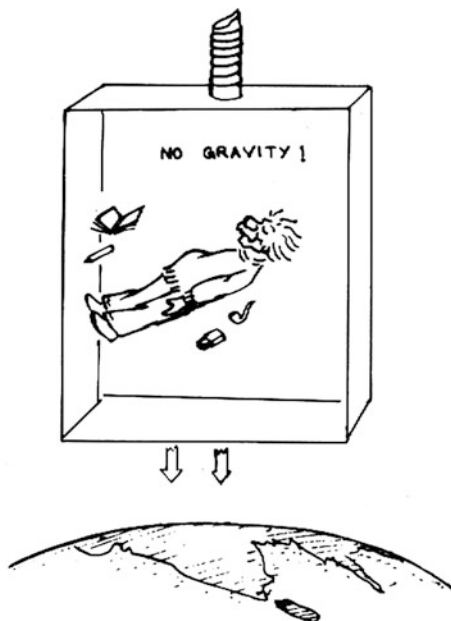
'A fact Galileo is believed to have demonstrated by dropping two objects of different masses from the tower of Pisa,' I mentioned.

'Well, it is felt that Galileo in his old age and infirmity could not have gone up the tower to perform that experiment, Alfie,' said George. 'Probably it is just a legend. He could have employed his inclined plane to show the effect. Some people believe that he came to the conclusion by pure logic, by *reduction ad absurdum*. If a heavier mass fell faster than a lighter one, as had been stated by Aristotle, what would happen if you joined the two together? The two would be acting against each other! In any case, the simple phenomenon became an extraordinarily powerful tool in the hands of Einstein. He wrote ecstatically about his realizing the importance of this phenomenon:

When, in 1907, I was working on a comprehensive paper on the special theory of relativity, there occurred to me the happiest thought of my life that, for an observer falling freely from the roof of a house, there exists—at least in his immediate surroundings—no gravitational field.'

'Oh yes, the happiest thought of the great man, I remember that,' I said.

'Let me be brief,' continued George. 'Let us perform Einstein's *gedanken experiment*, or *thought experiment*, involving the *Einstein Elevator*. Hopefully no one will get the idea of repeating it in real life, it is too dangerous you know. Suppose Einstein is inside his elevator and the shaft is cut off at his own behest. He is in free fall and so are all the objects around him—his pipe, match box, his notebook and pencil, so on. He feels no gravity at all, visually or otherwise. So, by free fall, equivalently in an appropriate accelerated frame—namely the Einstein Elevator—gravity has been eliminated. You agree?'



I nodded my agreement.

‘All right then. Now think of a rocket or a spaceship far away from the Earth in zero gravitational field,’ George went on. ‘Let the rocket zoom up with acceleration exactly equal to that on the surface of the Earth. Drop things, apples and oranges, they will all seem to fall as though they are on the Earth, as the floor of the rocket accelerates upwards. So then, you have created gravity by going into an accelerated frame, namely the rocket. You follow?’



I nodded again.

‘Here comes Einstein’s stroke of genius,’ announced George. ‘Einstein concluded that gravitation was in essence equivalent to acceleration. Whatever you observe in an accelerated frame, you must observe in a corresponding gravitational field. This is Einstein’s famous *equivalence principle*.’

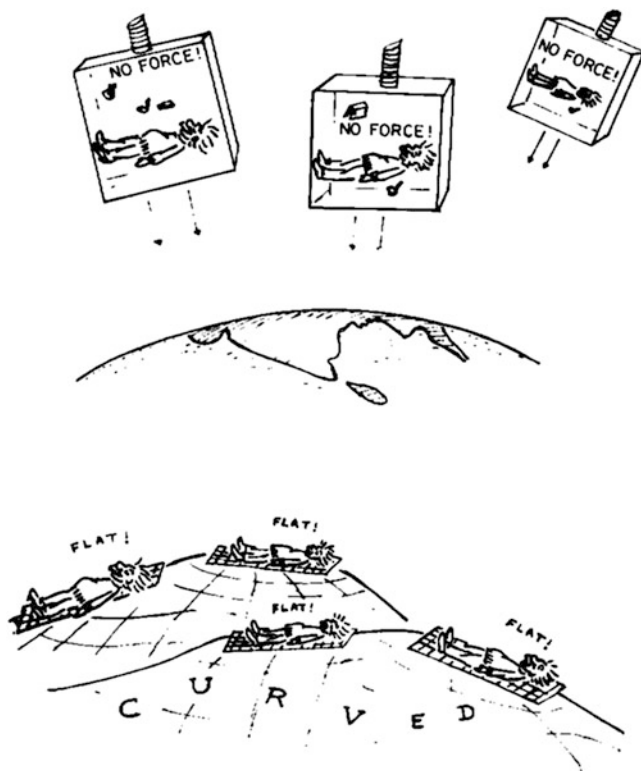
George had remarked how Einstein’s general relativity had been the outcome of pure logical reasoning. I was realizing the workings of such a simple but powerful process.

‘So far it has been all abstract thinking. How about some practical application? Sorry, Alfie, I have to keep repeating myself. Here comes the man’s genius again,’ George spread out his hands as if he was helpless in this matter. It was a bit comical though. ‘Send a ray of light across a stationary rocket. It streaks in a straight-line. Now let the rocket shoot up with acceleration. The light ray seems to hit a point lower than a point it encountered a moment earlier as it traverses the rocket. This happens every moment of its flight across the rocket accelerating upwards. The net result is that the light-ray appears to bend within the rocket. In other words, light bends in an accelerated frame. And the same thing must happen in a gravitational field according to Einstein’s equivalence principle! There you are, a new phenomenon predicted: gravitational bending of light!’

‘In Einstein’s time there were no spacecraft, I know,’ I said. ‘But, can this bending of light in a gravitational field be observed in nature or in laboratory?’

‘The effect is too minute, Alfie,’ answered George. ‘It can be observed only on astronomical scales, as we shall see. To continue, when there is no gravity, particles and light travel in straight-lines, the shortest path between two points, or *geodesics*

as they are called. On a flat sheet of paper, straight-lines form the geodesics. So, gravity-free spacetime is *flat spacetime*. That means, within the freely-falling Einstein Elevator you have a small patch of flat spacetime. But think of such elevators at various points all around the Earth at different heights. They all fall with different accelerations each containing a bit of flat spacetime. When you put them all together, you get a *curved spacetime*, just as patching together little flat areas on the Earth gives a curved two dimensional surface. In short, gravitation engenders a curved spacetime or gravitation is equivalent to spacetime curvature.'



All this seemed so simple and so logical. I was most eager to learn about the further steps taken by Einstein in developing his theory.

'Now, here is an idea that follows that of curved spacetime. First of all, why do particles move along curved paths in a gravitational field? According to Newton, it is because of the gravitational *force*. According to Einstein, there is no gravitational force, but only curved spacetime. In the absence of gravity, spacetime is flat, right? And in a flat spacetime, particles move along straight-lines that are the flat-spacetime *geodesics*. Let us keep in mind that geodesics are those curves along which the distance between two points happens to be the shortest. Now turn on gravity. Spacetime curves. Assume that particles and even light have no choice but to follow geodesics, the most natural curves imbedded in any spacetime. But the

spacetime is now curved. *Ipsa facto*, particles in a gravitational field, represented by curved spacetime, move along curved trajectories. That is Einstein's famous *geodesic hypothesis*. So, in spacetimes curved by gravity, the trajectories of particles and light are curved too. Conversely, if the trajectories are observed to be curved, then the spacetime in which they move is curved. In essence, Einstein's geodesic hypothesis demonstrates how curved paths lead to a curved spacetime.'

'Geodesic, the shortest path between two points,' I said. 'In a crooked world, the straightest path is crooked too.'

'So is your mind, Alfie,' laughed George. 'That was a lengthy explanation, wasn't it? But then, we cannot interrupt the chain of ideas that had led to the magnificent theory. But let me rest my tortured tongue.'

With that, George sat back and mopped his brow with his handkerchief. But not for long, since he is quite indefatigable when it comes to explaining his favourite subjects. Having had no more than a second or two of rest, George began again.

'Yes, we have touched upon the soul of general relativity,' George resumed. 'Now for some aspects of its corporeal frame. Einstein now held in his palm his beautiful curved spacetime representing gravitation. But, what about the actual theory based on his simple but profound ideas? What about the mathematical frame needed for setting this jewel in? Einstein had no idea how to go about it.'

'Aha, he should have attended Minkowski's math classes more regularly then,' I suggested.

'Well, perhaps Einstein found better help than formal instruction in mathematics,' responded George. 'His classmate at Zurich Poly, Marcel Grossmann, a brilliant mathematician no less, came to his rescue. Earlier, the same Grossmann had rescued Einstein from unemployment by getting him the job at the patent office in Bern through the good offices of his father Grossmann the elder. Now, he pointed out to Einstein what he needed for building up his theory: it was Riemannian geometry. Poor Einstein, lucky him really, had to master this branch of mathematics and then apply it to his own ideas. This took him several years of hard work, meandering through the mathematical maze, taking false turns, retracing his steps, and so on. After all this tortuous journey, he could finally write down the equations that governed the geometry of the spacetime, curved by gravitation. This geometry, in turn, was related directly to the mass distribution that produced the gravitation in the first place. Finally in the year 1915, he unveiled his grand theory, the general theory of relativity that was destined to transform our view of the Universe completely for ever.'

So we had arrived at the most important milestone in our cosmic adventure.

'The theory of theories was ready, the pudding had been cooked, but where was the proof of the pudding?' George raised his questioning eyebrows. 'Well, there were these three phenomena that go under the name of the *classical tests of general relativity*. First, the theory predicted that light or any radiation going from a stronger gravitational field to a weaker one was red-shifted. This is known as *gravitational redshift*. It is not Doppler shift, which is due to the relative motion of a source with respect to a receiver. Then again, let us not confuse the gravitational redshift with the *cosmological redshift* discovered by Hubble and

Humason. We shall talk about it later on. Gravitational redshift could be verified from stellar spectra as well as by eventual terrestrial experiments. Then there was the well known *perihelion precession of the planet Mercury*. The closest point of approach to the Sun, the perihelion, of Mercury did not close but continuously underwent precession by an amount of some five thousand seconds of arc per century. Newtonian gravity could account for most of it as due to the tug of other planets except for a teeny-weeny bit of 43 seconds of arc per century. And what do you think happened?’

‘Einstein’s general relativity accounted for it,’ it was an obvious guess.

‘Brilliant,’ George grinned. ‘After a long calculation, within the rigid framework of his equations with no leeway for any kind of fudging, Einstein could get the miniscule missing amount exactly. In 1916, he wrote to his friend, the renowned physicist Paul Ehrenfest in Holland about his spectacular achievement. Here, let me read the relevant line from the letter: *Imagine my joy at the result that the equations yield the correct perihelion motion for Mercury. I was beside myself with ecstasy for days!*’

This must have been a moment of extraordinary success of Einstein’s theory of general relativity.

‘Finally, we come to the third and perhaps the most important test of general relativity, namely the bending of light in a curved spacetime,’ stated George. ‘The story behind the prediction of this phenomenon is quite strange, you know. As early as in 1908, Einstein had calculated the amount by which a ray of light from a distant star would bend as it grazed the surface of the Sun. This was seven years before he had formulated his full-fledged theory. He had just combined Newtonian gravity with his equivalence principle and had obtained a value of 0.83 seconds of arc for the bending. Actually, Einstein had made an arithmetical mistake. The correct value should have been 0.87. In any event, how can one observe this effect? After all, the stars are not visible during the day time. Einstein had this wonderful suggestion that the light bending could be measured during a total solar eclipse when the stars do become visible. And Erwin Finlay-Freundlich, a German astronomer, went all the way to Russia to record this effect in 1914.’

‘What happened? Did he measure the light bending?’

‘No, the World War broke out and the poor man came back empty handed,’ answered George. ‘Einstein was most disappointed, to say the least. But it was a blessing in disguise.’

‘How is that?’ This was surprising.

‘Well, after he formulated his final theory, Einstein recalculated and found the light bending was exactly twice the value he had calculated—it was 1.75 seconds of arc,’ answered George. ‘If Finlay-Freundlich had measured this value, if Einstein had confirmed it after putting forward general relativity, maybe one could have felt that the theory had been tailor-made to account for the correct amount of bending. I don’t know. In any case, Arthur Eddington verified the correct value for the light bending during the total solar eclipse that occurred in the Portuguese Island of Principe off the western coast of Africa. This was in 1919. The ray of light bent by

gravity dazzled the whole world. And Einstein became a household name overnight.'

George smiled as he recollected some amusing anecdote.

'You know, Alfie, it seems someone asked Einstein how he might have felt if Eddington's result had not been in accordance with the general theory of relativity,' related George. 'And apparently Einstein had answered: *Then I would have been sorry for the Lord, for the theory is correct!* What supreme confidence, Alfie.'

George shook his head laughing. I laughed too and waited for George to move on to the next phase of the fantastic story.

George paused drumming his fingers on the armrest of his chair.

'Another phenomenon engendered by general relativity has proved to be of paramount importance, Alfie. It is the existence of *gravitational waves*,' George resumed. 'Believe it or not, these waves were predicted by Einstein himself on the basis of his theory.'

'There seems to be no end to that man's achievements,' I remarked. This was truly remarkable.

'You said it, Alfie,' agreed George. 'Until the advent of general relativity, everyone had been familiar with sound waves and electromagnetic waves. Their production, propagation, and detection were totally clear. Now, the motion of any kind of material objects produces gravitational waves consisting of ripples in the spacetime. These waves carry energy and have peculiar polarization properties quite different from electromagnetic waves.'

'If gravitational waves are generated so easily, have they been observed in the laboratory?'

'No, Alfie, gravitation happens to be an extremely weak force. Unlike electromagnetic waves, gravitational waves of enough strength can neither be produced nor detected in the laboratory. Consequently, here on Earth one may be able to detect only gravitational waves produced in astronomical events,' George answered. 'For decades now, there have been concerted efforts to build gravitational wave detectors and capture those elusive waves. Once this is done, it is hoped that a new window on the Universe would be opened up as has happened with light, radio waves, and X-rays.'

'We have covered enough of general relativity, Alfie,' said George after a while. 'We can proceed now to talk about its application to cosmology that opens up an overwhelming chapter in the study of the Universe. Let us take a break. I have to check my mail gathering dust in the department office you know. It is all junk mail. But I have to clear it to make room for the poor secretaries to fill the mailbox with more junk. On the way back, we can stop at the wending machines and energise ourselves with some cookies and coffee.'

I could see that George needed some respite and energising. I too needed some time to go over what I had heard about general relativity and refresh my memory.

Chapter 15

The Curved Cosmos

We were back from our expedition to the department office and the wending machines suitably energised. Without waiting too long, George began his recounting of the cosmological developments that followed in the wake of the birth of general relativity.

