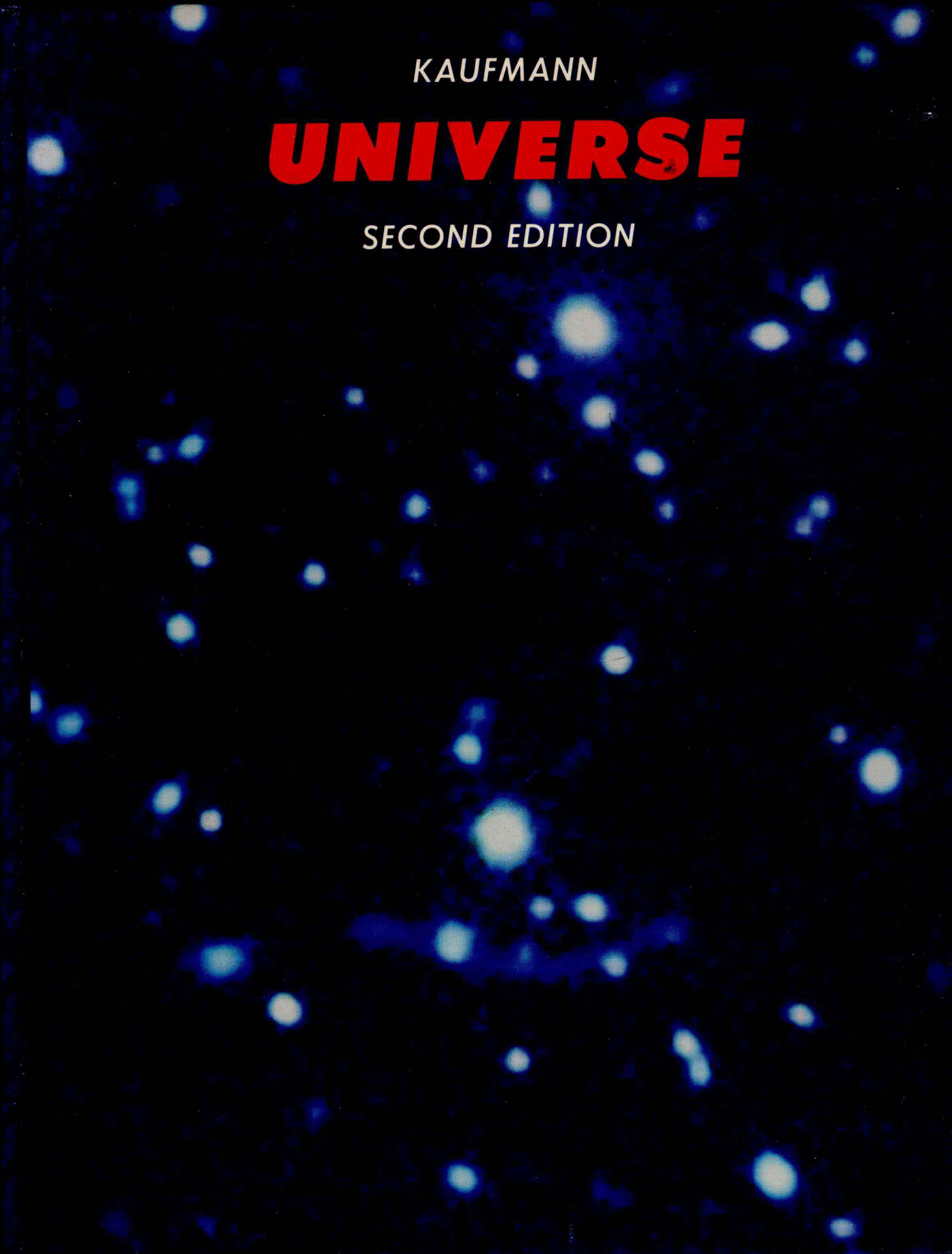
KAUFMANN

UNIVERSE

SECOND EDITION



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SECOND EDITION

William J. Kaufmann, III

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To Elayne R., with love

Front cover image
A giant luminous arc in a cluster of galaxies In 1987, Roger Lynds at Kitt Peak National Observatory and Vahe Petrosian of Stanford University announced their discovery of the huge luminous arc shown on the cover of this book. This arc is more than 300,000 light years long and is located in a remote cluster of galaxies. Many of the fuzzy spots on the cover photograph are galaxies in this cluster, which is roughly 5 billion light years from Earth. A giant elliptical galaxy is located near the center of curvature of the arc. For a sense of scale, you should know that a typical galaxy like our Milky Way measures about 80,000 light years in diameter. Astronomers are at a loss to explain this enormous glowing arc. (Courtesy of NOAO)

Back cover images
Top: The Horsehead Nebula This nebulosity is part of a large region of active star formation in the constellation of Orion. Radiation from newborn, massive stars causes the interstellar hydrogen gas to glow with a characteristic reddish hue. The dark features are produced by clouds of interstellar dust grains silhouetted against the background nebulosity. This nebula is about 1600 light years from Earth. (Anglo-Australian Observatory)

