

Preface to the Edition Published by Universities Press

The year 2009 was celebrated as the *International Year of Astronomy*. This was to commemorate the 400th anniversary of Galileo's pioneering observations with a telescope, observations that revolutionised man's perception of the heavenly bodies.

Four centuries later, we are in the midst of another golden era in astronomy. The advent of the space age has opened new windows to the Universe, resulting in spectacular discoveries and unprecedented progress in our understanding of the nature of celestial objects. At the same time, many new and outstanding questions have emerged. Indeed, there are clear indications that the resolution of some of these puzzles may require a major revision of fundamental physics itself. A deep connection between the *microcosm* and the *macrocosm* is becoming apparent.

This series of monographs entitled *The Present Revolution in Astronomy* is intended to convey the excitement of contemporary astronomy. The inspiration for writing these monographs was the enthusiastic response of the students who attended an intercollegiate course I taught for 5 years at St. Joseph's College in Bangalore. This course was not part of the regular academic curriculum, and was open to interested students and teachers from all the colleges in the city. Interestingly, more than half of the students in each batch were students of engineering, rather than pure science. And yet, they were fascinated by the lure of astronomy. Although the underlying theme of the course was *The Present Revolution in Astronomy*, my idea was to use astronomy as a *Trojan horse* to get the young students excited about the challenges that await them in the world of physics/astronomy, engineering and technology. It was the unanimous view of these students that I should develop these lectures into a series of books.

There is a second reason why I thought it would be worthwhile to write these books. Historically, astronomy has always had a great appeal among the general public. It is even more so today. The commissioning of new telescopes, and the discoveries made with them receive wide publicity in the print as well as the electronic media. Space Agencies like NASA, as well as leading astronomical observatories, have impressive Public Outreach programmes. And yet, here in India, hardly any of the universities offer astronomy as one of the subjects in the undergraduate curriculum. As a result of the lack of familiarity with the subject, very few students opt for a career in astronomy even though there are several truly

world class observing facilities in India. This series of books is intended to partly remedy this lacuna.

Now, a few words about the scope of these monographs and the style in which they are written. My primary objective is to introduce the reader, young and not so young (!), to the presently unfolding revolution in astronomy. We shall discuss the recent developments concerning a wide variety of topics: *the nature of the stars and their life history; the birth and death of the stars; the graveyard of stars—white dwarfs, neutron stars and black holes; galaxies; quasars; and the Universe at large.*

The monographs are not intended to be ‘textbooks’ in astronomy. Textbooks have to develop the subject in a pedagogical manner, dwell on the experimental methods and phenomenology, develop the mathematical aspects of the theory in a systematic manner, include problems and exercises, etc. While all these are needed to learn a subject seriously, conventional textbooks have a serious handicap. Introductory books ‘begin at the beginning’ and seldom convey the excitement surrounding contemporary developments. They tend to focus on questions that have been resolved, rather than highlight what is not known. In contrast, this series of books is intended to serve a different purpose. I hope they will give the reader an introduction to the recent developments, as well as highlight the outstanding and unsolved questions. I believe that a young reader would be more interested in the unsolved puzzles, for that is where the challenges lie.

The books have a very different flavour compared to the traditional astronomy books. For example, they do not discuss topics such as measurement of distances to celestial objects, determination of their masses, luminosities, etc. Nor do they dwell on coordinate systems to define their positions in the sky, the classification of their spectra, etc. While all these are ‘bread and butter’ issues, it is my view that a reader would learn these topics at a later stage in the normal course if he or she decides to become a practising astronomer. The emphasis in this series of monographs will be on physics, and for the following reason.

Among the many great discoveries made by Isaac Newton, perhaps the most profound was his assertion that *the Laws of Nature have universal validity*. In other words, the laws of physics that govern phenomena on Earth apply everywhere in the Universe. Today, we take this assertion by Newton as an axiom. Indeed, during the past couple of centuries, several seminal inputs to laboratory physics have come from astronomical observations. The discovery of the law of gravitation, emission and absorption lines in the spectrum of the atoms, the discovery of Helium, the first verification of the predictions of the Special Theory of Relativity and the General Theory of Relativity are some of the more important examples. This is not surprising. The range of densities, temperatures and pressure that are obtained in celestial bodies are staggering compared to what one encounters on Earth. For example, the densities range from 1 atom/cm³ to 10³⁷ atoms/cm³, and the temperatures range from 3 kelvin to 100 million kelvin—conditions that are hard for us to comprehend. Consequently, one encounters many new and exotic physical phenomena in celestial objects. Indeed, a few decades ago one would have said that *Astronomy is the home of physics*. Today, however, it would be more appropriate to say that *Physics is the home of astronomy*. We shall see the

reason for this paradigm shift as we progress in this series. Therefore, we shall concentrate on the physics of the celestial bodies—their nature, their stability, their central engines, their radiation mechanisms, etc.