‘Ah, where were we? Oh yes, we covered the genesis and the development of general relativity and three classical tests, didn’t we?’ resumed George. ‘Soon after that in 1917, Alfie, Einstein took up the grandest application of his theory to the entire Universe. Let us take note of the status of observations on cosmological scales of those times. Even the size and shape of the Milky Way were unknown, let alone the true expanse of the Universe. No large-scale changes in the sky on truly universal scales had been observed. Is it surprising then that Einstein assumed that the Universe was static? Nevertheless, he realized that his own field equations of general relativity would not allow such a solution. The Universe had to be either expanding or contracting. So what to do? Einstein decided to alter his equations by a teeny bit by adding what is known as the *cosmological term*, characterized by the *cosmological constant* denoted by the Greek letter *Lambda*. With this alteration, Einstein was able to obtain a static cosmological solution. But things changed fast.’

‘What happened next? This sounds like a fast-paced suspense story,’ I observed.

‘Indeed. The next investigator to arrive on the scene around the same time—I don’t want to say the scene of the crime, we are talking of cosmology and not crime, you know—was Aleksander Aleksandrovich Friedmann of Russia.’

‘Was he an observational astronomer or theoretical cosmologist or what?’ I asked.

‘He belonged to neither of the first two categories. You could say he happened to be a *what* on your list,’ George chuckled. ‘Friedmann had been trained in atmospheric science and had a degree in meteorology. In 1917, when Einstein was busy adding his cosmological term to accommodate a static Universe, Friedmann was heading a factory that manufactured aviation instruments. How do you like that?’

‘Sorry to keep repeating the fact—but another accidental astronomer added to my list,’ I commented. ‘But no match to the mule driver!’

‘By 1919, when general relativity had become big news, Friedmann had moved to Saint Petersburg and held a professorial position. He taught himself the general theory of relativity and turned his attention to its application to cosmology. Friedmann went along with the equations that dictated a dynamic Universe and derived the expanding universal model. And, of course, he was completely vindicated by the actual observational discovery of the universal expansion by Hubble and Humason.’

‘What was Einstein’s reaction to all this?’ I asked the obvious question.

‘Well, when Friedmann published his result in 1922, Einstein was reluctant to accept it, claiming that Friedmann had made a mathematical mistake,’ answered George. ‘It so happened that the mathematical error had been committed by Einstein himself. And in the following year, he gracefully conceded the fact and agreed that Friedmann had a valid cosmological model.’

‘And what about the cosmological term Einstein had added to his equations?’ I wanted to know.

‘Ah, it is a very well-known story. Possibly you have heard it too,’ said George. ‘When the expanding Universe became a firmly established fact, it seems that Einstein dubbed his introducing the cosmological term *the biggest blunder of my life!* Often, it is pointed out that had Einstein allowed his own original, unsullied equations without the cosmological term to guide him, he could have predicted the existence of an expanding Universe. What a missed opportunity, they shake their heads. Why should one expect that amazing man to be right all the time? Shouldn’t one take heart from his mistakes? We make mistakes too, don’t we? Well, let us see what Infeld has to say in this matter.’

George picked up the grey volume again and read from Infeld’s article. ‘Remember, writing in 1949, Infeld is referring to the 1917 paper of Einstein in which Einstein had invoked the cosmological term to generate a static model of the Universe. Here we go.

Although it is difficult to exaggerate the importance of this paper, . . . Einstein’s original ideas, as viewed from the perspective of our present day, are antiquated if not even wrong. I believe Einstein would be the first to admit it.

Yet the appearance of this paper is of great importance in the history of theoretical physics. Indeed, it is one more instance showing how a wrong solution of a fundamental problem may be incomparably more important than a correct solution of a trivial, uninteresting problem.

There you are. How perceptive and insightful are Infeld’s words! But, my dear Alfie, was the cosmological term a big blunder? Especially, *as viewed from the perspective of our present day*, not Infeld’s but our own?

George paused and gave one of his mysterious smiles. ‘The answer, my boy, is for me to know and for you to guess.’

‘Come on, George, don’t play this mystery game to torture me,’ I protested vehemently.

‘All in good time, Alfie. After all, the old fox may end up having the last laugh, as we shall see. Let us now get back to some important considerations regarding cosmological models.’

What could I do? I have learnt to be patient after all these years of interaction with George. The waiting has invariably proved to be worthwhile.

‘All right, I shall wait,’ I said pretending to be somewhat annoyed. ‘George, how exactly does the curved spacetime picture or formalism work in the case of the Universe?’

‘Excellent question, Alfie,’ approved George. ‘That is exactly what we are going to discuss next. In order to visualize spacetime, it is customary to think of a two-dimensional *rubber-sheet model*.’

‘I remember what you once told me, George. Quite insightful and charming you know,’ I recalled. ‘You said: *Although we live in a four-dimensional world, our awareness is limited to three dimensions, our imagination to two, and our view-points to one.*’

‘Did I say that? I don’t remember. I must jot down my own quotations,’ George seemed to be quite pleased with what I had conveyed to him. ‘Well, in order to visualize what goes on in the real curved spacetime, one thinks of what is popularly known as the two-dimensional rubber-sheet model. Take a rubber sheet or a trampoline.’

Before George could continue, I remembered the trampoline in the amusement park I had visited with Ptolemy. It had been so nice to watch the children jumping up and down, especially the toddler sitting in the dimple his weight had created in the trampoline and making a ball either roll down or circle round the dimple.

‘Alfie, wake up. Don’t get into one of your mysterious reveries,’ George admonished me. ‘Let me repeat. Take a rubber sheet or a trampoline. When there is no mass in it, it is flat. Place a heavy ball on it, then the ball creates a depression around itself, curving the rubber sheet. Little marbles will roll towards the big ball. A marble, shot normal to the line joining it to the ball, will circle around it like a planet around the Sun. Thus all the gravitational effects can be simulated by the rubber sheet. You can even imagine how light must bend as it moves in this curved two-dimensional space. Now, draw lines on the sheet to make a co-ordinate grid. It could be a Cartesian coordinate system with the lines perpendicular to one another if the rubber sheet is flat. On the other hand, if the sheet is curved, a curvilinear coordinate grid will have to be used, as in the case of the surface of the sphere. Every point on the sheet can be identified by giving its coordinates. Are you with me?’

I nodded to indicate that I was following every word of his explanation.

‘Good, now take such a sheet that is curved in general,’ George continued. ‘Each point on it can be identified by its coordinates, right? If the sheet remains unchanged, not only will the coordinates of the points remain the same, but also the distance between any two points will always be constant. This situation corresponds to Einstein’s static Universe. Is that clear?’

‘As clear as the crystal spheres of Aristotle,’ I smiled.

‘Impudent fellow,’ George smiled too. ‘Now here comes the interesting part. Let the rubber sheet start stretching. The coordinates of every point will remain the same, but the distance between any two of them will keep increasing with time. We now have a two-dimensional model for the expanding Universe as discovered by Friedmann. Got it?’

‘Yes, I understand it all,’ I confirmed. ‘You have been talking about only points, their coordinates, and distances between them on your rubber-sheet model of the Universe. Where did all the stars and the galaxies go?’

‘Aha, you noticed the subtle point, didn’t you?’ George nodded his appreciation. ‘Well, that is because Einstein’s static model and Friedmann’s expanding one were both mathematical constructs. The task of injecting some real physics into the universal models was left to the Belgian Roman Catholic priest, Monseigneur Georges Henri Joseph Édouard Lemaître.’

‘In the beginning was the Canon, in the end the Priest,’ I remarked.

‘The Canon and the cannon he fired will always stay with us, Alfie. We shall come to that shortly. But, let us talk about the priest, who made outstanding fundamental work in cosmology,’ George said. ‘Lemaître had a rather unusual career, you know. Let me tell you about it briefly. To begin with, he attended a Jesuit secondary school and then he joined the Catholic University in Louvain to study civil engineering. In 1914, he interrupted his studies to serve as an artillery officer in the Belgian army during the First World War, winning the Belgian War Cross with Palms, Alfie. Somewhat like Hubble, I must say. Returning to the University, he received his doctorate in mathematics in 1920. Once again, he stayed away from academics, entering a seminary in Brussels. After a while, he was ordained a priest in 1923. He pursued his studies thereafter at the University of Cambridge, where he was initiated into modern cosmology by no less a person than Arthur Eddington. That is not all. Then he worked with Harlow Shapley at the Harvard College Observatory and spent some time at the Massachusetts Institute of Technology. And finally he returned to Louvain University in 1927, where he worked for the rest of his life until 1966.’

‘Quite a career,’ I admitted. ‘What were his contributions to cosmology?’

‘As I told you, theoretical cosmology had been confined essentially to mathematical modelling until Lemaître appeared on the scene,’ George explained. ‘It was Lemaître who combined the mathematical model with physics and proposed an astronomically realistic expanding Universe. Not only that, he was the first one to derive the Hubble Law, which he published in 1927, two years before Hubble’s article appeared. Unfortunately, his paper did not receive the attention it deserved. Now, here comes his novel idea that has now become commonplace. We know that the galaxies are rushing away or, equivalently, the Universe is expanding. If we can go back in time, we would find the galaxies closer to one another than they are now, right? If we continue this backward time travel, galaxies too would come closer and closer to one another. Finally, we would reach a point when all the galaxies, all the matter and radiation in the Universe, would be together. The universal expansion must have started from such a state. Lemaître called this state as that of the *primeval atom*. He even proposed that the Universe had a *fireworks beginning* for its expansion.’

‘Ah, that is the Big Bang! Everyone knows about it nowadays.’

‘Yes indeed. Once again, unfortunately, Lemaître’s work was not properly recognized as it ought to have been during his active career,’ reflected George. ‘But he will always be remembered as a pioneer of physical cosmology.’

‘George, there are some questions that are commonly asked. Maybe you can answer them for me at least,’ I ventured.

‘Of course, Alfie. Fire away,’ invited George.

‘First of all, we know that galaxies are flying away with phenomenal speeds as observed from the Earth. If they are indeed rushing away from *us*, are *we* at the centre of the Universe? Does the Universe have a centre?’

‘Ah, you have raised one of the central questions of cosmology, no pun intended,’ George raised his forefinger as if to illustrate the word *raise!* ‘That brings back the canon and his canonical principle, pun intended. In fact, it is known as the *Copernican Principle*. Look at the solar system. There is nothing special about the Earth or any other planet in particular. They are all the same. Consider the Milky Way, our galaxy. There is nothing special about our Sun or any other star. They are all the same. So, one assumes that there is nothing special about our galaxy either. All galaxies are the same. This universal sameness is tantamount to the Copernican Principle, a generalisation starting with the Copernican model of the solar system. To reiterate, on large galactic scales, the Universe possesses similar properties, or the Universe is *homogeneous*. There is one other property of the Universe that is important. Turn your telescope in whichever direction you like, you will find the same large-scale structure, be it the density of galaxies, or the number of radio sources, and so on. This is known as *isotropy*. Of course, isotropy is consistent with homogeneity. We shall see that the isotropy of the Universe raises some important questions in cosmology.’

George took a short breather before proceeding with his further explanation.

‘Hubble and Humason discovered that the galaxies were rushing away from us by measuring their redshifts, didn’t they?’ resumed George. ‘First, let us see the reason for this *cosmological redshift*. It is quite simple. Suppose some source in a far off galaxy emits light, which is in the form of a wave. As the wave travels towards us, the Universe keeps expanding. As a result, the wave that is embedded in the spacetime gets continuously stretched out. Therefore its wavelength increases and light turns redder. There you are, you have your cosmological redshift. Simple enough, isn’t it? As an approximation, the formula for this redshift goes over to Doppler shift. That is what the H-H pair used in their observations. However, later on with advanced measurements the full formula for the cosmological redshift became indispensable.’

‘All right, what comes next?’ I asked with increasing interest.

‘Let us move on then,’ proceeded George. ‘According to the Copernican Principle, one must find this recession of galaxies irrespective of where the observation is made from, may be from another galaxy. Perhaps by another H-H pair living in Andromeda, who knows? There is no centre from which the Universe is expanding. The common two-dimensional model to illustrate this basic phenomenon is a balloon that is being inflated. Mark points all over the balloon with your pen to represent the galaxies. Be careful, don’t puncture it. Now when you blow air into it, the dots will move away from one another, not from any central point on the balloon.’

I was careful enough not get caught in another reverie revolving around Ptolemy’s amusement park, where I had seen George’s balloon-analogy happening.

‘A three-dimensional analogy is that of a raisin cake, the raisins being the galaxies. As the cake rises in the oven, the raisins move away uniformly from one another,’ George added.

‘Although I love raisin cakes, let me get back to your balloon,’ I said. ‘I can easily visualize the balloon expanding into the surrounding space. How about the Universe? What is it expanding *into*?’

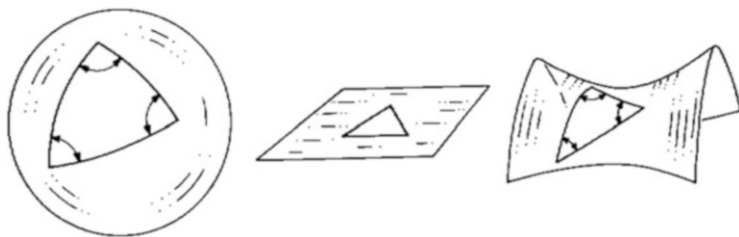
‘Aha, that is an oft-repeated no-no question,’ George shook his head. ‘There is nothing for the Universe to expand into. The three-dimensional space of the Universe is all there is. Think about some cosmologist-ants living on the expanding balloon. Unlike us, they are totally unaware of the third dimension. They will just say that their two-dimensional Universe is expanding—into what is a no-no question for them. So, don’t go mad, or madder than you are, trying to imagine a situation that does not—and cannot—exist.’

‘I recall what J. B. S. Haldane said about the Universe,’ I began.

‘For a change I know what he said: The Universe is not only stranger than we imagine, but stranger than we *can* imagine! Beautifully put,’ George completed the quotation.

‘Agreed,’ I said. Some people have the talent for expressing profound thoughts in the most telling ways. Haldane was one of them, I suppose. ‘Is there more to the homogeneity of the Universe than leading to the fact that there is no special cosmological centre?’

‘Yes, much more, and you anticipated what I was going to say next, as you often do,’ George went on to the next phase of the exciting story of the Universe. ‘The two properties, namely isotropy and homogeneity of the Universe turned out to be powerful tools in the hands of two mathematicians, the American Howard Percy Robertson and Arthur Geoffrey Walker of England. Just on the basis of these two fundamental properties, they showed that there were only three kinds of spatial geometries the Universe could possess. Here, let me show you the two-dimensional versions of these geometries. First you have the *elliptical space*, the surface of a sphere being the important special example. Then comes the *Euclidean space*, analogous to ordinary plane. And finally there is the *hyperbolic space*, saddle shaped or like a valley between two mountains. Forget not, Alfie boy, that the actual space is three-dimensional that cannot be, must not be, visualized. Incidentally cosmological models together bear the generic name in honour of the pioneers in the field: *Friedmann-Lemaître-Robertson-Walker Universe* or *FLRW Universe* for short.’



