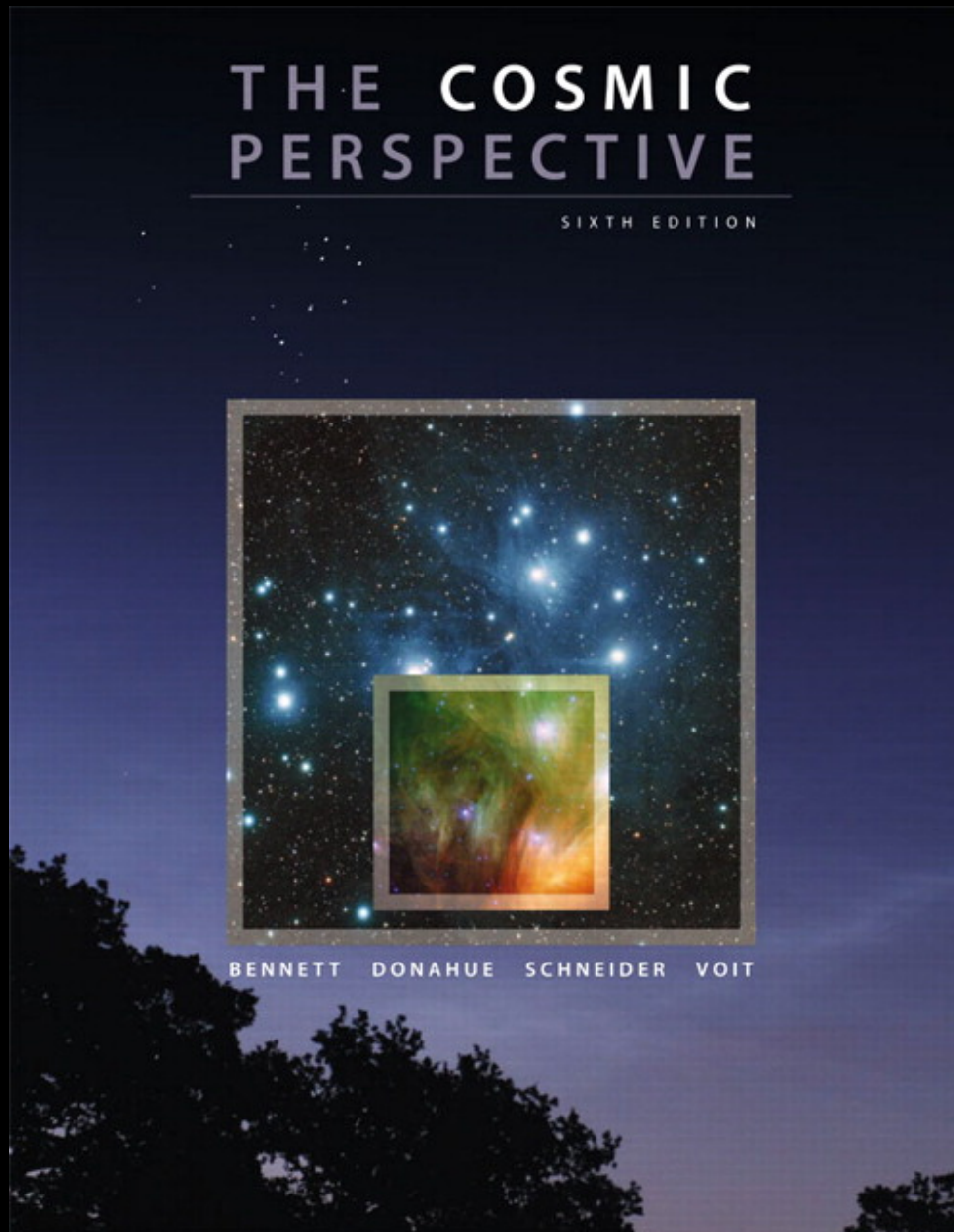


A scale model for cosmic time:  
use the letters in our textbook



# THE COSMIC PERSPECTIVE

SIXTH EDITION



BENNETT DONAHUE SCHNEIDER VOIT

## PREFACE

### FIRST PAGE OF TEXT

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This book grew out of our experience teaching astronomy to both college students and the general public over the past 30 years. During this time, a flood of new discoveries has fueled a revolution in our understanding of the cosmos but had little impact on the basic organization and approach of most astronomy textbooks. We felt the time had come to rethink how to organize and teach the major concepts in astronomy to reflect this revolution in scientific understanding. This book is the result.

