HORIZONS

Exploring the Universe

1995 Edition

Selected to accompany the telecourse *Universe: The Infinite Frontier*, produced by Coast Telecourses, airing on public broadcasting

Michael A. Seeds

Horizons

1995 EDITION

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Preface

Few of my friends ever greet me with a cheerful, "What's new?" They know an astronomer's news can keep them occupied for hours. We've located arachnoids on Venus, ice on Mercury, arcs around Neptune, jets in Orion, craters on asteroids, neutron stars in binaries, quasars in clusters, and dark matter everywhere, but we still can't find those pesky neutrinos. Astronomy is a dynamic science where new discoveries regularly alter our perception of reality. That is why we love it and why our students find it exciting. In this new edition of *Horizons: Exploring the Universe*, I have tried to present astronomy as a unified system of understanding that relates our students' personal existence to the basic processes in the universe, but I have also tried to express some of the excitement we feel when someone says, "What's new?"

MINIMUM TANGLE

The body of astronomical knowledge resembles a marionette with tangled strings. Each fact, observation, or principle is connected by inferences, assumptions, and theories to other facts, observations, and principles. The teacher's task is to untangle this marionette and make clear the logic of the connections. Just as a marionette has inherent in its design an untangled state, the body of astronomical knowledge has a state that makes the logic of the inferences, assumptions, and theories clearest. In this book, I have attempted to present astronomy in that state of minimum tangle.

By considering stars, galaxies, cosmology, and the solar system in that order, we simplify many of the evidential arguments and intuitive concepts so important to understanding astronomy. For example, by discussing star formation before the solar system, students recognize the solar nebula for what it is, a natural by-product of star formation. More important, by studying stars, galaxies, and cosmology first, students return to the solar system with a cosmic perspective on nature that places them and their planet into the universe, rather than constructing a universe around them.

Facts can be meaningful only when they are synthesized into a consistent description of nature. Thus, this book views the universe as a small set of natural processes that are responsible for a wide variety of phenomena and that explain a diverse assortment of objects. For example, galaxies, star clusters, individual stars, and planets are all expressions of the same process—gravitational contraction. Only the scale is different. This emphasis on

processes presents astronomy not as a collection of unrelated facts but as a unified body of knowledge.

In addition, this text presents astronomy as a case study in science. It distinguishes between observation and theory, between evidence and conclusion. We want our students to understand how science creates, tests, improves, or discards models of natural phenomena and thus more closely approximates a complete understanding of natural processes.

CHANGES IN THE 1995 EDITION

New discoveries and new images dominate this edition, but I have also taken this opportunity to make less obvious changes in the book, changes that will make it a more useful tool for the student and the instructor. Many instructors and students have written with suggestions and questions, and all of those have been considered for inclusion in this edition. Also, detailed reviews by experienced teachers have guided changes ranging from the revision of an entire chapter section to the alteration of a single word in a discussion. As always, the editors at Wadsworth have provided careful guidance on the use of language for maximum clarity. The changes in this edition have thus been drawn from many sources, but they are all aimed at helping students understand modern astronomy.

Major changes include the following:

- Throughout the book, many diagrams have been converted to modern, full-color artwork. Students spend more time looking at colorful, attractive diagrams and remember them better, so this seemingly cosmetic change has an important pedagogical goal.
- "Perspective: Climate and Ice Age" at the end of Chapter 3 has been rewritten to include new discoveries about Earth's past climate.
- "Galileo Galilei" in Chapter 4 has been completely rewritten to put his work into better historical perspective. This will help the students understand the importance of Galileo to the creation of modern science.
- "New-Generation Telescopes" in Chapter 5 has been entirely rewritten to include the newest developments and to clarify the new philosophy of telescope design that makes these new instruments possible.
- Many updates have been made concerning radio and space telescopes including a total revision of "The Hubble Space Telescope" in Chapter 5 and the discussion of the repair mission in orbit.
- The physics of sunspots in Chapter 7 has been updated and clarified with new observations.
- The section on spectroscopic binaries in Chapter 8 has been revised to include an example using real spectra.
- Revisions to the discussion of the mass-luminosity relation in Chapter 9 clarify the connection between observation and theory.
- "The Mystery of the Solar Neutrinos" in Chapter 9 has been totally rewritten to clarify the problem and include the latest results.
- "Perspective: The Orion Nebula" at the end of Chapter 9 has been almost completely revised to include new results.
- "The Search for Black Holes" in Chapter 11 is rewritten and updated with the latest results.
- "The Formation of the Galaxy" in Chapter 12 is totally rewritten to unify the discussion of the old and new theories.
- In Chapter 13 "Dark Matter in Galaxies" is completely rewritten and updated, and "Colliding Galaxies" is entirely rewritten to unify and clarify the discussion of evidence and theory.
- "A Model Quasar" in Chapter 14 has been revised and updated.
- The discussion of the density of the universe in Chapter 15 has been revised, expanded, and updated.
- In Chapter 17 "A Four-Stage History" of Earth has been totally rewritten to clarify the role of cratering. "The Surface of Venus" is completely revised to include the newest Magellan results. "Water on Mars" is a totally new section.
- In Chapter 18 "Uranus the Planet" is fully rewritten to better discuss the physics of the atmosphere. "Planet Neptune" has been completely revised to clarify the importance of its internal heat source. "The Origin of Pluto" has been totally rewritten to relate Pluto and Charon to the postulated icy planetesimals of the outer solar system.
- "Properties of Asteroids" in Chapter 19 is entirely revised to include a discussion of the shapes of asteroids as revealed by new radar and Galileo images.