‘I realize that reducing the possible cosmological spaces into just three categories is a tremendous feat of simplification,’ I was truly impressed, even if the mathematics involved was way beyond me. ‘But tell me, which of the three spaces actually corresponds to the Universe we live in.’

‘Well that depends on the matter content of our Universe,’ answered George. ‘Let me explain. Take the average density of the Universe. You can estimate it if you know how many galaxies happen to be there in a given volume. This volume is obviously huge since we are talking about galactic scales. There is a critical cosmic density that generates the Euclidean space. If the actual density of the Universe is more than the critical density, you get the elliptic space. And less than the critical density, then the Universe would be riding the saddle—the three-dimensional cosmic space would assume the shape of the hyperbolic model. Got it?’

‘Got it all,’ I replied.

‘All right then. Now, there is an extremely important correlation between the geometry and the evolution of the Universe, you know.’

‘What is that?’ The whole cosmic story was getting curiozier and curiozier as Alice might have put it.

‘Both the plane and the saddle are infinite in extent and they keep expanding forever,’ George said. ‘But they do slow down at different rates. As the Universe expands relentlessly, the stars will die out, the temperature will keep diminishing. And the Universe will die out a cold death infinitely slowly.’

‘What a tragedy!’ I exclaimed ‘*This is the way the world ends, not with a bang but a whimper.*’

‘Aha, I know that famous quote from T. S. Eliot,’ said George triumphantly. ‘Let me tell you how the Universe can end with a bang. Let us take the third alternative, the spherical analogue. It expands, slowing down all the time. Again the Universe will cool down with the stars dying out. Then it comes to a halt, and starts collapsing. For a while the Universe will be like what it is now. Then the galaxies come together and merge. Stars will collide and explode. Finally the Universe will end in a *Big Crunch* with all the matter and radiation coalescing together. Then the Universe will explode with a Big Bang and the whole process will repeat again and again. You have now an *oscillating* or a *cyclic Universe*.’

‘Well, you have at least a chance of reincarnation in a cyclic Universe. That is some comfort,’ I commented. ‘By the way, how big is this critical density?’

‘You must say how small, Alfie,’ George replied. ‘It is of the order of 10^{-26} kilograms per cubic metre, an amazingly small number. That translates into, say, 6 hydrogen atoms per cubic metre.’

‘Good heavens, such a minute number would decide the spatial curvature of our entire Universe?’ This was incredible. ‘How do you find out which of the three kinds of the Universe we are living in? Is it by measuring the average density of the Universe and comparing it with the critical density?’

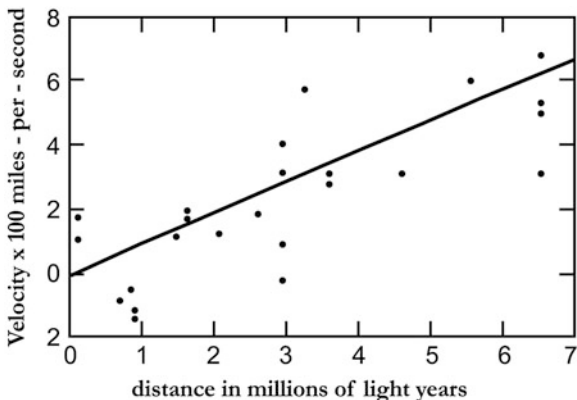
Questions came one after another in a natural sequence.

‘That is one way. It is not easy and there may be observational fine-tuning among the three alternatives, you know,’ answered George. ‘Another way is to find out the

rate at which the universal expansion is slowing down. The three models distinctly differ in their slowing down rates.'

'Can the Hubble Law give the answer to this question, George?'

'Yes and no,' smiled George. 'I shall explain those *yes and no* soon, fear not, Alfie. But first, let us take a closer look at that law. You see, Hubble and Humason's measurements were limited to galaxies that are comparatively close to us, even if millions of light years seem to be quite large. There is another complication with the velocities one measures for these galaxies. In general, galaxies have their own peculiar motions. For instance, the one in Andromeda is in fact moving towards us in addition to its cosmological recession. So, if the recessional velocity of a galaxy is not too high, its own peculiar velocity would be comparatively appreciable. As a result, the velocity measured may not follow the Hubble Law exactly. Take a look at this figure in the manuscript. It is the original Hubble plot showing velocities of galaxies and their corresponding distances. Do you see how those points are scattered? But look at the straight line drawn through them by Hubble showing his linear law.'



Yes, the points were pretty much scattered. But there was a bold straight line running in the middle of those dots showing the recessional velocities of galaxies as a function of their distances from us.

'We wouldn't allow any of our students to do any such thing with their experimental values and proclaim they have a linear law,' observed George. 'But Hubble was Hubble and he did it! Was it his intuition, conviction, or sheer audacity that drove him to draw that straight line, the simple straight line that governed the universal expansion? Who knows? Of course, as techniques improved, measurements went way beyond Hubble's observations on distances and velocities of galaxies. And the values that were obtained did lie along a straight line and showed that the velocities were directly proportional to the distances.'

'All right, the modern plot is a straight line,' I said. 'Then how can you tell which of the three cosmic models corresponds to the one we happen to inhabit?'

‘Aha, we come to the yes-or-no business on hand,’ George held up his forefinger. ‘Theoretically, one can compute how the Hubble Law graph changes with the three cosmologies. As I told you before, they give distinctly different rates of slowing down. On the other hand, even the modern Hubble plots based on observations do not shed any light on this. Why? Because, they are essentially just straight lines. In order to detect the actual slowing down, one has to make measurements on galaxies at enormously large distances. That also means galaxies far back in time. So, by comparing galactic speeds of way back in time with those that are nearer, or equivalently closer to us in time as well, one could determine the slowing-down rate. From this, one can deduce the curvature of the Universe. That is a tall order, Alfie.’

‘So, no one knows what sort of Universe we live in, is that it?’ I commented. ‘Ignorance is bliss. Ignorance on a cosmological scale is ecstasy.’

‘Ignorance comes in different shades, Alfie,’ responded George. ‘To get an idea of the slowing down of the Universe, or the *deceleration* of its expansion, one has to make observations on galaxies that are beyond 10 billion light-years. At such distances, those galaxies are so faint that uncertainties hamper the distance and redshift measurements. Yet, cosmological observations do indicate that we may be living in a spatially flat Universe.’

After a moment he added, his eyes shining mischievously, ‘Well, next time we meet, we shall talk about some dark secrets of the cosmos.’

I wondered what those dark secrets were. As I remarked earlier, this whole business with the Universe read like a suspense story. One should never turn to the last page to find out the ending. Then all the charm of reading the book is lost. Of course, we know that the cosmic saga has no ending. It is an ever continuing quest.

‘George, you explained how the three possible types of the Universe differ from one another in their slowing down rates,’ I said. ‘What about their origin? I mean do they all start expanding in the same way?’

‘Of course, all the three Universes begin their lives explosively with a Big Bang.’

‘All right, but how do you pin down that moment of creation of the Universe?’ I asked. ‘In other words, how do you determine the age of the Universe?’

‘Good question, Alfie,’ nodded George. ‘For that, we go back to the Hubble Law once again.’

‘Even if we try to shake off that Law, it follows us everywhere like a tail in a spy novel,’ I remarked.

‘Why don’t we work out the age of the Universe with some simple arithmetic, Alfie?’ invited George. ‘Let us make a simple assumption that the galaxies have been flying away from one another with constant velocities ever since the Big Bang. Take for instance our own Milky Way and any other galaxy. Then what would be the relation between the distance between them and the age of the Universe? Remember the age of the Universe is nothing but the time taken for the galaxy to reach its position now starting from the Big Bang.’

‘That is quite simple, George,’ I answered. ‘The distance would be the product of the recessional velocity and the age of the Universe.’

‘Excellent. But then, the Hubble Law tells us that velocity is proportional to the distance. The constant of proportionality is called, what else, the *Hubble Constant*, H_0 . Or equivalently, Hubble tells us that the distance between the galaxies is given by the velocity divided by his constant. But, just now you told me that the distance is nothing but velocity times the age of the Universe. Compare the two equations and, my dear Alfie, and tell me what would be the age of the Universe in terms of the Hubble constant.’

‘Let me see,’ I needed no more than a moment to come up with the answer. ‘*The age of the Universe T is just the reciprocal of the Hubble Constant H_0 !*’

‘Splendid. That is simple enough, right?’

‘Absolutely simple, George,’ I responded. ‘Now, two questions present themselves,’ I said. ‘First, why is there a subscript zero adorning the Hubble Constant?’

‘That is because the constant is supposed to have been measured *now*, at the present moment,’ answered George. ‘The constant need not be a real constant, but a varying quantity and H_0 is its present value. Also remember that the velocities are not constant either since the galaxies are supposed to be slowing down. What we have found out gives the simplest approximation for the age of the Universe as the reciprocal of the Hubble constant. But there are, of course, complications on both observational and theoretical fronts. Don’t strain your brain with these things, they might addle it even more than it is. All right, what is your second question?’

‘What *is* the age of the Universe? Did Hubble himself find it out too? And what is the modern value?’

‘I protest. You have asked three questions, not one,’ laughed George. ‘Hubble did estimate the age of the Universe from his observations. As we saw, the constant of proportionality he had determined was quite approximate and so was the age of the Universe he obtained. He estimated that the Universe came into existence some two billion years ago. This was quite an embarrassing situation. You know why? Because, by measuring the relative abundances of radioactive elements in the Earth’s crust, Lord Rutherford could fix the age of the Earth to be about three billion years. Furthermore, the oldest bacterial fossils have been found to be as old as three and a half billion years. Of course, we know that our Earth is around five billion years old. How could the Earth be older than the Universe? How could an egg be older than the hen that laid it? This was indeed a cosmological crisis!’

‘Well, Hubble’s estimate of the age of the Universe was much better than that of Archbishop Ussher, wasn’t it? Using the chronology found in the Old Testament, he fixed the moment of creation as nightfall preceding 23rd of October 4004 BC,’ I observed. ‘Of course the Archbishop’s finding was far more precise than Hubble’s. What do you think?’

‘These are high matters I don’t want to think about, Alfie,’ said George. ‘Coming down to Earth, as more accurate measurements were made, the age of the Universe was considered to lie somewhere between ten and twenty billion years. I leave the question of the most modern determination of the age in thrilling suspense till our next meeting.’

‘Thrilling suspense indeed, you mean excruciating anticipation,’ I grimaced. ‘All this is nice. But is there any evidence for the beginning of the Universe in a Big Bang?’

‘Yes, there is. The echo of the mighty explosion fills the entire space,’ George swept his hand to indicate all of our surroundings. ‘Of course that echo is not in the form of sound, but happens to be electromagnetic radiation. It is called the *Cosmic Microwave Background Radiation* or *CMB* for short. Let us first consider the genesis of this background radiation. Right after the Big Bang, the Universe was at an unimaginable temperature of some thousand trillion degrees. This *primordial fireball* consisted of nothing but radiation. Only during a long period of evolution, stretching over billions of years, atoms were created, stars, galaxies and planets formed, and finally life including humans emerged. What was the radiation doing in all this time while the Universe was expanding relentlessly? Think of radiation filling an enclosure that keeps expanding.’

‘Aha, we talked about the *blackbody radiation* in the context of the stars, didn’t we? The radiation cools down progressively,’ I recalled.

‘You are absolutely right,’ nodded George. ‘The phenomenally hot radiation that existed at the beginning of the Universe keeps cooling down. This radiation now permeates the entire space, the whole Universe, lurking in the background as CMB. Its discovery is a strange story in itself.’

George began recounting the story behind the discovery of CMB as he had termed it.

‘The year was 1964 and the place Holmdel, New Jersey, USA,’ George recalled. ‘Two astronomers, Arno Penzias and Robert Wilson, working at the Bell Telephone Laboratories’ Crawford Hill Laboratory, had built a large horn-shaped antenna. Their purpose was to observe and study the radiation emanating from a supernova remnant some 10,000 light years away. Their work was hampered by a constant noise that was proving to be an annoying nuisance. This unwanted hum seemed to be coming from every direction in the sky. The two astronomers couldn’t figure out the source of this continuous signal. They even cleaned up the white coating two pigeons had deposited within the big antenna and transported the pigeons far away, so that they would not return to the nest they had built within the antenna.’

‘Poor pigeons, they had been the true citizens of the Universe. Someone ought to have called the SPCA,’ I offered my opinion on the important matter.

‘Then CMB might not have been detected, Alfie,’ chuckled George. ‘To continue the story, the two astronomers realized that they had indeed detected some kind of genuine radiation coming from all directions. But, they had no clue as to its origin. It so happened that a group working at Princeton, almost right in the neighbourhood, not only knew what that radiation was, but were looking for it with their own equipment. Eventually, the nature of the crucial discovery became known to the concerned parties as well as to the rest of the scientific community.’

‘A happy ending indeed,’ I said. ‘Tell me more about this CMB.’

‘As we saw, the background radiation had originated from the time of the Big Bang,’ continued George. ‘As it had been in equilibrium within the primordial fireball, it had the typical black body spectrum. Remember, I showed you the

blackbody-radiation plots that displayed the peaks of the curves and the corresponding wavelengths for different temperatures? So, if you assumed that the newly discovered radiation was indeed of the blackbody type, then its temperature could be determined. It turned out to be around three degree Kelvin agreeing with theoretical calculations.'

George paused to give me time to soak in everything he had been describing.

'You know Alfie, often we theoreticians are ahead of our observational colleagues,' George said not without a tinge of pride. 'The possible existence of the radiation, remnant from the Big Bang, had been predicted by George Gamow, although his estimate of its temperature was somewhat higher than the actual value.'

'Ah, George Gamow the author of *Tompkins in Wonderland*,' I said. I had read and thoroughly enjoyed Gamow's writings.

'Gamow was a highly talented, witty, first-rate scientist who made important contributions to nuclear physics and cosmology. Well, more accurate measurements made by other astronomers at different wavelengths showed a perfect fit of observational data to the black-body spectrum corresponding to 2.73 Kelvin. Minor deviations from the black-body spectrum, genuine and not due to errors, are considered to be the signature of the emergence of structures in the early Universe leading to the formation of the galaxies. That is a whole different story, Alfie. I think we have talked enough about CMB.'

George pondered for a long moment.

'Another thing about the distant galaxies,' reflected George. 'Don't forget light takes millions and billions of years to travel from those galaxies to reach us. What does that mean? It means that we are seeing a composite of snapshots of the cosmos taken at different times, millions and billions of years apart. Think about that.'

Absolutely fascinating, I reflected. Everything about the Universe seemed to be strange. I remembered what Francis Bacon had to say about strangeness: *There is no excellent beauty that hath not some strangeness in the proportion*. By that token, the Universe did possess *excellent beauty*.

George pulled out a watch from an inside pocket of his jacket.

'Speaking of cosmic time, we have spent enough of it on a human scale, you know,' observed George looking at his watch.

I could see that the watch had been beautifully crafted and shone with an unusually soft sheen.

