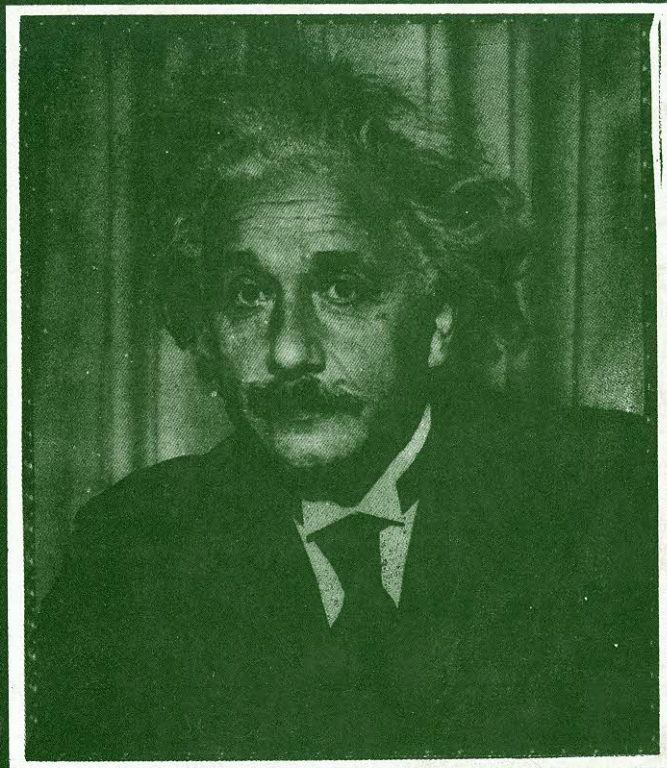


# 21st CENTURY ASTROPHYSICS



ap

*Editors*  
S K Saha  
V K Rastogi



## Preface

In the year 1905, Albert Einstein published four landmark papers, concerning (i) photo-electric effect for which he was awarded Nobel prize, (ii) Brownian motion, (iii) special theory of relativity that revolutionized physics, and (iv) the most famous equation of all time,  $E = mc^2$ . These papers, which appeared in *Ann. der Physik* provided the basis for fundamental developments of 20th century physics and of astrophysics in particular.

The year 2005 has been declared the 'World Physics Year' by UNESCO, the United Nations, and many national scientific and government organizations. It marks the centenary of these seminal papers. In this opportune moment, Anita Publications, (New Delhi) India takes pride in bringing out a book entitled, '21st Century Astrophysics'. We hope that this book will serve as an interface between the physicists and astrophysicists. Within a short span of time, we tried to collect a set of articles encompassing the fields of

- (i) relativistic astrophysics,
- (ii) stellar and galactic astronomy,
- (iii) Sun and solar systems, and
- (iv) observational techniques.

In 1930s, S Chandrasekhar in his answer to the question, 'what happens to a star once it has burnt all its nuclear fuel?', concluded that if the mass of the burnt core is less than 1.4 solar masses, which became known as the 'Chandrasekhar limit', the core ends up as a white dwarf. The core evolves to a neutron star if its mass falls between this and about 3 solar masses. Of course, beyond this limit, a black hole forms. This famous discovery of Chandra, for which he was awarded Nobel prize in 1983, marked the onset of the subject, called relativistic astrophysics. In this book, a few articles on dark matter, dark energy, and black-holes are devoted to this field. An enormous range of evidence indicates the presence of dark matter on all scales. Astronomical mass-luminosity (M/L) ratios on scales are larger than can be accounted for by visible stars and gas at any temperature and M/L increases systematically as one measures it on larger and larger distance scales. Blackholes are singularities in space time, in which gravitation dominates, while in a star, the gravitational force is balanced by gas and radiation pressure forces maintained by the nuclear reactions. In a white dwarf or in a neutron star, it is balanced by quantum degeneracy pressure. One of the papers also describes the mechanism of supernovae.

Stellar and galactic astronomy became rich in harvest by the development of observational techniques in the last century, particularly in the later half. In the last few decades, several large ground-based telescopes with sophisticated equipment came into existence. The subject has benefited by the development of large radio arrays as well; numerous radio galaxies were discovered. Moreover, space bound observations in X-ray and UV wavebands, are also in progress. Several articles dedicated to these aspects would provide a glimpse of the spectacular results that have been obtained so far.

