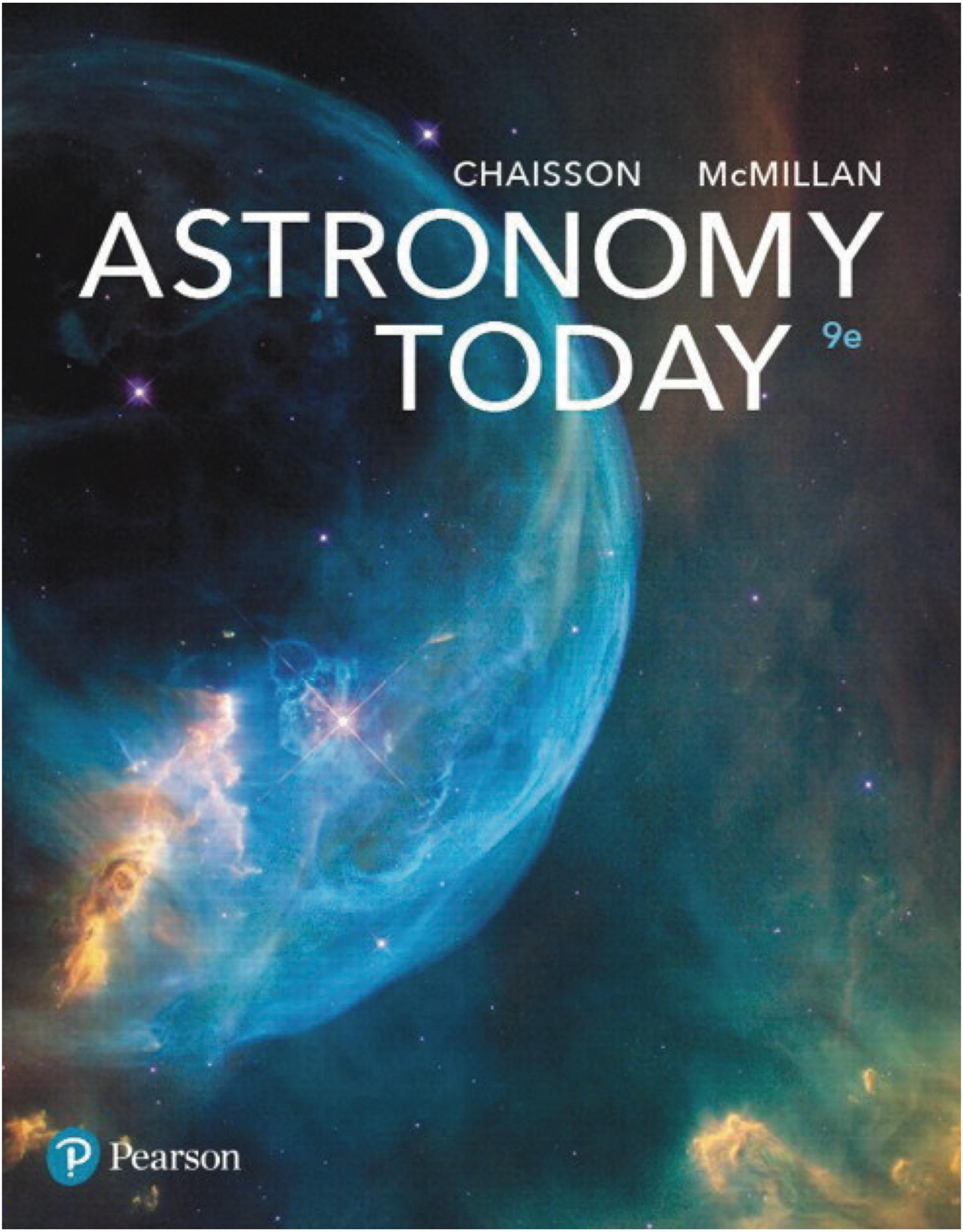
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Cover photo credits:
Main Edition: NASA, ESA, Hubble Heritage Team
Volume 1: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute
Volume 2: NASA, ESA, Digitized Sky Survey 2; Acknowledgement: Davide De Martin

Library of Congress Cataloging-in-Publication Data
Names: Chaisson, Eric. | McMillan, S. (Stephen), 1955-
Title: Astronomy today / Eric Chaisson, Harvard University, Steve McMillan, Drexel University.
Description: 9th edition. | Boston : Pearson, 2017. Contents: vol. 1. The solar system—vol. 2. Stars and galaxies.
Identifiers: LCCN 2016047507| ISBN 9780134450278 | ISBN 0134450272
Subjects: LCSH: Astronomy—Textbooks.
Classification: LCC QB43.3 .C48 2017 | DDC 520—dc23
LC record available at https://lccn.loc.gov/2016047507
2013019295

1 16
ISBN 10: 0134450272; ISBN 13: 9780134450278 (Student edition)
ISBN 10: 013456622X; ISBN 13: 9780134566221 (Volume 1)
ISBN 10: 0134566211; ISBN 13: 9780134566214 (Volume 2)
ISBN 10: 0134580559; ISBN 13: 9780134580555 (NASTA)

Pearson www.pearsonhighered.com

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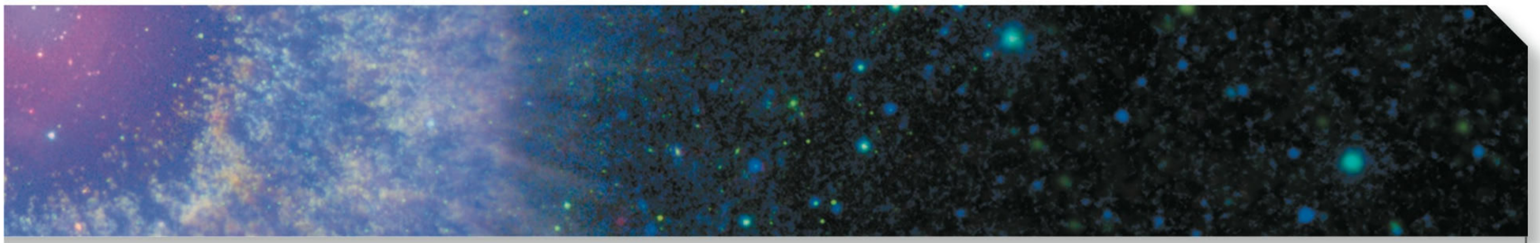