'Aha, you noticed my recent acquisition,' George said happily. 'It is a farewell gift from my colleagues at the university I was visiting. They say it is made of seven different metals with a dash of iron from a meteorite added.'

'I have heard that, once upon a time, swords of monarchs and sultans used to contain such meteorite metals to make the owner invincible,' I said. 'Maybe your watch will make you invincible in your fights with the faculty.'

'I hope so,' laughed George. 'Anyway, we have spent enough time today, Alfie. Next time, we shall move on to some really modern stuff including the surprise findings about the universal expansion.'

‘May I ask what surprise awaits me then?’ I asked knowing fully well what George was going to say.

‘Patience, my boy, all in good time,’ George’s answer was the usual one, not unexpected although disappointing. ‘Let us meet again here in my office. Then we can walk over to Bruno’s for his surprise dinner. Surprise will be the watchword of the day.’

I stuffed my bag with the books George was lending me, said goodbye to him, and was on my way home, happily whistling.

Chapter 16

The Cosmic Yin and Yang

I found George standing in his office, regarding with concentration two paintings propped up against the wall. Of course, they were reproductions. But nowadays with modern technology these reproductions are exceptionally true to the originals, bringing out their subtle nuances. I could easily identify them: *The Starry Night*, the famous painting by Van Gogh and *Philosophe en Lisant, Philosopher Reading*, by Rembrandt, exquisite works by the two masters, poles apart in their styles yet so effective.

‘My young colleagues in physics have launched a beautification programme in collaboration with the department of fine arts, you know,’ said George. ‘They want to put up some nice works of art along the corridor outside. And they have allowed us to select the ones we want across our own offices. And I have chosen these. What do you think?’

‘Excellent choice, George,’ I endorsed.

‘Let us sit down for a while, Alfie, and enjoy those beautiful creations,’ offered George.

George continued to gaze upon the paintings. I could see that he was pondering about other matters while admiring the two paintings in front of us.

‘Look at Van Gogh’s painting, Alfie,’ George broke the silence. ‘If you go too close to it, all you will see is nothing but the brushstrokes, lots of colourful, interesting details. Only when you stand back, would you see the whole picture with all the glowing stars and the swirling turbulence. It is the same with the Universe, isn’t it Alfie? There can be plenty of observational details, but only when you consider them from a distant perspective does the true aspect of the Universe emerge.’

‘What about Rembrandt?’ I queried.

‘Ah, Rembrandt, you don’t even see the brush strokes,’ commented George. ‘The whole canvas is filled with smooth, flowing vibrant colours against the rich dark background. That is what happens when one builds cosmological models. Galaxies are considered to make up the cosmic fluid described by their density, pressure, and velocity. It is just like a gas jar filled with gas—you don’t consider the

individual atoms and molecules, but just concentrate on the macroscopic properties. And the cosmological models constructed like this yield so much information.'

George paused allowing me to absorb the analogy. I found it not only lovely, but also very appropriate and effective.

'All right, where do we go from whatever we discussed last time?' George began. 'If I remember right, we talked about Hubble's law, which gives a linear relation between the galactic distances and their recessional velocities through the Hubble constant H_0 . In order to find out how the galaxies are slowing down, or decelerating, you have to compare their present velocities with their values way back in the past. How do you find out their velocities in the past? You find the velocities of galaxies that are far, far away. Since light from them takes a long time to reach us, we see them as they were in the remote past. In short, one has to make observations on galaxies that are as distant as possible, billions of light years from us. Is that clear, Alfie?'

'Yes, indeed,' I told George.

'As we have seen earlier, both Shapley and Hubble made use of Cepheid variables as their standard candles in respectively charting out the Milky Way and measuring the Universe,' George went on. 'Cepheid variables were quite adequate for the range of distances involved in their measurements. Although they are hundreds and thousands of times brighter than the Sun, they appear too faint if you want to make observations much farther. So, you need much brighter standard sources than the Cepheid variables.'

'Are there such stars with very high luminosities then?'

'Not ordinary or variable stars, but exploding ones,' said George. 'Remember, we considered Type Ia supernovae sometime ago? They are white dwarfs in binaries. When their companion keeps dumping gas on them, their masses keep increasing. When the Chandrasekhar limit is reached, they explode. The luminosities of these white dwarfs bursting out as Ia supernovae are the same since the conditions leading to the explosions are the same. They can therefore serve as standard candles.'

'How bright are they?'

'Well, they are some 100,000 times brighter than the Cepheid variables or around four billion times brighter than the Sun. So, you see, they can act as extraordinarily powerful standard sources for far-off cosmological measurements. But, there are problems.'

'There are always problems, I know. What are they?'

'Well, in the case of the Cepheids, they are always there waiting patiently to be observed. On the other hand, supernova explosions are naturally sporadic and unpredictable. You never know beforehand when they will occur. And where they will occur. You have to keep watching all the galaxies waiting for some fattening white dwarf to explode. But observational astronomers are quite diligent and smart enough to overcome these difficulties, so that these supernovae have indeed turned out to be reliable, bright standard candles.'

I realized that there must have been intense efforts and teamwork behind these findings. But, George was giving me a sweeping panoramic view of the Universe and details were out of place in his narration.

‘While there are problems, there are compensations too,’ reflected George. ‘There have been tremendous advances in technology, as you very well know. The good old photographic plates of Hubble’s time have been replaced by electronic detectors combined with computers. And then, one can make observations unhindered by the atmosphere with spacecraft carrying sophisticated telescopes like the *Hubble Space Telescope* or *HST*. What is the end result? Man’s reach into the realm of the galaxies has been extended as never imagined before.’

‘I remember Robert Browning’s quotation, George,’ I recalled. ‘*Ah, but a man’s reach should exceed his grasp, or what’s a heaven for?*’ It is so apt in this context, when astronomers keep aiming to extend the range of their observations all the time.’

‘I fully agree, Alfie. That quotation happens to be one of my favourites too, you know,’ responded George. ‘Well, we shall talk about the use of supernovae for cosmic explorations later on. For the moment, let us get back to the determination of Hubble’s constant and the age of the Universe. Suppose you repeat Hubble’s measurements on the Cepheid variables but now from the Hubble Space Telescope—how nice that the telescope too is Hubble. Now, you can look out to galaxies 25 times farther away than those that were accessible to him originally. There are some adjustments to be made in the data, but let us not worry about these details. The age of the Universe you get this way happens to be 13.6 billion years.’

‘So accurate?’ This was surprising.

‘Yes indeed, observational methods and theoretical calculations keep getting more and more sophisticated, and things get better and better’ said George. ‘However, you can take 13.6 billion years for the age of the Universe to be quite accurate.’

‘To quote good old Browning again, *Grow old along with me, the best is yet to be!*’ I repeated the well-known line. ‘I shall remember the age of the Universe as the lucky number 13 billion years!’

I must have told you before, maybe more than once, that George has the habit of leaning back in his chair, eyes closed, for a few moments before starting upon a new topic. That is what he did now.

‘Theoretical models of the Universe, like those with the three different spatial geometries, are like empty houses, Alfie,’ George began after his short spell of rest. ‘A house becomes a home with its own characteristics only when you fill it with suitable objects of your choice. It is the same with the Universe. Its properties including its evolution depend upon what it contains.’

‘You told me that the geometry of the Universe depends on the density of its contents,’ I recalled what I had learnt. ‘Below the critical density, the cosmological space is saddle shaped, above that density it is like a sphere, and if the actual density is the same as the critical value, then the Universe assumes a flat geometry. And the nature of the cosmic expansion is also decided by the geometry and therefore on the density.’

‘Excellent, you have it in a nutshell,’ approved George. ‘And how does one measure the density of the Universe?’

‘Oh, in principle, by adding up the mass of all the matter in a given huge volume—the sparkling stars, the glowing gases, and the shining galaxies. One can do that in different regions of space and get an estimate of the average density.’

‘Splendid, again. I like your adjectives—sparkling, glowing, and shining. In other words, we are talking about the *luminous matter* in the Universe. For a long time, it was only the luminous matter that held the attention of the astronomers. But the picture changed, when it was realized that the Universe harboured matter that was invisible, the *dark matter*, as it has come to be known.’

Yes, I had heard that term, the dark matter. One reads about such things in the newspapers nowadays, even if one does not get the real picture. Don’t ask me how one gets a picture at all if the matter is dark!

‘Dark matter does not emit light or any other electromagnetic radiation like radio waves. So astronomers cannot see it through their telescopes.’

‘Then how do you know it exists?’

‘Through its gravitational effects, Alfie. Gravity rules the world,’ said George almost triumphantly. ‘Let me explain the principle involved in hypothesizing the existence of dark matter. Suppose our Sun did not shine. Still, you could deduce its existence from the orbital motion of the planets going around it, can’t you? Suppose the matter contained in this dark Sun was spread out diffusely all over the solar system. The motion of any given planet depends upon the gravitational pull of the matter contained within its orbit. From this you can determine the total amount of the dark-Sun matter. Further, let us imagine that this invisible matter is mixed with some luminous matter as well. By studying the planetary motion, you find out the total mass involved. Deduct the visible portion, and, *voilà*, you have not only detected the invisible component, but also determined its proportion. Have I made myself clear so far?’

‘The answer to a redundant question is an emphatic yes,’ I nodded vigorously.

‘Fantastic—I am running out of my superlatives,’ smiled George. ‘Now, we move on from the hypothetical solar system filled with smeared out bright and dark Sun to our real Milky Way. Jan Oort, the famous Dutch astronomer, was the first one to point out the presence of dark matter in the Milky Way. One can compute the velocity of rotation of our galaxy as a function of the distance from the centre. But such a curve drawn from observations reveals that there ought to be more matter present than what is actually observed as luminous matter like stars and glowing gases. So this is the *dark matter*. As a matter of fact, the disk of our Milky Way seems to be cocooned within a large spherical halo of dark matter that extends beyond the visible part.’

As George and I had discussed, the expanding Universe alone was quite strange. But now, this dark matter was making it even stranger.

‘That is not all, Alfie,’ George went on. ‘There was this brilliant Swiss astrophysicist, Fritz Zwicky who worked at the California Institute of Technology or Caltech. He did extraordinarily original work, both theoretical and observational, in many fields including supernovae and neutron stars. Around the same time as Oort,

Zwicky too thought of dark matter to explain the orbital velocities of galaxies within clusters. This was truly a cosmic jump in the dark-matter scenario. Since then, lot of research has been carried out on dark matter. This invisible entity seems to pervade the entire Universe giving rise to many effects. For instance, dark matter can manifest itself through *gravitational lensing*.

‘Gravity acts as a lens?’

‘Yes, we saw how gravity bends light as per Einstein’s general relativity, didn’t we? Now suppose you have a far off bright source like a quasar. Let us have a galaxy between that quasar and ourselves. Then light from the quasar can be bent by the strong gravitational field of the galaxy coming to a focus at our telescope. Then we can see multiple images of the quasar. This has been observed. Now, replace the galaxy by the invisible dark matter. It will act as a lens, just like the galaxy, although you do not see it.’

‘Ah, a dark lens. Through a glass darkly, as the Good Book says!’

‘That is not all. Dark matter can play an important role in the structure formation in the early Universe leading to the birth of galaxies as well as their evolution. The imprint of dark matter on the cosmic microwave background, CMB, can be observed as small variations in different directions. These are *anisotropies* that may carry information on structures in the early Universe. So you see, Alfie, dark matter is of prime importance in cosmology. As a matter of fact, about 27 percent of the matter in the Universe happens to be dark. Isn’t that something?’

‘To say the least,’ I agreed. ‘But what is this dark matter made up of?’

‘One of your million-dollar questions as usual,’ George shrugged. ‘The obvious candidates were regular astronomical objects that are invisible, such as black dwarfs, neutron stars, and of course, black holes. But observations showed that they could form only a small fraction of the dark matter in the Universe. As a result, hypothetical particles have been considered to account for the dark matter, such as Weakly Interacting Massive Particles—WIMPS for short, axions, neutralinos, and so on. Let us not worry about them’

‘In short, nobody really knows,’ I remarked.

‘In short, nobody knows,’ echoed George.

Acquisition of cosmic knowledge seemed to have progressed at such different rates over time. Once, as in the case of the passage from myths to natural laws, it took centuries to make real progress. But in modern times, it seems that advances have been made in extraordinarily rapid succession. Or perhaps, bursts of enlightenment are always followed by periods of quiet exploration, who knows?

George was patiently watching me with interest as I was quietly musing to myself.

‘Are you ready for more dark at the end of the tunnel, Alfie?’ George broke the silence.

‘Yes, go ahead and reveal more of the dark secrets, George,’ I answered.

‘Well, after *dark matter* comes *dark energy*,’ proceeded George. ‘In 1998, one of the most unexpected observations was made, a real stunner. We saw how the supernovae of Type Ia could be used as powerful standard candles to observe really far off galaxies. We have often remarked that distance in space translates into

distance in time, the past that is. So observations were being made on galaxies as they were way back in the past, billions of years ago. Furthermore, their velocities could be determined from their redshifts. If they were slowing down, as everyone expected, the velocities should have been diminishing with time.'

'All this is clear enough. But where is the stunner?'

'They found that the Universe was not slowing down at all, but accelerating,' announced George in his dramatic manner. 'No one had expected this. After all, gravity pulls you back as it does in the case of a stone thrown upwards. How can it accelerate the expansion of the Universe?'

'I wait for the answer to your rhetorical question, George.'

'The answer to my rhetorical question is *dark energy*! While gravity is attractive, dark energy happens to be repulsive in its action. The negative pressure generated by it accelerates the expansion of the Universe. Moreover, observations indicate that this dark energy is homogeneous and constant in time.'

'You have essentially described the action of dark energy,' I observed. 'But what is the root cause of this elusive entity?'

'Elusive entity, that is the right description of dark energy,' said George. 'Let me give you a clue. What are the two important characteristics of dark energy? It is repulsive and, mind you, it is constant. Have we come across anything like?'

'Let me think,' I cudgelled my brains. Enlightenment hit me as it did when the apple is supposed to have fallen on Newton's head. 'Don't tell me it is Einstein's infamous cosmological constant, Lambda!'

'I tell thee that it is indeed the Lambda. But correction, not infamous but famous!' said George. 'We discussed the standard Friedman-Lemaître-Robertson-Walker universal models, didn't we? One can see theoretically that the lambda term can accelerate such a Universe if it is expanding and slow it down if it is contracting. Einstein's biggest blunder is the prime candidate for the dark energy!'

'You told me that dark matter makes up some 27 percent of the mass-energy in the Universe,' I recalled. 'How much of dark energy is there in our Universe?'

'Another surprise, it is about 68 percent,' smiled George.

'Dark matter and dark energy together account for, let me see, 95 percent of the mass-energy content of the Universe, while their luminous counterpart constitutes a paltry 5 percent!' This was incredible. 'This means that the *Yin*, the darker side, predominates way more than the *Yang*, the lighter side, in the Universe. I wonder what kind of coat of arms Niels Bohr would have designed had he known this!'

'Your thoughts go off in crazy directions, don't they, Alfie?' laughed George. He laughs easily as you might have noticed.

