中国科学院研究生教学丛书

星系形成

GALAXY FORMATION

Malcolm S.Longair

科学出版社 Springer

影印版

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2001

内 容 简 介

本书属于中国科学院推荐的研究生用原版教材。书中介绍了天体物理、宇宙学和星系形成的基本内容。本书重点介绍了宇宙物质、辐射和星系的形成，并对相对论天体物理学作了介绍。

本书可供天文、天体物理、物理、理论物理专业的本科生和研究生使用。

ISBN：7-03-008914-6/P·1252

图字：01-2000-2997

科学出版社 出版
北京东黄城根北街16号
邮政编码：100717
新蕾印刷厂 印刷
科学出版社发行 各地新华书店经销
*
2001年2月第 一 版 开本：710×1000 B5
2001年2月第一次印刷 印张：34 3/4
印数：1—1 500 字数：643 000
定价：68.00元
（如有印装质量问题，我社负责调换〈北燕〉）

《中国科学院研究生教学丛书》序

在21世纪曙光初露，中国科技、教育面临重大改革和蓬勃发展之际，《中国科学院研究生教学丛书》——这套凝聚了中国科学院新老科学家、研究生导师们多年心血的研究生教材面世了。相信这套丛书的出版，会在一定程度上缓解研究生教材不足的困难，对提高研究生教育质量起着积极的推动作用。

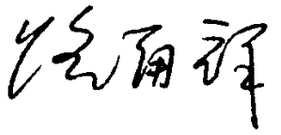
21世纪将是科学技术日新月异，迅猛发展的新世纪，科学技术将成为经济发展的最重要的资源和不竭的动力，成为经济和社会发展的首要推动力量。世界各国之间综合国力的竞争，实质上是科技实力的竞争。而一个国家科技实力的决定因素是它所拥有的科技人才的数量和质量。我国要想在21世纪顺利地实施“科教兴国”和“可持续发展”战略，实现邓小平同志规划的第三步战略目标——把我国建设成中等发达国家，关键在于培养造就一支数量宏大、素质优良、结构合理、有能力参与国际竞争与合作的科技大军。这是摆在我国高等教育面前的一项十分繁重而光荣的战略任务。

中国科学院作为我国自然科学与高新技术的综合研究与发展中心，在建院之初就明确了出成果出人才并举的办院宗旨，长期坚持走科研与教育相结合的道路，发挥了高级科技专家多、科研条件好、科研水平高的优势，结合科研工作，积极培养研究生；在出成果的同时，为国家培养了数以万计的研究生。当前，中国科学院正在按照江泽民同志关于中国科学院要努力建设好“三个基地”的指示，在建设具有国际先进水平的科学研究基地和促进高新技术产业发展基地的同时，加强研究生教育，努力建设好高级人

才培养基地，在肩负起发展我国科学技术及促进高新技术产业发展重任的同时，为国家源源不断地培养输送大批高级科技人才。

质量是研究生教育的生命，全面提高研究生培养质量是当前我国研究生教育的首要任务。研究生教材建设是提高研究生培养质量的一项重要的基础性工作。由于各种原因，目前我国研究生教材的建设滞后于研究生教育的发展。为了改变这种情况，中国科学院组织了一批在科学前沿工作，同时又具有相当教学经验的科学家撰写研究生教材，并以专项资金资助优秀的研究生教材的出版。希望通过数年努力，出版一套面向21世纪科技发展、体现中国科学院特色的高水平的研究生教学丛书。本丛书内容力求具有科学性、系统性和基础性，同时也兼顾前沿性，使阅读者不仅能获得相关学科的比较系统的科学基础知识，也能被引导进入当代科学研究的前沿。这套研究生教学丛书，不仅适合于在校研究生学习使用，也可釉作为高校教师和专业研究人员工作和学习的参考书。

“桃李不言，下自成蹊。”我相信，通过中国科学院一批科学家的辛勤耕耘，《中国科学院研究生教学丛书》将成为我国研究生教育园地的一丛鲜花，也将似润物春雨，滋养莘莘学子的心田，把他们引向科学的殿堂，不仅为科学院，也为全国研究生教育的发展作出重要贡献。



Foreword

For Deborah, Mark and Sarah

'Not another book on cosmology!', I hear the reader exclaim. 'Surely there are quite enough books on cosmology to satisfy everyone's needs?'

I was asked by Springer-Verlag to expand into a full-length book the set of lecture notes that I prepared in 1988 for the First Astrophysics School organised by the European Astrophysics Doctoral Network. The set of notes was entitled *Galaxy Formation* and was published as a chapter of the volume *Evolution of Galaxies: Astronomical Observations* (eds. I. Appenzeller, H.J. Habing and P. Lena, pages 1 to 93, Springer-Verlag Berlin, Heidelberg, 1989). In that chapter, I attempted to bridge the gap between elementary cosmology and the technical papers appearing in the literature, which can seem quite daunting on first encounter. The objective was to present the physical concepts and key results as clearly as possible as an introduction and guide to the technical literature.

The revision of these lecture notes into a full-length book was delayed by other projects. Specifically, I am completing a three-volume work for Cambridge University Press, entitled *High Energy Astrophysics*, (Volume 1, 1992; Volume 2, 1994; Volume 3, Cambridge University Press, Cambridge 1998). In addition, a further series of lecture notes on *The Physics of Background Radiation* was prepared for the 1993 23rd Advanced Course of the Swiss Society of Astrophysics and Astronomy, the topic of which was *The Deep Universe* (A.R. Sandage, R.G. Kron and M.S. Longair, Springer-Verlag Berlin, Heidelberg, 1995). Finally, I have completed a history of twentieth century astrophysics and cosmology, which has been published as Chap. 23 of a three-volume work entitled *Twentieth Century Physics* (eds. L.M. Brown, A. Pais and A.B. Pippard, IOP Publications, AIP Press Bristol, and New York 1995). It will be published in enlarged form as a full-length book by Cambridge University Press in 1999.

