Foundations of Astrophysics

Foundations of Astrophysics provides a contemporary and complete introduction to astrophysics for astronomy and physics majors. With a logical presentation and conceptual and quantitative end-of-chapter problems, the material is accessible to introductory astrophysics students taking a two-semester survey course. Starting with the motions of the solar system and a discussion of the interaction of matter and light, the authors explore the physical nature of objects in the solar system, and the exciting new field of exoplanets. The second half of their text covers stellar, galactic, and extragalactic astronomy, followed by a brief discussion of cosmology. This is a reissue of the original 2010 edition, which has established itself as one of the market-leading astrophysics texts, well known for its clarity and simplicity. It has introduced thousands of physical science students to the breadth of astronomy, and helped prepare them for more advanced studies.

Barbara Ryden received her Ph.D. in astrophysical sciences from Princeton University. After postdocs at the Harvard–Smithsonian Center for Astrophysics and the Canadian Institute for Theoretical Astrophysics, she joined the astronomy faculty at The Ohio State University, where she is now a full professor. She has more than 25 years of experience in teaching, at levels ranging from introductory undergraduate courses to advanced graduate seminars. She won the Chambliss Astronomical Writing Award for her textbook *Introduction to Cosmology*.

Bradley M. Peterson received his Ph.D. from the University of Arizona. He was a member of the astronomy faculty at The Ohio State University from 1980 until his retirement in 2015, after serving as Department Chair for nine years. He received the Distinguished Scholar Award from Ohio State; the Outstanding Achievement Award from his alma mater, the University of Minnesota; and the NASA Exceptional Service Medal. He was a community co-chair for the Science and Technology Definition Team for the Large, Ultraviolet, Optical, Infrared Surveyor (LUVOIR), a large mission-concept study for NASA Astrophysics, and is the author of *An Introduction to Active Galactic Nuclei*.

For Nancy and Kent —B.R.

For Jan, Evan, Ethan, Erika, Lizzie, Ellyn, Christopher, and Aden —B.M.P.

Foundations of Astrophysics

BARBARA RYDEN
The Ohio State University

BRADLEY M. PETERSON
The Ohio State University

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108831956
DOI: 10.1017/9781108933001

This book was previously published by Pearson Education, Inc., 2010

Reissued by Cambridge University Press 2021

Printed in the United Kingdom by TJ International Ltd, Padstow Cornwall 2021

A catalogue record for this publication is available from the British Library.

ISBN 978-1-108-83195-6 Hardback

Additional resources for this publication at www.cambridge.org/rydenpeterson

Contents

Preface

This book, like many textbooks, was inspired by teaching a class. The class in question was a two-quarter (5 hours per week) introductory survey course in astrophysics. The reader of this book, like the students in our course, is assumed to have studied a year of calculus (including differential and integral calculus, basic vector calculus, and a smattering of simple differential equations), as well as a year of calculus-based general physics. We assume that the reader has only a remote acquaintance, if any, with quantum physics, special relativity, or linear algebra.

Our fundamental goals for this book are twofold. First, we want to introduce students with a serious interest in physical science to the breadth of astronomy, preparing them for more advanced topical courses in the future. Second, we use astronomical examples to reinforce the physics that the students have already learned. To this end, we use SI (International System) units, which the students have already encountered in general physics class, rather than the cgs (centimeter, gram, second) units that are frequently encountered in the more advanced astronomical literature. Units that are peculiar to astronomers, such as parsecs, magnitudes, solar luminosities, and solar masses, are introduced as needed.

Our organization of the material is, in many respects, quite traditional. We start with the kinematics and dynamics of the solar system; then, after discussing the interaction of matter and light, we proceed to a discussion of the physical nature of objects in the solar system. We conclude our discussion of solar system astronomy with an examination of the solar system as illuminated by the exciting new field of exoplanets. The second half of the book covers stellar, galactic, and extragalactic astronomy, followed by a brief discussion of cosmology.

Our goals for the book, to some extent, dictate the relative emphasis placed on different fields of astronomy. Some particularly rich areas of astronomy, such as stellar populations, globular clusters, and the large-scale structure of the universe, are only briefly touched on. We regret the brevity with which we cover these and other fascinating topics in astronomy. However, we had to balance our desire to make the book of manageable size with our desire to cover thoroughly those topics that enhance understanding of important physical principles (such as blackbody radiation, physics of non-LTE gases, and gravitational accretion).

Our text benefited from criticism by many individuals. Most important, the book was shaped by several classes of undergraduate students at The Ohio State University,

who provided detailed feedback on nearly every aspect of the book. In particular, most end-of-chapter problems in this book have been heavily field-tested; our students never hesitated to point out when a problem was clumsily or ambiguously worded. Many of the remaining end-of-chapter problems are classic problems that appear in somewhat similar form in earlier textbooks. The textbooks from which we have adopted and adapted problems are cited in the Bibliography at the end of the textbook.

We are grateful for reviews of individual chapters by instructors with experience in teaching astrophysics at this level, notably Byron D. Anderson, Phil Armitage, Don Bord, Tereasa Brainerd, David Cohen, John Cowan, Richard A. Crowe, Carsten Denker, George Djorgovski, Stephen Gottesman, Kim Griest, Peter H. Hauschildt, John Huchra, Philip A. Hughes, Steven Kawaler, Jeremy King, Chip Kobulnicky, Donald G. Luttermoser, Kevin MacKay, Michael P. Merilan, Stan Owocki, Eric S. Perlman, Lawrence S. Pinsky, Gary D. Schmidt, James Schombert, Horace Smith, Steven Stahler, Curtis J. Struck, Paula Szkody, Dan Wilkins, Jeff Wilkerson, Richard M. Williamon, Gerard Williger, Vincent Woolf, Kausar Yasmin, and Dennis Zaritsky, as well as a number of anonymous reviewers. We incorporated much of the advice received from these individuals.

We are especially grateful to friends and colleagues at The Ohio State University who provided invaluable assistance. Richard Pogge provided help with both scientific and technical issues. Jessica Orwig prepared many of the figures and tables. Marc Pinsonneault, David Weinberg, and Molly Peeples provided information for figures. Finally, the fact that this is a real book rather than a pile of incoherent notes and scrawled drawings is due to our diligent production team at Pearson Addison-Wesley.