Which Version of *The Cosmic Perspective* Fits Your Course?

The first step in choosing a textbook is making sure that it is suitable for your course. The following information should help you make sure that you have chosen the right version of *The Cosmic Perspective* for your course.

Courses Suited to *The Cosmic Perspective*

The Cosmic Perspective is designed for use in introductory astronomy courses aimed primarily at nonscience majors, with essentially no prerequisites. In particular, this text should fit your course if it is any of the following:

- A college course in general astronomy.
- A college course focusing on the solar system.
- A college course focusing on stars, galaxies, and/or cosmology.
- A high school course in astronomy.

It is *not* designed for courses intended for physics majors or for upper level college courses, although some professors have had success using it in such courses (often by supplementing it with additional mathematics or physics material).

Alternate Versions of *The Cosmic Perspective*

The Cosmic Perspective is available in four versions tailored to particular course types. From the list below, you may choose the version best suited to the length, depth, and coverage of your course:

- *The Cosmic Perspective*, *Third Edition* (full version), ISBN 0-8053-8738-2. This is the most complete version of the book, containing sufficient material for astronomy courses ranging in length from one quarter to a full year.
- *The Solar System: The Cosmic Perspective, Third Edition*, ISBN 0-8053-8756-0. This version contains Chapters 1–15 and S1 of the full version of the book. It is designed for courses that focus on the solar system rather than on stars, galaxies, and cosmology.
- *Stars, Galaxies, and Cosmology: The Cosmic Perspective, Third Edition,* ISBN 0-8053-8757-9. This version contains Chapters 1–7, 15–24, and S2–S4 of the full version of the book. It is designed for courses that focus on stars, galaxies, and cosmology.
- *The Essential Cosmic Perspective, Second Edition,* ISBN 0-8053-8584-3. This condensed and simplified version of the full book is designed primarily for courses that provide an overview of all of astronomy but in less depth than offered in the full version of the book. *Note:* The third edition of *The Essential Cosmic Perspective* will be available in July 2004.

NOTE: Any of these versions may be ordered bundled with the Addison Wesley Astronomy Tutor Center (see below for information). There is no extra cost to students for the Tutor Center, but it will be included only *if you request the special bundle. Contact your local Addison Wesley sales representative if you would like to do this.*

Resources and Supplements for *The Cosmic Perspective*

The Cosmic Perspective is much more than just a textbook. It is a complete package of resources designed to help you and your students. In this section, we briefly describe the available resources.

The Astronomy Place Website (www.astronomyplace.com)—*the* On-line Resource for You and Your Students

As teachers, we've all had frustrating experiences with websites that claim to be educational but have steep learning curves, or with text websites that claim to be designed as study aids but don't really follow the text pedagogy or have much that is useful for students. As authors, we therefore decided to take matters into our hands with the Astronomy Place website—the website for *The Cosmic Perspective*—by working closely with other educators, programmers, and our publishing team in every aspect of the site's development. If you haven't already tried it out, we think you'll be very pleasantly surprised. Indeed, Astronomy Place has already proven to be the key study resource for tens of thousands of students using our text—and many of these students have made use of it even when their instructors had not made the site a requirement. For instructors, Astronomy Place offers a wealth of course management tools and other resources, as well as the peace of mind that comes from knowing that your students have an outstanding set of study aids available to them.

The following are among the many resources your students will find on the Astronomy Place website (see below for a discussion of the instructor resources):

- **Interactive, educational tutorials**: Our web tutorials focus on topics that traditionally give students the most difficulty and are designed to mimic the type of interaction that typically would occur during office hours. We now have a total of 18 full-length tutorials, which together include nearly 60 individual tutorial lessons (each focused on a key concept), 100 interactive tools, 125 animations, and some 450 tutorial questions. Working a full tutorial will typically take students between 15 to 45 minutes, depending on how well they understand the material to begin with. The text includes icons in section headers to point to relevant tutorials, and suggested tutorial activities can also be found in the Media Explorations section at the end of each chapter. The grid in Appendix 3 of this Instructor's Guide summarizes the places where the tutorials correspond to text material. *NOTE: The authors have been heavily involved in tutorial development to ensure that the tutorial pedagogy matches the text pedagogy and emphasizes key text ideas.*
- **On-line, multiple-choice chapter quizzes**: New for the third edition, the Astronomy Place website now has *two* quizzes for each chapter in the book. The first quiz focuses on basic definitions and ideas, while the second asks more conceptual questions. The quizzes are designed not only to test but also to teach: feedback is provided for both correct and incorrect answers, helping students consolidate their understanding (feedback with correct answers) and helping students understand where they went wrong (for incorrect answers). Quizzes vary slightly in length, but most have between 15–20 multiple choice questions. Students can use them for self-study, or you can use the course management resources to have scores sent directly to you as students complete the quizzes. *NOTE: Every one of the roughly 1,000 quiz questions was written by the authors of the book, ensuring that they focus on the truly important points and perfectly match the book pedagogy.*

- ***SkyGazer* Activity worksheets:** These worksheets are designed to be used with the *Voyager SkyGazer, College Edition,* software packaged with the textbook. Approximately 75 *SkyGazer* activities are included.
- **Animated Movies**: Ten 5-minute animated and narrated mini-movies that provide engaging summaries of key topics. The grid in Appendix 3 of this Instructor's Guide summarizes the places where the movies correspond to text material.
- **And much more**: Keyed to each chapter in the book, Astronomy Place includes student study resources such as chapter summaries, additional information on Common Misconceptions and Mathematical Insights, and chapter-specific links (including links for the end-of-chapter Web Projects). In addition, all Think About It questions and all end-of-chapter Problems are digitized for on-line assignments, and the entire textbook is available on-line in XML and can be browsed by topic.

All new copies of *The Cosmic Perspective* are shipped with a personal access kit for Astronomy Place. Access can also be purchased on-line with a credit card (e.g., for students who purchase used books). For those of you who wonder why there is a charge for the website, note that the development costs of Astronomy Place exceed $1 million to date. Clearly, it costs a lot of money to make strong educational resources. We give our publisher tremendous credit for making this huge investment and for offering it free with new textbooks, and we think you'll agree that the value it adds is well worth the small difference in price between new and used textbooks.

Additional Student Supplements for *The Cosmic Perspective*

In addition to the Astronomy Place website, three other very useful student supplements are available; note that the first two below are shipped free with every new copy of *The Cosmic Perspective.*

- ***Voyager SkyGazer, College Edition* (CD included free with all new books):** Based on *Voyager III*, one of the world's most popular planetarium programs, *SkyGazer* makes it easy for students to learn constellations and explore the wonders of the sky through interactive exercises. *Note:* This software retails for $50 as a stand-alone package, so it's a great deal that it comes free with a book! Appendix 1 offers general suggestions on how to integrate *SkyGazer* with your course, and the grid in Appendix 3 summarizes the places where the *SkyGazer* activities correspond to text material.
- **The Addison Wesley Astronomy Tutor Center:** This center provides one-on-one tutoring by qualified college instructors in any of four ways—phone, fax, email, and the Internet—during evening and weekend hours. Tutor Center instructors will answer questions and provide help with examples and exercises from the text. Students who register to use the Astronomy Tutor Center can receive as much tutoring as they wish for the duration of their course. Registration is free to students if you order a package that comes with the Tutor Center. Alternatively, students can purchase access to the tutoring separately. See www.aw.com/tutorcenter or contact your local Addison Wesley sales representative for more information about bundling the Tutor Center with your book order.
- ***Astronomy Media Workbook*** (ISBN 0-8053-8755-2): This supplementary workbook offers an extensive set of printed activities and more in-depth projects—suitable for labs or homework assignments—that use the Astronomy Place website tutorials and *SkyGazer* software.

Instructor Supplements for *The Cosmic Perspective*

The following supplements are available only to instructors:

- **Instructor Resources on Astronomy Place**: Astronomy Place includes an instructor's area with an on-line version of this *Instructor's Guide* and numerous other useful resources.
- **Course Management Resources**: You can integrate Astronomy Place with course management packages that can make your teaching life much easier. For example, post all your handouts, assignments, and other course announcements on-line, manage your on-line communication with your students, and keep an on-line grade book. You can even elect to receive scores or feedback when your students complete on-line quizzes or tutorials, as well as e-mailed answers from your students to homework questions (since all the Think About It and end-of-chapter questions from the book are on-line on Astronomy Place). The course management tools can either be integrated with tools your campus may have available (such as Blackboard or WebCT) or used within Addison Wesley's CourseCompass course management package. You can view a demo of how Blackboard or WebCT integrate with a course at http://cms.awlonline.com. You can view a demo and get more information about CourseCompass at www.coursecompass.com. We urge you to try these resources: they are pretty easy to set up, and once going they will save you a huge amount of time in managing your course and your grade book.
- **Cosmic Lecture Launcher CD** (ISBN 0-8053-8749-8): This CD provides a wealth of presentation tools to help you prepare your course lectures, including: a set of prepared PowerPoint® slides for every section in the textbook, which you can use as-is or customize; a comprehensive collection of high-resolution figures from the book and other astronomical sources that you can integrate into your lectures; and a library of more than 250 interactive applets and simulations. This CD is available free to qualified instructors; ask your local Addison Wesley sales representative if you have not yet received it.
- **Carl Sagan's *Cosmos* on DVD or Video:** The *Best of Cosmos* and the complete, revised, enhanced, and updated *Cosmos* series are available free to qualified adopters of *The Cosmic Perspective.* (Ask your local Addison Wesley sales representative about obtaining the series if your school has not already received it.) See Appendix 2 for suggestions on how to integrate the *Cosmos* series with the textbook.
- **Computerized Test Bank** (ISBN 0-8053-8745-5) and **Printed Test Bank** (ISBN 0-8053-8746-3): The test bank contains a broad set of multiple-choice, true/false, and free-response questions for each chapter. It also contains all of the on-line quiz questions for each chapter, in case you wish to repeat these questions on your exams. The CD version of the test bank allows you to edit questions, export questions to tests, and print the questions in a variety of formats.
- **Transparency Acetates** (ISBN 0-8053-8747-1): For those of you who use overhead projectors in your lectures, this set contains more than 200 images from the text. (*Note:* if you use a computer in your lectures, these are unnecessary, as all these images and many more are on the Cosmic Lecture Launcher CD, described above.)
- ***Instructor's Guide*:** (ISBN 0-8053-8748-X) This is the guide you are now reading, available in print or in the instructor's area of the Astronomy Place website.

Sample Course Outlines

The Cosmic Perspective, Third Edition is a comprehensive introduction to astronomy with enough material for two full semesters of course work. If you happen to have a two-semester sequence, you can cover the entire book (a total of 28 chapters, including the 4 supplementary chapters) at an average pace of one chapter per week. In all other cases, you will need to be selective in your coverage, depending on the length and emphasis of your course. To help you plan your course, the next several pages offer the following nine sample course outlines:

- Sample Outline 1: one-semester (14-week) course focusing on the solar system. (No prerequisite.)
- Sample Outline 2: one-semester (14-week) course focusing on the solar system but with more extensive coverage of the sky than Sample Outline 1. (No prerequisite.)
- Sample Outline 3: one-semester (14-week) course focusing on stars, galaxies, and cosmology. (No prerequisite.)
- Sample Outline 4: one-semester (14-week) course focusing on stars, galaxies, and cosmology with relativity and quantum ideas. (Assumes prerequisite covering earlier chapters in book or an "honors" level course.)
- Sample Outline 5: one-semester (14-week) course covering "everything"—i.e., solar system, stars, galaxies, and cosmology. (No prerequisite.)
- Sample Outline 6: one-semester (14-week) course covering "everything" with the solar system last. (No prerequisite.)
- Sample Outline 7: one-quarter (10-week) course focusing on the solar system. (No prerequisite.)
- Sample Outline 8: one-quarter (10-week) course focusing on stars, galaxies, and cosmology. (No prerequisite.)
- Sample Outline 9: one-quarter (10-week) course focusing on stars, galaxies, and cosmology with relativity and quantum ideas. (Assumes prerequisite covering earlier chapters in book or an "honors" level course.)

Before we get into the specific outlines, however, we address two common questions that may come up when you are deciding how to organize your course.

What if I Want to Teach Stars and Galaxies Before the Solar System?

The astronomical teaching community is somewhat split on the question of whether stars and galaxies should be taught before or after teaching about the solar system. Our opinion is that it does not matter very much which order you choose, as long as you follow good pedagogical practices. As a result, we have designed *The Cosmic Perspective* so that the sections on the solar system (Part III of the book) are essentially independent of the sections on stars, galaxies, and cosmology (Parts V and VI).

You therefore will have no difficulty if you choose to have your students cover the solar system last, and the only impact will be that you will need to ask your students to read the chapters in a different order than they appear in the book. We have included one sample outline (#6) for this ordering.

Note: In the future, we may consider producing an alternate version of the book with the chapters rearranged for a "solar system last" approach. Thus far, however, we have not seen a need for this, as those instructors using our book in this way have not had a problem in assigning the chapters to students in the order they choose. If you feel strongly about the need for such an alternate version in the future, please contact us so that we will be aware of the request.

To Math or Not to Math?

One of the challenges of any astronomy course is deciding how much mathematics to include. We have therefore designed *The Cosmic Perspective* to accommodate a wide range of levels of mathematics. In particular, nearly all the mathematics in our textbook is found in the Mathematical Insight boxes, so you can easily tailor your course to the appropriate mathematical level for your students. Thus, if you want a nonmathematical course, simply skip all the Mathematical Insight boxes. At the other extreme, if you want a course with a substantial amount of algebra-based mathematics, cover all the Mathematical Insight boxes. You can create a course with any intermediate level of mathematics by covering only selected Mathematical Insight boxes. Note that Astronomy Place (www.astronomyplace.com) has all the Mathematical Insight boxes on-line, in many cases with additional worked examples beyond those shown in the book. Note also that basic mathematical skills (such as scientific notation, unit analysis, and ratios) are covered in Appendix C of the textbook.