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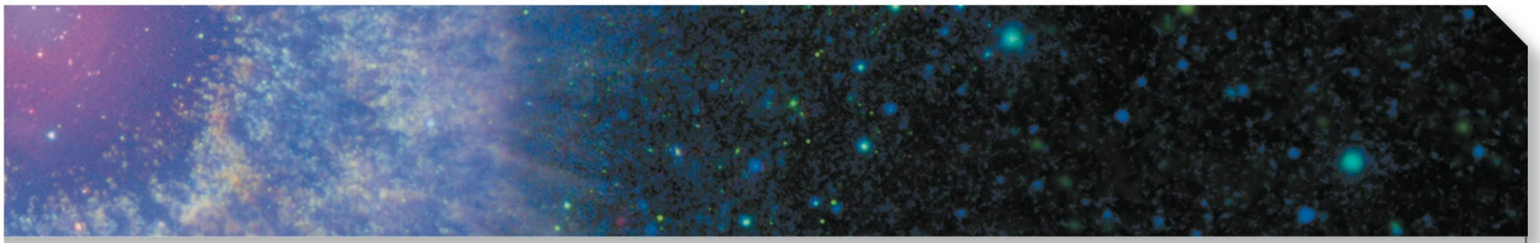

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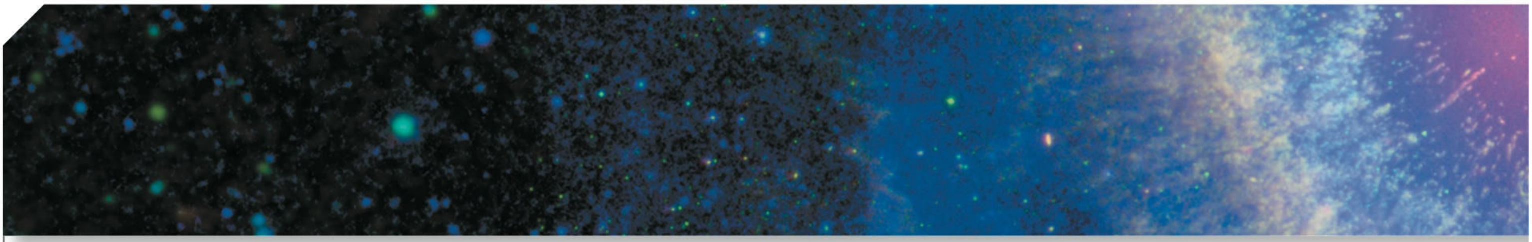

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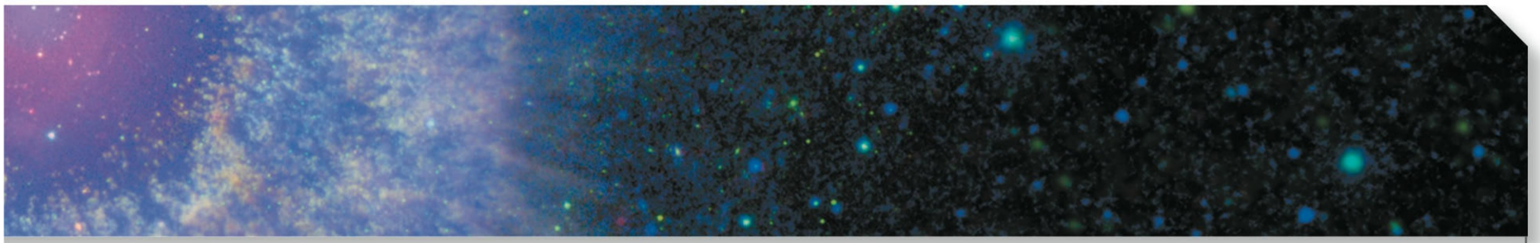

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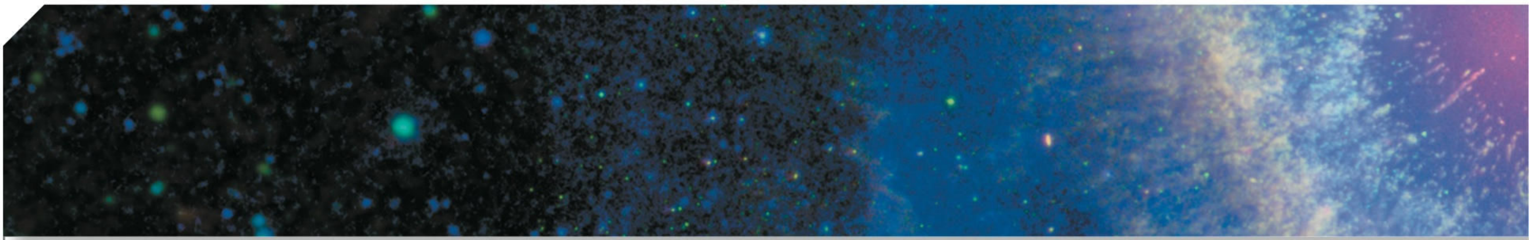

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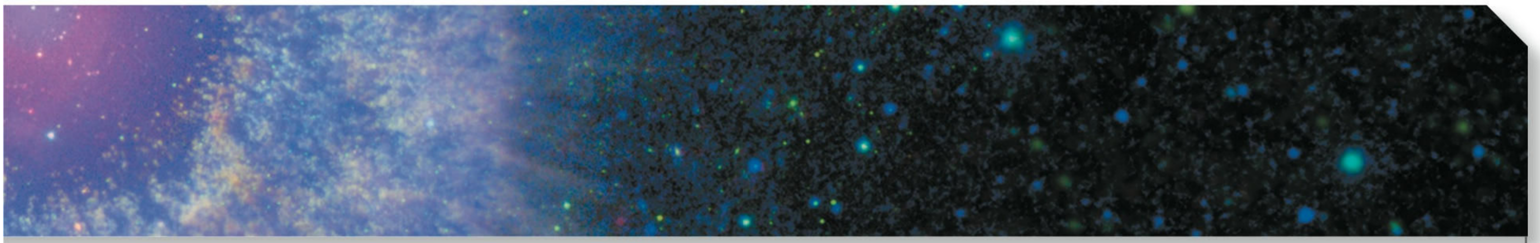

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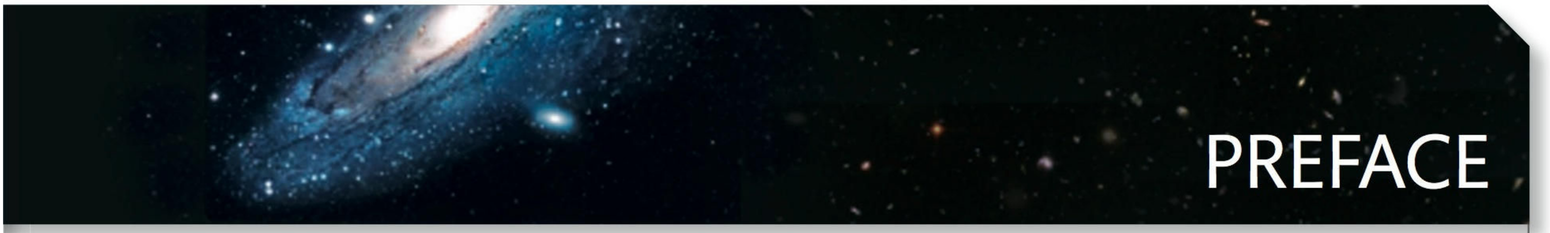


PREFACE

Astronomy is a science that thrives on new discoveries. Fueled by new technologies and novel theoretical insights, the study of the cosmos continues to change our understanding of the universe. We are pleased to have the opportunity to present in this book a representative sample of the known facts, evolving ideas, and frontier discoveries in astronomy today.