Systematic observations of the Sun and the solar system have been going on since the dawn of the last century. They are observations of sunspots, flares, magnetic fields, prominences etc. These phenomena take place on the solar surface. It was impossible to gather any information until recently on the interior of the Sun, since photons takes hundreds of thousand years to get out from the dense and opaque internal layers. At the end of the twentieth century *in-situ* measurements were made possible by solar neutrino flux and helioseismology. Like in a musical instrument, waves are travelling in all directions inside its interior, from the deep core to the surface. They may be classified as acoustic waves, Alfvén waves, shock waves etc. depending on the restoring forces and other mechanisms that come into play. Several articles are dedicated to these aspects in the third section of this book. A short paper on cometary science also figures in this section.

An optical interferometer allows an astronomer to investigate stars with much finer resolution than the largest single-aperture telescope would. Several such instruments are producing results. The upcoming large facilities with phased arrays will provide larger collecting areas and higher spatial resolution simultaneously. And in the twenty first century, we may envisage the development of hypertelescope with a sparse array of many mirrors forming a directly usable image of a celestial object. An article on the prospects of developing extremely large ground based telescope array using the concept of hypertelescope is included in the last section. The photoelectric effect discovered by Einstein has revolutionized how ultra-sensitive light detectors can be conceived of and has led to a quest, through the 20th century (and still going on), for the 'perfect detector' which is asymptotically feasible. Light detectors based on the photon counting systems have been much used in astronomy; an article reviewing the history of such systems is also included in this section.

Our sincere appreciation to all the authors for their contributions. We are indebted to our colleagues who have spent their valuable time to go through these articles in order to improve the presentation.

We express our gratitude to Er A Goyal, Managing Director KPL, Noida, India, for his interest during the processing of the book. We would like to put on record our appreciation of the enormous help extended by Ms Surabhi Singhal, Mr. Jitendra Vats and Mr. Manoj during the preparation of this book. Ms A Singh, Managing Editor, Anita Publications, undertook the publication of this book at a short notice and extended all possible cooperation.

Mr. Sanjay Sharma (Balaji Offset, Shahdra, Delhi) devoted fully his time and energy so that the book could be published in time.

One of the Editor (V K R) is thankful to Prof. J-J Kim for extending all possible help during the first reading of the manuscript, while staying at KAIST, Korea.

S K Saha

V K Rastogi

December 30, 2005

The ideals which have lighted  
My way, and time after time  
Have given me new courage  
To face life cheerfully, have been  
Kindness, Beauty, and Truth.  
The trite subjects of human  
Efforts, possessions, outward  
Success, luxury have always  
Seemed to be contemptible.

—Einstein

# 21st Century Astrophysics

## CONTENTS

Preface

### Section 1. Relativistic astrophysics

Dark matter: past, present, and future 1  
*Virginia Trimble*

The cosmological constant as a unifying link 16  
*C Sivaram*

Black hole accretion as black hole analogue 26  
*Tapas Kumar Das*

Theory of the thermonuclear supernovae 51  
*Peter Höflich*

### Section 2. Stellar and galactic astronomy

The coming of age of X-ray astronomy 70  
*K P Singh*

X-ray studies of active galactic nuclei 90  
*Poshak Gandhi*

Asymmetries in powerful extragalactic radio sources 108  
*Gopal-Krishna and Paul J Witta*

Spatio-kinematic studies of galactic planetary nebulae 134  
*B G Anandarao*

Recent results from the Be prototype star gamma Cassiopeiac 149  
*Ph Stee*

### Section 3. Sun and solar systems

Helioseismology 163  
*Eric Fossat*

Intense magnetic fields in the atmosphere of the sun 177  
*S S Hasan*

Hall-magnetohydrodynamic turbulence 196  
*V Krishan and S M Mahajan*

Magnetohydrodynamic waves in the solar corona 213  
*A Satya Narayanan and R Ramesh*

Comets and scientific method 224  
*Peter B Fellgett*

### Section 4. Observational techniques

From interferometers to hypertelescopes 228  
*Antoine Labeyrie*

100 years of photon-counting: the quest for the perfect eye 237  
*Sébastien Morel and Swapan K Saha*