When it comes to assignments, you can also tailor your homework to the mathematical level of your course. Problems that require mathematical manipulation are marked by an asterisk (*) in the end-of-chapter problem sets.

— Sample Outlines Begin on the Next Page —

Sample Outline 1: One Semester, Solar System Emphasis

General Notes:

- This outline assumes that your course has no prerequisite. It is based on assuming approximately 3 contact hours per week over a 14-week semester.
- This outline maximizes coverage of the solar system chapters by minimizing coverage of the sky and sky phenomena. If you wish to spend more time on the sky, see Sample Outline 2.

Week	Reading	Suggested Coverage
1	Chapter 1	Begin your course with the overview of modern astronomy in Chapter 1.
2	Chapters 2 and 3	Cover Chapter 2 briefly, emphasizing "basics" such as seasons and phases of the Moon. In Chapter 3, focus on the Copernican revolution and the hallmarks of science.
3	Chapters 4 and 5	Full coverage of these chapters; you probably will get only partially through Chapter 5 in this week.
4	Chapters 6 and 7	Finish covering Chapter 5. Then full coverage of Chapter 6 and very brief coverage of telescopes in Chapter 7.
5	Chapters 8 and 9	You should be able to cover Chapter 8 in one or two hours of class, then begin coverage of Chapter 9.
6	Chapter 10	Finish covering Chapter 9. Then full coverage of Chapter 10; you probably will get less than halfway through Chapter 10 in this week.
7	—	Finish covering Chapter 10.
8	Chapter 11	Begin full coverage of Chapter 11.
9	—	Finish covering Chapter 11.
10	Chapter 12	Begin full coverage of Chapter 12.
11	—	Finish covering Chapter 12.
12	Chapter 13	Full coverage of Chapter 13.
13	Chapter 14	Begin full coverage of Chapter 14.
14	(Chapter 24)	Finish covering Chapter 13. Optional: Cover life in the universe with Chapter 24.

Sample Outline 2: One Semester, Solar System/Sky Emphasis

General Notes:

- This outline is based on assuming approximately 3 contact hours per week over a 14-week semester.
- This outline includes more coverage of the sky and sky phenomena than Sample Outline 1. In order to incorporate this coverage, you will need to compress the coverage of other areas, as described in the "suggested coverage" column. This outline works best if you have access to a planetarium for teaching the sky phenomena.
- This outline assumes that your course has no prerequisite. If your course has a prerequisite that covered concepts in early chapters of the book, you can reduce the time spent on these chapters and increase the time spent on other chapters.
- This outline is also ideally suited to "honors" courses for more advanced students who can move more quickly through the course material.

Week	Reading	Suggested Coverage
1	Chapter 1	Begin your course with the overview of modern astronomy in Chapter 1. You may also wish to begin teaching students the major constellations in your local sky.
2	Chapter 2	Cover Chapter 2 in depth.
3	Chapter 3	Full coverage of this chapter.
4	Chapter S1	Full coverage of this chapter, ideally with the help of one or more planetarium visits.
5	Chapters 4 and 5	Full coverage of these chapters, which may be largely review for the "honors" students who took more science in high school.
6	Chapters 6 and 7	Full coverage of Chapter 6; brief coverage of telescopes in Chapter 7.
7	Chapters 8 and 9	You can probably go through most of Chapter 8 in one hour of class, then start in on Chapter 9, which may require continuation in Week 9.
8	Chapter 10	Complete Chapter 9, and begin on Chapter 10, which will probably require a week and a half.
9	Chapter 11	Complete Chapter 10 and begin on Chapter 11.
10	—	Complete coverage of Chapter 11. Students will now have a solid understanding of planetary geology and atmospheres.
11	Chapter 12	You should be able to cover Chapter 12 in one week, perhaps with some selective emphasis.
12	Chapter 13	You should be able to cover Chapter 13 in one week, again perhaps with some selective emphasis.
13	Chapter 14	You should be able to cover Chapter 14 in one week.
14	Chapter 24	Wrap up with discussion of life in the universe in Chapter 24.

Sample Outline 3: One Semester, Stars/Galaxies/Cosmology Emphasis

General Notes:

- This outline is based on assuming approximately 3 contact hours per week over a 14-week semester.
- This outline assumes that your course has no prerequisite. We recommend Sample Outline 4 if your course has a prerequisite that covered concepts in early chapters of the book.
- This outline does not cover Part 4 on relativity and quantum ideas; see Sample Outline 4 if you wish to cover these chapters.

Week	Reading	Suggested Coverage
1	Chapter 1	Begin your course with the overview of modern astronomy in Chapter 1.
2	Chapters 3 and 4	In Chapter 3, emphasize ideas of modeling, the Copernican revolution, and the hallmarks of science. Chapter 4 is short and can probably be covered in one hour of class time.
3	Chapters 5 and 6	Cover these chapters as fully as possible; this material may spill over into Week 4.
4	Chapter 7	Complete your coverage of Chapters 5 and 6, then use any remaining time to discuss telescopes in Chapter 7.
5	Chapter 15	Full coverage of this chapter.
6	Chapter 16	Full coverage of this chapter.
7	Chapter 17	Full coverage of this chapter.
8	Chapter 18	Full coverage of this chapter.
9	Chapter 19	Full coverage of this chapter.
10	Chapter 20	Full coverage of this chapter.
11	Chapter 21	Full coverage of this chapter.
12	Chapter 22	Full coverage of this chapter.
13	Chapter 23	Full coverage of this chapter.
14	Chapter 24	Use this week as needed to complete coverage described above. If you have time, cover Chapter 24 briefly.

Sample Outline 4: One Semester, Stars/Galaxies/Cosmology Emphasis with Relativity

General Notes:

- This outline is based on the assumption that Parts 1 and 2 of the text are essentially review for your students, as would be the case if either:
  - Your course has a prerequisite in which Parts 1 and 2 were already covered.
  - You have "honors" students with strong backgrounds in high school science.
- This outline is based on assuming approximately 3 contact hours per week over a 14-week semester.

Week	Reading	Suggested Coverage
1	Review: Chapters 1–7	Use this first week for a review as needed of the overview of the universe, the nature of science, and of key physical concepts.
2	Chapter S2	Introduce special relativity with Chapter S2.
3	Chapter S3	Finish covering Chapter S2, and begin covering Chapter S3.
4	—	Finish covering Chapter S3.
5	Chapter S4	Full coverage of this chapter.
6	Chapters 15 and 16	Full coverage of these chapters. May require continuation in Week 7.
7	Chapter 17	Full coverage of this chapter. May require continuation in Week 8.
8	Chapter 18	Full coverage of this chapter. This chapter should take less than a full week, since much will be review of concepts introduced in Chapters S2–S4. Thus, you can also use this week as needed to complete coverage described above.
9	Chapter 19	Full coverage of this chapter.
10	Chapter 20	Full coverage of this chapter.
11	Chapter 21	Full coverage of this chapter.
12	Chapter 22	Full coverage of this chapter.
13	Chapter 23	Full coverage of this chapter.
14	Chapter 24	Wrap up with discussion of life in the universe in Chapter 24.

Sample Outline 5: One Semester, "Everything" Course

General Notes:

- This outline assumes your course covers all of astronomy (i.e., both solar system and stars/galaxies/cosmology) in a single, 14-week semester (approx. 3 contact hours per week).
- Trying to cover all of astronomy in a single semester necessarily means making some compromises; this sample outline is only one of many possible options for such a course.
- NOTE: If you are teaching this type of one-semester "everything" course, you may wish to consider using the condensed version of our book—called *The Essential Cosmic Perspective*—which is expressly designed for one-semester "everything" courses.

Week	Reading	Suggested Coverage
1	Chapter 1	Begin your course with the overview of modern astronomy in Chapter 1.
2	Chapters 2 and 3	Cover Chapter 2 briefly, emphasizing seasons and phases of the Moon. In Chapter 3, focus on the Copernican revolution and the hallmarks of science.
3	Chapters 4 and 5	Full coverage of these chapters; you probably will get only partially through Chapter 5 in this week.
4	Chapter 6	Finish covering Chapter 5. Then cover Chapter 6 as fully as possible in the remainder of the week; emphasize the electromagnetic spectrum (Section 6.3) and the Doppler shift (Section 6.5) over other parts of this chapter.
5	Chapters 8 and 9	Cover Chapter 8 in one class period, skipping the material on spacecraft. Then cover the formation of the solar system in Chapter 9; de-emphasize the material on the heavy bombardment and radiometric dating, and limit time coverage of extrasolar planets (e.g., emphasize that they have now been found indirectly, but leave to students' own reading the details of detection strategies and their implications to ideas of planetary migration).
6	Chapters 10 and 11	In Chapter 10, emphasize the four geological processes and the geological tours of the terrestrial worlds. In Chapter 11, emphasize the greenhouse effect, sources/losses of atmospheric gas, and the comparative histories of Mars, Venus, and Earth.
7	Chapters 12 and 13	In Chapter 12, emphasize the overview of jovian worlds in Section 12.1 and satellites and rings in Sections 12.4 and 12.5. In Chapter 13, emphasize Pluto in Section 13.5 and cosmic collisions in Section 13.6.
8	Chapter 14	Cover this chapter as fully as possible in one week, with emphasis on the history and role of life on Earth and the "lessons from other worlds" in Section 14.6.
9	Chapters 15 and 16	In Chapter 15, emphasize the concepts of gravitational contraction and gravitational equilibrium in Section 15.1 and nuclear fusion and study of the solar interior in Section 15.3. In Chapter 16, emphasize the H–R diagram.
10	Chapter 17	Cover this chapter as fully as possible in one week; de-emphasize close binaries.
11	Chapters 18 and 19	In Chapter 18, move quickly through white dwarfs and neutron stars to allow more time for black holes (a topic of high student interest). In Chapter 19, emphasize galactic structure and motion as discussed in Sections 19.3 and 19.4.
12	Chapters 20 and 21	In Chapter 20, move quickly through galaxy types to allow more time for the distance scale (Section 20.3) and the age of the universe (Section 20.4). In Chapter 21, move quickly through general galaxy evolution in Sections 21.1 through 21.3; place emphasis on evidence for supermassive black holes in Section 21.5.
13	Chapters 22 and 23	In Chapter 22, emphasize the role of dark matter in the fate of the universe and the possibility of an accelerating expansion. Cover Chapter 23 briefly, emphasizing the key evidence that supports the Big Bang theory and how recent discoveries tie back to ideas of the accelerating cosmos.

14	Chapter 24	Wrap up with discussion of life in the universe in Chapter 24.

Sample Outline 6: One Semester, "Everything" Course (Solar System Last)

General Notes:

- This outline covers essentially the same material as Sample Outline 5, but rearranged to cover stars/galaxies/cosmology before the solar system.
- NOTE: If you are teaching this type of one-semester "everything" course, you may wish to consider using the condensed version of our book—called *The Essential Cosmic Perspective*—which is expressly designed for one-semester "everything" courses.

Week	Reading	Suggested Coverage
1	Chapter 1	Begin your course with the overview of modern astronomy in Chapter 1.
2	Chapters 2 and 3	Cover Chapter 2 briefly, emphasizing seasons and phases of the Moon. In Chapter 3, focus on the Copernican revolution and the hallmarks of science.
3	Chapters 4 and 5	Full coverage of these chapters; you probably will get only partially through Chapter 5 in this week.
4	Chapter 6	Finish covering Chapter 5. Then cover Chapter 6 as fully as possible in the remainder of the week; emphasize the electromagnetic spectrum (Section 6.3) and the Doppler shift (Section 6.5) over other parts of this chapter.
5	Chapters 15 and 16	In Chapter 15, emphasize the concepts of gravitational contraction and gravitational equilibrium in Section 15.1 and nuclear fusion and study of the solar interior in Section 15.3. In Chapter 16, emphasize the H–R diagram.
6	Chapter 17	Cover this chapter as fully as possible in one week; de-emphasize close binaries.
7	Chapters 18 and 19	In Chapter 18, move quickly through white dwarfs and neutron stars to allow more time for black holes (a topic of high student interest). In Chapter 19, emphasize galactic structure and motion as discussed in Sections 19.3 and 19.4.
8	Chapters 20 and 21	In Chapter 20, move quickly through galaxy types to allow more time for the distance scale (Section 20.3) and the age of the universe (Section 20.4). In Chapter 21, move quickly through general galaxy evolution in Sections 21.1 through 21.3; place emphasis on evidence for supermassive black holes in Section 21.5.
9	Chapters 22 and 23	In Chapter 22, emphasize the role of dark matter in the fate of the universe and the possibility of an accelerating expansion. Cover Chapter 23 briefly, emphasizing the key evidence that supports the Big Bang theory and how recent discoveries tie back to ideas of the accelerating cosmos.
10	Chapters 8 and 9	Cover Chapter 8 in one class period, skipping the material on spacecraft. Then cover the formation of the solar system in Chapter 9; de-emphasize the material on the heavy bombardment and radiometric dating, and limit time coverage of extrasolar planets (e.g., emphasize that they have now been found indirectly, but leave to students' own reading the details of detection strategies and their implications to ideas of planetary migration).
11	Chapters 10 and 11	In Chapter 10, emphasize the four geological processes and the geological tours of the terrestrial worlds. In Chapter 11, emphasize the greenhouse effect, sources/losses of atmospheric gas, and the comparative histories of Mars, Venus, and Earth.
12	Chapters 12 and 13	In Chapter 12, emphasize the overview of jovian worlds in Section 12.1 and satellites and rings in Sections 12.4 and 12.5. In Chapter 13, emphasize Pluto in Section 13.5 and cosmic collisions in Section 13.6.