#### Who Is This Book For?

*The Cosmic Perspective* is designed as a textbook for college courses in introductory astronomy, but is suitable for anyone who is curious about the universe. We assume no prior knowledge of astronomy or physics, and the book is especially suited to students who do not intend to major in mathematics or science.

*The Cosmic Perspective* provides a comprehensive survey of modern astronomy, and it contains enough material for a two-semester introductory astronomy sequence. It may also be used for one-semester survey courses if professors choose their areas of emphasis. However, instructors of one-term courses may also wish to consider our two shorter versions of this book: *The Essential Cosmic Perspective*, which covers a smaller set of topics and is tailored to meet the needs of comprehensive one-semester survey courses in astronomy, and *The Cosmic Perspective Fundamentals*, which covers only the most fundamental topics in astronomy and is designed for courses that address a more limited set of topics.

#### New to This Edition

The underlying philosophy, goals, and structure of *The Cosmic Perspective* remain the same as in past editions, but we have thoroughly updated the text and made a number of other improvements. Here, briefly, is a list of the significant changes you'll find in the sixth edition:

- **Fully Updated Science:** Astronomy is a fast-moving field, and numerous new developments have occurred since the

prior edition was published. The topics updated in this edition include the following:

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- **New Cosmic Context Two-Page Figures:** We have added three new *Cosmic Context* figures to the book, for a total of 18. These figures use two pages of fully integrated text, art, and photos to outline key processes and summarize major concepts. You'll find one of these figures at the end of each of the seven Parts of the book, and the rest appear within the main bodies of various chapters.
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- **MasteringAstronomy™ [www.masteringastronomy.com](http://www.masteringastronomy.com):** We have reached the point where *The Cosmic Perspective* is no longer just a textbook; rather, it is a “learning package” consisting of a printed text supported by deeply integrated, interactive media that we have developed to support every chapter of our book. For students, MasteringAstronomy provides a wealth of tutorials and activities to build understanding, while quizzes and exercises allow them to test what they've learned. For instructors, MasteringAstronomy provides the unprecedented ability to quickly build, post, and automatically grade pre- and post-lecture diagnostic tests, weekly homework assignments, and exams of appropriate difficulty, duration, and content coverage. It also provides the ability to record detailed information on the step-by-step work of every student directly to a powerful

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Now



Years past



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# Rough Order of Magnitude Estimate

= “ROM”

Very useful for “scoping out” concepts  
in astronomy

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### Themes of *The Cosmic Perspective*

*The Cosmic Perspective* offers a broad survey of modern understanding of the cosmos and of how we have built that understanding. Such a survey can be presented in a number of different ways. We have chosen to interweave a few key themes throughout the book, each selected to help make the subject more appealing to students who may never have taken any formal science courses and who may begin the course with little understanding of how science works. We built our book around the following five key themes:

- *Theme 1: We are a part of the universe and thus can learn about our origins by studying the universe.* This is the overarching theme of *The Cosmic Perspective*, as we continually emphasize that learning about the universe helps us understand ourselves. Studying the intimate connections between human life and the cosmos gives students a reason to care about astronomy and also deepens their appreciation of the unique and fragile nature of our planet and its life.
- *Theme 2: The universe is comprehensible through scientific principles that anyone can understand.* The universe is comprehensible because the same physical laws appear to be at work in every aspect, on every scale, and in every age of the universe. Moreover, while professional scientists generally have discovered the laws, anyone can understand their fundamental features. Students can learn enough in one or two terms of astronomy to comprehend the basic reasons for many phenomena that they see around them—phenomena ranging from seasonal changes and phases of the Moon to the most esoteric astronomical images that appear in the news.
- *Theme 3: Science is not a body of facts but rather a process through which we seek to understand the world around us.* Many students assume that science is just a laundry list of facts. The long history of astronomy can show them that science is a process through which we learn about our universe—a process that is not always a straight line to the truth. That is why our ideas about the cosmos sometimes change as we learn more, as they did dramatically when we first recognized that Earth is a planet going around the Sun rather than the center of the universe. In this book, we continually emphasize the nature of science so that

students can understand how and why modern theories have gained acceptance and why these theories may still change in the future.

