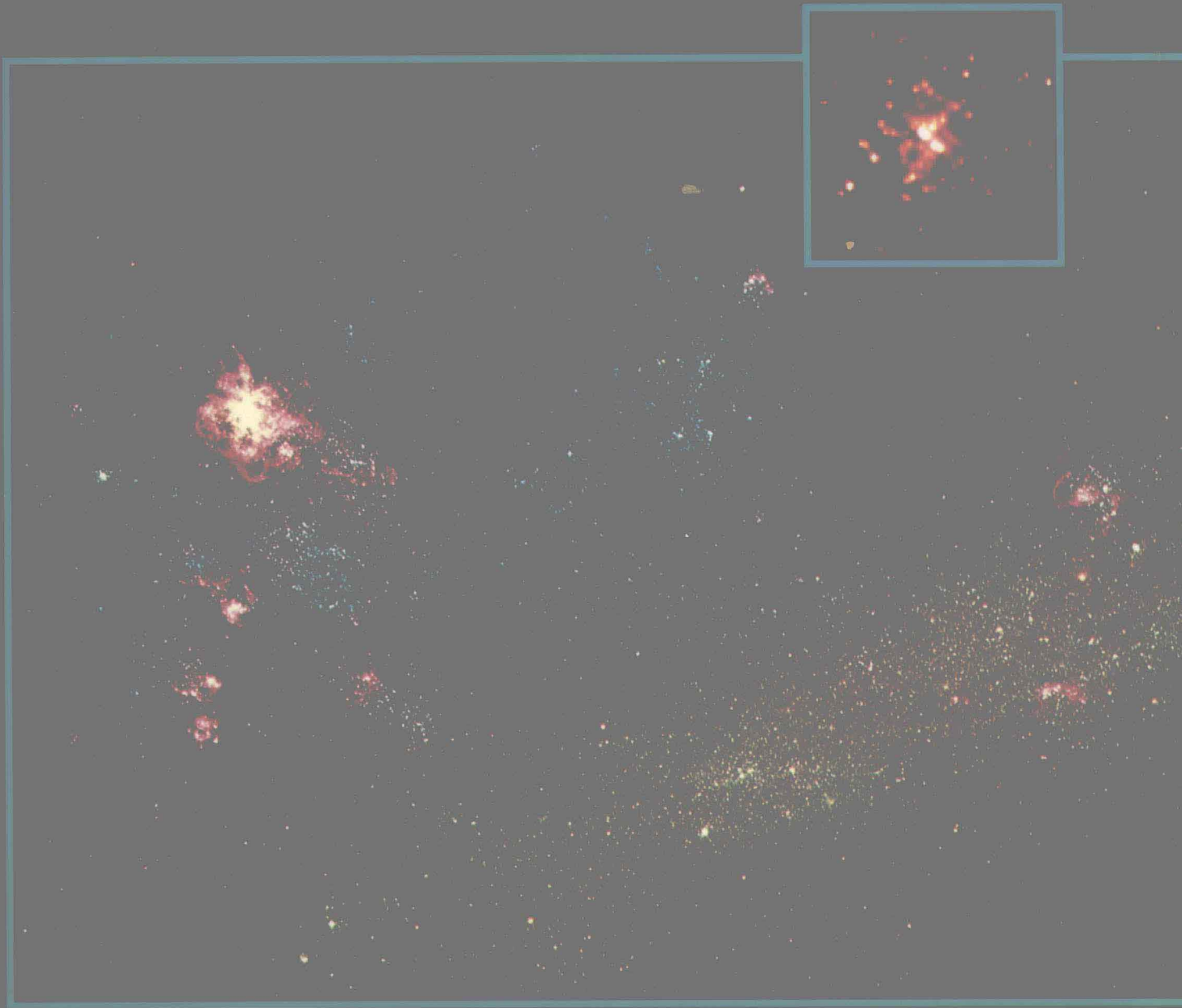


THE DYNAMIC UNIVERSE

AN INTRODUCTION TO ASTRONOMY ●●●●● FOURTH EDITION



THEODORE P. SNOW



FOURTH EDITION

The Dynamic Universe

An Introduction to Astronomy

Theodore P. Snow
University of Colorado at Boulder

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Cover Photo: The Large Magellanic Cloud, pictured on the cover, is a neighbor galaxy to our own Milky Way. This photograph reveals some of the fascinating components of the LMC, including its barlike central region (the yellow-white area running from lower center towards the right and slightly upward) and the brilliant regions of ionized gas, which show up as red, due to emission from hydrogen gas that has been heated by the intense radiation from hot stars. In the center of the Tarantula nebula, the prominent ionized region at the left, lies a very dense cluster of young, luminous stars which can only be distinguished with extremely fine images, too fine to be made by telescopes looking up through the Earth's atmosphere. The small boxed image, showing the inner portion of this cluster of stars, was obtained by the *Hubble Space Telescope*. (Main photo: © R.J. Dufour, Rice University. Inset photo: Nasa/Space Telescope Science Institute.)