13	Chapter 14	Cover this chapter as fully as possible in one week, with emphasis on the history and role of life on Earth and the "lessons from other worlds" in Section 14.6.
14	Chapter 24	Wrap up with discussion of life in the universe in Chapter 24.

Sample Outline 7: One Quarter, Solar System Emphasis

General Notes:

- This outline assumes a 10-week quarter. It covers essentially the same material as Sample Outline 1, but in one 10-week quarter instead of one 14-week semester. As a result, it covers more material each week. If you have 4 contact hours per week (e.g., 3 hours of lecture and 1 hour of recitation), you should be able to cover everything in the same depth as in the one-semester course. If you have only 3 contact hours per week, you will need to choose areas of emphasis within each chapter.
- If you wish to add coverage of the sky and sky phenomena as in Sample Outline 2, you should add 1 week on Chapter S1 by compressing the coverage of Chapters 8–14 into 5 weeks instead of 6.

Week	Reading	Suggested Coverage
1	Chapter 1	Begin your course with the overview of modern astronomy in Chapter 1.
2	Chapters 2 and 3	Cover Chapter 2 briefly, emphasizing basics such as seasons and phases of the Moon. In Chapter 3, focus on the Copernican revolution and the hallmarks of science.
3	Chapters 4 and 5	Full coverage of these chapters.
4	Chapters 6 and 7	Full coverage of Chapter 6, and only brief coverage of telescopes in Chapter 7.
5	Chapters 8 and 9	Full coverage of these chapters. If necessary, skip spacecraft in Chapter 8 and limit class time spent on radiometric dating and extrasolar planets in Chapter 9.
6	Chapter 10	Full coverage of this chapter.
7	Chapter 11	Full coverage of this chapter.
8	Chapter 12	Full coverage of this chapter.
9	Chapter 13	Full coverage of this chapter.
10	Chapters 14, 24	Full coverage of Chapter 14, and optional coverage of Chapter 24 if time allows.

Sample Outline 8: One Quarter, Stars/Galaxies/Cosmology Emphasis

General Notes:

- This outline assumes a 10-week quarter. It covers essentially the same material as Sample Outline 3, but in one 10-week quarter instead of one 14-week semester. As a result, it covers more material each week. If you have 4 contact hours per week (e.g., 3 hours of lecture and 1 hour of recitation), you should be able to cover everything in the same depth as in the one-semester course. If you have only 3 contact hours per week, you will need to choose areas of emphasis within each chapter.
- This outline assumes that your course has no prerequisite. We recommend Sample Outline 9 if your course has a prerequisite that covered concepts in early chapters of the book.
- This outline does not cover Part 4 on relativity and quantum ideas; see Sample Outline 9 if you wish to cover these chapters.

Week	Reading	Suggested Coverage
1	Chapter 1	Begin your course with the overview of modern astronomy in Chapter 1.
2	Chapters 3 and 4	In Chapter 3, emphasize ideas of modeling, the Copernican revolution, and the hallmarks of science. Chapter 4 is short and can probably be covered in one hour of class time.
3	Chapters 5–7	Cover Chapter 5 and 6 as fully as possible. Chapter 7 (telescopes) may be regarded as optional.
4	Chapters 15 and 16	In Chapter 15, emphasize the overview of the Sun in Sections 15.1 and 15.2 and nuclear fusion in Section 15.3. In Chapter 16, emphasize the H–R diagram.
5	Chapter 17	Full coverage of this chapter.
6	Chapter 18	Full coverage of this chapter.
7	Chapter 19	Full coverage of this chapter.
8	Chapters 20 and 21	Full coverage of these chapters. May require continuation in Week 9.
9	Chapter 22	Finish covering Chapter 21. Fully cover Chapter 22.
10	Chapters 23 and 24	Cover Chapter 23 as fully as possible in the final week. Wrap up with Chapter 24 if time allows.

Sample Outline 9: One Quarter, Stars/Galaxies/Cosmology Emphasis with Relativity

General Notes:

- This outline is based on the assumption that you do not need to spend class time on Parts I and II of the text, as would be the case if either:
  - Your course has a prerequisite in which Parts I and II were already covered.
  - You have "honors" students with strong backgrounds in high school science.
- This outline is also suitable for a course in relativity and cosmology if you de-emphasize the coverage of the H–R diagram and basic properties of stars and galaxies.

Week	Reading	Suggested Coverage
1	Chapter S2	Begin relativity, with full coverage of Chapters S2 and S3, to be spread out over weeks 1 through 3.
2	Chapter S3	Continue relativity.
3	—	Continue and conclude relativity.
4	Chapter S4	Quantum mechanics, with full coverage of this chapter.
5	Chapters 15 and 16	In Chapter 15, emphasize the overview of the Sun in Sections 15.1 and 15.2 and nuclear fusion in Section 15.3. In Chapter 16, emphasize the H–R diagram.
6	Chapters 17 and 18	In Chapter 17, emphasize nucleosynthesis and the supernova process. Cover Chapter 18 fully but quickly, since students will be well prepared after having studied Chapters S3 and S4.
7	Chapters 19 and 20	In Chapter 19, emphasize cosmic recycling in the star–gas–star cycle and evidence for dark matter in the Milky Way. Full coverage of Chapter 20.
8	Chapters 21 and 22	In Chapter 21, emphasize the general evolution of galaxies and evidence for supermassive black holes. Full coverage of Chapter 22, with special emphasis on the possible fates of the universe, including the possibility of accelerating expansion.
9	Chapter 23	Begin full coverage of Chapter 23.
10	Chapter 24	Finish discussion of Chapter 23. Wrap up with Chapter 24.

The Pedagogical Approach of *The Cosmic Perspective*

Our modern understanding of the cosmos is both broad and deep, making it impossible to cover all of what we know today in a one- or two-term introductory course. After all, professional astronomers typically take years to master just one subdiscipline of astronomical research, and even then the star specialists may be unfamiliar with much of planetary astronomy, and vice versa. Thus, success in an introductory astronomy course requires a carefully chosen set of key concepts presented with a coherent and integrated pedagogy. This is precisely what we have tried to offer in *The Cosmic Perspective*. We believe that you will be able to make more effective use of our text if you understand the how and why of its pedagogical approach. We therefore discuss this approach in some detail in this section.

Themes of *The Cosmic Perspective*

The Cosmic Perspective offers a broad survey of modern understanding of the cosmos and of how we have gained that understanding. Such a survey can be presented in a number of different ways. We have chosen to present it by interweaving a few key themes throughout the narrative, all chosen to help make the subject more appealing to students who may never have taken any formal science courses and who may enter the course with little understanding of how science works. The following are five key themes around which we built our book:

> *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 what has made our existence possible. Studying the intimate connections between human life and the cosmos not only give students a reason to care about astronomy, but also deepens their appreciation of the unique and fragile nature of our planet and its life.
>
> *Theme 2: The universe is comprehensible through science that can be understood by anyone.* The universe is comprehensible because the same physical laws appear to be at work in every aspect, on every scale, and in every epoch of the universe. Moreover, while the laws have generally been discovered by professional scientists, they can be understood by anyone. Students can learn enough in one or two terms of astronomy to comprehend nearly all the phenomena they see around them, 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 body of facts, but the long history of astronomy shows clearly that science is a process by which we learn about our universe, and 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. We continually emphasize the nature of science so that students can see how and why modern theories have gained acceptance, and understand why these theories may still be subject to 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 learning to appreciate the nature of science, students can follow astronomical developments for the rest of their lives. We therefore seek to motivate students enough so that they will have the desire to 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 both our beliefs and many of our actions. Although astronomy should not be construed to support any particular world-view, it certainly provides the foundations from which world-views are built. For example, a person's world-view would likely be quite different if they believed the Earth to be the center of the universe, instead of a tiny and fragile world in a vast cosmos. In many respects, the role of astronomy in shaping world-views represents the deepest connection between the universe and the everyday lives of humans.

Pedagogical Principles of *The Cosmic Perspective*

No matter how you choose to teach your course, it is very important to present material according to a clear set of pedagogical principles. The following list summarizes the major pedagogical principles that we focused on in the writing of every chapter, section, paragraph, and sentence in the book:

- *Stay focused on the "big picture."* No matter how well we teach, within a relatively short time (a year, say) our students will inevitably forget most the specific facts they learn in any course. Therefore it is critical that even as we delve into details, we always stay focused on the "big picture" ideas that we hope our students will retain long after the course is over. For us, these key big picture ideas are the themes we have outlined above. Throughout the text, you will find that we have made decisions on what details to include—and what to leave out—by asking whether they help support the big picture themes that we want students to take away from their course.
- *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. (As Yogi Berra said, "If you don't know where you're going, you'll probably end up someplace else.") Because most students enter introductory courses with little prior knowledge of astronomy, it is critical to give them a mental framework for the subject before they begin. We therefore begin the book (Chapter 1) with a broad overview of modern understanding of the cosmos—our cosmic address and origins, the scale of the universe, and motion of the universe. This allows us to give students at least a general understanding of such things as the levels of structure in the cosmos, how vastly the scale of the solar system and galaxy differ (and remember that students often confuse the two terms), what we mean by a beginning in a Big Bang, and what we mean by the idea that the universe is expanding. Once students have this basic overview in their heads, it is much easier for them to make sense of all the details that follow. We maintain this "context first" approach in the rest of the book as well. For example, we always begin chapters by telling students what we hope to learn and why, and we always review the context at the end of each chapter (in the end-of-chapter sections called "The Big Picture").

- *Make the material relevant.* It's human nature to be more interested in subjects that seem relevant to our lives.[1] Thus, while there's nothing wrong with emphasizing that science is often driven by inherent curiosity, we are more likely to reach our students if we emphasize the many connections between astronomy and their personal concerns. Indeed, this idea of relevance lies behind the choice of our themes listed above. It also has practical implications to the way we structure the text. For example, when studying the solar system we emphasize how learning about other planets helps us understand our own (since Earth is clearly relevant to everyone); when studying stars we emphasize that we are "star stuff" (to quote Carl Sagan) in the sense that the atoms of our body were forged in stars; and when studying galaxies we emphasize that we are also "galaxy stuff" in the sense that galaxies are necessary for the cosmic recycling that makes possible multiple generations of stars.
- *Emphasize conceptual understanding over "stamp collecting" of facts.* All too often, astronomy is presented as a large set of facts to remember. As discussed earlier, students inevitably forget these facts after the exams are over. If we want students to retain something of value from their astronomy course, we must emphasize just a few key conceptual ideas that we use over and over again. For example, students encounter the laws of conservation of energy and conservation of angular momentum over and over throughout the book, and students learn about how terrestrial planets are shaped by just a few basic geological processes. We find that students retain such learning far better than when they are asked to memorize facts.
- *Proceed from the more familiar and concrete to the less familiar and abstract.* It's well known that children learn best by starting with concrete ideas and then generalizing to abstractions later. In fact, the same is true for all of us at any age. To the extent possible, when introducing new ideas we should always seek "bridges to the familiar" (a term coined by our colleague Jeff Goldstein of the Challenger Center for Space Science Education). For example, in our chapters on energy, gravity, and light, we begin with "everyday" experiences that can be expanded upon and generalized as we discuss the much more abstract physical laws of the cosmos. Similarly, in our chapters on terrestrial geology and atmospheres, we begin with ideas that are familiar from everyday observations of our own world. We can carry this idea forward even with topics like galaxies; for example, we start our chapter on galaxies beyond the Milky Way (Chapter 20) by showing the Hubble Deep Field, because it allows students to use their own senses to see that galaxies have different shapes, sizes, and colors. Once they experience these concrete ideas for themselves, we can begin to ask more abstract questions about why galaxies differ.
- *Use plain language.* Surveys have found that the number of new terms in typical introductory astronomy books is larger than the number of words taught in many first courses in foreign languages. In essence, this means the books are teaching astronomy in what looks to students like a foreign language. Clearly, it will be much easier for students to understand key astronomical concepts if these concepts can be explained in plain English, without resort to unnecessary jargon. We have therefore gone to great lengths to eliminate jargon as much as possible, or at minimum to replace standard jargon with terms that will be easier to remember in the context of the subject matter. For example, instead of "lunar regolith" (a term you'll find in nearly all texts but which even most astronomers don't know), we refer to "powdery lunar soil"—which is in essence what the regolith is. As an example of a case where standard jargon can be replaced with something more meaningful, consider the two basic mechanisms for supernovae. One mechanism involves an explosion at the end of the life of a massive star,

[1] As an example that may carry weight for many instructors, consider investments in the stock market. Twenty years ago, few faculty knew anything about the market, but today nearly all of us follow the markets and have a fairly deep understanding of how they work. What changed? The development of retirement plans for which we must make choices ourselves made the markets relevant and gave us a reason to learn about them.

which is generally called a Type II supernova (but also includes some Type Ib and Ic supernovae). The other mechanism involves white dwarfs in binary systems, and is known to astronomers as a Type Ia supernova. Most books use these Type I/II terms, but we find students understand and remember them much better when we refer to the two basic types simply as massive star supernovae and white dwarf supernovae.[2]

- *Recognize and address student misconceptions.* Students do not arrive as blank slates. Most students enter our courses not only lacking the knowledge we hope to teach, but often holding misconceptions about astronomical ideas. Therefore, in order to teach correct ideas, we must also help students recognize the paradoxes in their prior misconceptions. This recognition creates the conditions under which they can undergo "conceptual change" from a misconception to a correct conceptual understanding. We address this issue in a number of ways in our text, the most obvious being the presence of our many "common misconceptions" boxes. These summarize commonly held misconceptions and explain why they cannot be correct.