- The discussion of SETI in Chapter 20 has been updated with the first results from META.

CONTINUING FEATURES

Many useful features have been retained and updated. "Perspectives," which appear at the end of several chapters, introduce new and interesting ideas that allow students to review and apply the principles covered in the chapter. These Perspectives might discuss the development of a theory, the synthesis of hypotheses from data, the testing of theories by observation, or the meaning of statistical evidence.

Study aids for each chapter include a chapter summary, a list of new terms, review questions, discussion questions, problems, and recommended readings. The first time a new term appears in the text it is set in **boldface.** These terms are defined in the glossary. The review questions are nonquantitative and could lead to essay answers that can be found in the text. Discussion questions may go slightly beyond the text and ask the student to consider the implications of the material in the chapter. These discussion questions may be useful to stimulate class discussion. The problems are quantitative or involve mathematical reasoning. (Answers to even-numbered problems appear at the end of the book, and to odd-numbered problems in the Instructor's Manual.) The recommended reading, which is intended for the student, ranges from *National Geographic* to *Science.* Instructors may wish to guide students in selecting appropriate reading material.

ANCILLARIES

- An *Instructor's Manual* contains course outlines, suggestions for planetarium programs, main concepts, outlines, test questions for each chapter, as well as sources of supplies, films, books, and charts.
- *Testing software* for both the IBM-PC and MacIntosh environments is available.
- *Wadsworth Astronomy Transparencies* consist of one-, two-, and four-color acetates showing illustrations from Wadsworth astronomy texts.
- *Voyages Through Space and Time* by Jon Wooley, Eastern Michigan University, contains projects for use with VOYAGER, the Interactive Desktop Planetarium, and is for sale to students. Cross-references to *Voyages* appear at the ends of pertinent chapters in the text, where its use would lend further understanding to topics covered in the chapters.
- *Introductory Astronomy Exercises* by Dale Ferguson, Baldwin-Wallace College, contains a wide variety of laboratory exercises and is for sale to students.
- *The Laser Disc Universe* is a HyperCard stack that ties *Horizons* to the widely used laser discs *Astronomy, The Sun,* and *Voyager Gallery* from Optical Data.

Available through an adoption incentive program:

- *Software* for classroom demonstrations or laboratory instruction is available in two formats: *The Sky* for IBM-PCs and compatibles, and VOYAGER, the Interactive Desktop Planetarium for MacIntosh.
- The *videotape series* "The Astronomers" is available as individual tapes or as part of a series.

For more information about any of the above, contact your Wadsworth sales representative.

ACKNOWLEDGMENTS

My thanks to the many students and teachers who have responded so enthusiastically to *Horizons: Exploring the Universe.* Their comments and suggestions have been very helpful in completing this new edition. I would especially like to thank the numerous reviewers whose careful analysis and thoughtful suggestions have been invaluable in refining *Horizons: Exploring the Universe* as a teaching tool.

The people listed in the illustration credits were very kind in providing photographs and diagrams. Special recognition goes to the following, who were always ready to help locate unusual images from their institutions: Frank Bash, McDonald Observatory; Michael Belton, National Optical Astronomy Observatories; Patricia Bridges, U.S. Geological Survey; Jeff Butler, Lancaster County Planning Commission; Linda Carroll, U.S. Geolog-

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Mike Seeds
Lancaster, Pennsylvania

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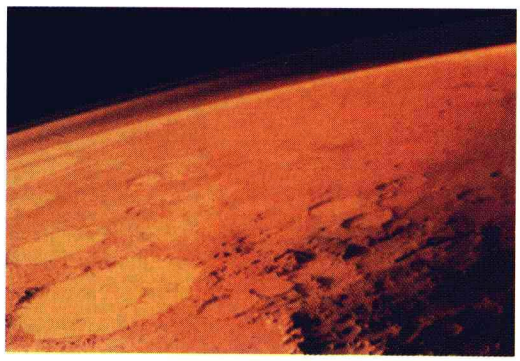
To the Reader



You will approach retirement around the year 2040, and your children about 2065. Your grandchildren will not be retiring until almost 2100. You and your family will live through a century of exploration unlike any in the history of this planet. You will see explorers return to the moon, and your children could be the first colonists in lunar cities. Your grandchildren may reach Mars, mine the asteroid belt, explore the icy satellites of Jupiter and Saturn, or leave the solar system bound for the stars. A century ago the airplane had not been invented. Whatever humanity is like a century in the future, we can guess that it will be deeply involved in the exploration of the solar system. Astronomy, the study of the universe beyond the clouds, helps us understand what we will find when we leave earth.