'All right, Alfie, we have covered enough of the Universe so far,' said George. 'I would like to wrap up things with one or two details. We talked about the *isotropy* of the Universe, didn't we?'

'Oh yes, the Universe looks the same in every direction of observation,' I recalled. 'Even the cosmic microwave background is by and large isotropic too.'

'That is right,' acknowledged George. 'Even if you look at two regions of the sky on opposite sides, one hundred and eighty degrees apart, they have the same features. This universal isotropy cannot be explained by the standard model of

the Universe we have been talking about. Those chunks far apart, as well as the others, haven't had a chance to interact with one another even with light or other kinds of electromagnetic radiation mediating between them.'

'Then how do you account for the isotropy of the cosmos?'

'Well, around 1970s and 1980s, a novel scenario for the evolution was proposed. It is known as *inflation*,' answered George. 'Let me briefly describe this inflation idea. The details are quite complicated. It was proposed that in the very early epoch the Universe expanded at a phenomenally rapid rate. Let me give you a rough idea of how fast this sudden expansion was. The size of the Universe is supposed to have blown up from below that of an elementary particle to the size of, say, a melon in an exceedingly minute fraction of a second. This process helped smooth out spacetime by making regions of space that were once close enough within the highly compact Universe to get mixed up with each other well. This way, the entire Universe would become homogeneous and isotropic as it is observed today. This is like kneading clay or dough thoroughly and then spreading it uniformly in every direction.'

'Sounds pretty remarkable,' I commented.

'Yes indeed,' agreed George. 'Inflation also solves the so-called *flatness problem*. We talked about the three generic shapes of cosmological space, namely those of a sphere, a saddle, and in between a flat plane. Our Universe seems to be essentially flat with the cosmic density being close to the critical value. The smoothening effect of inflation has also been shown to make the Universe flat. Another important feature of inflation is that it brings in quantum effects and particle physics into the fold of cosmology. Quantum fluctuations in the early Universe are supposed to have led to structure formation, which in turn generated galaxies. Obviously that is a very important aspect of the large-scale picture of the Universe today.'

At that point, both of us fell silent. I knew that George was tired. And I had plenty of information to digest.

'This much is enough for today, Alfie,' said George. 'Perhaps, during our dinner we will be able to discuss a bit of the most recent developments in cosmology. Of course, we won't dilute the pleasure Bruno has to offer.'

George got up and stretched.

'The Universe is not static and we shouldn't be either,' remarked George. 'Let us walk over to Bruno's, Alfie. I am sure his surprise dinner will be the grand finale to our cosmic journey.'

We left the physics department and strolled across the campus that had quieted down. Our walk towards Bruno's was a pleasure as our anticipation and appetite steadily built up.

Chapter 17

Food for the Future

I felt that there was something different this time, when George and I entered Bruno's. Usually, one of us would be already seated at our favourite table waiting eagerly for the other to arrive. This time we were both together. It felt a bit strange.

I was surprised to see that there was already someone sitting at our table. Instinctively, he turned around. I was elated to recognize the invader of our privacy. It was our good old friend, the young astronomer Mike Brown, flashing his ever-present boyish grin.

'Surprised, Alfie?' George too grinned. 'Yes, I invited Mike to join us for Bruno's special dinner. I wanted him to come down—how did you put it? Yes—from his mountain of meditation.'

Mike stood up as we strode towards our table. We happily shook hands.

'Hope we didn't keep you waiting too long, Mike,' said George.

'I wish you had, George,' replied Mike. 'I could have enjoyed another one of this delicious exotic drink,' Mike pointed to a tall glass in front of him. It contained a cloudy white liquid, which I could not recognize.

'What is it?' enquired George. 'Is it some kind of wine?'

'Search me, I don't know,' shrugged Mike. 'Definitely non-alcoholic. I asked the waiter. Either he didn't know or didn't want to tell me. Just smiled and left. Maybe Bruno will enlighten us.'

'Non-alcoholic! First, this guy Alfie turns me into a vegetarian. Now, Bruno wants me to be a teetotaler. What goes on here?' George spread out his hands in feigned helplessness.

One of the waiters brought two tall glasses of the cloudy white drink and placed them in front of George and me. He withdrew hastily before we could speak to him, looking at us from the corner of his eye with a hint of a smile on his lips.

I took a sip of the drink. It tasted smooth, gently sweet, soothing, and absolutely delicious. As he sipped, George's face brightened with pleasure.

'This is superb. I don't mind becoming a teetotaler after all,' said George and added quickly. 'Temporarily that is. But where on Earth is Bruno?'

As if in answer to George's query, Bruno appeared at the kitchen door, a serious expression on his face. I felt that he was leading someone else. But we could not see the person behind him, as Bruno's big figure covered our view.

Then things happened quickly. I could hear the tinkling laughter of the person following Bruno, taking me back a few years in time. Bruno moved away smiling. I watched George, gazing intently at what was happening in front of him. His expression went through a series of fast transformations—curiosity, incredulity, recognition, finally unbounded exuberant joy.

'Sunny, Sunny! My God, you gave me a heart attack,' George exclaimed holding out his arms.

Sunny, who had made a surprise appearance, ran into his arms. The two hugged each other for a long time. It was like a father greeting his daughter whom he had not seen in a long time.

'Surely you remember Sunny, don't you? Sunny is the short and sweet version of her longer name, Sunitha,' said George proudly. 'It was wonderful to have her working with me for her doctoral degree. And now she is a full-fledged faculty member at one of the top universities.'

Of course, I remembered Sunny and the other two graduate students of George. I had had a great time interacting with them.

Soon after this happy commotion had subsided, our attention turned to the young girl who had followed Sunny. She seemed to be in her early teens. She had lustrous skin, sharp features and her dark eyes shone brightly. She was carrying a guitar apparently with loving care.

'Meet my kid sister, Namratha,' announced Sunny. 'You may call her Nam to save time and energy.'

All three of us greeted Nam warmly.

'Well, Sunny, your sister seems to be fond of her guitar,' observed George.

'Yes sir, she is attached to her guitar or the guitar is attached to her. Both are the same according to relativity,' Sunny laughed. 'She used to be the lead-singer-guitarist in her group called *Nam's Nanosingers*. They even cut a disk, which became quite popular.'

Ah, I remembered the song with the title, *In the Darkness of the Rising Sun* about the atomic bomb that was dropped on Hiroshima. That song was extremely moving and I had included the lyric in the book *Einstein's Enigma*. So, this was Nam of that group! I told George and Mike about this. George, to whom I had quoted the text of the song, was quite impressed. Nam just smiled shyly.

'I am truly impressed, Nam,' acknowledged George. 'Sunny, your sister looks like she is still in high school, but she is already famous, what do you know.'

'Nam dear, why aren't you in school? Won't you be punished for being a truant?' Sunny shook Nam by her shoulders and laughed. She turned to us and said, 'Actually, Nam is well into her doctoral thesis in experimental biology. Nam, tell them about your research.'

'I am working on *prions*—proteins that have become delinquent—using yeast. The results of our research are expected to be important to humans too,' Nam was quite brief. 'My thesis will be titled, *East meets Yeast*.'

‘Amazing,’ said George admiringly. ‘I know Sunny’s father who is an astrophysicist like me. How come you chose biology as your subject, Nam?’

‘That is because our mother is a biologist,’ answered Nam. And then she added with a serious face, ‘Sunny and I have divided our parents genetically, our father following Sunny and our mother following me. They happen to be good scientists, as they have inherited our genes.’

‘Nam, you are impossible,’ Sunny burst out laughing. We couldn’t help joining her.

Bruno, who had disappeared for a while, came in carrying a tray with six glasses filled with the delicious drink we had tasted. He joined us at our table.

‘At last, the mystery will be solved,’ said George. ‘What is this unearthly drink of yours, Bruno?’

‘Ask, Sunny,’ smiled Bruno. ‘She got it specially for us.’

‘It is in fact a very earthly drink,’ explained Sunny. ‘It is tender coconut water.’

Ah, my memory went back to my sojourn in India. Yes, I had tasted the soothing drink taken down straight from the top of a coconut tree. A daredevil had climbed up the tree and had brought down a whole bunch of tender coconuts. With his machete, he had trimmed the top and had made a hole in the middle. I had drunk the water that was inside using a straw he had kindly provided for me.

‘I must go help Joe with cooking,’ Bruno went back to the kitchen after he had finished his drink.

‘All right, let us think of the Universe for a bit. It will build up our appetites,’ said George. He thought for a moment and added, ‘What about Nam? Won’t she be bored?’

‘If you are capable of explaining your Universe to a barmaid, you can explain it to a biologist,’ said Nam dryly.

‘Rutherford is supposed to have said the first half of that statement to Niels Bohr. How do you know that? Not many people have even heard about it,’ George was quite surprised and so was I.

‘It so happens that I have read *Einstein’s Enigma*, where it is mentioned,’ answered Nam. ‘In any case, Sunny will clarify later what I don’t understand. Maybe she will do a better job at it.’

‘All right Namms, you win,’ George was obviously quite happy with the girl. He turned to Mike and said, ‘Mike, you have been quite silent, you know. What is new with the Universe?’

‘I am a silent observer, George. I am enjoying myself,’ replied Mike. ‘What is new with the Universe? There is hot stuff coming out from the coldest part of the Earth.’

‘See Alfie, what happens to people in your presence? Even Mike has become mysterious,’ George unjustly admonished me.

‘Not being mysterious, George, but dramatic!’ Mike corrected George. ‘Recently, there has emerged extraordinary data from Antarctica about the early Universe. So you see, it is indeed hot stuff on the Universe coming from the coldest part of our Earth! This takes some explaining.’

Mike took a couple of sips of his tender coconut water before proceeding with his recounting of the new observations.

‘All right guys, I shall try my best to explain briefly the new observations that have excited all cosmologists. But, if you need more details, I am sure you can find them by yourselves,’ began Mike. ‘The observational equipment at the South Pole has been christened Background Imaging of Cosmic Extragalactic Polarization, or BICEP2, telescope. Cosmologists believe that when the Universe was incredibly young—a mere 10^{-35} second after the Big Bang—it underwent a period of extremely rapid expansion, known as *inflation*. That number indicating the infancy of the Universe translates to ten times trillion-trillion-trillionth of a second. At that time, the volume of the Universe shot up by a factor of up to 10^{80} in a tiny fraction of a second. Again, that number means 1 followed by 80 zeroes! One can’t even imagine such numbers, can one? Anyway, about 380,000 years after the Big Bang, the Cosmic Microwave Background or CMB—the thermal remnant of the Big Bang—came into being. Over the years, CMB has been studied extensively.’

‘Ah, George has told me about CMB, its discovery and its properties, as well as about inflation,’ I said.

‘I am sure he has, Alfie. And I am certain Sunny knows it all and will explain it to Nam later on,’ responded Mike. ‘Well, coming back to inflation, it solved several problems like the isotropy of the Universe and the fact that the cosmic space has a flat geometry. Not only that. The quantum fluctuations inherent to the inflationary phase are believed to have become the seeds for the growth of structure in the Universe—everything from stars to galaxies.’

‘All this is nice, Mike,’ interjected George. ‘But tell us what is relevant for flexing our BICEPs.’

‘Patience, man, patience, as you often tell Alfie here,’ smiled Mike. ‘Scientists also believe that rather extreme gravitational conditions prevailed during the Universe’s infancy. I guess you people know about gravitational waves. Well, primordial gravitational waves are thought to have propagated throughout the Universe during the first moments of inflation. This would have produced the so-called cosmic gravitational-wave background, or CGB, similar to CMB that came about later on. This gravitational-wave background would, in turn, have left its own unmistakably characteristic imprint on the polarization of the CMB. And it is this polarization that BICEP2 has been looking for. The whole experiment was like looking for a needle in a haystack. Such a finding, if firmly established, would be truly profound.’

‘This means that gravitational waves act as the brush that paints the portrait of the early Universe on the black canvas of the CMB,’ I summed up in my own style.

‘Quite a poetic description, Alfie,’ Mike nodded his appreciation. ‘Of course, as with all important discoveries, this one too ought to be confirmed independently by other experiments. And that has to happen in the future.’

At that point, Sunny and Nam got up without a word and disappeared into the kitchen.

‘Why did they go away?’ wondered Mike. ‘It is all so mysterious.’

‘It is a riddle wrapped in a mystery inside an enigma,’ I quoted Winston Churchill.

The riddle was soon unwrapped. The procession from the kitchen, now more or less in the reverse order in comparison to the earlier one, emerged from the kitchen. Nam followed by Sunny who led Bruno, Joe, and one of the waiters. Bruno was carrying a bottle of wine along with three glasses. Joe’s smile exuded satisfaction. I could not make out what the waiter was carrying on the large tray he was holding up.

Bruno placed the three glasses and the bottle on our table.

‘Aha, I am not being forced to be a teetotaler after all,’ George’s face lit up.

Bruno displayed the bottle for us to see. ‘Special wine from India made with Shiraz grapes, courtesy our two dear girls here.’

‘Exquisite,’ exclaimed George after tasting the wine Bruno had poured into our glasses.

‘Yes, there are people who grow grapes and make excellent wine in our own region in the southern part of India,’ explained Sunny.

‘Move over Bordeaux, here comes Bangalore,’ added Nam.

‘But why aren’t you two girls drinking?’ Mike asked.

It was Nam once again who answered Mike’s question in a thick outlandish accent. ‘We never drink.’ Pause. ‘Wine!’

‘Good heavens, that is Bela Lugosi from the movie classic, *Dracula*,’ recalled George laughing.

The waiter who had been watching the goings on with a smile placed on our table three plates holding the first course and withdrew.

I looked at the circular shiny brown dish folded in half, slightly puffed up probably because of some sort of filling. My taste-buds were immediately stimulated.

‘This dish is typically south Indian,’ Sunny explained. ‘It is called *masaalé dosé*. The batter is made with lentils and rice nicely fermented for a day or two. Please, don’t call it a pancake.’

‘Our *dosé* is thin, crisp, and can be folded, whereas a pancake is thick, soft, and refuses to be folded,’ added Nam.

George opened the *dosé* in front of him and looked inside. ‘Yes, the outside is glistening with shades of brown and it is delicately crisp. Look at the stuffing inside. Light yellow—looks like potato-based—sprinkled with green peas and pieces of red bell-peppers. A colourful feast for the eyes. And look at the little holes all over the outer shell, surely the result of fermentation.’

I had never heard George waxing so lyrical about food before. He took a piece of this exotic dish and closed his eyes in rapture.

‘This is heavenly, out of this world,’ exulted George. ‘If I were to choose only one dish to eat for the rest of my life, this is it.’

I agreed with George. And I could see from Mike’s expression that he did too.

‘Why aren’t you two girls joining us?’ asked George.

‘Chefs never eat their own creation,’ answered Sunny. ‘While helping Joe, who already knew how to make this dish, we nibbled quite a bit.’

Nam took up her guitar and started playing.