Note: The above pedagogical ideas are discussed in more detail (and with a slightly different presentation) in the article "Strategies for Teaching Astronomy," by Jeffrey Bennett, in *Mercury*, Nov/Dec 1999.[3] The article is also posted in the instructor's area of the Astronomy Place website (www.astronomyplace.com) and on Jeff's personal web page (www.jeffreybennett.com).

The Topical Structure of *The Cosmic Perspective*

In order to implement the themes and pedagogical principles described above, we had to make decisions about how we would treat the major topical areas of astronomy. We decided to organize the book broadly into six major topical areas, referred to as Parts I through VI in the table of contents. In this section, we describe each of the six major parts, with a short description of its pedagogical approach and how it may differ from the approach you may have used if you taught in the past from different texts.

Part I—Developing Perspective (Chapters 1–3, S1)

Basic Content. As the Part title suggests, the three main chapters here are designed to give students a general perspective that we will build upon throughout the rest of the book. Chapter 1 offers an overview of modern understanding of the cosmos, thereby giving students perspective on the entire universe. Chapter 2 provides an introduction to basic sky phenomena, including seasons and phases of the Moon—perspective on how phenomena we experience every day are tied to the broader cosmos. Chapter 3 discusses the history and nature of science, offering a historical perspective on the development of science and giving students perspective on how science works and how it differs from nonscience. Note that this chapter includes discussion of the Copernican revolution and Kepler's laws. The supplementary (optional) Chapter S1 goes into more detail about the sky, including celestial timekeeping and navigation.

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[2] The Type I/II designations are based on spectra (Type II have hydrogen lines and Type I do not), which is why there is not a one-to-one correspondence with the presumed mechanisms (white dwarf or massive star undergoing supernova). In the past, before we had a good idea of the mechanisms, it made sense to teach from the directly observable phenomena of spectra. Today, however, we think it makes far more sense to teach based on the mechanisms.

[3] Jeff also has a talk for science faculty based on these ideas that he has given at numerous colleges and universities. If you are interested in having him present the talk at your school, contact him directly: jeff@bigkidscience.com or jbennett@casa.colorado.edu.

Pedagogical Approach—The Big Picture, The Process of Science, and Integrated History. The basic pedagogical approach in these chapters is designed to make sure students get their "big picture" overview and context for the rest of the book, and to make sure they develop an appreciation for the process of science and how science has developed through history. In addition, please note that:

- Chapter 1 gives a fairly comprehensive overview of modern astronomy, including an introduction to ideas of the Big Bang, the expanding universe, and the mystery of dark matter. In a sense, this chapter covers nearly all of the important ideas that we want students to take away from their course, so that the rest of the book is simply reinforcement and filling in the details.
- We believe that historical ideas of astronomy are much more meaningful when taught in context rather than as a separate "track" in an astronomy course. We therefore introduce the accomplishments of many ancient cultures in the context of how they relate to what we consider science today, and introduce Greek ideas of astronomy through the context of the modeling (e.g., the transition from the geocentric model to Copernican model) that has become the foundation of modern science. (Note also that we have taken extraordinary care to make sure that our historical discussions are based on the most current understanding of history; to help ensure accuracy, noted historian of science Owen Gingerich reviewed our historical material.)

How and Why Is Our Approach Different? Traditionally, most introductory astronomy textbooks have begun with the sky as viewed by the ancients, and then gradually worked through astronomical topics in a fairly historical progression, so that ideas of the expanding universe and modern cosmology come only at the very end of the book. If these books offer any "big picture" overview at all in the beginning, it has typically been limited to structural hierarchy and perhaps a bit of scale. Our approach of introducing all the major cosmological ideas in Chapter 1 is clearly different from this traditional approach. To understand why we believe our approach is more successful with students, it's useful to consider both the potential advantages and drawbacks of the traditional approach. The potential advantage of the traditional approach is this: if students fully absorb it, they recreate for themselves the thought patterns and paradigm shifts that led from ancient superstitions about the sky to modern understanding of the universe. Clearly, that would lead to a fairly deep understanding of the scientific process. Unfortunately, we believe that this potential advantage is almost impossible to realize in practice, for two major reasons.

- First, the traditional approach in essence asks students to recreate the thinking produced over thousands of years by some of the greatest minds in history—all with just a few hours of study per week for a few months. We do not think this is realistic, and we believe that students who seem to succeed at it are almost always those students who enter the course with prior knowledge of the types of big picture ideas that we cover in our Chapter 1. Thus, we believe the potential advantage instead becomes a practical unfairness, because it puts students with prior knowledge at a competitive advantage over those for whom a course with no prerequisites is truly designed.
- Second, because the traditional approach leaves all mention of cosmology to the very end of the course, it leaves this material at risk of being lopped off due to time constraints. That is, in the very common situation that you must slow your pace of coverage, the traditional approach could mean that you never get to talk at all about such things as the expanding universe, dark matter, and the Big Bang. Given that these topics permeate virtually all of modern astronomy, we think it almost criminal to risk the possibility that students will leave an introductory astronomy class without at least having been introduced to them.

We authors began our teaching careers following the traditional approach, and it was its failure for so many students that convinced us to change. Our experience, and that of others who have made the same change, tells us that our "big picture" approach will allow a far greater fraction of your students to learn and retain key astronomical ideas than will the traditional approach.

Part II—Key Concepts for Astronomy (Chapters 4–7)

Basic Content. These chapters cover concepts that are necessary to understand the material in the rest of the book. Chapter 4 covers basic ideas of matter and energy—the types of energy (kinetic, potential, radiative), conservation of energy, the atomic structure of matter, phase changes, and energy levels in atoms. Chapter 5 covers Newton's laws and gravity, including discussion of the "why" of Kepler's laws, of the origin of tides and tidal forces, and of the many astronomical concepts that can be understood by considering orbital energy. Chapter 6 covers the nature of light and spectra, including the electromagnetic spectrum, the particle and wave nature of light, the formation of spectral lines, the laws of thermal radiation, and the Doppler effect.[4] Chapter 7 covers telescopes and astronomical observing techniques.

Pedagogical Approach—Bridges to the Familiar. These chapters lay the groundwork for understanding astronomy through what is sometimes called the "universality of physics"—the idea that a few key principles governing matter, energy, light, and motion explain both the phenomena of our daily lives and the mysteries of the cosmos. We approach this material by following the principle of building "bridges to the familiar." Each chapter begins with a section on science in everyday life, in which we remind students how much they already know about scientific phenomena from their everyday experiences. We then build on this "everyday knowledge" to help students learn the formal principles of physics needed for the rest of their study of astronomy.

How and Why Is Our Approach Different? All introductory astronomy textbooks include discussion of key physical ideas, but our approach differs from what you may have found in other books in at least three key ways:

- Our Chapter 4 is probably unique among astronomy texts in offering a single, simple summary of basic ideas of matter and energy. Although this material should in principle be review for anyone who has taken high school science, we find that students need the review and benefit from having it put into an astronomical context.
- Most introductory texts tend to start with the abstract laws (such as Newton's laws) and then give examples of them in action. Following our principle of building from the concrete to the abstract, we always begin with everyday experiences first. We believe this helps students learn the physical laws in a way they are more likely to understand and retain.
- We place more emphasis on conservation laws and their implications for things like orbital energy than most other texts. This helps build the foundation for applying these same laws to processes at work throughout the universe.

Part III—Learning From Other Worlds (Chapters 8–14)

Basic Content. This is our section about our planetary system. This set of chapters begins with a broad overview of the solar system in Chapter 8, including a 10-page tour that highlights some of the most important and interesting features of the Sun and each of the nine planets in turn. In the remaining chapters of this Part, we seek to explain these features through a true comparative planetology approach, in which the discussion emphasizes the processes that shape the planets,

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[4] The physicists may notice an underlying but unstated subtext to these chapters: Chapter 4 covers the scalar quantities of matter and energy, Chapter 5 discusses vector quantities in dealing with motion, and Chapter 6 on light involves vibrations of a vector field.

rather than the “stamp collecting” of facts about them. Chapter 9 uses the concrete features of the solar system presented in Chapter 8 to build student understanding of the current theory of solar system formation, and to explore how the theory has been affected by discoveries of planets around other stars. Chapters 10 and 11 focus on the terrestrial planets, covering key ideas of geology and atmospheres, respectively. In both chapters, we use examples drawn from our own planet Earth to help students understand the types of features that are found throughout the terrestrial worlds and the fundamental processes that explain how these features came to be. We then conclude each of these chapters by summarizing how the various processes have played out on each individual world. Chapter 12 covers the jovian planets and their moons and rings. Chapter 13 covers small bodies in the solar system—asteroids, comets, and Pluto. It also covers cosmic collisions, including the impact linked to the extinction of the dinosaurs and a discussion of how seriously we should take the ongoing impact threat. Finally, Chapter 14 turns our attention back to Earth. Having already studied and understood all the ways in which Earth is similar to other worlds, this chapter covers how and why Earth is different, with emphasis on the role of life. (FYI: As noted earlier, Part III is essentially self-contained and independent of the chapters on stars, galaxies and cosmology. Thus, you can feel free to cover Part III after stars and galaxies if you so choose.)

Pedagogical Approach—True Comparative Planetology. We offer a true comparative planetology approach, in which the discussion emphasizes the processes that shape the planets, rather than the “stamp collecting” of facts about the individual planets. As always, we begin with the concrete and familiar. For example, Chapter 8 presents the very concrete ideas of the solar system’s basic layout, while Chapter 9 then explains how that layout came to be. Similarly, in the other chapters we always begin with things that may be familiar from Earth or that are at least easy to see on other planets, and then move on to explain how these things came to be.

How and Why Is Our Approach Different? Virtually every other introductory textbook covers the planets in a “march of the planets,” covering them individually rather than through our process-oriented comparative planetology approach. Why did we choose to do something so different? There are four major reasons:

- First and foremost, we are convinced that students learn and retain much more from the comparative planetology approach. The traditional approach teaches lots of facts about the planets—facts that tend to be quickly forgotten after exams (e.g., where is Caloris Basin located again?). In contrast, our emphasis on processes means students only need to learn a few key ideas that they can then apply over and over to phenomena on Earth or other worlds.
- Of almost equal importance, our approach helps students see the relevance of planetary science to their own lives by enabling them to gain a far deeper appreciation of our own unique world. With the traditional approach, students can legitimately ask, “why should I care about the names of volcanoes on Mars?” With our approach, students see how the study of volcanoes on Mars and elsewhere allows us to learn more about Earth and the conditions under which life is possible.
- We sincerely believe that the traditional approach is now outdated. Covering planets individually made perfect sense when we did not know a lot about them. But as more spacecraft show us the planets in more and more detail, and as we discover more and more planets in other solar systems, the idea of simply adding more detailed coverage of the planets quickly becomes untenable. The comparative planetology approach allows students to see how rapidly accumulating new discoveries fit into our overall understanding of how planets work—or, in some cases, how they force us to modify our theories of planetary processes.
- Finally, with our emphasis on how and why planets work, students’ minds are better prepared for the future of planetary science. What do we still need to learn about planets in our own solar system? What should we expect from discoveries of planets around other stars? Are the

conditions for life in the universe rare and random, or do they follow the same principles operating in our solar system? Students using this textbook will be ready to understand and appreciate planetary science for the rest of their lives.

Part IV—A Deeper Look at Nature (Chapters S2–S4)

Basic Content. ***These chapters are labeled "supplementary" because coverage of them is optional.*** The three chapters of Part IV cover special relativity (Chapter S2), general relativity (Chapter S3), and key astronomical ideas of quantum mechanics (Chapter S4). Covering them will give your students a deeper understanding of the topics that follow on stars, galaxies, and cosmology, but the later chapters are self-contained so that they may be covered without having covered Part IV at all.

Pedagogical Approach—Ideas of Relativity and Quantum Mechanics are Accessible to Anyone. These chapters all begin with sections summarizing the basic ideas that we will cover, then proceed to explain the ideas, then discuss the evidence and implications of the ideas. The main thrust throughout is to demystify relativity and quantum mechanics by convincing students that they are capable of understanding the key ideas despite the reputation of these subjects for being hard or counterintuitive.

How and Why Is Our Approach Different? Well, the big difference is that no other introductory text devotes full chapters to relativity and quantum ideas as we do. So why do we do it? Here are three major reasons:

- Many of the most important and most interesting ideas of modern astronomy really cannot be understood unless students have a solid foundation in relativity and quantum mechanics. For example, while nearly every book offers a rubber sheet analogy for the curvature of spacetime near a black hole, without much more discussion students will completely miss the point of the analogy and may even take it literally—picturing a black hole as a funnel-shaped structure! Similarly, when introducing the important meaning of the observable universe, we expect students to take it for granted that faster-than-light travel is not possible—but of course students want to know why. (Worse yet, many students assume that saying you can't go faster than light is like past engineers saying you can't break the sound barrier—which leads them to conclude that scientists are closed-minded and cynical!) Newsworthy ideas of the overall geometry of the universe, such as what we mean when we say that new WMAP results support a flat universe, also require relativity. Quantum ideas are no less important, and not only because of the role they play in understanding light and spectra. For example, quantum ideas are needed to understand the degeneracy pressure that supports brown dwarfs, white dwarfs, and neutron stars, as well as to understand cosmological ideas such as inflation in the very early universe.
- We want to demystify these topics and show students that they can indeed understand these important astronomical ideas. There's a common myth that relativity and quantum ideas are too hard for the average person. (Consider the still-persistent urban legend that only 12 people in the world understand relativity.) As in our theme 2 above, we want students to feel that all of science is accessible to them, if it is presented simply and clearly. Thus, taking the time to do relativity and quantum ideas "right" seems well worth the effort.
- Students love it. Nearly all students have at least heard of things like the prohibition on faster-than-light travel, curvature of spacetime, and the uncertainty principle. But few (if any) enter an introductory astronomy course with any idea of what these things mean. They are naturally curious, and get great satisfaction from discovering that they can actually understand these topics. Indeed, in our courses in which we've covered these topics, end-of-course surveys have consistently found that a plurality of students chooses relativity as their favorite part of their astronomy course.