Astronomy Today has been written for students who have taken no previous college science courses and who will likely not major in physics or astronomy. It is intended for use in a one- or two-semester, nontechnical astronomy course. We present a broad view of astronomy, straightforwardly descriptive and without complex mathematics. The absence of sophisticated mathematics, however, in no way prevents discussion of important concepts. Rather, we rely on qualitative reasoning as well as analogies with objects and phenomena familiar to the student to explain the complexities of the subject without oversimplification. We have tried to communicate the excitement we feel about astronomy and to awaken students to the marvelous universe around us.

We are very gratified that the first eight editions of this text have been so well received by many in the astronomy education community. In using those earlier texts, many teachers and students have given us helpful feedback and constructive criticisms. From these, we have learned to communicate better both the fundamentals and the excitement of astronomy. Many improvements inspired by these comments have been incorporated into this new edition.

Focus of the Ninth Edition

From the first edition, we have tried to meet the challenge of writing a book that is both accurate and approachable. To the student, astronomy sometimes seems like a long list of unfamiliar terms to be memorized and repeated. Many new terms and concepts are introduced in this course, but we hope students will also learn and remember how science is done, how the universe works, and how things are connected. In the ninth edition, we have taken particular care to show how astronomers know what they know, and to highlight both the scientific principles underlying their work and the process used in discovery.

New and Revised Material

Astronomy is a rapidly evolving field and, in the three years since the publication of the eighth edition of *Astronomy Today,* has seen many new discoveries covering the entire spectrum of astronomical research. Almost every chapter in the ninth edition has been substantially updated with new information. Several chapters have also seen significant reorganization in order to streamline the overall presentation, strengthen our focus on the process of science, and reflect new understanding and emphases in contemporary astronomy.

In addition to updates throughout the text on the numbers and properties of the many astronomical objects, the many substantive changes include:

- New discussion in Chapter 5 of next-generation telescopes and high-resolution astronomy.
- Updated information and imagery in *Discovery 5-1* on the ALMA array.
- New discussion in Chapter 8 of ice on the Moon.
- Additional coverage in Chapter 8 of Mercury's surface and interior based on *Messenger* data.
- New discussion in Chapter 10 of the depletion of the Martian atmosphere.
- Expanded coverage in Chapter 10 of the *Curiosity* rover on Mars and its findings so far.
- Update in Chapter 11 on the changing appearance of Jupiter's Great Red Spot.
- New material in Chapter 11 on the 2016 *Juno* mission.
- Updated discussion in Chapter 11 of the internal structure of Ganymede.
- New discussion in Chapter 12 of storms on Saturn.
- Expanded coverage in Chapter 12 of lakes and other features on the surface of Saturn's moon Titan.
- Additional material in Chapter 12 on Saturn's moon Enceladus.
- Update in Chapter 13 on the return of Neptune's Dark Spot.
- New coverage in Chapter 14 of the *Dawn* mission to Ceres.
- Extensive discussion in Chapter 14 of the *Rosetta* mission to comet 67 P/Churyumov–Gerasimenko.
- Completely revised presentation of Pluto in Chapter 14 based on data from the *New Horizons* mission.
- Updated and rewritten presentation in Chapter 15 of exoplanet searches and properties.
- New material in Chapter 15 on direct imaging as an exoplanet detection technique.
- Expanded discussion in Chapter 15 of exoplanet composition.
- Presentation in new *Discovery 15-1* of gravitational microlensing as an important exoplanet detection technique.
- Updated discussion in Chapter 15 of habitable zones and planetary systems in star clusters.

- Additional material in *Discovery 16-1* on *the Solar Dynamics Observatory.*
- Substantially improved discussion and imagery in Chapter 16 of the sunspot cycle.
- New coverage in Chapter 17 on the *GAIA* astrometric mission.
- Additional material in *Discovery 19-1* on brown dwarfs, clarifying the distinction between brown dwarfs and planets.
- Improved text and imagery in Chapter 19 on the observational evidence for various stages of star formation: ALMA imagery of protostellar collapse; *HST* observations of protoplanetary disks.
- Improved simulations of star cluster formation in Chapter 19.
- Expanded discussion in *Discovery 20-2* of mass loss from giant stars.
- Emphasis in Chapter 22 of the connection between hypernovae and black holes.
- Expanded treatment in *Discovery 22-1* of relativity and time dilation.
- Rewritten discussion of gravitational radiation in *Discovery 22-1*, including extensive coverage of the 2015 LIGO detections.
- Reconsideration in Chapter 22 of the existence of black holes, in the light of the new LIGO findings.
- New coverage in Chapter 23 of the "X" in the Milky Way bulge and its implication for our Galaxy's history.
- Expanded material in Chapter 23 on the "S stars" in the Galactic center and energetic outflows from the Galactic center into the halo.
- Updated discussion of extremophilic life in Chapter 28.
- Consistent distance scales in all figures, helping students gain an understanding of the vastness of the universe.
- Numerous replacement images for currency and clarity, and updated art throughout the text.

The Illustration Program

Visualization plays an important role in both the teaching and the practice of astronomy, and we continue to place strong emphasis on this aspect of our book. We have tried to combine aesthetic beauty with scientific accuracy in the artist's conceptions that adorn the text, and we have sought to present the best and latest imagery of a wide range of cosmic objects. Each illustration has been carefully crafted to enhance student learning; each is pedagogically sound and tied tightly to the nearby discussion of important scientific facts and ideas. This edition contains more than 100 revised figures that show the latest imagery and the results learned from them.