Having stated the objective of this series of books, I must add that I do not assume any astronomical background from the reader. A knowledge of physics at, say, the *Halliday and Resnick* level would be quite adequate to get started. We shall develop the rest of the background as we go along. To meet the stated objectives, I shall often be required to sacrifice rigour in the arguments in favour of simple analogies and qualitative arguments. And I shall do so without any apologies! I shall consider my efforts worthwhile if these books manage to convey the excitement of contemporary astronomy. As for the younger readers, I do hope that these books will arouse their interest sufficiently enough for them to want to pursue the topics further by going to more learned books.

When I was young, I had the pleasure and privilege to read the marvellous books by great masters like Sir Arthur Eddington, Sir James Jeans and George Gamow, books in which they explained the developments in physics and astronomy in the early part of the last century. There are several recent books, written in a similar vein, by leading physicists and astrophysicists, of the present epoch. And then there is the 'Internet'! This series of monographs represents my very humble efforts in the same spirit.

This Volume

In the first volume in this series, entitled *What Are the Stars?*, I discussed the nature of the stars, their stability and the origin of the energy they radiate. One of the fascinating things about stars is that they evolve as they age. This evolution is different for stars of different masses. How stars end their lives when their supply of energy is exhausted also depends on their mass. This volume is devoted to a discussion of the evolution of stars and their ultimate fate. Historically speaking, astronomers first worried about the ultimate fate of the stars, even before the details of their evolution became clear.

I have divided this volume into two parts. The Part I is an account of the remarkable predictions made during the 1920s and 1930s concerning the ultimate fate of the stars. Since much of this development hinged on the emerging quantum physics, I have given a detailed introduction to the relevant physics. These topics will be useful to you should you decide to pursue studies in condensed matter physics, nuclear physics, astrophysics, etc.

Part II is a summary of the life history of stars. This discussion is divided into three parts: low-mass stars like our Sun, intermediate-mass stars, and massive stars.

As you read this volume, you will discover that much of contemporary astrophysics has been built on the foundations erected by Subrahmanyan Chandrasekhar in the 1930s. Since this volume has been written during his birth centenary, I have included in it a brief biographical sketch of Chandrasekhar.

Acknowledgments

The idea of this series was first suggested by the students who attended the intercollegiate course on astronomy and astrophysics that I taught for a number of years at St. Joseph's College in Bangalore. This suggestion was strongly endorsed by Dr. P. Sreekumar of the ISRO Satellite Centre. The enthusiastic response of the student community to the series of books entitled *Vignettes in Physics*, written by Dr. G. Venkataraman, as well as Venkataraman's eloquent and sustained persuasion that I should write a similar series on contemporary astronomy, gave me the conviction I needed to undertake this task. A further impetus came when the Jawaharlal Nehru Memorial Fund bestowed on me the *Jawaharlal Nehru Fellowship* in 2007 to get started on this project. In 2009, the Nehru Centre in Mumbai was very kind to give me a Fellowship for 2 years to continue with the project. I am very grateful for both these Fellowships. I started out as a condensed matter physicist, but later wandered into astronomy! My first introduction to astronomy came from my father at an early age. The inspiration to pursue it and the attempt to popularise it, came first from my illustrious teacher Subrahmanyan Chandrasekhar (at the University of Chicago), and later from Profs. Martin Rees (Cambridge University), Ed van den Heuvel (University of Amsterdam) and V. Radhakrishnan (at the Raman Research Institute, Bangalore). I am most grateful to them for having inspired me. I would like to express my special thanks to NASA, ESA, and the international astronomical fraternity for the many wonderful images reproduced in these volumes.

G. Srinivasan

Life and Death of the Stars

Srinivasan, G.

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