Part V—Stellar Alchemy (Chs. 15–18)

Basic Content. These are our chapters on stars and stellar lifecycles. Chapter 15 covers the Sun in depth, so that it can serve as our concrete model for building an understanding of other stars. Chapter 16 describes the general properties of other stars, how we measure these properties, and how we classify stars with the H–R diagram. Chapter 17 covers stellar evolution, tracing the birth-to-death lives of both low- and high-mass stars. Chapter 18 covers the end points of stellar evolution: white dwarfs, neutron stars, and black holes.

Pedagogical Approach—We are Intimately Connected to the Stars. Perhaps we can best describe our approach here as "less is more." Today, we know so much about stars that the primary challenge in teaching them is deciding what NOT to cover. We therefore have chosen to focus on those aspects of stars that support our themes—especially those aspects that reveal our intimate connections to the stars (e.g., nucleosynthesis). In order to make sure these themes stand out clearly, we deliberately leave out many other "details" that students would surely forget soon anyway.

How and Why Is Our Approach Different? The basic structure of our chapters on stars is the same as that used in nearly all textbooks. We believe this similarity simply reflects the fact that the basics of stellar evolution have been well-understood for decades, so that by now everyone has converged on an optimal order of presentation. Nevertheless, you'll still find at least two important differences between our coverage of stars and that in most other textbooks:

- Our "less is more" approach, as discussed above. If you want students to memorize facts about Herbig-Haro objects or the many different types of binary star systems—or if you want to quiz them on standard jargon like Type I and II supernovae, asymptotic-giant branch stars, or hydrostatic equilibrium—then we may not be the book for you. But if you want students to truly understand the connections between stars and human existence, and to be amazed by the bizarre objects left behind when stars die, then we think you'll like our approach.
- Most books include substantial discussion of the interstellar medium along with their discussion of stars and star birth. We choose instead to leave our discussion of the interstellar medium to a later chapter—Chapter 19 on the Milky Way. Why? Because aside from the simple idea that interstellar clouds can contract under gravity, none of the other details of the interstellar medium are needed to understand star formation. In contrast, the workings of the interstellar medium are crucial to understanding galactic "ecology," and thus belong with the discussion of the Milky Way.

Part VI—Galaxies and Beyond (Chapters 19–24)

Basic Content. These chapters cover galaxies and cosmology. Chapter 19 presents the Milky Way, emphasizing that it is a gravitationally confined system that gradually turns gas into stars while continually enriching it with heavier elements. Chapter 20 covers the observed properties of galaxies and shows how measurements of their distances and velocities lead us to deep insights about the size and age of the universe. Chapter 21 relates the currently incomplete story of galaxy evolution by presenting the clues we have gathered from our own Milky Way, distant galaxies, starburst galaxies, and active galactic nuclei. Chapter 22 focuses on dark matter, showing why we believe it exists, what it might be, and how it influences the fate of the universe. This chapter also includes discussion of the possible acceleration of the universal expansion and the so-called "dark energy." Chapter 23 looks at the early universe, presenting the evidence that favors the Big Bang model. Finally, Chapter 24 covers life in the universe. Note that this last chapter can be covered without any of the other chapters in Parts IV through VI; indeed, some instructors choose to cover Chapter 24 immediately after Chapter 14.

Pedagogical Approach—Present Galaxy Evolution in a Way That Parallels the Teaching of Stellar Evolution, and Integrate Cosmological Ideas In the Places Where They Most Naturally Arise. Given the success and general agreement on the pattern of organization for teaching stars, it seems wise to use a parallel structure for galaxies. For example:

- Chapter 19 presents the Milky Way as a paradigm for galaxies in much the same way that Chapter 15 uses the Sun as a paradigm for stars.
- Chapter 20 presents the variety of galaxies and how we determine key parameters such as galactic distances, making it somewhat analogous to the Chapter 16 presentation of the variety of stars and how we determine key parameters for the H–R diagram.
- Chapter 21 discusses the current state of knowledge regarding galaxy evolution, just as Chapter 17 covers stellar evolution.
- The relationship between Chapters 22–23 (dark matter and the Big Bang) and Chapter 17 (stellar corpses) is somewhat looser, but similarities include showing where astronomy makes contact with the frontiers of physics and discussing some of the most exciting ideas in modern astronomy—the ideas that draw many students into astronomy courses in the first place.

Throughout these chapters, we integrate cosmological ideas as they arise. For example, students first encounter dark matter when we discuss the rotation curve of the Milky Way in Chapter 19. We go into depth on Hubble's law in Chapter 20 because of its importance to the cosmic distance scale and our understanding of what we see when we look at distant galaxies. We devote an entire chapter to dark matter and the fate of the universe because the two ides are so inextricably linked and so fundamental to our current view of the cosmos.

How and Why Is Our Approach Different? Once again (as in Part III), we have an approach that is fundamentally different from that used in nearly all other introductory astronomy textbooks. The traditional approach found in other books goes something like this: morphology and structure of the Milky Way; "normal galaxies" discussed via the traditional Hubble tuning fork classification; "active galaxies" discussed as distinct set of entities from "normal" galaxies; and, finally, cosmology, including Hubble's Law and the Big Bang. Quite frankly, we believe this traditional approach is outdated in light of discoveries made over the past three decades or so. For example:

- The traditional approach gives students very little reason to care about the Milky Way, since it is basically full of facts about its shape and structure. In contrast, our emphasis is on the Milky Way as a cosmic recycling plant, making it possible for generations of stars to live, die, and chemically enrich the interstellar medium—a clear prerequisite to our own existence. The ideas may still be a bit esoteric, but at least they become relevant to each and every one of us.
- The traditional emphasis on Hubble's galaxy classification scheme made sense decades ago when astronomers hoped that the tuning fork diagram might turn out to be as important to understanding galaxy evolution as the H–R diagram is to understanding stellar evolution. But it has not turned out that way. Instead, the most fundamental distinction between galaxy types is between those with gas-rich disks (spirals) and those without them (ellipticals), and we are rapidly building an understanding of what factors play a role in a galaxy's type. These are the types of issues that we emphasize with our evolutionary approach to galaxies.
- The traditional distinction between "normal" and "active" galaxies just does not hold water any more. Many galaxies that would have formerly been called "active" are actually quite ordinary except for their unusually bright galactic nuclei. Indeed, the correlation between bulge mass and AGN mass suggests that all galaxies may have a black hole of some kind in their core—it is possible that at some point in time, all galaxies were "active." Other so-called "active galaxies" are now clearly seen as galaxies that may previously have been quite normal but are now in disarray for some reason or other. We therefore discuss galaxy evolution as a single,

coherent subject in which various forms of "activity" are seen in context as transient events that occur in the lives of some galaxies.

- The traditional approach keeps cosmology fairly distinct from the study of galaxies. But the formation and evolution of galaxies is so inextricably linked to initial conditions (e.g., seeds of structure present in the cosmic microwave background) and the overall evolution of the universe (e.g., ongoing expansion even as large-scale structures may still be forming) that we do not believe they should be separated. Indeed, to our minds, trying to teach galaxies without cosmology is like trying to teach biology without the theory of evolution—it leaves out the key element of the modern paradigm. We have therefore woven galaxy evolution and cosmic evolution together, and we believe this approach gives students a deeper understanding of both.
- The traditional approach leaves little room for a coherent discussion of the two things now thought to dominate the mass-energy of the universe: dark matter and dark energy. As a result, these topics usually are presented in a way that leads to an incomplete and fragmented understanding and a lot of unnecessary mystification. By devoting an entire chapter (Chapter 22) to dark matter and its importance to large-scale structure and the fate of the universe, we are able to give students a solid understanding of the greatest mysteries in modern astronomy. Indeed, this pedagogical structure allows the integration of ideas of universal acceleration and dark energy so smoothly that we did not even have to make any major changes to our text to accommodate these recent discoveries.

Chapter Structure in *The Cosmic Perspective*

So far, we have given you a fairly extensive description of the pedagogical rationale for *The Cosmic Perspective*. But on a day-to-day basis, what really matters is the structure of the presentation in the text, since that is how your students will encounter all of our pedagogy. If you thumb through the book, you'll quickly notice that each chapter follows a similar structure, designed to make it easy both for students to study and for you to choose what topics you wish to emphasize in your course. Here is a brief overview of the chapter structure and how it should help you and your students.

Basic Structural Elements

All chapters in the book follow the same basic structural flow, which consists of the following elements:

- **Chapter Opening Quotation**: Every chapter begins with a short quotation, usually from a well-known historical or cultural personality, designed to draw connections between the chapter topic and other human endeavors.[5]
- **Learning Goals**: These are presented as key questions at the start of each chapter. They are designed to give students context for the material to come and to help students focus their attention on the most important concepts ahead.
- **Chapter Introduction**: Prior to the first numbered section (e.g. Section 3.1), each chapter has two to three paragraphs that describe why the chapter material is important and interesting and offer a brief road map of how we will cover it.
- **Numbered Sections (Chapter Narrative)**: The bulk of each chapter comes with the numbered sections that present the narrative and all of the inter-narrative features (such as Common Misconceptions and Special Topics boxes, and icons to indicate when and where students can find relevant tutorials on the Astronomy Place website).

[5] It's perhaps worth noting that the quotations tend to be much appreciated by students whose primary interest is in social sciences, humanities, or the arts, because it shows them that science is not isolated from these other pursuits.

- **The Big Picture**: This end-of-chapter feature helps students put what they've learned in the chapter into the context of the overall goal of gaining a new perspective on ourselves and our planet.
- **Chapter Summary**: Coming at the end of the chapter narrative (just before the problem set), these return to the questions in the learning goals with answers that help reinforce student understanding of key concepts presented in the chapter.
- **End-of-Chapter Questions**: Each chapter ends with several sets of questions that can be used for study, discussion, or assignment (answers and solutions for most of them are included in the chapter-by-chapter sections of this Instructor's Guide). They are organized into three subcategories, as follows:
  - **"Does it Make Sense?" Questions:** These questions ask the students to evaluate a simple statement that is designed to help them focus on important concepts from the chapter. They should be quite easy for students who understand the concept, but nearly impossible for students who don't understand it—thus pointing those students to their need for further study. Note that the "Does it Make Sense?" heading is sometimes replaced with a slight variation, such as "True or False?" or "Surprising Discoveries?," but in all cases the basic idea is for students to evaluate a statement and explain their reasoning clearly. Note also that, in at least some cases, it is possible to make a case for either answer (e.g., sensible or nonsense), so that the most important part of a student's answer is how well they defend their choice.
  - **Problems:** The rest of the basic "problem set" comes under this heading. The problems are generally arranged from easier to harder and, to the extent possible, follow the order of presentation in the chapter. *Problems with an asterisk require mathematical manipulation, generally following methods described in Mathematical Insight boxes.*
  - **Discussion Questions:** These questions are meant to be particularly thought-provoking and generally do not have objective answers. As such, they are ideal for in-class discussion or extended essays.
- **Media Explorations**: Each chapter ends with a section or page of "Media Exploration," which is designed to highlight some of the many media resources available to aid students in studying the chapter material.
  - For those chapters in which Astronomy Place tutorials are relevant, we have included short sets of sample questions that can be assigned along with the tutorial to focus on the issues relevant to that chapter. (Additional tutorial questions can be found in the tutorials themselves and in the *Astronomy Media Workbook* supplement; ISBN 0-8053-8755-2.)
  - Every Media Explorations section concludes with one or more "Web projects" designed for independent research. The projects typically ask students to learn more about a topic of relevance to the chapter, such as a current or planned mission. Students can find useful links for all the Web projects on the Astronomy Place website.
- **On-line Quizzes**: Finally, although they do not appear in the printed book, the two on-line quizzes for each chapter should be considered an integral part of the chapter. They are the best way for students to check that they have really grasped the key chapter concepts.

Additional "Feature" Elements

Within the main narrative of each chapter, you'll find a number of pedagogical elements that appear whenever they can help illuminate important topics. These features include all of the following:

- **Key Concept Figures**: We have tried to make sure that every important concept in the book is accompanied by some type of figure that summarizes it visually. Thus, students can get an overview of all the key chapter concepts by studying the illustrations (with their captions), then go back to read the chapter in detail.