Middle: An annular eclipse of the Sun This composite of six images shows the progress of a solar eclipse that occurred on December 24, 1974, as viewed from Costa Rica. At the time of this eclipse, the Moon was near apogee, its farthest distance from Earth. The Moon's disk was therefore too small to cover the Sun completely and a ring, or annulus, of light was seen around the Moon at mid-eclipse. (Courtesy of Dennis di Cicco)

Bottom: A spiral galaxy Vigorous star formation in this galaxy is occurring along graceful spiral arms which are outlined by numerous glowing nebulae and bright, newborn stars. Various processes can compress interstellar gases and trigger such star formation. This galaxy, called NGC 4303 or M61, is located in the constellation of Virgo at a distance of about 50 million light years from Earth. (Palomar Observatory)

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Preface

The popularity of astronomy as a general science course is due in large measure to the inherent intrigue of its subject matter. Since earliest times people have been fascinated by topics that astronomers explore today: the creation of the universe, the formation of the Earth and other planets, the motions of the stars, the structure of space and time. Armed with the powers of observation, the laws of physics, and the resourcefulness of the human mind, astronomers survey alien worlds, follow the life cycles of stars, and probe the dim and distant reaches of the cosmos.

Astronomy raises our consciousness because it investigates phenomena and explores realms far removed from our daily experience. Many of the objects that astronomers study are far too vast, distant, or intangible to ever sample directly; indeed, many of the phenomena that are observed today occurred very long ago. When viewed in the context of the evolution of the universe, even the dimensions of space and time take on new meaning.

I have tried, however, to convey more than the intriguing nature of our physical universe. I also describe how astronomers have come to know what they know. To show students how scientists reason must be an objective of any first science course. By studying the methods that astronomers have used in exploring the universe, we can learn something about the nature of scientific inquiry.

Organization

This text is designed for both one- and two-term courses. The level of coverage here is generally more comprehensive and contains a little more mathematics than that found in the sister text *Discovering the Universe*. While comprehensive, this second edition of *Universe* has a flexible, modular structure.

The book's twenty-nine chapters are easily divided into two nearly equal parts, the first half dealing with introductory material and planetary astronomy, and the second half treating stars, galaxies, and cosmology. Instructors may emphasize either half of the book according to preference, covering more or less of the detail as time and the preparation of the students permit.

The traditional Earth-outward organization of this text emphasizes how our understanding of the universe developed and invites the reader to share in the excitement of astronomical discovery. The first celestial objects to be examined are those that were observed by the ancient astronomers. Moving outward from the planets to the stars and galaxies, older Earth-based observations and the questions that they provoke are augmented or even supplanted by newer observations, including those from outside the visible range and those made from space. These new observations in turn raise new questions, which draw the reader on to the outer limits of our universe and our understanding.

The first six chapters introduce the foundations of astronomy, including descriptions of such naked-eye observations as eclipses and planetary motions and such basic tools as Kepler's laws, the fundamental properties of light, and the optics of telescopes. A discussion of the formation of the solar system in Chapter 7 prepares the reader for the next ten chapters, which cover the planets in outward order from the Sun. One of these chapters deals with the Galilean satellites, which are terrestrial worlds in their own right.

Chapter 18 introduces stellar astronomy by describing stars in general, and in Chapter 19 one particular star, the Sun, is examined in detail. In Chapters 20 through 24, stellar evolution is described chronologically from birth to death. Molecular clouds, star clusters, nebulae, neutron stars, black holes, and various other phenomena are presented in the sequence in which they naturally occur in the life of a star, thus unifying the wide variety of objects that astronomers find scattered about the heavens.

A survey of the Milky Way introduces galactic astronomy in Chapter 25; this is followed by two chapters on galaxies and quasars. The final two chapters, on cosmology, emphasize exciting recent developments in our understanding of the physics of the early universe.

Major changes in this edition

The first step in planning the second edition of *Universe* was to compile and examine reactions to the first edition. A questionnaire sent to hundreds of instructors who had used *Universe* in both the United States and Canada, provided a most enlightening and inspiring impetus for this revision. Many of the improvements made in the second edition reflect the good judgment and class experience of numerous text users, reviewers, and friends.

Two major organizational changes were made in this edition. The first involves the treatment of light. Virtually all topics relating to the physics of electromagnetic radiation, from Wien's law to atomic structure, are now consolidated in one chapter near the beginning of the book. This chapter, entitled "The Nature of Light and Matter," provides a complete and satisfying orientation to this critical yet basic topic, and increases the text's flexibility as well. For instance, a course on stellar astronomy could begin with the introductory chapters on gravitation and light (Chapters 4 and 5) and proceed directly to Chapter 18 without any loss of continuity.