Back Cover Photo: One of the twenty-seven radio dishes of the *Very Large Array* near Socorro, New Mexico. (National Radio Astronomy Observatory.)

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PREFACE

To study astronomy is, in a sense, the most human thing we can do. What distinguishes us from lower creatures, if not our curiosity, our compulsion to explore and discover? And what exemplifies this compulsion better than the study of the universe?

We probe the heavens (and the Earth) by all possible means, and we do it for no other reason than to learn whatever there is to be known. Astronomy has produced many useful byproducts, of course, and could be (and often is) justified solely on that basis. That is not the real reason for astronomy, however.

This textbook represents an attempt by an astronomer to share both the knowledge and the intellectual gratification of our science. There is considerable beauty in the universe for the eye and mind to behold. Just as it is visually stimulating to gaze at a great glowing nebula or a colorful moon, it is pleasing to the intellect to grasp a new understanding of one of the grand themes of the cosmos. It is hoped that the reader of this book will gain by doing both.

This textbook is intended for the student who has not chosen science as his or her major area of study, but who needs an appreciation of science as a vital aspect of preparation for a career. It is as important for such a student to gain some perspective on the general nature of science as it is to learn a great deal of specific information about a particular discipline in the sciences. For that reason, this text stresses the philosophy and outlook of the scientist as well as the knowledge we have gathered about the physical universe we live in.

It is probably as important for the student to understand *how* we know what we know as it is to understand *what* we know. In this era of instantaneous communication and universal access to information, we need more than ever to be able to discriminate among competing hypotheses, to be able to judge the reasonableness of ideas that are advanced. This text in astronomy is written with the underlying theme that to know the workings of science is one of the most important tools we have for meeting the challenges of our technological society.

This edition, like its predecessors, covers the entire scope of astronomy, from the most nearby objects to

the most distant, from the smallest to the largest. Many questions are left unanswered, because there is so much we do not know, and because it is important for students to be aware of that. Not knowing the answers, but knowing how to pursue them, is the essence of science.

This fourth edition has some new features, and of course reflects all the exciting new developments in astronomy that have occurred since the third edition was published. Particularly noteworthy are the major revision of the section on the solar system and the addition of Mathematical Methods inserts at the ends of the chapters.

Now that the age of *Voyager* is over, and eight of the nine planets have been visited by probes from Earth, a reorganization of the chapters on the solar system is timely. The *Voyager* spacecraft have largely revolutionized our knowledge of the outer planets, turning what was a collection of mysterious, faraway objects into a set of related bodies that seem a little closer to us, in mind if not in place. New themes and new understanding have emerged. In the new solar system section (Chapters 8 through 16) we now start with a new general planetary science chapter, in which an overview of the system is given, along with explanations of the major physical processes that affect the planets. With this as background, the student then explores the planets individually, but with some reorganization as compared to previous editions (for example, the Moon and Mercury are now discussed in the same chapter, as are Jupiter and Saturn). One result of this reorganization is the reduction, by one chapter, of the overall length of the book. The section ends, as in the past, with a chapter summarizing the formation of the system, but now this chapter includes a unified discussion of rings and moons, which are known today to be general phenomena associated with the giant planets. It is hoped that this revised section will provide the student with a more modern, cohesive picture of our system of planets, and of the modern planetary scientist's approach to its study.

The other major change in this edition is the addition of some quantitative material. The Mathematical Methods inserts are designed to supplement the text

for those instructors and students who wish to work with the numerical representations that form the essence of astrophysics. These brief sections are set apart from the main text so that they will not disrupt the smooth flow of the chapters, but are readily at hand for those who want to study them. In each Mathematical Methods insert a single concept is presented and explored, and can form the basis for new problems and questions if the instructor so desires.