- **Wavelength/Observatory Icons:** For astronomical photographs (or art that might be confused with photographs), we include simple icons that identify the wavelength band of the photo or identify the figure as an art piece or computer simulation. Alongside the wavelength icon for photos, we also include an icon to indicate whether the image came from ground-based or space-based observations.
- **Think About It**: This feature, which appears as short questions integrated into the narrative, gives students the opportunity to reflect on important new concepts. It also serves as an excellent starting point for classroom discussions. Answers or discussion points for all the Think About It questions can be found in the chapter-by-chapter sections of this Instructor's Guide.
- **Cross-References:** When we discuss a concept that is covered in greater detail elsewhere in the book, we include a cross-reference in brackets. For example, "[Section 5.2]" means that the concept being discussed is covered in greater detail in Section 5.2.
- **Common Misconceptions**: These boxes address and correct popularly held but incorrect ideas related to the chapter material. In a few cases in which the boxes focus on misconceptions perpetrated by television or movies, the boxes carry the title "Movie Madness."
- **Mathematical Insights:** These boxes contain most of the mathematics used in the book and can be covered or skipped, depending on the level of mathematics that you wish to include in your course.
- **Special Topic Boxes**: These boxes contain supplementary discussion of topics related to the chapter material but not prerequisite to the continuing discussion.
- **Glossary**: Although not part of the chapter flow, the glossary should be considered another pedagogical element tied to the chapters, since it makes it easy for students to look up important terms.

Getting the Most Out of Each Chapter

The chapter structure is designed so that it is easy for students to study effectively and efficiently. Nevertheless, it may be useful to suggest the following study plan to your students:

- Begin by reading the Learning Goals to make sure you know what you will be learning about in this chapter.
- Before reading in-depth, start by skimming the chapter and focusing only on the illustrations. Study each illustration and read the captions so that you will get an overview of the key chapter concepts.
- Next, read the chapter narrative. Try to answer the Think About It questions as you go along, but you may save the other boxed features (Common Misconceptions, Special Topics, Mathematical Insights) to read later.
- After reading the chapter once, go back through and read the boxed material. Also look for the tutorial icons that tell you when there is a relevant tutorial on the Astronomy Place website. If you are having difficulty with a concept, be sure you try the tutorial.
- Study the Chapter Summary by first trying to answer the Learning Goals questions for yourself, then checking your understanding against the answers given in the summary.
- Check your understanding by trying the on-line quizzes. Do the basic quiz first, and make sure you clear up any difficulties you have with it before you try the conceptual quiz.

Preparing Your Course: Suggestions for First-Time Astronomy Teachers

If you've taught astronomy before, then you know how much work you must put into course preparation in order for the course to run smoothly and seamlessly for your students. This section is intended to help reduce that workload by giving you some suggestions that we've found useful in preparing our own courses. It is primarily intended for those of you who are new to teaching astronomy; if you've been teaching for many years, they you probably already have your own good systems for course preparation.

What is Teaching All About?

Forgive us for pontificating, but before we get into details of course preparation we'd like to make a general point about teaching:

- This may sound strange, but if you'll think about it you'll realize that you can't "teach" anyone anything. The only way that any of us ever learn is by learning for ourselves. Your job as a teacher is to make learning possible. If you simply try to "pour" facts into student heads, it won't work. But if you motivate them, encourage them to work at learning, and answer their questions, you will be a great teacher.

General Notes on Course Preparation

The broad range of material covered in introductory astronomy courses can be intimidating to teach, especially if your primary scientific training was not in astronomy. (FYI: A large fraction of the people teaching introductory astronomy courses have degrees in physics rather than astronomy.) Here are a few general suggestions that will help you stay ahead of your students and keep your course running smoothly. We apologize if they seem obvious, but for some new instructors they will be useful.

- **Be Clear About Your Expectations of Students.** Perhaps the single most important thing you can do to help your students achieve success in science is to lay out clearly what it takes for them to succeed in your class. Thus, before your course begins, you should decide what you intend to ask of your students—for example, how much homework you will assign (see p. 33), when exams are scheduled, whether work with Astronomy Place tutorials is optional or required, and how you will determine final grades. Once you have made your decisions, you should communicate them clearly to students. This communication can be done in at least three ways:
  - Prepare a syllabus that lays out all your expectations and grading policies clearly. This syllabus can then serve as the single reference for students whenever they have questions about class logistics or if they begin to struggle or fall behind. Appendix 4 offers a sample syllabus from one of our own courses, which you can use or modify as you wish.
  - Spend some time on the first day of class going over your syllabus and making sure that students understand that they should take your expectations seriously.
  - Throughout the course, continue to emphasize your expectations, especially to students who are not meeting them. *We strongly believe that the vast majority of students will rise to meet your expectations.*

One caveat: don't be inflexible. You will inevitably encounter a wide variety of issues with different students, and sometimes the expectations you set before the course begins may prove to be too high or too low. Be willing to make adjustments in your expectations if necessary, and remember that your job is not to be perfect but rather to do the best that is possible with the teaching situation into which you are thrown.

- **Read the Chapters and Try the Assignments You Give to Students.** Although it may seem obvious that you should do what you ask of your students, we've found a depressing fraction of college professors (across all subjects) who, for example, assign reading that they've never read themselves or assign problems that they haven't tried to solve themselves. Clearly, you cannot anticipate student questions or understand the problems they run into if you don't know what they've been reading and working. Ideally, you would read all the assigned chapters before your course begins. Realistically, as some of you may have very little prep time available, you can succeed by skimming the chapters before the course begins and reading them in depth a day or two ahead of when you expect students to have read them.
- **Try to Be Consistent With the Text (Especially with Jargon).** Students learn best when the reading, assignments, class lectures, and discussions all reinforce one another. This is not to say that you cannot deviate at all from the textbook presentation; it only means that you should strive for as much consistency as possible and that you should acknowledge it when you choose to do things differently. For example:
  - In many cases, it may work quite well if you present a topic in class in a different way than we present it in the book or include a topic that we don't cover at all in the book. However, since students are (hopefully) reading the book, it's important that you let them know when and why you are doing something differently, so that they don't become confused (e.g., asking themselves, "who's right, the book or the prof?"). In other words, it's fine to say, "the authors do it this way, but I prefer this other way," but not fine to simply do the other way without acknowledging that it's different from what they are reading.
  - Consistency of jargon is particularly important. Remember that we have worked hard to reduce jargon in *The Cosmic Perspective*. If you then use the standard jargon in class, it will only confuse students. For example, if you talk about Type I and II supernovae when we talk about white dwarf and massive star supernovae, you'll lose the intended benefit of the jargon reduction.
- **Become Familiar With the Study Resources Available To Your Students.** No matter how well you teach or how good our book, many of your students will still have difficulty in your course. Thus, one of your most important jobs as a teacher is to help steer these students to resources that will help them overcome their difficulties. Obviously, you cannot steer them well unless you know what resources are available. In particular, you should familiarize your self with all of the following:
  - *The study resources on the Astronomy Place website, especially the tutorials and the on-line quizzes.* For many students, making good use of these resources will be all they need to overcome their difficulties with course material.
  - *The Addison-Wesley Astronomy Tutor Center.* It would be nice in principle if you could hold enough office hours to accommodate all student needs, but in reality it's probably impossible. The Tutor Center, when used effectively, can be a big help by giving students a way to get help when you are not available. (Remember that your students can have free access to the Tutor Center, but only if you order your books bundled with it. See www.aw.com/tutorcenter or talk to your local Addison Wesley sales representative for more information about the Tutor Center.)

- *Campus resources for students, such as tutoring centers, study skills workshops, and counseling services.* Most college campuses offer at least some resources to help students who are having difficulty. Some campuses have tutor centers staffed by undergraduate or graduate students. Many campuses offer study skills workshops for students who don't know how to study efficiently. Most campuses offer counseling services, which may help students whose difficulties stem from issues that may not be directly related to your course. Sadly, the students who most need these services are usually the ones who are least likely to know that they exist. Therefore, you can do your students a great service if you are sufficiently familiar with the available campus resources to point your students in the right direction.

- **Stay Current With Astronomical News.** Astronomy generates frequent headlines in the news media, and we believe that a major goal of an astronomy course should be to get students sufficiently interested in the subject that they become lifelong followers of the astronomical news. One of the best ways to help generate this enthusiasm is for you to bring current astronomical news into your class. You should follow the news closely for reports of discoveries or missions that may be relevant to your class. It's well worth taking a few minutes out of your planned lecture to report on an exciting new discovery, even if it's in a different area of astronomy than the area you are covering at that moment. (After all, if you run out of time for your prepared material in the lecture, you can always post your notes or remind students to be sure they've studied the relevant portions of the book!)
- **Set Up an Effective Course Management System.** Course management means things like entering grades from assignments and exams and keeping track of everything that gets turned in. It's not glamorous, but it's very important to have a good system, especially if you have a large class. You'll save yourself time in the long run if you spend some time up-front to put together a good system. Remember that Addison Wesley offers a variety of on-line course management resources that can make your life much easier. (As noted earlier, see demos for Blackboard or WebCT at http://cms.awlonline.com, and for CourseCompass at www.coursecompass.com. Contact your local sales rep for more information.)
- **Share Resources and Ideas With Other Instructors.** Just as your students should never feel helpless when they run into difficulties, you should never feel like you are alone as a teacher. There are lots of other astronomy teachers out there with lots of great ideas, and there's always some way to share the load. For example:
  - If you teach at a school where multiple instructors are teaching the same course from the same textbook, try to share resources, teaching ideas, and plans for homework assignments or exams. If possible, hold a weekly meeting of all the instructors where you can simply discuss your experiences so that you all get the benefit of each others' insights.
  - If you are the only person teaching the course at your school, seek out others who may have taught the course in the past or teaching colleagues at other schools. Again, it is always valuable to share ideas. Meetings of the American Astronomical Society (AAS) and American Association of Physics Teachers (AAPT) often have sessions on the teaching of astronomy, and you may also find these well worth attending.
  - If you need supplements or have questions or difficulties with any materials for *The Cosmic Perspective*, you can always contact your local Addison Wesley sales representative. And, again, you can also feel free to e-mail the authors with your questions or comments (see the first page of the IG for e-mail address).

Setting Your Grading Policy

A key part of setting student expectations is making sure that you have a clearly stated grading policy. Setting such a policy can be more difficult than it sounds, and depends in part on the time you have available for grading work. Nevertheless, as a general guideline, we recommend basing grades on some combination of the following:

1. Homework sets consisting of selections from the end-of-chapter problems, assignable work from the tutorials on the Astronomy Place website, or activities based on the *SkyGazer* software. We generally recommend homework scheduled on a regular basis, such as weekly or every other week, because it makes it possible for students to budget their time in this and other courses. Of course, homework requires grading, which may limit how much you can assign; please see "Selective Homework Grading" below (p. 36) for suggestions on making the grading work manageable.
2. Some set of quizzes and/or exams; e.g., you might choose short weekly quizzes (or completion at home of some of the on-line quizzes), and one or two longer midterms and a final exam.
3. One or more projects, selected from the Web projects on the Media Explorations page of each chapter.

Weighting the Components of the Final Grade

Once you decide what to assign, you must assign a weight to each component in the final grade. Again, the weight will depend on your personal style and resources for grading. However, we have some personal opinions that we'll now share with you:

- In science, we have a tendency to base grades strictly on content knowledge. For example, in a physics course for majors, those who can solve the problems get high grades and those who can't get low grades. However, we believe that in a course for nonscience majors, grades should reflect effort at least as much as content knowledge. The reason is simple: because an introductory astronomy course has no prerequisites, students enter with a wide range of prior content knowledge. Thus, if you base your grades strictly on content knowledge, you may effectively be grading students as much on what they knew before your course as you are on what they know after it. To take an extreme example, we know of many instances in which science or engineering majors have enrolled in introductory astronomy courses, even though these courses are not really intended for them. Not surprisingly, these students can often "ace" the exams, even without studying very much, because they already are adept at science and may have learned much of this material in high school. Clearly, letting these students "skew the curve" would be unfair to those students for whom the course is really intended. By making effort a part of the grade, we not only level the playing field, but we also make sure that even these advanced students must do enough work so that they actually learn something new.
- The best way to reward effort is to make homework and projects count as a substantial fraction of the final grade. This is particularly true of essay-type questions, in which students must write clearly and demonstrate an ability to defend their answers, as opposed to simply getting an answer right or wrong. We like to further reward effort by making the exams closely tied to the homework, so that those who really understood what they were doing on the homework are likely to get good grades on the exams because the questions cover similar concepts.
- Regarding exams: again, in science we have a tendency to ask exam questions that check whether students can "go beyond" the concepts learned in class. This is a great way to pick out those most likely to succeed among our science majors, but we urge you to resist the temptation to ask such questions in nonscience classes. The basic work of learning a science is challenging enough for nonscience students, and we should be quite satisfied if they learn the key concepts presented in the book or in class. This is not say that you should avoid challenging questions—only that the questions should be challenging in the sense of making students think hard about something that they studied, rather than in the sense of asking them to think of something entirely new that was not covered in class.

You can choose for yourself how to balance these ideas in weighting your grades. A policy that we have used is shown on the sample syllabus in Appendix 4.

The Grading Scale

The primary question in setting a grading scale is whether to use a curve or a "straight" scale. There's really no right answer to this question, but our own preferences lean toward a straight scale for one key reason: We feel an obligation to combat the rampant grade inflation on college campuses. With a curve, it's too easy to succumb to student pressure (and these days parent pressure, too) and decide that "average" should be a B or an A– rather than a C. In contrast, if you set a policy that a weighted average of 90% on all assignments constitutes an A–, it is very difficult for anyone to argue with you.

An added advantage of the straight grading scale is that it allows you tell the students straight-faced (no pun intended) that you are willing to give each and every one of them an A—all they have to do is work hard and learn the material. Moreover, if you follow our guidelines above about rewarding effort, it really does become possible for even the most science-phobic students to rise up and get an A (we've seen it happen many times!). Don't worry about this causing grade inflation, though—sadly, not all of your students will put in the necessary effort. You'll end up with an average course grade that makes you look like one of the toughest instructors on campus, while your students will still come away feeling that you gave them a fair chance to earn whatever grade they were aiming for.