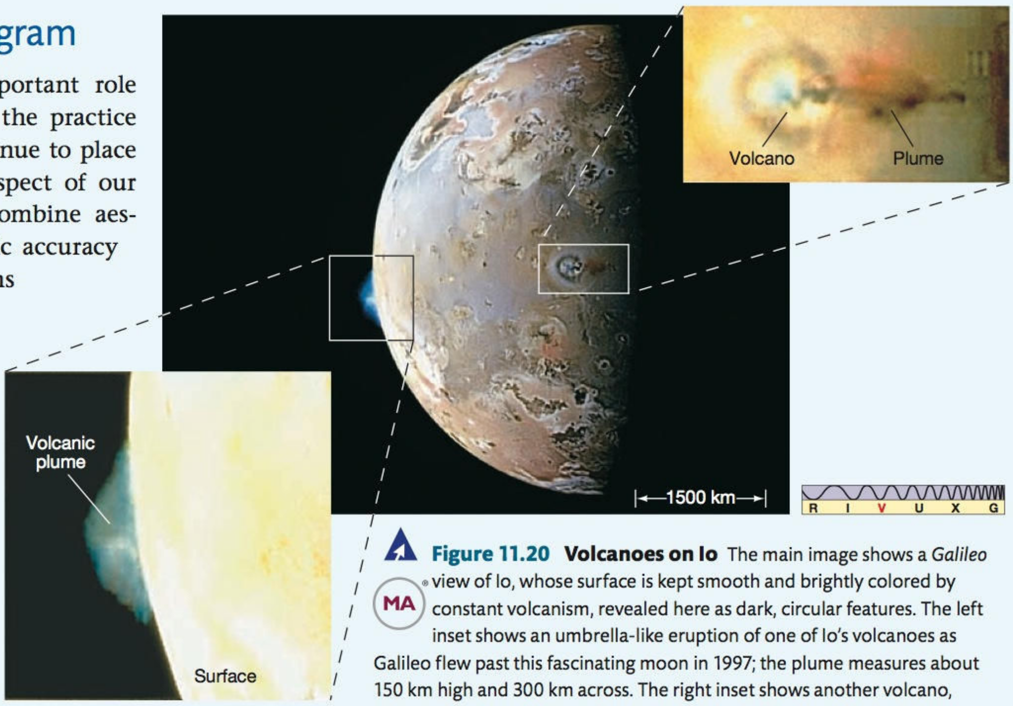


Figure 11.20 Volcanoes on Io The main image shows a *Galileo* view of Io, whose surface is kept smooth and brightly colored by constant volcanism, revealed here as dark, circular features. The left inset shows an umbrella-like eruption of one of Io's volcanoes as Galileo flew past this fascinating moon in 1997; the plume measures about 150 km high and 300 km across. The right inset shows another volcano, this one face-on, where surface features here are resolved to just a few kilometers. *(NASA)*

Compound Art It is rare that a single image, be it a photograph or an artist's conception, can capture all aspects of a complex subject. Wherever possible, multiple-part figures are used in an attempt to convey the greatest amount of information in the most vivid way:

- Visible images are often presented along with their counterparts captured at other wavelengths.
- Interpretive line drawings are often superimposed on or juxtaposed with real astronomical photographs, helping students to really "see" what the photographs reveal.

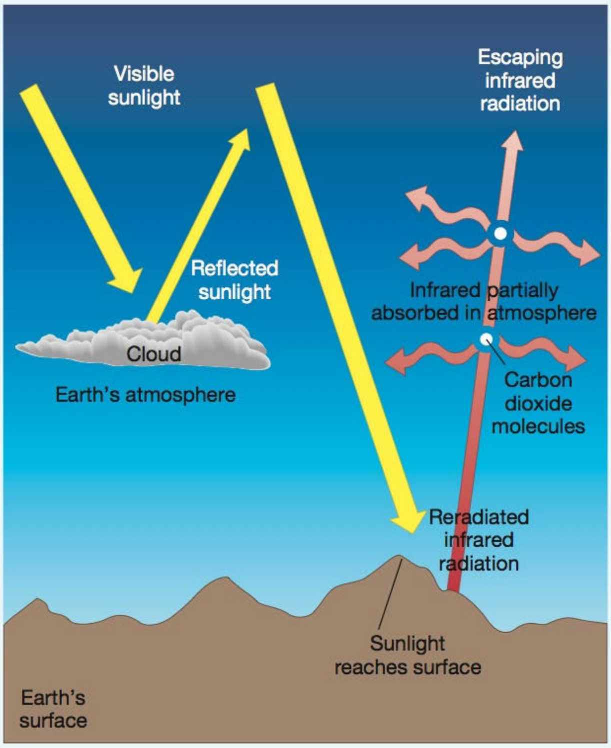


Figure 7.5 Greenhouse Effect Sunlight that is not reflected by clouds reaches Earth's surface, warming it up. Infrared radiation reradiated from the surface is partially absorbed by carbon dioxide (and also water vapor, not shown here) in the atmosphere, causing the overall surface temperature to rise.

- Breakouts—often multiple ones—are used to zoom in from wide-field shots to close-ups so that detailed images can be understood in their larger context.

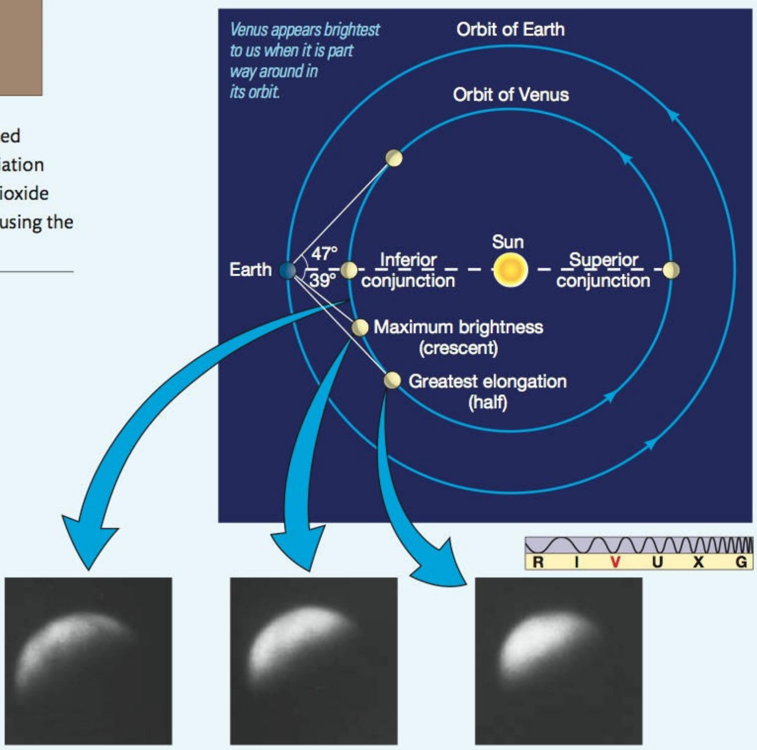
Figures and Photos Icons throughout the text direct students to dynamic, interactive versions of art and photos on MasteringAstronomy®. Using online applets, students can manipulate factors such as time, wavelength, scale, and perspective to increase their understanding of these figures.

NARRATED Figures Narrated Figures are brief videos that step students through complex figures from the text, expanding students' understanding of fundamental concepts in a presentation that includes narration, enhanced visuals, and one to two embedded questions, followed by short, one- to two-question Mastering activities that are graded. They mirror how an instructor might present a topic in class and can be assigned as homework, self-study, or as part of a pre-lecture program.

Figure Annotations The ninth edition incorporates the research-proven technique of strategically placing annotations (which always appear in blue type) within key pieces of art, fostering students' ability to read and interpret complex figures, focus on the most relevant information, and integrate written and visual knowledge.

Full Spectrum Coverage and Spectrum Icons 

Astronomers exploit the full range of the electromagnetic spectrum to gather information about the cosmos. Throughout this book, images taken at radio, infrared, ultraviolet, X-ray, or gamma-ray wavelengths are used to supplement visible-light images. As it is sometimes difficult (even for a professional) to tell at a glance which images are visible-light photographs and which are false-color images created with other wavelengths, each photo in the text is accompanied by an icon that identifies the wavelength of electromagnetic radiation used to capture the image.



