High energy astrophysics is one of the most exciting areas of contemporary astronomy, covering the most energetic phenomena in the universe. The highly acclaimed first edition of Professor Longair's book immediately established itself as an essential text book on high energy astrophysics. In this complete revision, the subject matter has expanded to the point where two volumes are desirable. In the first a thorough treatment is given of the physical processes that govern the behaviour of particles in astrophysical environments such as interstellar gas, neutron stars, and black holes. Special emphasis is placed on how observations are made in high energy astrophysics and the limitations imposed on them. The tools of the astronomer and high energy astrophysicist are introduced in the context of specific astronomical problems. The material in Volume 1 leads to a study of all kinds of high energy phenomena in the Galaxy and the universe, given in the second volume.

This book assumes that readers have some knowledge of physics and mathematics at the undergraduate level, but no prior knowledge of astronomy is required. The pair of books covers all aspects of modern high energy astrophysics to the point where current research can be understood.

High energy astrophysics

Volume 1
Particles, photons and their detection

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Second edition

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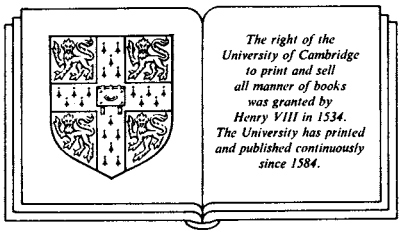

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For Deborah

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Preface

It is a pleasure to produce a second edition of *High energy astrophysics*. Writing the first edition was great fun and it corresponded rather closely to the lecturing style in which I had presented high energy astrophysics in the period 1973–7. Although I updated the material of the first edition to 1980 when the manuscript was sent to the press, it still remained in essence a lecture course. The reception of the book was encouraging and the time is now ripe for revising the contents considerably in the light of more recent developments and of changing perspectives about what should be included in an introduction to high energy astrophysics.

In preparing the revised edition, I have aimed to include a much broader range of astrophysical topics into the text. Whilst the first edition contained many useful tools for high energy astrophysics, many more examples can be given of their practical application in astrophysical problems. There is now a need to give more thorough treatments of phenomena such as accretion discs and the astrophysics of extragalactic radio sources, of active galactic nuclei and of compact objects. For much of the new material I have taken as a basis my recent review article 'The new astrophysics' which was published in the volume *The new physics* (Cambridge University Press, 1989) but again brought up to date.

I have, however, aimed to maintain as many of the positive features of the first edition as possible. In particular, I maintain the informal style and have no hesitation about using the first person singular or expressing my personal opinion about the material under discussion. I will emphasise strongly physical principles and the discussion of general results rather than particular models which may have only ephemeral appeal.

My general approach to astrophysics was set out in the first edition. Physics and astrophysics have a symbiotic relation. On the one hand, the astrophysical sciences are concerned with the application of the laws of physics to phenomena on a large scale in a Universe. On the other hand, new laws of physics are discovered through astronomical observations and their astrophysical interpretation. In these ways, the new astrophysics, of which high energy astrophysics is perhaps the most important ingredient, is just as much a part of modern physics as laboratory physics.

My other aim is similar to that already expressed in the preface to the first

edition and in my book *Theoretical concepts in physics* (Cambridge University Press 1984, 1986, 1987) and that is to give undergraduates a feeling for what it is like to undertake research at the limits of present understanding. Astrophysics is fortunate in that many of the fundamental problems can be understood without a great deal of new physics or new physical concepts. Thus, the text may be considered valuable as an introduction to the way in which research is carried out in the astrophysical context.

Unfortunately, in preparing the revised edition, it became obvious that the material could not be contained within one reasonably-sized volume and I have therefore, with considerable reluctance, split the text into two volumes. *Volume 1* is concerned with establishing most of the basic tools needed for the high energy astrophysics which can be tried and tested within the Solar System. We will continually make forward reference to the use of these tools in purely astrophysical situations. There is considerable emphasis upon techniques of observations of high energy particles and photons, both from the surface of the Earth and from above the Earth's atmosphere. Some attention is given to the properties of cosmic ray particles since these are the only particles which we can detect on Earth which originate in astrophysical sources outside our own Solar System. We have a unique opportunity to understand the behaviour of these particles in magnetic fields through their dynamics in the interplanetary magnetic field and in collisionless shocks when they encounter the shock wave which surrounds the Earth's magnetosphere. In my opinion, this is an area which has not received its due attention from those astrophysicists who wish to understand the behaviour of charged particles in the somewhat more exotic circumstances of active galactic nuclei and black holes. There is a strong emphasis upon observation in this volume, my belief being that it is important to understand the observational limitations which exist in each astronomical waveband in order to assess the feasibility of some of the more demanding observations which one would certainly wish to carry out. I do not shrink from tackling topics which do not normally appear in text books on astrophysics, such as the economics and politics of high energy astrophysics.

In *Volume 2*, we will adopt a much more straightforward approach to the 'traditional' problems of *high energy astrophysics* – I use this term in the way in which it is normally used nowadays, although I would hate to have to try to define it.

Malcolm Longair
Edinburgh, Scotland and Cambridge, Massachusetts, USA.

May 1990.

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There are many people whom it is a pleasure to thank for help and advice during the preparation of this volume. Just as the first edition was begun during a visit to the Osservatorio Astronomico di Arcetri in Florence, so the second edition could not have been completed without the Regents' Fellowship of the Smithsonian Institution which I held at the Harvard-Smithsonian Astrophysical Observatory during the period April–June 1990. I am particularly grateful to Professors Irwin Shapiro and Giovanni Fazio for sponsoring this visit to Harvard during which time the final drafts of Chapters 1–10 were completed. During that period, I had particularly helpful discussions with Drs Eugene Avrett, George Rybicki, Giovanni Fazio, Margaret Geller and many others. I am particularly grateful to them for their advice.

Much of the preliminary rewriting was completed while I was at the Royal Observatory, Edinburgh. Among the many colleagues with whom I discussed the contents of this volume, I must single out Dr John Peacock who provided deep insights into many topics. In completing the final chapter on the high energy astrophysics of the Solar System, I greatly benefitted from the advice of Professors John Brown, Carole Jordan and Eric Priest. Not only did they point me in the correct directions but they also reviewed my first drafts of that chapter. I am especially grateful to them for this laborious task. Many colleagues made helpful suggestions about corrections and additions to the first addition among whom Dr Roger Chevalier provided an especially useful list.

To all of these friends and colleagues I make the usual disclaimer that any misrepresentations of the material presented in this book is entirely my responsibility and not theirs. Finally, I acknowledge the unfailing support of my family, Deborah, Mark and Sarah who have contributed much more than they will ever know to the completion of this book.