‘I shall first play some light Italian music in Bruno’s honour and a Spanish piece by Granados. I shall then move on to a melody in the Indian *raga* called *Bhairav* that has a touch of the middle-east.’

After we had finished the first course and the table had been cleared away, we relaxed for some time listening to Nam’s enchanting music.

After he had finished eating the first course, George asked almost like a greedy child, ‘May I have one more?’

Sunny replied in the manner of a stern mother, ‘No way, you will lose your appetite for the other courses to come.’

George pulled a long face and told Sunny, ‘As Macduff or MacDuck said to Lady Macbeth, cruelty thy name is woman!’

Before I could respond to George’s recently acquired habit of deliberately misquoting classics, Nam said without stopping her lovely music, ‘*Frailty, thy name is woman. Hamlet’s soliloquy, Act I, Scene ii!*’

‘How does the kid know that?’ George was genuinely surprised.

‘Among other things, Nam is into the theatre,’ said Sunny with pride.

‘Let us get back to the BICEP2 search,’ George picked up the thread of our earlier discussion after a pause. ‘Such observations would bring together so many features of our Universe. We have a whole range of phenomena—CMB the whisper from the Big Bang, gravitational waves that are yet to be observed by terrestrial detectors, inflation with its quantum fluctuations leading to galaxies that form the Universe. In a way, it completes the circle, doesn’t it?’

‘All those phenomena are macroscopic and classical except the quantum fluctuations,’ pointed out Sunny.

‘You are absolutely right, Sunny,’ acknowledged George. ‘Ah, the ever elusive quantum! Physicists have been trying to quantize gravitation for decades now without significant success. Gravity seems to be a tough customer. No one has been able to unify it with the other three forces in nature either—electromagnetic, weak, and strong.’

‘But why do you have to quantize gravity?’ I asked.

‘Why do we need quantum gravity?’ George repeated my question. ‘Well, Alfie, we have been talking about the Big Bang essentially beginning with the primordial fireball when all the matter and all the radiation in the Universe were confined to a small volume of extremely high temperature and density. But, theoretically one can go back in time even further and hit a point as the origin of the Universe. Mathematically, this point is known as a *singularity* where the curvature of the spacetime becomes infinite. Ironically, all the equations that dictated the evolution of the Universe starting from this point break down precisely around that point. That is disastrous to say the least. Physically, density and temperature too become infinite, since all the matter and radiation are now condensed to a point. That is disaster doubled.’

‘So, what is the solution to this cosmic devastation?’ I enquired.

‘The solution, my dear Alfie, is supposed to be provided by quantum gravity,’ answered George not without a hint of a smile. ‘Quantum gravity is supposed to

smear out the dreaded singularity within a radius of about 10^{-33} centimetre or so. That is the range within which the effects of quantum gravity manifest themselves.'

'Have the theorists achieved this process of smearing out?' was my natural next question.

'I am afraid not,' George shook his head. 'Until we have a definite theory of quantum gravity, this may not be accomplished. But physicists are heroically going about finding such a theory with partial success. Some claim that not only have they smeared out the singularity, but are able to connect our Universe to its phase earlier to the singularity.'

'St Augustine spoke of a scholar who asked the question: *What was God doing before he created Heaven and Earth?* The scholar himself answered the question: *He was preparing a Hell for those who ask such questions.*' I recalled from my memory.

'I now know where some of my friends doing quantum gravity are headed!' George commented with relish.

Ah, now for our second course, I thought as I saw the waiter making his way towards our table. This time, Sunny and Nam did not have to rush to the kitchen since everything seemed to have been pre-arranged.

'Our second offering is *pulao*, variously known as pilaf, pilav, pilau, plov, polu and palaw, depending on where it comes from,' announced Sunny. 'It is grainy *basmati* rice simmered to perfection in mildly spiced vegetable broth with several chunks of colourful vegetables added. It is served with a side dish of *mughlai kofta*, a special kind of fritter in a delicately spiced sauce, a legacy from the golden age of the great Moghuls. It has been specially adapted for vegetarians by using the rarest of rare ingredients, namely lotus root.'

Eyes closed, George savoured the combination of the two culinary delights and sighed deeply with supreme satisfaction.

'If this is the type of food they serve in India, then I shall go settle down in that country,' announced George.

'Please don't, you will be trampled by elephants,' warned Sunny.

'Bitten by king cobras,' added Nam.

'Run over by bullock carts. Although the bullocks have horns, they make no sound.'

'Yogis will force you to lie half naked on a bed of nails.'

'These kids are too much,' guffawed George. Sunny and Nam gave their tinkling laughter in unison. How could Mike and I not join those jolly three?

Once we had finished eating and the table had been cleared, we resumed our discussion again.

'I have a question or two for you guys,' I began addressing both Mike and George. 'Mike explained the BICEP2 experiment. Gravitational waves bring their messages from the early Universe and write them on the blackboard of CMB. That is really nice. But it is all about the past. What about the future? I mean the prospects of future research as well as the future of the Universe itself.'

‘Excellent question, Alfie,’ Mike nodded. ‘Let me go ahead as the harbinger, since nowadays theorists seem to be following in our footsteps. First of all, you have heard about dark matter and dark energy, haven’t you?’

‘Yes, George has told me those dark secrets of the Universe. But what about Sunny and Nam?’ I looked at the two girls who were eagerly following our dialogue.

‘Don’t worry about us,’ assured Sunny. ‘I know a bit of those secrets. I shall fill in the cosmic voids for Nam later on.’

‘Fine then,’ continued Mike. ‘At any given time, we cannot think too far ahead in time, can we? Now, some of the most important questions in cosmology centre around the observed acceleration of the Universe and its theoretical explanation. The dark energy responsible for this acceleration needs a lot more exploration. I don’t mean more of the same kind of observations that have been made, but vastly improved ones. For instance, the Hubble Space Telescope or HST has been doing a marvellous job in exploring the Universe. There has been a lot of debate as to whether it should be retired or rejuvenated. Hopefully, the capacity of HST will be enhanced and it will be able to aid, even if it is to a limited extent, the observations on distant galaxies. That could throw some light on the dark energy. That last bit of an oxymoron was spontaneous, not pre-planned.’

Mike chuckled before going on.

‘Probably, more important than extending the life of HST are new space missions that are being planned to push further our knowledge of dark energy,’ continued Mike. ‘For instance, HST’s worthy descendent is going to be the *James Webb Space Telescope* or *JWST* for short. It is a large orbiting telescope designed to make observations in the infrared frequencies. That is the spectral range in which high-redshift supernovae occurring in really distant galaxies predominantly emit their radiation. Ultimately, JWST is expected to replace HST. That is not all. There are plans afoot to design and look into the possibility of creating what is known as *SNAP*. That acronym stands for *SuperNova Acceleration Probe*. SNAP will be dedicated to the extensive study of dark energy. It is a very ambitious project indeed. The Probe will be equipped with a big telescope comparable to HST, a camera of the highest possible quality, and a spectrograph that can operate in the whole range of wavelengths from infrared to ultraviolet. It is expected to offer important information on some 2000 supernovae.’

‘Aha, two thousand is a magic number. That is about the number of galaxies Hubble happened to study,’ I observed. ‘All right, tell us about the discoveries that are expected to emerge out of all these high-powered space missions.’

‘Well, for one thing the acceleration of the universal expansion seems to be constant,’ answered Mike. ‘With more far-reaching and accurate observations, one can hopefully find out whether it is really a constant or whether it has changed in the past. Another important question is the combined action of the two dark opposing siblings—dark matter and dark energy. Dark matter attracts, while dark energy repels. Consequently, dark matter decelerates the universal expansion, while dark energy accelerates it. Was there a switch from one action to the other, from deceleration to acceleration? This is an important question the answer to which is

ardently sought after. In short, the future of cosmology promises to be quite exciting.'

Sunny, who had been listening intently, turned to George. 'So far so good with all the observations to come,' she commented. 'We theorists cannot sit quietly, can we? So tell us what is happening on the theoretical front.'

'I am sure you could have done the job yourself, Sunny,' George wagged his finger. 'All right, age before beauty. Let me do the honours. Now, as Mike pointed out, the acceleration of the universal expansion has been shown to be constant. That is one reason why Einstein's cosmological constant λ has been considered to be the prime suspect. Remember, Einstein disowned his baby when the Universe was discovered to be expanding and not static. This was in 1917, nearly a century ago. Since that time, the constant has had a varied life. Although Einstein rejected it, Eddington held on to it. As a matter of fact, he attributed the expansion of the Universe discovered by Hubble and Humason to the accelerating effect of the cosmological constant! But, many theorists wanted to abandon the constant, although some of them found it useful in building their cosmic models. Of course, now that constant has made a comeback in a dark disguise. Or, shall we say the ugly duckling has turned out to be a swan?'

'So it is all smooth sailing then?' I asked.

'To repeat the oft-repeated refrain, patience, Alfie, patience,' George laughed. 'Here comes the real big problem. For Einstein, λ was a mathematical adjustment to accommodate a static Universe within the framework of his general relativistic field equations. But what is its physical origin? Quantum field theorists have tried to generate the constant from the vacuum fluctuations. What we call vacuum is supposed to be seething with virtual particles that are continuously created and annihilated. The Russian physicist Yakov Zel'dovich had shown that these vacuum quantum fluctuations generated a constant energy equivalent to the cosmological constant. But it was 100 magnitude larger than what could be accommodated in a realistic cosmic model. That number happens to be around 0.7 or so. In 1962, Zel'dovich and his younger colleague Igor Novikov wrote: *After a genie has been let out of a bottle. . . legend has it that the genie can be chased back only with great difficulty.* Now with the dark energy stealing away the cork of the bottle, it looks like that the genie cannot be chased back into the bottle at all! How can one reduce the huge theoretical value of the constant to what has been observed? No one knows.'

'In other words, what cannot be cured must be endured, at least for the time being,' I said. 'Mike was talking about the possibility of the acceleration varying with time. What about that?'

'Well, an unvarying acceleration is supposed to be due to the cosmological constant as we have been saying,' George resumed. 'Theorists have been thinking of other alternative explanations for dark energy that accommodate a changing acceleration. For instance, one of them is *quintessence*, an invisible field that repels and therefore accelerates the expansion of the cosmos. Remember, in antiquity this term referred to the ether or the fifth element of nature together with the other four—Earth, fire, water, and air. The new quintessence can lead to varying cosmic

acceleration. Another possibility is the presence of an energy called *phantom field* whose density increases with time, causing an exponential cosmic acceleration. This would result in such a speed that it could break the nuclear forces in the atoms and end the Universe in some 20 billion years in what is termed the *Big Rip!*

‘What, in 20 billion years the Universe will be ripped off?’ I exclaimed. ‘What does that mean?’

‘Don’t ask me, it is all conjecture. I am just a down-to-earth theorist,’ answered George.

‘As Sherlock Holmes says: *Ah, my dear Watson, there we come to the realm of conjecture, where the most logical mind may be at fault,*’ I quoted.

‘Ah, my dear Alfie, write it down for me. I want to add it to my collection of quotations,’ said George.

‘You mean your bag of misquotations,’ I laughed.

Before he could protest, George was distracted by the sight of our smiling waiter marching towards us holding aloft his tray as usual.

There were five bowls, not three, in front of us.

‘Oh yes, we are joining you for dessert,’ Sunny informed us. ‘We would never dream of missing our favourite sweet.’

The small bowl in front of me contained two disks that looked like cookies soaking in thick, creamy milk coloured with saffron. There were slivers of blanched almonds and chopped pistachios floating around in the milk.

‘This refreshing delicacy is called *rasamalai*,’ Sunny explained. ‘*Rasa* means juicy and *malai* means cream. Let me not keep you from enjoying it by elaborating on the recipe. Just try it.’

George was already tasting a small piece of rasamalai along with the creamy saffron milk and pieces of nuts.

‘Oh, this is divine,’ sighed George.

Having tried a bit of my dessert, I fully agreed with George. I instinctively knew that so did Mike.

All of a sudden, Mike turned to me and asked, ‘By the way, Alfie, have you found a suitable title for George’s book?’

I was taken completely by surprise by Mike’s question to say the least. I had not given any thought to the task George had assigned me. Probably, it had been working in my subconscious for all I knew.

‘Oh, yes,’ I said without hesitation. ‘George, how about *Universe Unveiled?*’

‘Universe Unveiled, Universe Unveiled,’ George repeated the words as though he was turning around my proposed title in his mind. After a moment or two of thinking he said, ‘I like it, Alfie. It conveys everything I have tried to put into the book. Thank you, Alfie, thank you.’

Unbidden, words seemed to tumble from my mouth. ‘George you could also add the subtitle, *The Cosmos in My Bubble Bath.*’

‘What are you talking about, Alfie?’ George seemed to be startled by my suggestion. ‘Do you mean multiverse consisting of billions or even infinite number of Universes bubbling around? I don’t intend to include theories that have no contact with reality.’

‘I am with you, George,’ agreed Mike. ‘I am told that these hypothetical Universes cannot even be observed. As far as we observers are concerned, if they cannot be observed, they do not exist. They are not part of reality.’

‘Reality attained through observation,’ I pondered. ‘With all your hypotheses, theories, and philosophies, do you think you will ever reach ultimate reality?’

Surprisingly, the answer to my question came from Nam who said quietly, ‘Ultimate reality is the ultimate illusion!’

‘You said it Nam, you said it,’ George clapped his hands and laughed like a child.

At that moment, Bruno accompanied by Joe came over.

‘Is everything all right?’ asked Bruno.

‘All right? It has been a superb dinner, Bruno,’ complimented George as Mike and I nodded emphatically.

‘Inspired by Sunny and Nam,’ acknowledged Bruno.

‘The problem, Bruno, is how will you match this meal in the future?’ wondered George.

‘Maybe we will hire Sunny and Nam permanently and turn this into an Indian-Italian restaurant. How do you like that?’ smiled Bruno.

‘Excellent idea, do that,’ George immediately welcomed this novel idea.

‘Well, you people look cramped behind the table,’ observed Bruno. ‘We have created a nice little patio as part of our renovation. You could sit there and talk more comfortably, you know.’

Bruno led us to the lovely little patio outside the dining area. We found it most relaxing to unwind there beneath the cloudless night sky, a gentle breeze blowing in. We enjoyed the ambience, absorbed in one’s own thoughts. George sat in silence cradling his chin in his two palms. After a while he spoke up.

‘You know, we have been talking about the latest developments in cosmology and even its possible future course,’ George began. ‘Whatever has been happening with the Universe in the recent past as well as at present has been revealed by fabulous observations supported by brilliant theoretical ideas. But, as we have seen, those phenomena had their origins right at the beginning of the Universe. The Universe has evolved continuously over billions of years. But, the imprints of the initial conditions can never be erased away. And it is the same with cosmology.’

George paused. My mind went back to the day he had handed over the manuscript of his book. Whatever he had told me about cosmology at that time seemed like the prologue to his book. Now, he seemed to be delivering its epilogue.