NARRATED Figure 9.2 Venus's Brightness Venus appears full when it is at its greatest distance from Earth, on the opposite side of the Sun from us (superior conjunction). As its distance decreases, less and less of its sunlit side becomes visible. When closest to Earth, it lies between us and the Sun (inferior conjunction), so we cannot see the sunlit side of the planet at all. Venus appears brightest when it is about 39° from the Sun. (Compare Figure 2.12.) *(Insets: UC Regents/Lick Observatory)*

Other Pedagogical Features

As with many other parts of our text, instructors have helped guide us toward what is most helpful for effective student learning. With their assistance, we have revised both our in-chapter and end-of-chapter pedagogical apparatus to increase its utility to students.

Learning Outcomes Studies indicate that beginning students have trouble prioritizing textual material. For this reason, a few (typically five or six) well-defined Learning Outcomes are provided at the start of each chapter. These help students structure their reading of the chapter and then test their mastery of key concepts. The Learning Outcomes are numbered and keyed to the items in the Chapter Summary, which in turn refer back to passages in the text. This highlighting of the most important aspects of the chapter helps students prioritize information and also aids in their review. The Learning Outcomes are organized and phrased in such a way as to make them objectively testable, affording students a means of gauging their own progress.

LEARNING OUTCOMES

Studying this chapter will enable you to

1. Summarize the composition and physical properties of the interstellar medium.
2. Describe the characteristics of emission nebulae, and explain their significance in the life cycle of stars.
3. List the basic properties of dark interstellar clouds.
4. Specify the radio techniques used to probe the nature of interstellar matter.
5. Explain the nature and significance of interstellar molecules.

The Big Picture The Big Picture feature on every chapter opening spread encapsulates the overarching message that each chapter imparts, helping students see how chapter content is connected to a broad understanding of the universe.

The Big Picture

Stars are everywhere in the night sky. The naked eye can distinguish about 6000 of them, spread across 88 constellations. With binoculars or even a small telescope, millions more become visible. The total number of stars, even in our local cosmic neighborhood, is virtually beyond our ability to count. By analyzing the light from millions of distant stars, astronomers have learned a great deal about stellar properties—their masses and radii, their luminosities, even their ages and destinies. Stars tell us more about the fundamentals of astronomy than any other class of objects in the universe.

The Big Question Each chapter now ends with a broad, open-ended query that is intended to ignite students' curiosity about the still-unanswered questions at the forefront of astronomical research. The Big Question builds on the material presented in the chapter and invites students to speculate on the larger scope of what they have just learned.

The Big Question

We will see in the next few chapters that, once you specify the mass and composition of a star, its structure and future evolution are largely set. But are the masses of newly formed stars pretty much the same everywhere, or do they vary systematically from place to place in our Galaxy and beyond? Astronomers generally assume the former, since that's the only practical way we can do astronomy, but is it true? At the cutting edge of research, astronomers are now testing this fundamental assumption against state-of-the-art observations.

Concept Checks We incorporate into each chapter a number of "Concept Checks"—key questions that require the reader to reconsider some of the material just presented or attempt to place it into a broader context. Answers to these in-chapter questions are provided at the back of the book.

CONCEPT Check

▶ Why do astronomers draw such a clear distinction between the inner and the outer planets?

Process of Science Checks Each chapter now also includes one or two "Process of Science Checks," similar to the Concept Checks but aimed specifically at clarifying the questions of how science is done and how scientists reach the conclusions they do. Answers to these in-chapter questions are also provided at the back of the book.

PROCESS OF SCIENCE Check

▶ In what sense are the comets we see *un*representative of comets in general?

Data Points (NEW) Data Points sidebars in each chapter, based on data captured from thousands of students, alert students to the statistically most common mistakes made when working problems on related topics in MasteringAstronomy®.

Concept Links In astronomy, as in many scientific disciplines, almost every topic seems to have some bearing on almost every other. In particular, the connection between the astronomical material and the physical principles set forth early in the text is crucial. Practically everything in Chapters 6–28 of this text rests on the foundation laid in the first five chapters. For example, it is important that students, when they encounter the discussion of high-redshift objects in Chapter 25, recall not only what they just learned about Hubble's law in Chapter 24 but also refresh their memories, if necessary, about the inverse-square law (Chapter 17), stellar spectra (Chapter 4), and the Doppler shift (Chapter 3). Similarly, the discussions of the mass of binary-star components (Chapter 17) and of galactic rotation (Chapter 23) both depend on the discussion of Kepler's and Newton's laws in Chapter 2. Throughout, discussions of new astronomical objects and concepts rely heavily on comparison with topics introduced earlier in the text.

It is important to remind students of these links so that they recall the principles on which later discussions rest and, if necessary, review them. To this end, we have inserted "concept links" throughout the text—symbols that mark key intellectual bridges between material in different chapters. The links, denoted by the symbol ∞ together with a section reference, signal that the topic under discussion is related in some significant way to ideas developed earlier and provide direction to material to review before proceeding.

Key Terms Like all subjects, astronomy has its own specialized vocabulary. To aid student learning, the most important astronomical terms are boldfaced at their first appearance in the text. Boldfaced Key Terms in the Chapter Summary are linked with the page number where the term was defined. In addition, an expanded alphabetical glossary, defining each Key Term and locating its first use in the text, appears at the end of the book.

H–R Diagrams and Acetate Overlays All of the book's H–R diagrams are drawn in a uniform format, using real data. In addition, a unique set of transparent acetate overlays dramatically demonstrates to students how the H–R diagram helps us to organize our information about the stars and track their evolutionary histories.

More Precisely Boxes These boxes provide more quantitative treatments of subjects discussed qualitatively in the text. Removing these more challenging topics from the main flow of the narrative and placing them within a separate modular element of the chapter design (so that they can be covered in class, assigned as supplementary material, or simply left as optional reading for those students who find them of interest) will allow instructors greater flexibility in setting the level of their coverage.

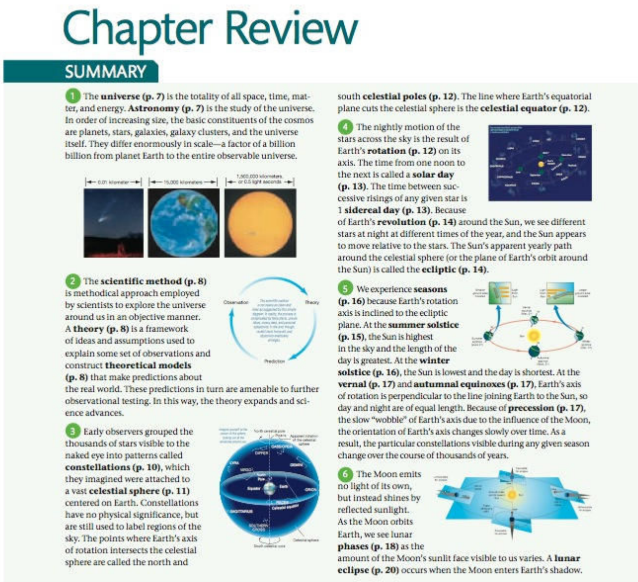
Discovery Boxes Exploring a wide variety of interesting supplementary topics, Discovery boxes provide the reader with insight into how scientific knowledge evolves and emphasizes the process of science.