- *Theme 4: A course in astronomy is the beginning of a lifelong learning experience.* Building upon the prior themes, we emphasize that what students learn in their astronomy course is not an end but a beginning. By remembering a few key physical principles and understanding the nature of science, students can follow astronomical developments for the rest of their lives. We therefore seek to motivate students enough that they will continue to participate in the ongoing human adventure of astronomical discovery.
- *Theme 5: Astronomy affects each of us personally with the new perspectives it offers.* We all conduct the daily business of our lives with reference to some “world view”—a set of personal beliefs about our place and purpose in the universe that we have developed through a combination of schooling, religious training, and personal thought. This world view shapes our beliefs and many of our actions. Although astronomy does not mandate a particular set of beliefs, it does provide perspectives on the architecture of the universe that can influence how we view ourselves and our world, and these perspectives can potentially affect our behavior. For example, someone who believes Earth to be at the center of the universe might treat our planet quite differently from someone who views it as a tiny and fragile world in the vast cosmos. In many respects, the role of astronomy in shaping world views may represent the deepest connection between the universe and the everyday lives of humans.

### Pedagogical Principles of *The Cosmic Perspective*

No matter how an astronomy course is taught, it is very important to present material according to a clear set of pedagogical principles. The following list briefly summarizes the major pedagogical principles that we apply throughout this book. (The *Instructor Guide* describes these principles in more detail.)

- *Stay focused on the big picture.* Astronomy is filled with interesting facts and details, but they are meaningless unless they fit into a big picture view of the universe. We therefore take care to stay focused on the big picture (essentially the themes discussed above) at all times. A major benefit of this approach is that although students may forget individual facts and details after the course is over, the big picture framework should stay with them for life.
- *Always provide context first.* We all learn new material more easily when we understand why we are learning it. In essence, this is simply the idea that it is easier to get somewhere when you know where you are going. We therefore begin the book ([Chapter 1](#)) with a broad overview of modern understanding of the cosmos, so that students can know what they will be studying in the rest of the book. We maintain this “context first” approach throughout the book by always telling students what they will be learning, and why, before diving into the details.

## sample

count

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## “ROM” calculation for Bennett text as a scale model for cosmic time

- Sample a “typical” page (without illustrations)
- About 50 letters per line
- 58 lines per column
- 2 columns per page

----> About 5800 letters per text page



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## “ROM” calculation for Bennett text as a scale model for cosmic time

- 5800 letters per page
- x 800 pages ----> About 4.6 million letters

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- Deduct about 40% for pictures:
  - > The textbook contains about 2.5 million letters(!)

“ROM” calculation for Bennett text as a  
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- Age of the Sun?

“ROM” calculation for Bennett text as a  
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- Age of the Sun? ~ 5 billion years

“ROM” calculation for Bennett text as a  
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- Age of the Sun? ~ 5 billion years  
= 5,000,000,000 years
- Years/letter:  $5,000,000,000 / 2,500,000$