‘All our fascinating discoveries in cosmology had their beginnings centuries ago. Cosmology too has evolved in all that time,’ George continued. ‘Let us not look down upon the ancient myths. They were the earliest attempts to explain what people saw in the heavens. Even then, the astronomers of antiquity were making their heroic advances into the unknown realms of the night sky. Then came Copernicus. How can anyone describe the complete break from tradition he made, a leap of imagination from appearance to reality? Human thought would never be the same after that. Think of all the pioneering discoveries made by giants like Tycho Brahe, Kepler, and Galileo. Again, how can one estimate the

contributions made by Newton? I am not speaking of his individual monumental discoveries, but his ushering in the age of universal laws, his setting science within the framework of mathematics. Of course, he was to find his match in Einstein. Einstein's general relativity, a unique stroke of genius, pervades every aspect of cosmology today. Even if his theory were to be superseded by another one, I don't think the basic tenets of his theory would ever be done away with. Einstein will always be reigning supreme.'

This time George paused for a longer while. He was perhaps pondering over the entire superstructure of cosmology. Every one of us waited in eager anticipation.

'I feel that whatever we have been learning about the Universe is like a story, a ballad, handed down from generation to generation,' resumed George slowly. 'But it is not exactly the same story. It changes continuously even if by minute amounts. The story we tell our children today will have changed by the time they relate that story to their children. That is what makes it so fascinating.'

George nodded a couple of times and went on.

'The study of our Universe is like a tree. We may see immediately only the fresh foliage adorning its top. But beneath it all are the old roots, the sturdy trunk, and the spreading branches. There may be other growths as well supported by that tree. Then again, all our explorations are made up of many strands of coloured threads weaving the grand tapestry of the cosmos. It is like separate streams, each starting from a different point, bringing its own riches, and finally merging with the vast reservoir of knowledge.'

George sat back, hands folded, eyes closed as though he had nothing more to say.

Sunny and Nam exchanged glances. Their minds seemed to work in unison. Nam started to strum her guitar rhythmically producing the same note again and again. I recognized what she was achieving remarkably well. Nam was simulating the repeating sounds of the Indian *ektara*, a single stringed musical instrument used by *Sufi* singers. The two girls sang together a folk song in an Indian language. After each line, they translated its meaning taking turns.

Listen, listen my friend! Listen, my beloved companion!

You are my mighty tree, I am your creeper

Entwined around your neck, I smile in happiness

Listen, listen my friend! Listen, my beloved companion!

My heart says you are the ocean and I your river

Making waves I wind my way to meet my love

Listen, listen my friend! Listen, my beloved companion!

The haunting soulful song ended with Sunny and Nam singing the last line in a long stretch that must have wafted far into the night carried by the gentle wind. It was a beautiful lyrical reflection of what George had been saying about the nature of the Universe.

The silence was absolute. I realized that Bruno and his crew had lined up behind us listening to the singing of the two lovely young girls.

Sunny and Nam got to their feet, rushed to George and each gave him a big hug. Then they started hugging everybody. And all of us began indulging in this mad and wonderful activity, everyone hugging everyone else, laughing and dancing.

When the tumult had subsided, George spoke up.

‘Bruno, my friend, how can I . . .’ George stopped seeing Bruno’s upraised hand. ‘All right, I won’t thank you.’

‘Come back soon, all of you,’ said Bruno with warmth.

‘Where are you two girls headed?’ asked George.

‘We are going back to our friends with whom we are staying,’ answered Sunny. ‘Nam and I will drop in at your office tomorrow.’

‘Do that girls, do that,’ said George and smiled at Mike. ‘I suppose I don’t have to ask about your plans, Mike.’

‘Yes sir, I go back to the Observatory, my mountain of meditation. My wild nightlife begins,’ said Mike.

‘As for you, Alfie, you must have finished reading the manuscript. Now, get ready to correct the proofs,’ smiled George. ‘Yes, we shall meet soon, very soon.’

As I walked home after that magical evening, I looked up at the stars above as I always do. They had never seemed brighter or happier.

Chapter 18

Far Horizons

Soon after reaching home, I looked through George's manuscript. Sure enough, the last chapter dealt with whatever George had discussed during the incredible evening. I quickly went over that section just to have all the ideas crystallized in my mind. Then, following George's example, sat back eyes closed, hands folded in my lap, just relaxing. But how long can one relax like that? I got up and picked up a note book in which I usually jot down interesting quotations I have come across.

As I thumbed through my book of quotations, I came upon the lines that had been penned by the poet Archibald MacLeish:

A small planet of a minor star at the edge of an inconsiderable galaxy in the immeasurable distances of space.

How can one even attempt to describe the vastness of our Universe? Awesome, infinite, unimaginable. . . what words can one use?

I came across several thoughts expressed by Blaise Pascal in his *Pensées* that were so apt in the context of our cosmos. I have often thought about the kind of emotions the expanse of our Universe would inspire. Wonder and awe no doubt, but here is what Pascal felt: *The eternal silence of these infinite spaces terrifies me*. Yes, it can be terrifying, especially when we consider our own place in space and time. Then again, Pascal ponders over this aspect of man's existence as well: *I find myself tied to one corner of this vast expanse, without knowing why I am put in this place rather than in another, nor why the short time which is given me to live is assigned to me at this point rather than at another of the whole eternity which was before me or which shall come after me*. What would we have gleaned about our Universe had we lived in another distant galaxy either way back in the past or far in the future? We do not know. Sitting in our own little corner of the Universe, we have been able to perform the incredible feat of learning so much about our cosmos stretched out in space and time. Underlying all our observations, all our ideas, all our theories is one most important ingredient: human thought. Perhaps, Pascal had the last word on that too: *Man is but a reed, the most feeble in nature; but he is a thinking reed!*

That sums up the basis of all that we know about the Universe and all that we will ever come to know.

Well, thinking makes one tired, doesn't it? So, off I go to my bathroom to have all my fatigue, both physical and mental, dissolve away.

The bubbles seemed to be in more profusion than ever. They were everywhere seemingly in competition to massage my body. That was normal, I would say. But strangely enough, there were also a number of them concentrated around my head gently caressing it. Those bubbles were not accompanied by sparkling specks or by swirling spirals. They were perfectly clear and almost transparent. This was a surprise.

'Surprised about the nature and distribution pattern of the bubbles, are we?' softly chuckled my bathtub, Khasbath. 'Well, your last thoughts happened to be about thinking, weren't they? Thinking about thinking, sounds strange, doesn't it, boss? But that is what some philosophers do and get paid for it too, don't they?' Another chuckle before moving on, 'Those bubbles today represent the thought process, boss. Look at them. They are clear like pure consciousness on which one's experience etches the thoughts. Like thought, they can expand. Look, boss, look. They interact, they merge, they produce other bubbles, all like thoughts. Some burst and go out of existence, just like the thoughts you have lost or dismissed.'

There was a long pause before the bathtub spoke again.

'All right, boss, enjoy your bubble bath. Let your thoughts take flight on the wings of fantasy. Yes, it will be an exciting journey.'

In the silence that followed, I closed my eyes and surrendered to the bubbles that would soon transport me to an entirely different plane of perception.

I could hear beautiful music emanating from somewhere nearby. Yes, I could recognize it. It was one of Mozart's violin sonatas. I soon came to the source of that music.

Eyes closed, a rapturous smile playing on his face haloed by wispy white hair sat the violin player. I gasped with astonishment as immediate recognition dawned on me. It was none other than Al, the owner of the little shop selling bathtubs among other things. Strangely, he looked exactly like the great man whom my bathtub keeps referring to as the Master. His first name too began with the two letters *Al*, did it not?

When the music he was playing ended, Al opened his eyes. His smile that greeted me was as always gentle and kind.

'I had told you that we would meet again, had I not? So, we meet again, my friend,' said Al happily. 'Oh yes, that was one of Mozart's violin sonatas I was playing. You know how I feel? I think that the music of Mozart is of such purity and beauty that one feels he merely found it—that it had always existed as part of the inner beauty of the Universe waiting to be revealed. It seems Mozart himself sometimes used to say that he felt like he was not composing so much as taking dictation. Dictation from whom, my young friend? From Nature, from the Universe, from God?'

‘Life without playing music is inconceivable for me,’ Al declared. ‘I live my daydreams in music. I see my life in terms of music. I get most joy in life out of music. I never go anywhere without my violin.’

After a somewhat long pause, Al looked up at me with an amused smile.

‘A little while ago, you were reflecting upon the act of thinking, were you not?’ Al obviously knew about my ponderings focused on Pascal’s *Pensées*. ‘You felt that the faculty of thinking was the supreme gift given to man that could unlock the secrets of the Universe, did you not? I perfectly agree with you. Please allow me to tell you my own experience in this important matter. Before I can explain, I must do something important too.’

Al started twirling a lock of hair on his forehead and said in broken English, ‘I vill a little t’ink!’

It seems that is how he spoke whenever he was confronted with some difficult problem to solve. On the other hand, I was sure that talking about thinking was no problem to him at all.

Al paused presumably recalling his past experience that had touched upon some aspects of thought.

‘Long ago, I was asked to write about my life under the heading, *Autobiographical Notes*. Let me quote the first sentence I wrote, *here I sit in order to write. . . something like my own obituary,*’ laughed Al. ‘That is how you feel if you were to write about yourself in your old age.’

Al drummed his finger on his chin before continuing.

‘It is best if I recount exactly what I wrote about the feeling of wonder one gets when looking at the world with fresh eyes,’ said Al and went on to quote further from what he had written in his *Autobiographical Notes*. ‘For me it is not dubious that our thinking goes on for the most part without the use of signs, or words, and beyond that to a considerable degree unconsciously. For how, otherwise, would it happen that we *wonder* spontaneously about some experience? This *wondering* seems to occur when an experience comes into conflict with a world of concepts which is already fixed in us. Whenever such a conflict is experienced hard and intensively it reacts back on our thought world in a decisive way. The development of this thought world is in a certain sense a continuous flight from *wonder*.’

A dreamy look came upon Al’s face.

‘A wonder of such nature I experienced as a child of four or five years, when my father showed me a compass. That this needle behaved in such a determined way did not at all fit into the nature of events, which could find a place in the unconscious world of concepts, I mean the effects connected with direct touch. I can still remember—or at least believe I can remember—that this experience made a deep and lasting impression on me. Something deeply hidden had to be behind things. What man sees before him from infancy causes no reaction of this kind; he is not surprised over the falling bodies, concerning wind and rain, nor concerning the Moon or about the fact that the Moon does not fall down, nor concerning the difference between living and non-living matter.’

There was a long pause before Al spoke again.

‘Let me tell you, my friend, what I might have experienced in the case of the Universe,’ said Al in a conspiratorial manner. ‘I just thought about it now, so I have never mentioned it before. When I considered the Universe as it had been known for ages, ever since the time of Aristotle, I thought nothing happened on a large scale. The Universe was static. So, I put in the cosmological term in my equations. That explained how one could build a model of the Universe in which nothing changed. This model belonged to the thought world. There was no *wonder* in it. Then it was discovered that the Universe was expanding! That was the moment of *wonder*. That magical moment was followed by more observations and more theorizing. Aha, that is what constituted the continuous flight of the thought world from wonder!’

I felt exceptionally privileged to hear the impromptu thoughts of Al that seemed to have been conveyed exclusively to me.

‘Enough of all this philosophical talk about thinking,’ Al held up his hand. ‘To quote the famous words of the Bard, *there are more things in heaven and Earth, my friend, than are dreamt of in your philosophy!* We shall meet again in a short while. Before that, you must go see my dear priestly friend, who is waiting for you.’

Lovingly, caressingly, Al picked up his violin and bow. He closed his eyes, and drew the bow long and soft on the strings of his violin as the silken sound emanating from it seemed to fill the entire Universe once again.

The man I saw now was smiling broadly as he read what looked like a letter. He was stocky, if not fat. He had a pink round face, which looked even rounder with his circular metal-rimmed spectacles on. His cheeks shone like polished apples. On the whole, his countenance made you feel that he was always happy and contented. He wore a tight black suit, waistcoat of heavy wool, and a high stiff collar. It was Georges Lemaître, to whom Al had referred to as his dear priestly friend. I recognized him from the photographs I had seen.

‘Ah, you have come here straight from your meeting with the great man. That must have been a wonderful experience.’

Lemaître removed his spectacles, polished them, pinched the bridge of his nose between his thumb and forefinger, and put on the glasses back.

‘You know, I had the good fortune of spending some time together with Albert Einstein, whom you met,’ recounted Lemaître. ‘This was at the California Institute of Technology, or simply Caltech, in the USA. That was a fantastic time for me. Einstein and I used to take frequent walks together deeply absorbed in our discussions. He was so famous that newspaper reporters always followed us at a distance hoping to get some story or the other. They joked that whenever the physicist—Einstein that is—and the priest—that is me—went for a walk, the *little lamb* followed them. The little lamb indeed! That was their short hand for the cosmological constant λ !’

Lemaître’s cheeks shone as he laughed heartily at his recollection and continued.

‘Yes, we did discuss the little lamb constantly. Einstein was willing to listen to me although he thought it was not needed at all, since the Universe was not static as he had imagined. Such rejection must have made the poor little thing quite sad.’

A big smile lit up Lemaître's face. I wondered what amused him now. All this was so interesting. This priest was so different from the serious Canon I had visited ages ago.

'In those days I used to smoke cigarettes, you know,' said Lemaître. 'As you perhaps know, Einstein used to smoke a pipe. His wife Elsa did not want him to smoke too much for the sake of his health. He was allowed only a small quantity of tobacco. So what does he do? He takes my cigarettes, opens them up, and fills his pipe with the tobacco he had pulled out from them.'

Lemaître laughed again shaking his head. He removed his glasses, wiped his tears of merriment, put back the glasses, and went on.

'Getting back to the lambda term, Einstein thought it was ugly. Maybe he felt that the little lamb was in reality a black sheep. Here, let me read from the letter he wrote to me.'

Lemaître picked up the sheet of paper he had been looking at with amusement before he started talking to me.

'It is dated September 26, 1947, quite late in the day when so much had already been discussed about cosmology,' Lemaître reflected. 'It begins with dear Professor Lemaître—that is me—thank you very much for your kind letter etc., etc. Here comes the last line of the first paragraph: *It is true that the introduction of the lambda term offers a possibility, it may even be that it is the right one.* Aha, the adamant man bends a bit, doesn't he? But he changes his tune immediately. Let me read what he writes in detail: *Since I have introduced this term I had always a bad conscience. I found it very ugly indeed that the field law of gravitation should be composed of two logically independent terms which are connected by addition. About the justification of such feelings concerning logical simplicity it is difficult to argue. I cannot help but feel it strongly and I am unable to believe that such an ugly thing should be realized in nature.*'

Lemaître put down the letter and shook his head. '*Ugly! Ugly* the famous man calls the poor little lamb,' laughed Lemaître. 'Often ugly things are quite useful, aren't they?'