End-of-Chapter Questions, Problems, and Activities (Extensively Revised)

- Each chapter incorporates **Review and Discussion Questions**, which may be used for in-class review or for assignment. As with the Self-Test Questions, the material needed to answer Review Questions may be found within the chapter. The Discussion Questions explore particular topics more deeply, often asking for opinions, not just facts. As with all discussions, these questions usually have no single "correct" answer. Questions identified with a **POS** icon encourage students to explore the Process of Science, and each Learning Outcome is reflected in one of the Review and Discussion questions, marked by **LO**. **BP (NEW)** questions relate to the Big Picture item at the start of the chapter.
- Each chapter also contains **Conceptual Self-Test Questions** in a multiple-choice format, including select questions that are tied directly to a specific figure or diagram in the text, allowing students to assess their understanding of the chapter material. These questions are identified with a **VIS** icon. Answers to all these questions appear at the end of the book.
- The end-of-chapter material includes **Problems**, based on the chapter contents and requiring some numerical calculation. In many cases the problems are tied directly to quantitative statements made (but not worked out in detail) in the text. The solutions to the problems are not contained verbatim within the chapter, but the information necessary to solve them has been presented in the text. Answers to odd-numbered Problems appear at the end of the book.
- Heavily revised in this edition, the end-of-chapter material now ends with collaborative and individual **Activities**

relevant to the material presented in the text. These range from basic naked-eye and telescopic observing projects to opinion polls, surveys, group discussions, and astronomical research on the Web.

Chapter Review Summaries The Chapter Review Summaries, a primary review tool, are linked to the Learning Outcomes at the beginning of each chapter. Key Terms introduced in each chapter are listed again, in context and in boldface, along with key figures and page references to the text discussion.



Chapter Review

SUMMARY

1 The **universe (p. 7)** is the totality of all space, time, matter, and energy. **Astronomy (p. 7)** is the study of the universe. In order of increasing size, the basic constituents of the cosmos are planets, stars, galaxies, galaxy clusters, and the universe itself. They differ enormously in scale—a factor of a billion billion from planet Earth to the entire observable universe.

2 The **scientific method (p. 8)** is methodical approach employed by scientists to explore the universe around us in an objective manner. A **theory (p. 8)** is a framework of ideas and assumptions used to explain some set of observations and construct **theoretical models (p. 8)** that make predictions about the real world. These predictions in turn are amenable to further observational testing. In this way, the theory expands and science advances.

3 Early observers grouped the thousands of stars visible to the naked eye into patterns called **constellations (p. 10)**, which they imagined were attached to a vast **celestial sphere (p. 11)** centered on Earth. Constellations have no physical significance, but are still used to label regions of the sky. The points where Earth's axis of rotation intersects the celestial sphere are called the north and south **celestial poles (p. 12)**. The line where Earth's equatorial plane cuts the celestial sphere is the **celestial equator (p. 12)**.

4 The nightly motion of the stars across the sky is the result of Earth's **rotation (p. 12)** on its axis. The time from one noon to the next is called a **solar day (p. 13)**. The time between successive risings of any given star is 1 **sidereal day (p. 13)**. Because of Earth's **revolution (p. 14)** around the Sun, we see different stars at night at different times of the year, and the Sun appears to move relative to the stars. The Sun's apparent yearly path around the celestial sphere (or the plane of Earth's orbit around the Sun) is called the **ecliptic (p. 14)**.

5 We experience **seasons (p. 16)** because Earth's rotation axis is inclined to the ecliptic plane. At the **summer solstice (p. 15)**, the Sun is highest in the sky and the length of the day is greatest. At the **winter solstice (p. 16)**, the Sun is lowest and the day is shortest. At the **vernal (p. 17)** and **autumnal equinoxes (p. 17)**, Earth's axis of rotation is perpendicular to the line joining Earth to the Sun, so day and night are of equal length. Because of **precession (p. 17)**, the slow "wobble" of Earth's axis due to the influence of the Moon, the orientation of Earth's axis changes slowly over time. As a result, the particular constellations visible during any given season change over the course of thousands of years.

6 The Moon emits no light of its own, but instead shines by reflected sunlight. As the Moon orbits Earth, we see lunar **phases (p. 18)** as the amount of the Moon's sunlit face visible to us varies. A **lunar eclipse (p. 20)** occurs when the Moon enters Earth's shadow.

Instructor Resources

MA® *www.masteringastronomy.com*

MasteringAstronomy® is the most widely used and most advanced astronomy tutorial and assessment system in the world. By capturing the step-by-step work of students nationally, MasteringAstronomy® has established an unparalleled database of learning challenges and patterns. Using this student data, a team of renowned astronomy education researchers has refined every activity and problem. The result is a library of activities of unique educational effectiveness and assessment accuracy. MasteringAstronomy® provides students with two learning systems in one: a dynamic self-study area and the ability to participate in online assignments.

MasteringAstronomy® provides instructors with a fast and effective way to assign uncompromising, wide-ranging online homework assignments of just the right difficulty and duration. The tutorials coach 90 percent of students to the correct answer with specific wrong-answer feedback. Powerful post-diagnostics allow instructors to assess the progress of their class as a whole or to quickly identify an individual student's areas of difficulty. Tutorials built around text content and all the end-of-chapter problems from the text are available in MasteringAstronomy®. A media-rich self-study area is included that students can use whether the instructor assigns homework or not.

Instructor Guide Revised by James Heath (Austin Community College), this online guide provides sample syllabi and course schedules; an overview of each chapter; pedagogical tips; useful analogies; suggestions for classroom demonstrations; writing questions, selected readings, and answers/solutions to the end-of-chapter Review and Discussion Questions and Problems; and additional references and resources. ISBN 0-13-455418-3

Test Bank An extensive file of approximately 2800 test questions, newly compiled and revised for the ninth edition. The questions are organized and referenced by chapter section and by question type. The ninth edition Test Bank has been thoroughly revised and includes many new Multiple-Choice and Essay questions for added conceptual emphasis. This Test Bank is available in both Microsoft® Word and TestGen® formats. ISBN 0-13-455413-2

Instructor Resource Area in Mastering Astronomy This instructor resource area resides in MasteringAstronomy® and provides every electronic asset professors will need in and out of the classroom. The area not only contains an Instructor's Resource Manual, but also all text figures in jpeg and PowerPoint formats, including additional images, star charts, as well as the animations and videos from the MasteringAstronomy® Study Area. The area also contains TestGen®, an easy-to-use, fully networkable program for creating tests ranging from short quizzes to long exams. Questions from the Test Bank are supplied, and professors can use the Question Editor to modify existing questions or create new questions. It also contains chapter-by-chapter lecture outlines and conceptual "clicker" questions in PowerPoint. It is available in both PC and Mac formats.