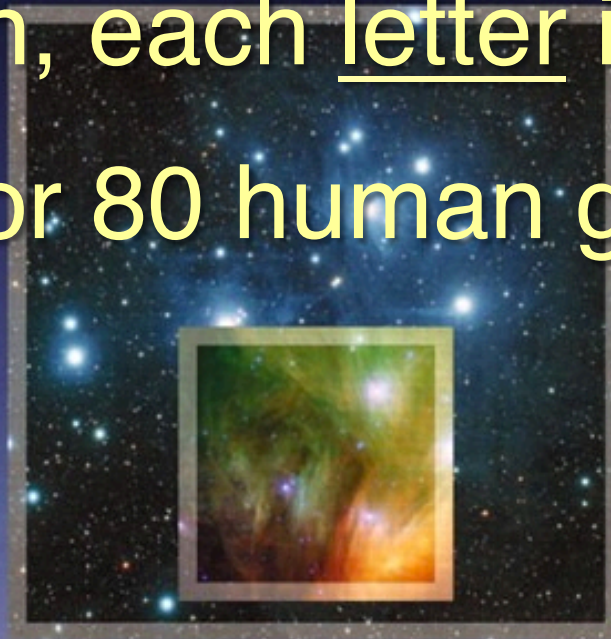
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= 2,000 years per letter(!)

# THE COSMIC PERSPECTIVE

SIXTH EDITION

So, if the whole textbook represents the age of the Sun, each letter is equivalent to 2,000 years (or 80 human generations)



BENNETT DONAHUE SCHNEIDER VOIT



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12,000 yrs ago  
= 10,000 BC



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**Homo sapiens rises**

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# A SCALE MODEL FOR COSMIC TIME

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**18,000,000 yrs ago**

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# PREFACE

## The human era

We humans have gazed into the sky for countless generations. We have wondered how our lives are connected to the Sun, Moon, planets, and stars that adorn the heavens. Today, through the science of astronomy, we know that these connections go far deeper than our ancestors ever imagined. This book tells the story of modern astronomy and the new perspective, *The Cosmic Perspective*, that astronomy gives us of ourselves and our planet.

This book grew out of our experience teaching astronomy to both college students and the general public over the past 30 years. During this time, a flood of new discoveries has fueled a revolution in our understanding of the cosmos. This had little impact on the basic organization and approach of most astronomy textbooks. We felt the time had come to rethink how to organize and teach the major concepts of astronomy to reflect this revolution in scientific understanding. This book is the result.

### Who

**1,000,000 yrs ago**  
The *Cosmic Perspective* is suitable for all one who is curious about the universe. We assume no prior knowledge of astronomy or physics, and the book is especially suited to students who do not intend to major in mathematics or science.

*The Cosmic Perspective* provides a comprehensive survey of modern astronomy, and it contains enough material for a two-semester introductory astronomy sequence. It may also be used for one-semester survey courses if professors choose their areas of emphasis. However, instructors of one-term courses may also wish to consider our two shorter versions of this book: *The Essential Cosmic Perspective*, which covers a smaller set of topics and is tailored to meet the needs of comprehensive one-semester survey courses in astronomy, and *The Cosmic Perspective Fundamentals*, which covers only the most fundamental topics in astronomy and is designed for courses that address a more limited set of topics.

### New to This Edition

The underlying philosophy, goals, and structure of *The Cosmic Perspective* remain the same as in past editions, but we have thoroughly updated the text and made a number of other improvements. Here, briefly, is a list of the significant changes you'll find in the sixth edition:

- **Fully Updated Science:** Astronomy is a fast-moving field, and numerous new developments have occurred since the

# A SCALE MODEL FOR COSMIC TIME

and easy-to-use Gradebook, and evaluate results with a sophisticated suite of diagnostic tools. Among the changes you'll find to the MasteringAstronomy site for this edition are the following:

- A set of new tutorial problems which focus on math review and building quantitative skills for courses with quantitative requirements
- A set of interactive tours which explore celestial objects using WorldWide Telescope (WWT)
- A set of Group Work Activities to foster active and collaborative learning in the classroom
- RSS feeds from a variety of notable astronomy publications
- A fully customizable myeBook product with embedded links to multimedia and glossary terms

### Themes of *The Cosmic Perspective*

*The Cosmic Perspective* offers a broad survey of modern understanding of the cosmos and of how we have built that

prior edition was published. The topics updated in this edition include the following:

- New developments in the study of extrasolar planets and planetary systems, including early results from *Kepler*
- Discussion of the IAU decision to create a "dwarf planet" category
- New results and images from spacecraft exploring our solar system, including *Phoenix* on Mars, *Cassini* at

**First homework assignment: stare at the textbook & try to visualize the time it took to shape the Earth and its lifeforms.**

Each chapter concludes with a new set of questions designed to help students build their visual interpretation skills so that they can better understand the many types of visual information used in astronomy. Answers are given in the back of the book so that students can use them to review before exams.