All these works contain material central to the problems of galaxy formation and it therefore seemed a good idea to abstract from them an improved version of the original plan for the book on galaxy formation. A revised plan was all the more necessary because of the quite remarkable developments in observational and theoretical cosmology which have taken place in the decade

since the original set of notes was written. Thus, the present volume is much more than a recycled and concatenated version of published works. I have rewritten and rethought the original versions, expanded some parts, brought everything up-to-date and included new material.

I often find that I understand things best, and present them most clearly, when I have to prepare them for students, at either the undergraduate or the post-graduate level, and so I have adopted the same form of presentation here. I have intentionally presented the material in an informal, pedagogical manner, and tried to avoid getting bogged down in formalities and technicalities. If the material becomes too difficult, I simply summarise the key points, give some appropriate references and pass on. My approach is to reduce the problems to their simplest form and rationalise from these examples the results of more complete analyses. Wherever it is feasible without excessive effort, we will attempt to derive exact results. The level of presentation is intended to be appropriate for a final-year undergraduate or first-year post-graduate course of lectures. In other words, it is assumed that the reader has a good grasp of basic physics but does not necessarily have the appropriate background in astronomy, astrophysics or cosmology. My aim has been to write a user-friendly book, taking particular care to expound carefully areas where I have found students have difficulty.

When I wrote the original set of lecture notes on galaxy formation, my objective was to tell the story of modern astrophysical cosmology from the perspective of one of its most important and fundamental problems of cosmology — how did the galaxies come about? I enjoy this approach to the exposition of modern cosmology because, to do the problem justice, it is essential to introduce the whole of what I call *classical cosmology*, as the framework for the discussion. This approach has, for me, the great advantage of concentrating upon a crucial problem of astrophysical cosmology rather than regarding the objective of cosmology as being simply the delineation of a preferred cosmological model, however interesting that is in its own right. As we will show, the origin of galaxies is one of the great cosmological problems and it can potentially provide us with unique and direct information about the physics of the very early Universe.

One final warning is in order. I make no claim that this presentation is complete, unbiased or objective. You should regard the book as my own impressions and opinions of what I consider to be the important issues of modern astrophysical cosmology. Others would tell the story in a completely different way and put emphasis upon different parts of what is unquestionably a multi-dimensional story. I will endeavour to include as wide a spectrum of ideas and opinions as possible but the text will inevitably be incomplete. I do not worry about this – it should encourage you to read as widely as possible in order to neutralise my prejudices and biases.

Good Luck!

Acknowledgements

Many people have contributed directly, or indirectly, to my understanding of the contents of this book. Perhaps the most important influence has been Peter Scheuer, who first introduced me to the physics of astrophysical cosmology. His approach and methods have very strongly influenced the way I have understood and taught this material over the years. I am very grateful to Immo Appenzeller, Harm Habing and Pierre Léna for the opportunity to give the lecture course in Les Houches in 1988. In preparing that set of lecture notes, I greatly benefitted from the advice of John Peacock and Alan Heavens who read parts of the typescript and offered very helpful comments. John Peacock very kindly allowed me to use part of his lecture notes in preparing some of the material for the original chapter. John has now written up his own notes in book form and it will soon be published by Cambridge University Press under the title *Cosmological Physics.* In my view, John's book is a brilliant achievement and I urge all interested readers to become familiar with his deep insights. Some of the text of the present book is based upon joint work with Rashid Sunyaev which dates from the period 1968 to 1980. I fully acknowledge Rashid's contributions to clarifying my own understanding.

The invitation to deliver the 1993 course of lectures on the background radiation, as part of the 23rd Course of the Swiss Society of Astrophysics and Astronomy, came from Gustav Tammann, Bruno Binggeli and Hermann Buser and I am grateful for their kindness and hospitality at Les Diablerets. The history of 20th Century Astrophysics and Cosmology was commissioned by Brian Pippard on behalf of the editors of *20th Century Physics* and I am grateful to him for his perceptive comments on that article.

I am particularly grateful to Bob Williams and his colleagues at the Space Telescope Science Institute at Baltimore, where I was a Visiting Fellow from September to December 1997. Without this sabbatical term at the Institute, the completion of this text would have been impossible. Special thanks are due to the staff, graduate students and research fellows at the Institute and at Johns Hopkins University, who kindly acted as guinea pigs on whom I 'battle-tested' portions of this book. Many of the research workers at the Institute gave generously of their time in discussing many of the topics discussed in the text; the discussions with Ron Allen, Michael Fall, Harry Fergusson, Mario Livio, Duccio Macchetto and Piero Madau were especially helpful. The writing was enormously aided by access to the excellent library facilities at the Institute and I am most grateful to Sarah Stevens-Rayburn and her colleagues, especially 'Chopin', for their kind assistance. Martin Harwit kindly read the book very carefully and made a number of helpful suggestions, which I have gratefully incorporated into the final text.

Finally, the book is dedicated to my family, Deborah, Mark and Sarah, whose constant love, support and patience have made it possible.

Summer 1998 *Malcolm Longair*, Cambridge and Baltimore.

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