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Student Resources

MA www.masteringastronomy.com

This homework, tutorial, and assessment system is uniquely able to tutor each student individually by providing students with instantaneous feedback specific to their wrong answers, simpler subproblems upon request when they get stuck, and partial credit for their method(s) used. Students also have access to a self-study area that contains practice quizzes, self-guided tutorials, narrated and interactive figures, animations, videos, and more.

Pearson eText 2.0 is available through MasteringAstronomy®, either automatically when MasteringAstronomy® is packaged with new books, or available as a purchased upgrade online. Allowing the students to access the text wherever they have access to the Internet, Pearson eText comprises the full text, including figures that can be enlarged for better viewing, and embedded narrated and interactive figures where relevant. Within Pearson eText students are also able to pop up definitions and terms to help with vocabulary and the reading of the material. Students can also take notes in Pearson eText using the annotation feature.

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Sky and Telescope Based on the most popular amateur astronomy magazine, this special student supplement contains nine articles by Evan Skillman, each with a general overview and four question sets focused on the issues professors most want to address in this course: General Review, Process of Science, Scale of the Universe, and Our Place in the Universe. ISBN 0-321-70620-X

Lecture-Tutorials for Introductory Astronomy, 3rd Edition
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Observation Exercises in Astronomy This workbook by Lauren Jones contains a series of astronomy exercises that integrate technology from planetarium software such as Stellarium, Starry Night College, WorldWide Telescope, and SkyGazer. Using these online products adds an interactive dimension to students' learning. ISBN: 0-321-63812-3

Astronomy Labs: A Concept-Oriented Approach This modular collection of 40 conceptually-oriented astronomy labs by Nate McCrady and Emily Rice is housed in the Pearson Custom Library for easy creation of a customized lab manual. The labs cover astronomy content from the night sky and the Solar System to extragalactic topics and cosmology and engage students in higher levels of Bloom's taxonomy: application, synthesis, and analysis. Most of the labs use only inexpensive everyday objects, such as flashlights, construction paper, theatre gels, etc., and many labs require no additional equipment or materials. Instructors can select only those labs that they wish to include in their custom lab manual and the final price will be based on the number of labs selected. ISBN-13: 9780321861771

Acknowledgments

Throughout the many drafts that have led to this book, we have relied on the critical analysis of many colleagues. Their suggestions ranged from the macroscopic issue of the book's overall organization to the minutiae of the technical accuracy of each and every sentence. We have also benefited from much good advice and feedback from users of the first eight editions of the text. To these many helpful colleagues, we offer our sincerest thanks.

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The publishing team at Pearson has assisted us at every step along the way in creating this text. Special thanks go to content producers Alyc Helms, Lizette Faraji, and Rebecca Groves, who managed the many conflicting variables and looming deadlines that are a part of a multifaceted publication such as this. Executive editor Nancy Whilton steered this edition through all its phases. Production manager Jason Hammond of SPi Global has done an excellent job of tying together the threads of this very complex project, made all the more complex by the necessity of combining text, art, and electronic media into a coherent whole. Special thanks are in order to cover and interior designer Jeff Puda for making the ninth edition look spectacular and to Marilyn Perry and Mark Ong for guiding the overall look of the book. We would also like to express our appreciation to Jenny Moryan for updating and maintaining the media resources in the MasteringAstronomy® Study Area and to Christina Cavalli, author of the MasteringAstronomy® Narrated Figures.

Eric Chaisson
Steve McMillan

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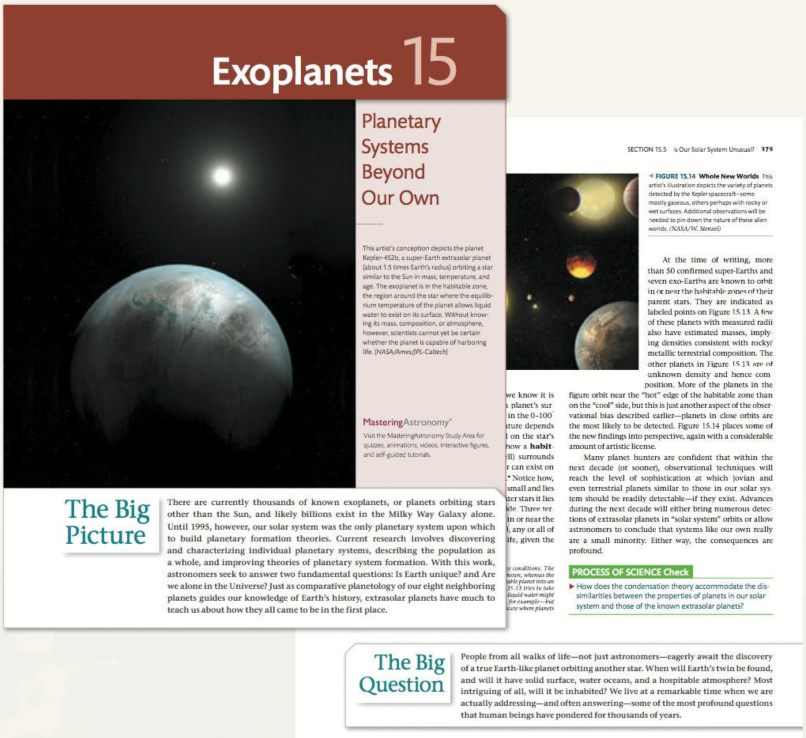
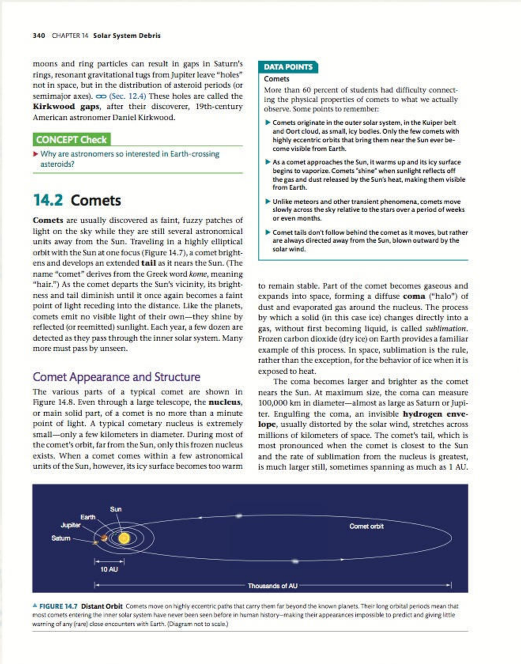
ASTRONOMY TODAY 9e

Based on cutting-edge scientific and education research, authors bring together the story of astronomy



Significantly Enhanced!