Setting Your Homework Policy

As discussed above, we suggest assigning at least some homework unless a lack of grading resources makes it completely impossible. The key issue is deciding precisely what and how much to assign. You have a lot of choices. The book alone has far more end-of-chapter problems than you could reasonably assign to your students, and on top of that you have the option of assignments based on the web tutorials, *SkyGazer*, and other projects. A good way to decide what to assign is read through the various problems and projects and then decide which ones you'd like to emphasize. When selecting particular problems for assignment, you may wish to consider the following:

- The "How to Succeed" section in the Preface recommends that students in a 3-credit class expect to spend about 2–3 hours per week on homework (i.e., on working problems; not counting time for reading the text or preparing for exams). Thus, we suggest you seek to assign homework that you believe the average student can complete within this 2–3-hour-per-week guideline.
- As a guideline to help you estimate the appropriate length for a homework assignment, we've found that homework will generally take an average student roughly 4 times as long as it takes you. For example, if you can do a set of problems in 1 hour, the same set will take an average student about 4 hours. Of course, this guideline may vary depending on the level of your students and your own speed of work, so adjust accordingly from experience.
- We recommend a mix of easier and harder problems. For example, from a particular chapter you might assign three or four of the "Does it Make Sense?" questions, two or three more extended problems, and one longer essay or Web project.
- Although weekly homework is a good idea in principle, you may choose to give homework somewhat less often so that, for example, homework is not due in the same week as a major midterm.

Finally, to ensure that students turn in their homework in an appropriate fashion (e.g., not done in crayon!), we suggest you make use of our guidelines on "Presenting Homework and Writing Assignments," which appear in Appendix 5.

Selective Homework Grading

How are you going to grade all that homework? This is one of the most challenging questions in teaching, since we rarely have enough resources to grade all the work that we'd like to assign. We therefore recommend that rather than shortening the assignments, you instead use a selective grading strategy. That way students still get the benefit of the learning that homework entails (and homework really is the best way to learn), while you are able to assign grades in a practical and fair way. Our recommended strategy goes like this:

- Tell students in advance that you will grade only a few of the problems that you assign. Although some students will complain about turning in "extra" work that you do not grade, most will recognize that you are assigning this work for their benefit.
- In addition to grading a few problems in detail on each assignment, also assign part of their grade based on a skim of its completeness and presentation. A quick scan is usually all you need to figure out who really put in effort and did a good job and who didn't. For example, if you say that a homework assignment is worth 10 points, reserve 2 points for this overall "presentation" score while grading 4 other problems for 2 points each. (On a 10-point homework scale, we usually award half-points as needed; thus, the 2 points can essentially become 2, 1.5, 1, 0.5, or 0, which corresponds to A, B, C, D, F.) While the 2 points for "presentation" may seem rather small given that it actually represents most of the work the students turned in (since you grade in detail only a small fraction of the problems), it is a strong motivator for success. For example, even if students guessed correctly which problems you were going to grade in detail, getting a presentation score of 0 for not doing the rest would mean a maximum possible score of 8 on the homework assignment (which is a B– on our straight scale). Thus, students who want a good grade will be forced to work hard on the entire assignment. Moreover, those who put in the effort necessary to get the full 2 points for presentation usually have done all their work carefully and well, so these 2 points help to reward effort (which, as noted earlier, we think is very important).
- Hand out or post detailed solutions to all the problems you assign so that students can check for themselves whether they did ungraded exercises correctly.
- Try to make at least some exam questions directly test concepts from the homework. In that way, students will feel that working the exercises was beneficial because it helped them do better on the exam. This, along with the laws of statistics, will ensure that your homework grading policy is fair even though you do not grade everything.

Homework Help

We encourage you to find ways to provide your students with plenty of homework help on request. (Don't forget the availability of the Addison Wesley Astronomy Tutor Center as a source of homework help.) Again, because of the varying science backgrounds of students in introductory courses, this is the only way to ensure that those with weak backgrounds still have a chance at success. We have found that one good approach is to offer students unlimited help—with the caveat that they'll get this help only if they have already tried the problems themselves. We go so far as to tell students that, if necessary, we'll lead them step-by-step through everything they must do to write down a correct solution (in reality, it very rarely comes to this point). This policy not only makes students feel confident that they can succeed in your class if they are willing to put in the effort, but also has the effect of helping prevent procrastination. After all, students who wait to start on their homework until the night before it is due will have no time left to take advantage of your offer of help.

Setting Your Testing Policy

Studying for tests actually helps students consolidate their learning. Thus, it is a good idea to give quizzes and exams even if you assign extensive homework. Here, we discuss a few considerations that concern testing policy.

Multiple-Choice or Essay?

It's widely acknowledged that short-answer or essay-type questions are a better diagnostic of student understanding of particular concepts than are multiple choice questions. However, this advantage must be weighed against two drawbacks to essay-type exams: (1) They take much longer to grade than machine-readable multiple-choice exams; and (2) because the questions take longer to answer, an essay-type exam cannot be as comprehensive as a multiple-choice exam with the same time limit. Different instructors will of course weigh the pros and cons of essay-type exams differently, and much will depend on the number of students in your class and the availability of grading resources. Again, there is no right answer, and you will come to your own conclusions about what works best for you.

However, we wish to make one general recommendation: If you have only enough grading resources (e.g., just yourself!) for *either* homework or essay-type exams but not both, we believe that the grading resources are better spent on the homework, which means going with machine gradable multiple-choice exams. Our reason is simple: While essay-type questions provide a better diagnostic of what students have already learned, homework is a way of getting them to learn in the first place. Thus, if you must choose, the option that forces students to do homework is far more likely to result in greater student learning.

Should You Give Short Quizzes?

We have found that, because of the rapid pace at which students encounter new concepts in astronomy courses, it is useful to give frequent quizzes. There are two basic ways in which you can do this:

- Using Addison Wesley's course management resources, you can receive scores when your students complete the on-line quizzes. Because there are two quizzes for each chapter in the book, this will ensure that your students are continually studying enough to consolidate their learning. A good strategy is to require that students complete the basic quiz for a chapter before you cover that chapter in class, then complete the conceptual quiz for the chapter a day or two after you complete your class coverage of the chapter.
- Alternatively, you might give a weekly multiple-choice quiz designed to take, say, 15–20 minutes. The drawback to this idea compared to use of the on-line quizzes is that it uses up some of your class time. The advantages are that you can cover more than one chapter at once, you can choose your own questions, and you can monitor against potential cheating. Note: if you go this route, be sure to make answers available immediately after the quiz so that students can think about their answers while the quiz is fresh in their minds. (With the on-line quizzes, the feedback is immediate after each question.)

How About Exams?

Quizzing will help your students a great deal, but it still tests only small chunks of material at a time. To really ensure that your students put everything they are learning together, we suggest that you also give at least one longer midterm and a final exam. Personally, we tend to favor two midterms and the final exam, mainly to give students more "practice" at studying. Ideally, the exams should count enough toward the final grade so that students will be forced to study and learn, but no so much as to put overwhelming pressure on those students who may have fears of in-class testing. A few other notes that may be of interest:

- Remember that a midterm is a learning experience while a final is a testing experience. That is, students can learn from their mistakes on a midterm, but when the final is past they are unlikely to ever look at the material again.
- Given the above statement, we have sometimes implemented strategies designed to maximize the learning that students get from their midterm mistakes. For example, we may promise to repeat difficult questions on the final (thereby giving students the message that they really must go back and see what they did wrong).
- A more labor-intensive strategy for midterm learning is to offer what we call "exam rebates." After the graded exam is returned, we offer the students the opportunity to earn back up to half of the points they lost on the exam. To get these "rebate" points, they must write a short essay for each question that they missed in which they not only explain the correct answer but also explain what they now realize was wrong with their original answer. For students, going through this process is a great way to figure out what they have been misunderstanding and to get themselves onto a better learning track. We have had many cases in which students fail the first midterm, but after going through this rebate process they have improved their studying so much that they get A's on subsequent exams. Note that the "up to half back" usually also gives such students an opportunity to overcome their poor scores. For example, a student who fails with a score of 50 (out of 100) can use the rebates to raise their score to 75—making it much easier for them to get a B or A average overall when they do well for the rest of the term. (The question sometimes arises as to whether this offer should be open even to the A students; e.g., do we allow a student who gets a score of 96 to use the rebates to raise their score to 98? Our answer is yes, though we don't go out of our way to encourage it since such a student is clearly doing well anyway.)
- If you are feeling especially generous, you might even offer to replace midterm scores with final scores for students who do better on the final. We don't recommend doing this every term, since otherwise word will get out and students won't study hard for your midterm, but it can be a useful motivator if you happen to have a class that does much worse than you hoped on a midterm. (*Note:* Some instructors have offered a gambling variation on this theme, in which students tell you in advance (either before the final or just as they turn it in but before it is graded) whether they want to have their midterm score replaced. Those who choose the replacement option get the replacement score whether it is better or worse than the original. Personally, we aren't big fans of gambling in general, but some teachers think this is a good way to go.)

The Test Bank

It's not easy to write good test questions, so we encourage you to take advantage of the Test Bank available with this book (in both printed and computerized form). Why reinvent the wheel when others have already gone to great length to write exam questions? You may use questions from the Test Bank directly, modify them as you wish, or simply use it to get ideas for questions you write yourself.

- Note that all the questions that appear in the on-line quizzes also appear in the Test Bank. You may wish to focus on these if you want to "reward" those students have spent time with the on-line quizzes as a study aid.

The First Day of Class

OK, so you've set all your policies, made your syllabus, and now you are ready to face students on the first day of class. What should you do? We believe that your primary goals on the first day should be: (1) make sure students understand your expectations; and (2) motivate them by starting in on the big picture ideas of Chapter 1. A few notes:

- Be sure not only to go over your syllabus, but also to point students to the section of the book's Preface titled "How to Succeed in Your Astronomy Class." This section emphasizes that students should expect to study 2–3 hours outside class for each hour in class. We have found that most students are not accustomed to this much studying in their classes, but it is crucial to success in science. Thus, your students will be unaware that your class requires this much work unless you tell them so explicitly.
- Let's say the above another way: Tell you students that you can provide them with **the key to their success in your course**: They must put in real effort. If you go with our guidelines above on grading, students will understand that effort = success, while lack of effort = failure.
- If you have a small class, spent a little time learning student names, and perhaps going around the room so that students can introduce themselves. After all, one of the advantages of a small class is that it can lead to collaborative learning, but collaboration will only occur if the students get to know one another.
- Finally, we have found it very useful to assign something like the following "Assignment 1" on the first day of class. It will not only help students get "up and running" with the text website, but will also provide you with direct student contact and some understanding of what has motivated these students to be in your class.

Suggested First Day Assignment

Feel free to hand this out verbatim or modify as you wish:

Assignment 1 (due by second day of class)

Go to the text website, www.astronomyplace.com. Spend at least 1 hour exploring the site. After you have completed this exploration, send a single e-mail message to your instructor (or TA). In your e-mail message, you should:

1. Make a brief, clearly organized list that includes your name, student ID number, a telephone number where you can be reached during the semester, your status in school (e.g., freshman, sophomore, etc.), and a list of any prior astronomy classes you have taken (including names of instructors, if you remember them).
2. Write one or two paragraphs telling us what you hope to get out of this class.

3. Write two or three paragraphs briefly describing what you learned from your "Web surfing." What was your favorite feature of the Astronomy Place website, and why? If you explored links to other sites, which site was your favorite, and why?

Structuring Class Sessions

After the first day, you can and should expect students to come to class prepared. The structure of each class period will depend on how frequently you meet and how long the class lasts. Nevertheless, we recommend a few general strategies:

- Remember that students may be coming to your class with other things on their mind. Help them get on track by spending a few minutes at the beginning of each class reviewing where you left off the last time. Then save the last couple of minutes of class to review the topics covered that day (which helps them consolidate what they've just learned) and to tell students what will be covered next time (which helps them be prepared for the next class).
- *Expect* your students to do the assigned reading, and show that you expect it by avoiding direct repetition of what is in the book during your lectures; focus your class time on the more difficult concepts. *Note:* You can reinforce the need for your students to come prepared by requiring them to complete the on-line basic quiz for a chapter before you begin covering the chapter in class. If you really want to encourage early studying, you might allow multiple attempts to get the best possible score—but only up to the time that class begins. This gives even weak students a chance to get a high score, as long as they start early enough.
- Consider trying new techniques to make your lectures more interactive. A few such techniques are discussed in the next section of this *Instructor's Guide*.
- Show your students that you care. Expect them to attend class and participate in any discussions or activities. Constantly remind them that help is available if they need it. If you have a student who misses class or an assignment, call the student to ask if everything is OK and, at least the first time, offer a way for them to make up the missed work. You'll be amazed at how quickly you can turn around some students with the simple act of a phone call that makes them feel that you care.

Evaluating Your Teaching

We recommend that teachers always ask their students for feedback on what is working and not working in their teaching, and this is especially important in science classes where material builds over the course of the term. There are many ways to get this feedback. Here are two evaluation strategies that have worked well for us.

Post-Lecture Evaluations

This evaluation exercise asks for anonymous feedback at the end of a class period. It is best tried after you've "hit your stride" in the class, but early enough in the term so that you can still incorporate what you learn from the feedback—e.g., you might try it after a class about a third of the way into your course, then repeat it around the two-thirds point. Here's how it works:

Stop your class a couple of minutes before the end of period and ask students to briefly answer the following three questions before they leave. You can either ask them to write on a piece of scratch paper or hand out a prepared form. Either way, be sure that the feedback is anonymous:

1. What constructive criticism do you have on how this class is taught?
2. What's good about the way this class is taught?
3. What's the main thing you learned in today's class?

