Preface

High-energy astrophysics is a very poorly defined field. The energy of the photons emitted by a system is neither a necessary nor a sufficient consideration to determine whether the study of the system should be part of high-energy astrophysics or not. Indeed many topics studied with radio astronomy techniques traditionally belong to high-energy astrophysics, while the interior of stars, where the temperatures are very high, is excluded. The domain is essentially defined by tradition, a slightly awkward concept for a field that is only a few decades old.

High-energy astrophysics is a very lively part of astrophysics. This is due to the fact that the subject only really started after the beginning of the space age, in the 1960s. It is only then that astrophysicists could place their instruments outside the atmosphere that blocks nearly all radiation except for some windows in the visible, infrared and radio parts of the electromagnetic spectrum. The very unexpected discoveries of the first X-ray sources (outside the Sun) from space led to the very active development of a succession of ever more sophisticated instruments, firstly on rockets, and then satellites, that were to cover the electromagnetic spectrum from the very far infrared (with the Herschel mission) to high-energy gamma rays (with the Fermi telescope). The most powerful instruments in the X-ray and gamma ray domains include XMM-Newton, Chandra, INTEGRAL and Fermi. The first two are large X-ray telescopes, one specialised in imaging (Chandra) the other in spectroscopy (XMM-Newton). INTEGRAL is sensitive above a few keV and up to some MeV. However, other observational tools in all domains of the electromagnetic spectrum are used in high-energy astrophysics, including optical, infrared and radio telescopes. Since 2005 or so very high-energy gamma ray astrophysics, in the GeV–TeV parts of the photon spectrum, has seen some remarkable successes with the discovery of many tens of sources.

High-energy astrophysics has unveiled a Universe very different from that only known from optical observations. Objects emitting most of their radiation in the optical domain are dominated by thermal emission with temperatures of a few to several thousand degrees. These are stars, and collections of stars, mainly in the form of galaxies. The evolution of these objects happens on timescales given by

E/L, where E is the energy available in the form of nuclear fuel and L is their luminosities. The typical time scales resulting from this consideration are measured in millions to billions of years. In contrast, high-energy astrophysics has revealed many types of objects in which typical variability timescales are as short as years, months, days, and hours (in quasars, X-ray binaries, etc.), and even down to milliseconds (in gamma ray bursts). The sources of energy that are encountered are only very seldom nuclear fusion, and most of the time gravitation, a paradox when one thinks that gravitation is, by many orders of magnitude, the weakest of the fundamental interactions.

The understanding of the objects revealed by high-energy astrophysical observations in the last decades, of the physical conditions met in these objects, and of the physical processes at work in these conditions are nowadays part of the culture of astrophysicists. High-energy astrophysics is not only specialised knowledge for those active in the field, but it is also relevant for those active in other domains of astronomy. This book aims at presenting this scientific culture for astronomers of all domains and at providing those intending to be active in high-energy astrophysics a broad basis on which they should be able to build the more specific knowledge they will need. It is also hoped that the book will help students in recognising physical processes when they are revealed by observational signatures in contexts that may differ widely from those presented here.

Since the general subject is ill defined, the author enjoys a large freedom in the selection of topics discussed. The choice of subjects treated here is therefore rather subjective, and others would certainly have made different choices. Mine are the result of my own curiosity over the years.

This book evolved from lectures given to masters and Ph.D. students at the University of Geneva since the early 1990s. The book has two main parts. In the first part we start from the physical process, e.g. an emission process, discuss it, try to lay down the physics involved, and then proceed to present one example in which the process is at work in nature. In the second part, we take an opposite view and start from a type of object (e.g. X-ray binaries) and proceed to understand their nature as far as possible. While there are no dedicated instrumentation sections, some observational techniques and instruments will be introduced as we proceed.

As far as possible we aim at being self-contained. This involves following rather closely some parts of classical textbooks, which is an option preferred to trying to re-invent the derivation of classical results, almost certainly less well than available already. This is acknowledged in the bibliography section of the corresponding chapters. The text is intended for readers close to the end of a master's course or early in a Ph.D. programme in physics or astronomy.

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