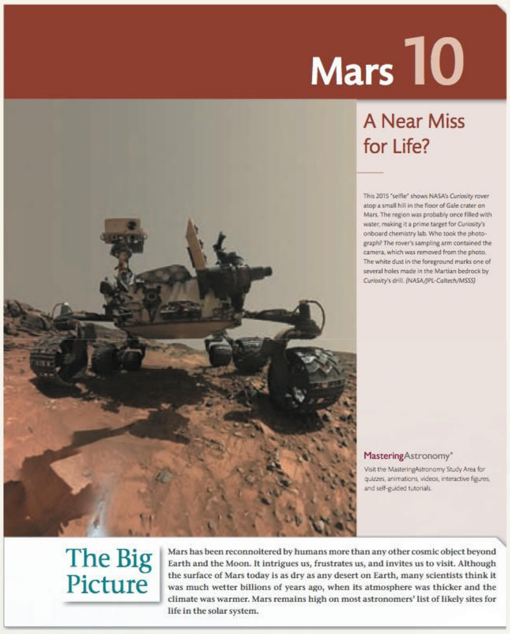
Big Picture theme, now woven throughout each chapter, helps students see connections between topics in the text and their everyday lives. Each chapter begins with **a Big Picture** opener, continues with Big Picture callouts throughout the chapter, and concludes with end-of-chapter Big Picture Questions, engaging students in a titillating narrative and helping them recognize themes.



NEW! **Data Points** side bars, based on data captured from thousands of students using MasteringAstronomy®, alert students to the most common mistakes made in working problems on related topics.

UPDATED! New author-team member, Emily Rice, applies education research to **restructure end-of-chapter content** in the ninth edition. Newly **redesigned discussion sections** as well as **Individual and Collaborative Activities** now facilitate an active classroom.

New discoveries engage students by helping them realize astronomy is happening right now and all around them



Mars 10

A Near Miss for Life?

This 2015 "selfie" shows NASA's *Curiosity* rover atop a small hill in the floor of Gale crater on Mars. The region was probably once filled with water, making it a prime target for *Curiosity's* onboard chemistry lab. Who took the photograph? The rover's sampling arm contained the camera, which was removed from the photo. The white dust in the foreground marks one of several holes made in the Martian bedrock by *Curiosity's* drill. *(NASA/JPL-Caltech/MSSS)*

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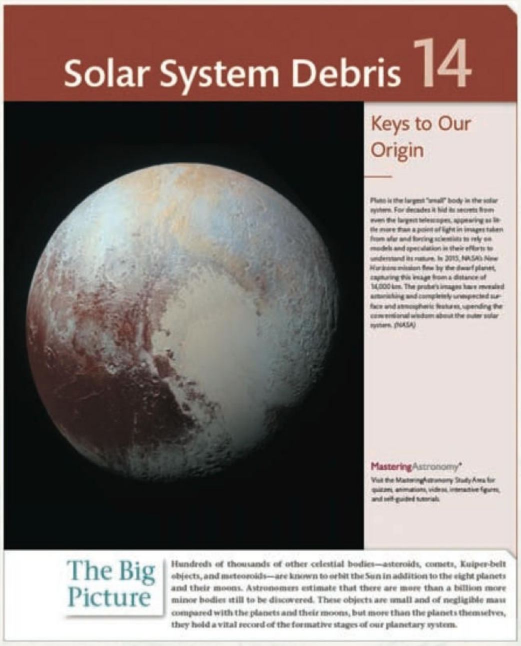
The Big Picture

Mars has been reconnoitered by humans more than any other cosmic object beyond Earth and the Moon. It intrigues us, frustrates us, and invites us to visit. Although the surface of Mars today is as dry as any desert on Earth, many scientists think it was much wetter billions of years ago, when its atmosphere was thicker and the climate was warmer. Mars remains high on most astronomers' list of likely sites for life in the solar system.

Chapters 10–12 include late-breaking updates from the Juno and Mars Maven Missions including discoveries from the Curiosity and new information on Saturn.



Solar System Debris 14

Keys to Our Origin

Pluto is the largest "small" body in the solar system. For decades it hid its secrets from even the largest telescopes, appearing as little more than a point of light in images taken from afar and forcing scientists to rely on models and speculation in their efforts to understand its nature. In 2015, NASA's New Horizons mission flew by the dwarf planet, capturing this image from a distance of 14,000 km. The probe's images have revealed astonishing and completely unexpected surface and atmospheric features, upending the conventional wisdom about the outer solar system. *(NASA)*

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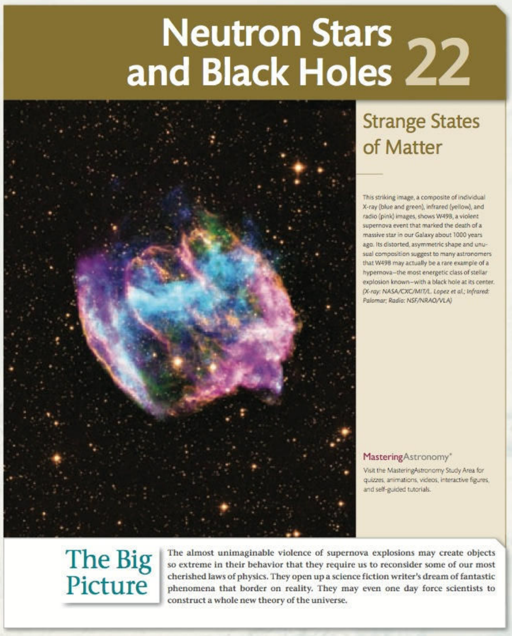
The Big Picture

Hundreds of thousands of other celestial bodies—asteroids, comets, Kuiper-belt objects, and meteoroids—are known to orbit the Sun in addition to the eight planets and their moons. Astronomers estimate that there are more than a billion more minor bodies still to be discovered. These objects are small and of negligible mass compared with the planets and their moons, but more than the planets themselves, they hold a vital record of the formative stages of our planetary system.

Chapters 14 & 15 reflect recent discoveries regarding solar system debris from the Dawn Mission at Ceres, the New Horizon Mission, and exoplanet searches and properties including the recent discovery of a potentially habitable planet around Proxima Centaur.



Neutron Stars and Black Holes 22

Strange States of Matter

This striking image, a composite of individual X-ray (blue and green), infrared (yellow), and radio (pink) images, shows W49B, a violent supernova event that marked the death of a massive star in our Galaxy about 1000 years ago. Its distorted, asymmetric shape and unusual composition suggest to many astronomers that W49B may actually be a rare example of a hypernova—the most energetic class of stellar explosion known—with a black hole at its center. *(X-ray: NASA/CXC/MIT/L. Lopez et al.; Infrared: Palomar; Radio: NSF/NRAO/VLA)*

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The Big Picture

The almost unimaginable violence of supernova explosions may create objects so extreme in their behavior that they require us to reconsider some of our most cherished laws of physics. They open up a science fiction writer's dream of fantastic phenomena that border on reality. They may even one day force scientists to construct a whole new theory of the universe.

Chapter 22 now contains the latest information on gravitational radiation and black holes, particularly the connection between hypernovae and black holes.