Note: You might think that only the first question is important, but the second gives a more balanced view of your teaching, and the third offers a valuable insight into whether students got what you had intended out of that day's class.

Feedback on Homework

We have also found it very useful to ask students for feedback that they can turn in with their homework assignments. We do this by including the following optional question at the end of each homework assignment:

> *Question X. Comments (please answer, but this will not be graded): How long did this homework assignment take you? Please comment on the assignment and the class in general. For example: Do you feel you are understanding the material? Do you feel that what you are learning will be beneficial to you? Other comments or suggestions?*

If you feel that anonymity is the only way to get honest responses, you can ask students to turn in their answers to this question separately from their graded papers. However, we've found that in many cases we can get more useful information by having the answers with the graded papers. For example, it's useful to know whether those who said the homework was easy were really the ones who did well. In addition, we've often found that we can write personal notes back to the students on their papers, thereby helping them understand specific difficulties that they called out in their comments. Moreover, we've found that that lack of anonymity is usually not a deterrent to honest comments when the comments are associated with homework—perhaps because they are already "exposing" themselves with their written assignment, students often are quite willing to tell you exactly how they feel about all the work they just completed.

Notes on Interpreting Evaluations

We all put a great deal of effort into teaching and would like our evaluations to show an appreciation for all we do for the students, so it can be very disappointing when student evaluations tell you that you're not the greatest teacher in the history of the planet—or something even worse! This can be especially true if you are new to teaching, and thus have not yet developed the thick skin of old-timers. We therefore offer a few suggestions on how to get the most out of your teaching evaluations:

- First and perhaps most important, remember these are comments on a task to which you have been assigned and NOT comments on you as a person. Especially if you are new to teaching, the personality that comes across in class may be very different from the personality that your friends see. If the students hate you, it just means you may want to do some things differently next time. It does not make you a bad person or even a bad teacher—just a teacher with room for improvement.
- Students will write all kinds of strange things on course evaluations, so use a filter to decide which comments truly represent constructive criticism and which comments can be safely ignored. For example, students may complain about class being too early in the morning, which is clearly not your fault. Or if ten students say you gave just the right amount of homework and one says you gave too much, the one may just have had too big a course load. (We've even seen complaints like "the professor made me think too much," which you might take as a compliment!) A good guideline can be the amount that students write—those who make the effort to give you extensive comments usually have something worthwhile to say.
- Develop your thick skin: No matter how well you teach, some students will write horrible things about you that you don't deserve. This may be because they just didn't "click" with you, or because they happened to be having a bad day when you handed out the course evaluation, or because they are just mean people. Regardless, remember that the point of the evaluations is

to help you improve your teaching. If you can extract some constructive criticism from the negative comments, then great—but if they only make you feel bad, then you should feel free to ignore them.

- As a corollary to the above, remember that it's not easy to get positive comments, especially in large classes that students take only to fulfill a requirement. Students have a lot going on in their lives. If someone says that they loved your class, it means you have succeeded in breaking through the "noise" of everyday life to touch that person in a very deep way. If even a modest fraction of the class rates you highly, you've done a great job. (If you manage to get half your students saying they loved your class, you are the teacher of the year.) Allow yourself to feel good about the positive comments, even while you try to learn from the negative ones so that you can be even better the next time.

Suggestions on Making Your Lectures Interactive

We're now ready to discuss how you can attempt to break out of "lecture mode," changing learning from a passive to an active experience. This is particularly important in large classes, but the methods described below are also effective in smaller classes. Some of these ideas are formally developed pedagogical tools with published references, while others are just simple ideas that may keep your students engaged during class. It's not possible (or recommended) to implement many of these at once, nor will all suggestions match an individual instructor's teaching style. We encourage you to read through the ideas and pick out the ones that will help you most. We hope that they will make class time more enjoyable for you and your students.

Basic Interactions

You may have noticed the following curious effect: The more students you have in your class, the fewer actively participate in basic question-and-answer interactions. Although you may ask "Are there any questions?" you've probably noticed that few take advantage of the opening. And when you ask a question, only a few hands come up, and they're always the same ones. Statistically speaking, they're not likely to be female or minority students. Here we offer a few suggestions on how to improve simple interactions without changing your class structure very much.

- First, note that success in all interactive teaching depends on keeping control over your classroom—it is important that students do not become rowdy or discourteous. To help you keep control over your classroom, we suggest that you emphasize the importance of the guidelines on common courtesy discussed in Appendix 4 with our sample syllabus.
- One simple way to involve the whole class is to convert each question into a yes/no or multiple-choice question and ask students to vote for their answer. For example, ask "Does the full moon rise at sunrise, noon, sunset, or midnight?" A vote (by show of hands, color-coded cards, or electronic transmitter) is a good way to tell whether students have understood a recent topic well enough for you to move on. It also forces the students to think and participate to some degree.
- Regarding the tally of votes as in the above bullet: There are also new technologies to allow students to interact in class with electronic transmitters. Student participation can thereby be recorded and graded, with very positive effects on participation, attendance and understanding. An example of this approach is described in a short article and set of view graphs compiled by TCP author Nick Schneider. These are posted and available for download at http://ganesh.colorado.edu/nick/TeachTech1.pdf and http://ganesh.colorado.edu/nick/TeachTech2.pdf.
- You can expand the discussion by calling on students who have indicated one opinion or another to explain their viewpoints. Another way of involving a larger fraction of the class is calling on students instead of waiting for volunteers. If you use this method, be sure to read "Avoiding Intimidation" below.
- Even the physical action of raising hands is better than just listening. Try other techniques to involve the students physically. Ask them to stand for yes votes instead of raising hands. Have them do simple demonstrations whenever possible (e.g., demonstrate parallax by asking them to hold their hands out with an extended index finger at arm's length). If you are conducting a demonstration at the front of a large lecture hall, give them the opportunity to leave their seats and file by so they can see the demonstration up close.

- Nonscience majors are keenly aware that instructors are often looking for the one "right answer," and doubt that they actually know it. You can break the ice in classroom discussions by including topics that have more than one answer. Examples range from opinion questions (e.g., "Do you think there's other intelligent life in the universe?" "How much is it worth spending on space exploration?") to lists (e.g., "What can you learn about a star with telescopes?" "What kinds of geological features are present on Venus?"). With practice, general questions like these can extend into more challenging and interesting questions, such as the Discussion Questions provided at the end of each chapter.
- Perhaps the most important point to keep in mind is that good discussion requires good questions. Try to spend a few minutes before each class period coming up with good questions. The Think About It features in our textbook are often excellent starting points and have the advantage that students who have done the reading will already have some answers in mind.

Collaborative Learning

The unifying theme behind the suggestions that follow is challenging students to work through thought-provoking questions, to discuss them with their neighbors, and to gain confidence and practice in working with new ideas.

- You can make classroom questioning even more interactive by encouraging students to work together to determine the right answer. Allow students to break into discussion groups of two or three for a couple of minutes. This gets everyone talking, often arguing for their answer in an animated way. Students learn to discuss scientific issues and end up learning from their peers. Reconvene the class with some prearranged signal like dimming the lights. You can either call for another "vote" for the right answer or poll individual groups to get an explanation for the answer they chose. One version of this approach has been carefully designed and tested under the names ConcepTests and Peer Instruction; the book and website are listed below under "Resources on Interactive Teaching."
- A variation on this method uses index cards for student answers. Students can exchange the cards to learn from their neighbors. The instructor can then ask students if the card they are holding has an interesting or useful answer. The exchange of cards ensures anonymity (see "Avoiding Intimidation" below) and usually brings out more thoughtful (or amusing) responses than students will volunteer on their own. Alternatively, students can collaboratively answer questions on worksheets distributed in class.
- Another variant uses demonstrations as the focal point of discussion. Specifically, a well-designed, thought-provoking demonstration is set up and described—but not performed. (Galileo's classic test of dropping balls of different masses is a good example.) Students then discuss in small groups what they think will happen and report their predictions. The demonstration is then performed, and students reconcile the results with their predictions (if necessary).

Avoiding Intimidation

Perhaps the biggest obstacle to classroom participation—particularly in large lecture classes—is intimidation. Even students who know the right answer or who have a genuinely intelligent question may not feel comfortable speaking in front of a few hundred fellow students. Many of the approaches described above are designed to eliminate this problem. The small group breakouts are particularly effective. First, almost all students will speak in small groups and have their point of view validated or corrected before being called on. Second, asking "What did your group conclude?" takes the burden off the individual—the credit or blame is shared with those around you. Third, frequent use of any of the techniques described here will show that participation and active learning are more important than looking smart. Here are a few other notes:

- Be aware that body language can also set the tone for discussions. Avoid looking impatient or disapproving. When calling on students to speak, use an open-handed inviting gesture instead of pointing with the index finger. Also be aware that student responses may not be audible throughout the classroom; repeat the main points of student responses if necessary.
- Make it clear that there is no such thing as a dumb question. Make some attempt to answer all questions; if a student asks a question that you don't understand, ask him/her to clarify the question in a polite way. If you still don't understand it, help students avoid embarrassment by suggesting that they come talk to you about their questions after class; say something like "I see what you are getting at, but I don't want to take class time right now. Can you talk to me about it after class?" *Note:* If you are short on time, it is better to say that you cannot take any more questions than to give unsatisfactory answers.
- On occasion you may ask students a question that they get utterly wrong. While they may be in good company, the embarrassment they feel in class may have a long-lasting effect. Some students may even stop attending class if they fear further embarrassment. It's therefore important to help students to a better ending, even if it takes a while. One of the best ways to take the embarrassment away from the student is to take the blame on yourself, the instructor. Statements like "Perhaps I worded my question in a roundabout way" or "That's the right approach if you just consider …" will take the sting off the student. Then back up to a related question that you are certain the student will get right. Then, you can move forward with that student (if you think he/she can get the concept) or move on to another student. Emphasizing the importance of working out the right answer (as opposed to already knowing it) will help in the long run. The suggestions of the following section will also make you, the instructor, less threatening and more human.

Personalizing the Impersonal Classroom

Lecture mode tends to distance the instructor from the students, but there are a number of ways to bridge that gap.

- Do what you can to bring your audience close to you:
  - In large lecture halls, ask students to move forward so you don't have students concentrated in the back with lots of empty seats near the front.
  - In smaller classrooms, ask students to rearrange furniture to form a semicircle so they can see each other as well as you.
- In any lecture period there is probably at least one common experience that is relevant to the lecture topic. You can draw students into discussion by asking "Have you been watching the Moon recently? Did anybody notice what phase it's in?" Or "Have any of you ever traveled to the Southern Hemisphere?" Or "How many of you caught the latest picture from Hubble on the front page?" After you see a few nodding heads, ask someone to expand on what they have seen, read, or experienced. Even small interactions like these familiarize students with talking in class and demonstrate the relevance of their experience and interests to the class material.
- Most of us are so busy that we rush into class just before the period starts and rush out afterward. But the few minutes before and after class are often the times when students are most in need of your time—and not just for homework answers. If at all possible, arrive a few minutes before class and stay long enough to answer questions afterward. Striking up brief conversations not related to the course offers another way to set students at ease talking to you. (If you have a decent sound system in your lecture hall, you might try playing some music in the few minutes before class; it will help students relax, and the end of the music will signal the beginning of class.)

- Many instructors are surprised at how much help students need in their course, but how little help they seek. If you wish more people took advantage of your office hours, try renaming them "review sessions" on your syllabus. Consider holding one of your office hour periods on "neutral ground" in a cafeteria or common area.
- Students often feel isolated in large classes, which makes them less likely to participate in discussions. Encourage them to learn their neighbors' names early in the semester. (The collaborative learning method described above offers a natural means.) Help students organize study groups, for example, by encouraging interested students to meet in front after the lecture. If feasible, have your students write or e-mail you a few sentences about themselves, their interests, and what they hope to get out of the class. (See "A Suggested First-Day Assignment," page 39.)
- Our final suggestion involves the daunting task of learning student names. While there are legendary instructors who have memorized classes of hundreds, most of us cannot. But chances are that you can learn a lot more names than you think if the information is presented to you in a usable form: names and faces together. One convenient method requires a digital camera and just a few minutes of class time: Have your students write their names on pieces of paper with a magic marker. Parade your students past the camera and take their pictures while they hold their papers in front of them. With more than one camera, you can enlist student help to take pictures even faster. Most cameras come with software that allows you to print many small pictures per page. You can also combine the pictures into a movie file that you can step through frame by frame. If you don't have a digital camera, a camcorder can be used in a similar way. After only a few times looking over the pictures, you'll be surprised at how many students you know by name. It's possible to learn classes of up to 100 students with this method with less than an hour's total effort. For smaller classes, you can take group photos with an instant camera and have the students sign their names. Some instructors prefer to use a seating chart. Try whatever method works for you. Calling on students by name has a remarkably positive effect on the tone of the class.

Resources on Interactive Teaching

Peer Instruction, by Eric Mazur, published by Prentice Hall, ISBN 0-13-565441-6. http://galileo.harvard.edu/.

Mysteries of the Sky: Activities for Collaborative Groups, by Adams and Slater, Kendall Hunt, ISBN 0-7872-5126-7. http:/www/montana.edu/~wwwph/research/phys_ed.html.

Cooperative Learning Activities in Introductory Astronomy for Non-science Majors, by Deming, Miller, and Trasco, available from the author. Contact Grace Deming, Dept. of Astronomy, U. Maryland, College Park, MD 20742.

Science Teaching Reconsidered, National Research Council, National Academy Press, ISBN 0-309-05498-2.