Fundamentals of Astrophysics

This concise textbook, designed specifically for a one-semester course in astrophysics, introduces astrophysical concepts to undergraduate science and engineering students with a background in college-level, calculus-based physics. The text is organized into five parts covering: stellar properties; stellar structure and evolution; the interstellar medium and star/planet formation; the Milky Way and other galaxies; and cosmology. Structured around short easily digestible chapters, instructors have flexibility to adjust their course's emphasis as it suits them. Exposition drawn from the author's decade of teaching his course guides students toward a basic but quantitative understanding, with "quick questions" to spur practice in basic computations, together with more challenging multipart exercises at the end of each chapter. Advanced concepts such as the quantum nature of energy and radiation are developed as needed. The text's approach and level bridges the wide gap between introductory astronomy texts for nonscience majors and advanced undergraduate texts for astrophysics majors.

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Preface

This book grew directly out of class notes developed from over a decade of teaching a one-semester course of the same title to second- and third-year undergraduate science and engineering majors at the University of Delaware (UD). Although structured within UD's Department of Physics and Astronomy, in which I am a faculty member, generally only about a third of the *c*. 30 students in the class are physics or astronomy majors; others major in engineering (mechanical and chemical), biology (including biophysics), chemistry, and computer science. The main prerequisite is a year of college-level, calculus-based physics, along with associated math courses. There is *no* presumption of prior, direct study of higher-level physics such as relativity, quantum physics, electricity and magnetism, and thermodynamics. Indeed, there is no presumption of prior study in astronomy, not even from a descriptive "Astronomy for Poets" course. This and such upper-level physics concepts are introduced as needed.

Grounded in development for that course, this text is specifically targeted to be a bridge between the copious number of introductory astronomy texts aimed mainly at nonscience majors, and the handful of astrophysics books aimed at upper-level physics majors, which thus assume a background well beyond just first-year physics. Its moderate length, moreover, also distinguishes this from books that are at a similar level, but are so extensive as to be more suited as a reference than an instructional text.

Within this context, the goal of this book is to help guide such students to a broad understanding of the *Fundamentals of Astrophysics*, ranging from basic properties of stars to the principles of Big-Bang cosmology, all within the structure of a one-semester course. The aim for coverage within a single semester naturally presents some significant challenges, for both the students and the instructor. Over more than a decade as an instructor, I have in various semesters experimented with de-emphasizing some topics, sections, and even chapters, in favor of others. For instance, as the course notes developed to include areas of increasing topical interest, e.g., the discovery and modeling of the ever-growing number of exoplanets, it has been necessary to de-emphasize or even skip other chapters or topics, for example streamlining coverage on galaxies to focus on the Hubble expansion with the goal of getting through at least to the scale-factor and Cosmic Microwave Background (CMB) sections of the cosmology chapters.

This need for flexibility in instructor choice was the main factor setting the book's basic structure, with a large number (33) of relatively short (~5–10 pages) chapters that themselves are broken up into ~1–3 page "sections." In general, I find most chapters can be covered in one or two lectures, and some shorter ones can even be combined into a single lecture.

The chapters are, in turn, organized into five "parts." The longest of these is Part I on the basic properties of stars, which aims to provide students with an understanding of how we are able to determine their physical properties from measurements of mere points of light; it includes 14 relatively brief chapters, concluding with one on the Sun. (Although this provides a reality check on our idealized portrait of stars as static spheres of gas, I often skip it for brevity, as well as other less-central topics such as stellar rotation.) Part II then reviews stellar structure and evolution within the framework of single stars. Less basic aspects such as evolution of interacting binaries are deferred, e.g., to a student exercise on the Algol paradox.

Part III then links discussion of the interstellar medium (ISM) with formation of stars and planetary systems. The last is a burgeoning topic of ever-growing scientific and even public interest, and the aim here is to give a basic overview of the detection and modeling methods. Part IV next extends the discussion to our Milky Way and other galaxies, including the Hubble expansion of the universe. This leads naturally to the Part V review of Big-Bang cosmology, grounded within a Newtonian treatment of the expansion, and the associated formation of the CMB. The main text concludes with a chapter on the eras of the early universe, including the notion of an early era of rapid inflation.

To supplement this five-part narrative grounded in astrophysics, four appendices summarize key background physics topics on: (1) atomic structure; (2) excitation and ionization; (3) opacity; and (4) radiative transfer.

In keeping with the broad educational mantra that students learn best by doing, each chapter ends with a section containing questions and exercises. The former are relatively short and focus on one or two concepts that the students should be able to answer relatively quickly once they have read and studied the chapter; I often use selected questions for in-class discussions or quizzes, to encourage and test students on doing the assigned reading (which frankly can be quite a challenge).

The exercises are longer, with multiple parts, and are generally intended for weekly homework assignments. Some are still pretty straightforward "plug-ins" to chapter formulae; but others are intended to be more challenging and thought-provoking, in some cases even introducing extensions not directly covered in the text (e.g., the "Ledoux criterion" in Exercise 4 of Chapter 17). Others aim to connect astrophysical concepts to student major interests, e.g., the "space elevator" (Exercise 6 in Chapter 10), which relates gravitational binding of orbits to mechanical engineering. The very last exercise (Exercise 5 in Chapter 33) directs the students to research the concept of a "multiverse," and discuss whether this even constitutes a scientific theory.

Finally, while this book was developed and written for a one-semester course, it could readily also serve as the core text for a two-semester sequence, allowing for a more leisurely and in-depth coverage of the full breadth, supplemented perhaps by linkage to related advanced topics, such as those listed in the instructor resources, which can be found at www.cambridge.org/owocki.