Preface

The branch of high energy astrophysics that studies the sky in energetic γ-ray photons – *gamma-ray astronomy* – is destined to play a crucial role in the exploration of non-thermal phenomena in the Universe in their most extreme and violent forms. The great potential of the discipline allows an impressive coverage of a diverse range of "hot topics" in modern astrophysics and cosmology, in particular (i) the origin of galactic and extragalactic Cosmic Rays, (ii) acceleration and radiation processes in extreme astrophysical conditions, e.g. in pulsar magnetospheres, in the vicinity of accreting black holes, in relativistic outflows like the quasar jets and the pulsar winds; (iii) the nature of enigmatic transient phenomena like the γ-ray bursts (GRBs); (iv) cosmological issues connected with the diffuse background radiation and intergalactic magnetic fields; the search for dark matter in the form of WIMPs through their characteristic annihilation radiation, and tests of non-acceleration ('top-down') scenarios for the production of the highest energy particles observed in Cosmic Rays, *etc.*

The results from the Compton Gamma Ray Observatory (GRO) have confirmed a number of these prime motivations of gamma-ray astronomy. Many classical representatives of different galactic and extragalactic source populations, e.g. pulsars, supernova remnants, giant molecular clouds, quasars, which were predicted as potential MeV/GeV γ-ray emitters, are now among the almost 300 γ-ray sources detected by EGRET, and approximately 30 sources detected by COMPTEL. The nature of most of these sources remains, however, unknown. Moreover, the origin of γ-radiation from even firmly identified objects is poorly understood. This clearly justifies future gamma ray missions with new generation detectors like the Gamma-ray Large Area Space Telescope (GLAST). GLAST, with its advanced performance, has been carefully designed for deep surveys of the

sky in γ-rays with an ambitious aim of providing *"γ-ray astronomy with thousands of sources*" in the energy region from tens of MeV to 10 GeV. Also, since most EGRET sources do not exhibit spectral cutoffs in the 1-10 GeV region, the extension of their study into the unexplored region beyond 10 GeV is another important issue for the GLAST. Meanwhile, the area limitations of space-borne detectors compels the study of Very High Energy (VHE) photons above 100 GeV to remain (except for the specific topic related to the diffuse extragalactic γ-ray background) the domain of ground-based gamma-ray astronomy.

The recent exciting observational results and theoretical predictions supply a strong rationale for the systematic study of primary γ-radiation in the VHE domain. Further improvement of the detection technique will be linked to stereoscopic observations of air showers with imaging Cherenkov telescope arrays with energy thresholds as low as 10 GeV, angular resolutions better than a few arcminutes, and flux sensitivities approaching to $10^{-13}\,\mathrm{erg/cm^2s}$. This will elevate the status of the field, which currently can be characterised as an *"astronomy with a few sources"*, to the level of truly *observational* discipline.

The further study of the sky in high energy γ-rays promises a new path towards understanding of the non-thermal phenomena in the Universe. It is expected that with forthcoming powerful space-borne and ground-based detectors, gamma-ray astronomy will enter a new era with an objective of providing crucial insight into a number of fundamental problems of astrophysics and cosmology. This necessitates a comprehensive discussion of major motivations and objectives of this rapidly developing field.

When writing this book, I tried to highlight the principal objectives of the field, as well as to demonstrate its relevance and links to other branches of Astronomy and Cosmology. Preference has been given to three topical areas - the *Origin of Cosmic Rays*, the *Physics and Astrophysics of Relativistic Jets*, and *Observational Cosmology*. One chapter of the book is devoted to the discussion of principal γ-ray production and absorption mechanisms, with emphasis upon the processes that play dominant roles in the high and very high energy domains.

The chosen topics are among the scientific interests of the author. Also, a substantial part of the book is based on my own studies performed in close collaboration with my colleagues. Many results and conclusions reflect, to a large extent, my understanding of the subject in general, and my assessment of the achievements, as well as existing difficulties, ambiguities and "nasty problems" of the field. Therefore I cannot exclude a somewhat subjective

(but hopefully not completely wrong) character of some parts of the book concerning both the interpretation of observations and the preference given to certain methods and approaches in phenomenological and theoretical studies.

This book would have not been possible without intensive collaboration with my co-workers. Also, I have profited and learned a lot from discussions with numerous colleagues working in the field of high energy astrophysics. Special thanks must go to Armen Atoyan and Paolo Coppi for many years of fruitful collaboration. I am indebted to a large number of friends and colleagues for their invaluable contributions to the different aspects of our joint projects in several areas of high energy astrophysics: C. Akerlof, S.Bogovalov, J. Cronin, L. Costamante, E. Derishev, L. Drury, G. Heinzelmann, W. Hofmann, D. Horns, T. Kifune, S. Kelner, J. Kirk, H. Krawczynsky, A. Plyasheshnikov, G. Rowell, V. Sahakian, D. Schramm (deceased), R.A. Sunyaev, T. Takahashi, A. Timokhin, Y. Uchiyama, V. Vardanian (deceased), H.J. Völk. Finally, I am grateful to Phil Edwards for his careful reading of the manuscript and important comments.