- **MasteringAstronomy™ [www.masteringastronomy.com](http://www.masteringastronomy.com):** We have reached the point where *The Cosmic Perspective* is no longer just a textbook; rather, it is a "learning package" consisting of a printed text supported by deeply integrated interactive media that we have developed to support every chapter of our book. For students, MasteringAstronomy provides a wealth of tutorials and activities to build understanding, while quizzes and exercises allow them to test what they've learned. For instructors, MasteringAstronomy provides the unprecedented ability to quickly build, post, and automatically grade pre- and post-lecture diagnostic tests, weekly homework assignments, and exams of appropriate difficulty, duration, and content coverage. It also provides the ability to record detailed information on the step-by-step work of every student directly to a powerful

principles that govern our universe. The universe is comprehensible because the same physical laws appear to be at work in every aspect, on every scale, and in every age of the universe. Moreover, while professional scientists generally have discovered the laws, anyone can understand their fundamental features. Students can learn enough in one or two terms of astronomy to comprehend the basic reasons for many phenomena that they see around them—phenomena ranging from seasonal changes and phases of the Moon to the most esoteric astronomical images that appear in the news.

- **Theme 3: Science is not a body of facts but rather a process through which we seek to understand the world around us.** Many students assume that science is just a laundry list of facts. The long history of astronomy can show them that science is a process through which we learn about our universe—a process that is not always a straight line to the truth. That is why our ideas about the cosmos sometimes change as we learn more, as they did dramatically when we first recognized that Earth is a planet orbiting around the Sun rather than the center of the universe. We continually er

**18,000,000 yrs ago**

students can understand how and why modern theories have gained acceptance and why these theories may change in the future.

- **Theme 4: A course in astronomy is the beginning of a learning experience.** Building upon the prior themes emphasize that what students learn in their astronomy course is not an end but a beginning. By remembering a few key physical principles and understanding the nature of science, students can follow astronomical development for the rest of their lives. We therefore seek to motivate students enough that they will continue to participate in the ongoing human adventure of astronomical discovery.
- **Theme 5: Astronomy affects each of us personally with new perspectives it offers.** We all conduct the daily business of our lives with reference to some "world view"—a personal beliefs about our place and purpose in the universe that we have developed through a combination of schooling, religious training, and personal thought. World view shapes our beliefs and many of our actions. Although astronomy does not mandate a particular world view, it does provide perspectives on the architecture of the universe that can influence how we view ourselves and these perspectives can potentially affect our actions. For example, someone who believes Earth is the center of the universe might treat our planet differently from someone who views it as a tiny speck in the vast cosmos. In many respects, differences in shaping world views may represent a connection between the universe and the evolution of human societies.

### Major Principles of the Cosmic Perspective

When an astronomy course is taught, it is very important to provide material according to a clear set of pedagogical principles. The following list briefly summarizes the major pedagogical principles that we apply throughout this book. (*The Instructor Guide* describes these principles in more detail.)

- **Stay focused on the big picture.** Astronomy is filled with interesting facts and details, but they are meaningless unless they fit into a big picture view of the universe. We therefore take care to stay focused on the big picture (essentially the themes discussed above) at all times. A major benefit of this approach is that although students may forget individual facts and details after the course is over, the big picture framework should stay with them for life.
- **Always provide context first.** We all learn new material more easily when we understand why we are learning it. In essence, this is simply the idea that it is easier to get to the point where you know where you are going. We therefore begin the book (**Chapter 1**) with a broad overview of the modern understanding of the cosmos, so that students can know what they will be studying in the rest of the book. We maintain this "context first" approach throughout the book by always telling students what they will be learning, and why, before diving into the details.