'Well, it was discovered that the Universe was expanding,' continued Lemaître. 'I was able to build a model for it and realized that the Universe must have begun its expansion from a highly condensed state. I thought this was a cold quantum state, I mean a state completely described by quantum theory. However, I believed that the expansion must have started from such a state with some kind of fireworks. Yes, this was the *fireworks-origin of the Universe*. Well, the scientists who came after me have shown that the original state was not only extremely dense but also inconceivably hot, not cold at all as I had imagined. They called it the *primordial fireball*. And the explosion that triggered the expansion of the Universe is known as the *Big Bang*! Quite descriptive, though the violence of such an explosion is unimaginable. What is even more unimaginable is the fact that both space and time came into existence at the origin of the Universe.'

Lemaître's eyes sparkled as he added, '*It was a day without yesterday.*'

To think of space and time coming into existence at that moment! *A day without yesterday*—that was a lovely description indeed.

Lemaître was about to go on with his exposition. But he was surprised to find that Al or Einstein had quietly materialised beside him. I was astonished by his unexpected appearance too.

‘Go on, go on, don’t pay any attention to me,’ chuckled Einstein as he reached out and picked up Lemaître’s pack of cigarettes lying on the table. He pulled out a few of them, opened them up and filled his pipe with the tobacco he had extracted. Then he lit his pipe and puffed on it contentedly, listening and watching with a big smile.

‘See, what I told you? He is incorrigible,’ Lemaître shook his head.

‘Ah, you were talking about the Universe, were you not?’ Einstein’s eyes were shining. As he continued, he seemed to be speaking to himself forgetting the presence of others. ‘Astronomers have found out so much about our cosmos. I think that the most incomprehensible thing about the Universe is that it is comprehensible.’

Einstein pondered for a moment and declared, ‘I want to know how God created this world. I want to know His thoughts, the rest are details. I often wonder whether God had any choice in creating the Universe at all.’

‘Do you remember what Niels Bohr told you in 1927 during the Fifth Solway Conference?’ asked Lemaître with a gentle smile.

‘How can I forget what dear Niels said to me at that time? When I heard about Werner Heisenberg’s uncertainty principle, I commented that God did not play dice. Einstein, stop telling God what to do, Bohr reprimanded me.’ Einstein laughed boisterously.

At that moment, out of nowhere, appeared a strange figure. He was dressed like the legendary sleuth Sherlock Holmes. His clothes were the same as what Holmes is supposed to have worn—a long coat, cape, and a checked cap. Like Holmes, he was holding a pipe in one hand, while in the other he held a magnifying glass through which he was peering at the sky.

Both Einstein and Lemaître were perplexed to say the least.

‘*Lieber Gott*, it is none other than our friend, Eddington!’ exclaimed Einstein. ‘Why is he dressed like that? What is he doing? Is he trying to measure the bending of light in broad day light?’

Then Eddington spoke. ‘I am a detective in search of a criminal—the cosmological constant. I know he exists, but I do not know his appearance. For instance, I do not know if he is a little man or a tall man. . . The first move was to search for footprints at the scene of the crime. The search has revealed footprints, or what look like footprints—the recession of the spiral nebulae.’

‘I was quoting from the public talk I gave at the International Astronomical Union’s meeting in Cambridge, Massachusetts, in 1932,’ explained Eddington. ‘If the repulsion exerted by the cosmological constant could make the Universe static, why can’t it accelerate the Universe at the early stages and lead to the expansion observed by Hubble and Humason?’

‘Did you mention the possible accelerating effect of the constant lambda?’ Lemaître looked up at Eddington in surprise. ‘Well, the modern-day astronomers

have made a rather surprising discovery recently that may have some connection to what you just said.'

'What do you mean *recently*?' interjected Einstein. 'All things are relative you know. Especially time. *Ja, ja*, time is often the culprit as I discovered long ago. I shouldn't say *long ago* either, since time is relative. Anyway, tell us about the latest discovery of the astronomers.'

'As I was saying, astronomers have made an unexpected discovery. Actually a stunning one I must admit,' continued Lemaître. 'They were observing extraordinarily bright supernovae occurring in different galaxies that enabled them to estimate the distances to very far-off galaxies. That meant they were looking at those galaxies as they were way back in time. In the process, they found out that the expansion of the Universe is not slowing down at all. *It is actually accelerating!*'

'Good heavens, how can that be?' exclaimed Einstein. He seemed to be pretending to be surprised. But it was not convincing. 'What might be the explanation for this strange behaviour?'

'Well, they think that there must be some agency that is pushing away the Universe making it expand faster than believed earlier,' answered Lemaître. 'Some kind of force or some kind of energy must be responsible for this. They call it *dark energy*.'

'Earlier they had *dark matter*, didn't they?' said Eddington. 'Let us not take it lightly—no, I am not playing with the words *light* and *dark*. Those clever chaps can observe the bending of light by the dark matter. They are following in my footsteps, eh? Anyway, it is called *gravitational lensing*.'

'I see, in the beginning was dark matter and now this dark energy. Don't they know matter and energy are the same?' remarked Einstein and continued.

'I tell you what I think. They call them dark, because they are in the dark. I thought that God said *let there be light*, maybe the Devil countered Him by proclaiming *let there be dark!*' Einstein exploded with laughter and then added, 'Oh, I am sorry, I shouldn't be saying such things in the presence of a priest. In any event, I think it is the *dark age of cosmology!*'

'Here is something that should interest you,' said Lemaître, looking steadily at Einstein. 'One of the candidates for this dark energy is, hold your breath, the cosmological constant λ !'

'What do you know, the little lamb was not a black sheep after all although black and dark are closely related to each other! *Wunderbar!*' beamed Einstein. 'The biggest blunder of my life strikes again. I am having the last laugh after all.'

With that remark he threw back his head and burst out into his characteristic laughter. His whole body shook as he roared. The entire Universe seemed to vibrate with his booming laughter as it echoed from galaxy to galaxy.

'Well, my friends, Universe is boundless and so is its study,' commented Einstein recovering from his long laughter. 'There are far horizons in our cosmic knowledge. They keep receding as we move towards them. But then, that is what makes all our explorations so exciting, is it not?'

Then Einstein's visage took on a serene expression. He was looking far into space—perhaps beyond speeding swirling galaxies, beyond the Universe in its immense expanse.

Oblivious of the presence of his two colleagues, he whispered to himself, 'Out yonder there is an immense cosmos that stands before us like a great eternal riddle, at least partially accessible to our inspection and thinking. The contemplation of this cosmos beckons like a liberation.'

After a moment or two, he turned to his two companions, 'It is time to go, my friends. I think the others are waiting for us.'

The three of them gave me a warm smile and waved in a gesture of farewell. And they began to walk away chatting, laughing, and animatedly gesticulating. As they moved on some distance, I could see that there were three others who had appeared in front of them. I immediately recognized them: Humason passing his flask of Panther Juice to Hubble, while Shapley looked on with an amused smile. Slowly, steadily, more and more people started materializing and marching ahead. I could identify them all: a dignified lady holding herself erect, Miss Henrietta Swan Leavitt; in front of her, joyously holding hands, was the Herschel family; preceding the three of them were the four giants walking abreast—Tycho Brahe, Kepler, Galileo and, slightly apart from those three and absorbed in thought, Isaac Newton—following their great leader Nicolaus Copernicus; several steps ahead of them, the three astronomers of antiquity, Aristarchus, Aryabhata, and Omar Khayyam engaged in joyful conversation. I was thrilled to see that leading them all was Aristophanes accompanied by his chorus of frogs, hopping and frolicking as usual. I thought I could even hear at that distance the croaking of their quaint refrain.

That procession of some of the greatest contributors to the knowledge of our Universe marched on slowly, steadily, towards the horizon and faded away.

'That was some cosmic parade, boss,' I was woken up from my reverie by those words whispered by my friend, Khasbath.

The clear, transparent bubbles were feverishly moving around in the bathwater. That meant the thought process induced by them was still active.

'You are so fortunate, boss,' continued my bathtub. 'You were in the presence of the Master himself. He told you about his own thinking, didn't he? And you could participate in the great time those three wonderful gentlemen had together—the Master, the astronomer disguised as a detective, and the priestly cosmologist.'

I could not agree more with my bathtub.

'Well, it has been a long, tortuous cosmic journey we have taken, absolutely fabulous,' reflected my bathtub. 'When you started learning about the immensity of the Universe you said that it was—how did you put it?—*not the end, not the beginning of the end, not even the end of the beginning, but the beginning of the beginning!* So it is not the end of the road, boss. The quest goes on.'

Yes, the quest will go on. More and more knowledge of the Universe will be gained. But will I have an opportunity to learn it all as joyfully as I have been doing all these days? I would be missing that pleasure. That thought brought on a wistful feeling.

‘Are you feeling sad, boss? Whatever for?’ There was a mild reproach in the bathtub’s voice. ‘It is not over. There is so much to talk about. What about life beyond Earth? Are there living beings, even intelligent ones perhaps, lurking somewhere in the Universe? Maybe in another planetary system, in another galaxy, there is a boss taking bath in his beloved talking bathtub, who knows? Forget the Universe. What about history, philosophy, the workings of the inner spaces of the mind? There is no end to it, is there? No, boss, you will be learning about all this I am sure and we will be talking about whatever you have learnt and more. But for now, you are tired. Enjoy your bath for a while and then go to bed.’

The bathtub fell silent. I felt comforted and relaxed. I luxuriated in the still warm bathwater surrounded by countless bubbles. Then there was a sudden surge of those bubbles, a veritable explosion, and they swarmed all over me, pleasantly messaging every part of my body. Then slowly, gently, they melted away.

Having dried myself, I was about to move out of the bathroom. Then I heard the words distinctly.

‘Good night, boss,’ said Khasbath clearly. ‘Take care and may peace be with you.’

‘Good night, Khasbath, and peace be with you too,’ I answered.

I went to bed and fell into the most beautiful dreamless sleep ever.

Foundations of Facts and Fantasies

Please allow me to paraphrase what I wrote in *Einstein's Enigma or Black Holes in My Bubble Bath*. Often, written words form the foundation stones and the building blocks of all information and knowledge, imagination and fantasy. Don't you agree? No doubt I learnt a great deal about the Universe from my discussions with George and Mike. But, even they would have gathered their information and knowledge to a considerable extent from their study of books, articles, and original papers. Well, I too have benefited greatly from my own reading of several books and articles. What I learnt from them not only added to my understanding of the Universe, but also stimulated my imagination and, let me admit it, what may pass for my fantasies. I have listed below some of the books and essays I have read more or less in the order in which the contents of the present book unfold.

As you can see, the first book that appears in the list of books is *Einstein's Enigma*. After all, the present book happens to be, in some sense, a sequel to it. As a matter of fact, the Prologue is based on the first chapter of the previous book. Furthermore, there is inevitable overlap between the earlier parts of the two books that deal with the basic aspects of the Universe. I believe that you will find it rewarding and enjoyable to read *Einstein's Enigma*. Also, there are a number of books listed there that may prove to be of interest to you.

As in the case of *Einstein's Enigma*, many of the descriptions given by the past founders of cosmology as well as dialogues among them are based on their original writings. These appear in the fantasies induced by the magical bubble bath. I felt that it would be nice to create some poems and songs for the book: for instance, the lyrics for the chorus of frogs accompanying Aristophanes, translation of Aryabhata's original Sanskrit verse, and Omar Khayyam's impromptu quatrains. Likewise, I drew the cartoons in the book. I hope you found them enjoyable. The song towards the end of Chapter 17, *Food for the Future*, is based on S. D. Burman's haunting Hindi song, *Suno Mere Bandhu Re!* You can listen to it on You Tube.

Let me stop here. I am sure you have your own list of books that you have read and enjoyed. It is my ardent hope that you have now found more titles to add to that list.

I am so happy that you joined me on this joyous passage through space and time. As many wished me during the journey, farewell for now and may peace be with you. Till our worldlines meet again then!

List of Some Selected Books

- C. V. Vishveshwara, *Einstein's Enigma or Black Holes in My Bubble Bath* (Copernicus Books – An Imprint of Springer Science + Business Media, 2006)
- Roy A. Gallant, *The Constellations: How They Came to Be* (Four Winds Press, 1979)
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- Arthur Koestler, *The Sleepwalkers* (Penguin Books, 1982)
- Dava Sobel, *The Planets* (Penguin Books 2006)
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- Oliver Lodge, *Pioneers of Science* (Dover, 1960)
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- Galileo Galilei, *Dialogue Concerning Two Systems of the World: Ptolemaic and Copernican*, Stillman Drake (Translation), (University of California Press, 1967)
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- Dava Sobel, *Galileo's Daughter* (Fourth Estate, 1999)
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- William Stukeley, *Memoirs of Sir Isaac Newton's Life [1752]* (Taylor and Francis, 1936)
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- Isaac Newton, *Philosophiae Naturalis Principia Mathematica. The Principia: Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of the World*, Translated into English by Andrew Mott in 1729. Revised and supplied with an historical and explanatory appendix by Florian Cajori (University of California Press, 1946)
- Gale E. Christianson, *Edwin Hubble: The Mariner of the Nebulae* (Institute of Physics Publishing, 1995)
- Paul Arthur Schilpp (Editor) *Albert Einstein: Philosopher – Scientist* (Tudor Publishing Company, 1951)
- Albert Einstein, *Ideas and Opinions* (Bonanza Books, 1988)
- Philipp Frank, *Einstein: His Life and Times* (Jonathan Cape, 1948)
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Robert Frost, *Selected Poems of Robert Frost* (Barnes & Noble Books, 1993)

Sherwood Santos (Translation), *Greek Lyric Poetry* (W. W. Norton, 2005)

Acknowledgements

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As it always happens, I might have left out by oversight the names of others who have helped me during the preparation of the book. My sincere thanks are due to them, even if I do not know who they are at the moment.

And finally, I thank you, dear reader—whoever you are and wherever you are—with all my heart. Without you, what would be the use of this book?

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7. Tides	Vishveshwara, C.V. (2006), <i>Einstein's Enigma or Black Holes in My Bubble Bath</i> , Springer-Verlag, Berlin, Heidelberg	p. 41
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9. Dante's Cosmos	Drawn by B. Srikanth	p. 48
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About the Author

Specializing in Einstein's general theory of relativity, C.V. Vishveshwara has worked extensively on the theory of black holes, making major contributions to this exciting field of research since its very beginning.

After receiving his PhD from the University of Maryland, and subsequently serving on the faculties of New York University, Boston University, and University of Pittsburgh, he returned to his hometown of Bangalore, India, where he joined the Raman Research Institute as Professor and retired as Senior Professor from the Indian Institute of Astrophysics.

Besides being the author of a number of technical papers and editor of several books on relativity, astrophysics, and cosmology, Vishveshwara has written popular articles on various topics in science. During his tenure as the founder-director of Jawaharlal Nehru Planetarium in Bangalore, he produced many planetarium programmes. These programmes have proved to be exceedingly popular because of the simple and attractive manner in which difficult concepts have been presented.

Vishveshwara's cartoons have been published in journals and conference proceedings. He has drawn a few new ones for the present book as he did for his highly acclaimed previous book, *Einstein's Enigma or Black Holes in My Bubble Bath*.