A second significant organization change concerns the treatment of cosmology. In this second edition, virtually all of the more "standard" cosmological issues are discussed in Chapter 28. It would thus be quite appropriate to end an astronomy course with that chapter. Chapter 29 was created for those who wish to go on to consider the interface between cosmology and particle physics. Entitled "Physics of the Early Universe," Chapter 29 introduces several unifying theories and deals with such speculative and exciting ideas as cosmic strings and eleven-dimensional spacetime. This challenging, optional chapter explores topics in which research is today proceeding at a fevered pitch. The student will learn that physicists are at the brink of tackling questions like: Why is there only one dimension of time, yet three dimensions of space?

Many smaller, yet equally important, revisions enhance the rest of the text. The text was, of course, updated throughout. The planets chapters have been streamlined and strengthened through the deletion of extraneous details. Coverage of Uranus and Comet Halley reflects our latest findings. A discussion of mass-transfer in close binary systems has been added. In light of SN 1987A, the treatment of supernovae was enlarged and now includes some details about exploding white dwarfs. Explanations for spiral structure in galaxies now include stochastic, self-propagating star formation. And, finally, the discussion of galactic evolution has been greatly amplified. With these changes, I have ventured to create a comprehensive yet entertaining text that gives a fair and accurate picture of the full scope of astronomy.

Pedagogical emphasis

The student's ease in understanding astronomy continues to be a major objective of this text. Each chapter begins with a brief, one-paragraph abstract that gives the reader a clear idea of the chapter's contents. The chapter headings, in the form of declarative sentences, highlight main concepts. A formal summary outlines the essential facts addressed in each chapter. Each chapter concludes with a series of questions grouped into three categories: review, advanced, and discussion. Answers to questions that require computation (marked by an asterisk) appear at the end of the book. Care has been taken to include some questions whose answers require reasoning rather than just memorization. Roger Culver of Colorado State University deserves special recognition for his many contributions here.

Boxed inserts set aside the text's more technical and/or mathematical material. Many review key formulas and the calculations that lead to astounding discoveries. Others contain technical reference information, such as the orbital and physical data for each planet. Still others present arguments, taking an idea raised in the text a step further. Boxes may be omitted without loss of continuity. This segregation permits greater flexibility in an instructor's use of the text and allows students to easily locate and review topics to which they may wish to refer again.

Illustrations

Color illustrations greatly enhance the effectiveness of this book. Most astronomy texts contain only a sampling of color photographs, usually segregated from the corresponding narrative. In this text, however, color photographs are integral to the text and are incorporated throughout. Color pictures are indispensable to a truly modern view of astronomy. Color is now routinely used by astronomers in a wide variety of circumstances. One glance at a color photograph of a planet's cloudtops or of the glowing gases of a nebula reveals significant details about the object that cannot be gleaned from a black-and-white view. X-ray, infrared, and radio views of the sky are now very comprehensibly displayed in extraordinary computer-generated false-color images. The incorporation of color pictures in the main body of the text not only makes reading and learning easier, but reflects how astronomy is practiced today.

Essays

It is again a great pleasure to include the essays of six renowned astronomers, who offer their personal views on topics of especially current interest. These exceptional essays round out the book and give it a depth and quality that could not have otherwise been possible:

Astrology and astronomy	Owen Gingerich
Extraterrestrial life	Frank D. Drake
The outlook for space science	Peter B. Boyce
Supercomputers in astronomy	Larry L. Smarr
The Hubble Space Telescope: A bridge into time and space	Riccardo Giacconi
The edge of spacetime	Stephen W. Hawking

Ancillaries

It is a pleasure to announce the availability of the following outstanding ancillaries to the second edition of *Universe:*

A *Computerized Test Bank* has been prepared by T. Alan Clark, The University of Calgary, Alberta, Canada. Included on this IBM-PC-based testing program are multiple-choice questions, indexed by chapter and topic category, and a flexible edit feature which allows instructors to include their own questions.

A set of slides is available to accompany *Universe.* The 60 slides contain a selection of line illustrations reproduced directly from the text. Both the *Computerized Test Bank* and *Slide Set* are free to adopters of 100 or more copies of the text.

An *Instructors Manual* has been prepared by Thomas H. Robertson, Ball State University and Andrew Franknoi, Astronomical Society of the Pacific. It contains chapter synopses, hints for teaching and discussion, and a current list of resources for teaching.

Andrew Fraknoi's very successful *Universe in the Classroom: A Resource Guide for Teaching Astronomy* is an invaluable book for teaching ideas, resources, experiments, and other related activities.

For more information and to request copies of these supplements please contact:

Marketing Department
W. H. Freeman and Company
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New York, NY 10010

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Finally, I thank Dwight Nicholson at the University of Iowa as well as Jack Connors and Beth Avery, who hunted down typos and errors in the first edition. Although we have made a valient effort to make this an error-free edition, some mistakes may have crept in. I would appreciate hearing from anyone who finds an error or who wishes to comment on the text. You may write to me in care of the publisher. I will respond personally to all correspondence.

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