Living in the next century might be enough justification for taking an astronomy course, but there are other reasons. The coming years will see tremendous advances in science and technology, advances that will confuse anyone not familiar with how science progresses from data to hypothesis to theory to natural law. Should your state permit nuclear waste disposal sites? Should you support construction of orbiting solar power stations? Should you give your children massive doses of vitamin C to combat colds? To resolve such technical issues, you need to apply some of the methods of science. Thus, as you study astronomy in the pages that follow, look at it as an example of scientific reasoning. Distinguish between data and theory, and notice how hypotheses are tested over and over.

Yet another reason for taking an astronomy course is to satisfy your natural curiosity. Having heard about black holes, the expanding universe, or the rings of Saturn, you may want to know more about them. Satisfying your own curiosity is the most noble reason for studying anything.

Curiosity might lead you to consider astronomy as a career, but you should know that the field is very small and jobs are hard to find. You might, however, consider astronomy as a hobby—an activity for personal satisfaction and enrichment. The magazines listed here will keep you up to date with the rapid advances in the field and give you some ideas for further projects, such as telescope building and astronomical photography:

Astronomy, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187

The Griffith Observer, 2800 East Observatory Road, Los Angeles, CA 90027

Mercury, Astronomical Society of the Pacific, 390 Ashton Ave., San Francisco, CA 94112

The Planetary Report, The Planetary Society, 65 N. Catalina Ave., Pasadena, CA 91106

Sky and Telescope, Sky Publishing Corporation, P.O. Box 9111, Belmont, MA 02178-9111

All these reasons for taking astronomy are reasonable, but the most important reason is astronomy's cultural value. The one reason you should study astronomy, the reason your school goes to the expense of teaching the course for you, is that astronomy tells you about your place in nature. It shows you our tiny planet spinning in space amid a vast cosmos of stars and galaxies. It takes you from the first moment of creation to the end of the universe. You will see our planet form, life develop, and our sun die. This knowledge has no monetary value, but it is priceless if you are to appreciate your existence as a human being.

Astronomy will change you. It will not just expand your horizons, it will do away with them. You will see humanity as part of a complex and beautiful universe. If by the end of this course you do not think of yourself and society differently, if you don't feel excited, challenged, and a bit frightened, then you haven't been paying attention.

M.A.S.

ABOUT THE AUTHOR

Mike Seeds is Professor of Astronomy at Franklin & Marshall College, as well as director of the college's Joseph R. Grundy Observatory. An active researcher on photometry of short-period variable stars, he includes among his other research interests archeoastronomy and telescope automation. He is the Principal Astronomer in charge of the Phoenix 10, the first robotic telescope. In 1989 he received the Christian R. and Mary F. Lindback Award for Distinguished Teaching. In addition to writing textbooks, Seeds frequently contributes to journals and creates educational computer programs for students in his own courses. He has also published educational software for toddlers! Seeds is the author of *Foundations of Astronomy, Third Edition*, for Wadsworth, as well as *Astronomy: Selected Readings* (Benjamin/Cummings, 1980), and (with Joseph R. Holzinger) *Laboratory Exercises in Astronomy* (Macmillan, 1976).

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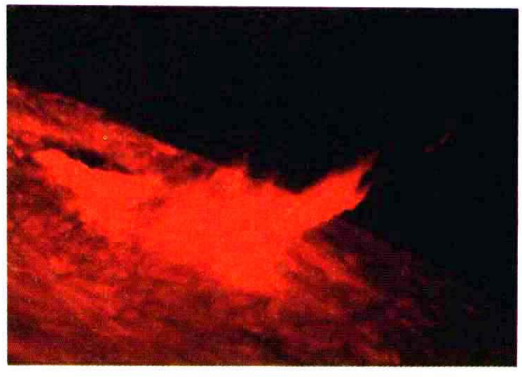

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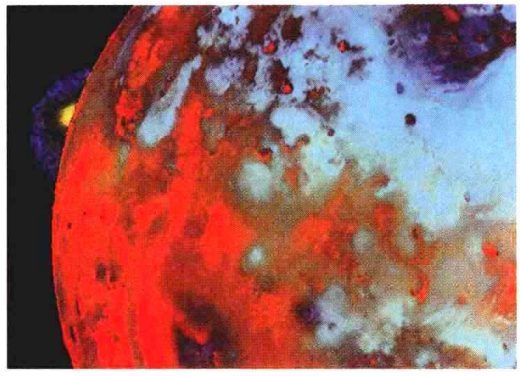

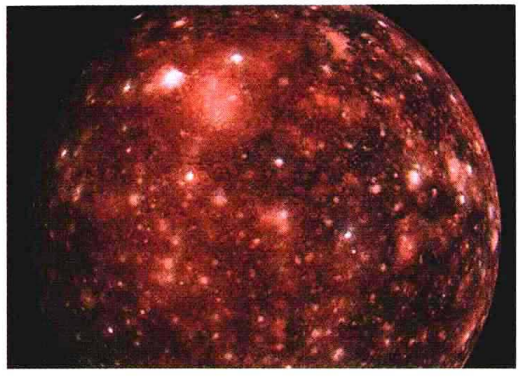

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