Of course the *Hubble Space Telescope* receives a great deal of attention in this edition, with many references throughout, as well as a Special Report section in Chapter 7 which presents the latest results available (as of November, 1990). While it is widely known that the *HST* was launched earlier this year and that subsequently optical problems were discovered, the reader may be surprised to learn how productive the instrument still is expected to be, and how much impact it will have on astronomy, even in its crippled state.

Other significant updates in this edition include up-to-date descriptions of new planetary probes such as *Magellan*, which is mapping Venus as we go to press, and *Galileo*, which has embarked on its 5-year journey to Jupiter. Several stunning images of details on the surface of Venus are included, revealing the fact that the clouded planet may be more Earth-like geologically than previously suspected.

In addition to these changes in the written content of the book, the new edition also incorporates many new illustrations. As always, we have obtained new photographs and data where available, but in this edition we also have replaced many of the drawings as well. Now virtually all of the original line drawings from the two-color versions of the book (editions 1 and 2) have been replaced with full color drawings. Several entirely new illustrations have been created as well, helping to make this the most visually clear and stimulating edition to date.

Comprehensive factual data are incorporated into the Appendices, which have been updated for new information (as provided by the *Voyager* planetary encounters, for example). In addition, several Appendices have been expanded, including those on stellar data, interstellar molecules, major telescopes, and groups and clusters of galaxies.

The arrangement of the text remains traditional, with an introductory section on the background of astronomy, both in history and in basic physics; a section on the solar system, dealing with the planets as individuals before discussing interplanetary bodies and then the formation of the entire system; one on stars and their

lives and deaths; a section on the structure and evolution of our galaxy; a set of chapters on extragalactic astronomy and the universe as a whole; and a final, brief section on the possibilities that life may exist elsewhere. At the beginning of each of these sections is an introduction that leads the student into the material, and at the end of each is a Guest Editorial in which a leading scientist in the field shares his or her thoughts on current problems or controversies and future directions for research.

The book is designed so that the sequence of sections may be easily altered. For example, if it is desired to teach the sections on stars, the galaxy, and the universe before discussing the solar system, one need only skip directly from Chapter 7 to Chapter 17 and then go on to the end before returning to Chapter 8, where the solar system studies begin. The chapter on the Sun leads into the section on stars, so that skipping or delaying the solar system discussion will not prevent the student from learning about the nearest and best-understood star. The overview and summary chapters on the solar system (Chapters 8 and 16) include enough information on the Sun that the discussion of the system as a whole and its formation is complete as it stands.

The well-received Astronomical Insights have been carried over into this edition, with a substantial number of new ones included. These inserts, placed within the chapters, describe people, discoveries, or current controversies or new hypotheses related to the subject matter of the text. They are meant to enhance the students' enjoyment of the material, or add understanding of complex topics, but above all they are designed to increase understanding of the scientific process.

Supplemental materials for this text include an updated version of the *Study Guide*, authored by Jeffrey O. Bennett and the undersigned (both University of Colorado), and a revised edition of the *Instructor's Manual* by Stephen J. Shawl (University of Kansas). As before, the *Instructor's Manual* contains helpful discussions of strategies in teaching, provides a large number of exam questions (with answers), and gives complete answers to all the review questions from the main text. The *Study Guide*, intended to help the student get maximum benefit from the text, contains brief chapter summaries, lists of key words and phrases, self-tests, and complete bibliographies of articles on relevant topics, taken from a wide assortment of magazines and journals. In addition to the *Study Guide* and the *Instructor's Manual*, another aide to teaching is offered to large adopters of the text: a set of transparencies

for use with overhead projectors, including many in color, showing a number of useful diagrams and illustrations from the text.

At every step during the preparation of this text, vital assistance was provided by a number of people, whose help is acknowledged with gratitude (with apologies to anyone inadvertently omitted). The most important guidance and support was provided by my wife, Connie; by the West Publishing Company editor, Denise Simon; and by the production editor, Ann Rudrud of West. The new and improved drawings were prepared by Larissa A. Worth of Alexander Teshin Associates. A very important contribution to the overall quality and accuracy of the book was made by Steve Shawl, who scrutinized the galley proofs and, as he has during the preparation of earlier editions, made many useful suggestions regarding content as well.

Among my colleagues at the University of Colorado and elsewhere, several have helped by either reviewing sections of the text, providing new figures, or updating data for tables and Appendices. Particularly generous in this connection were A. Stern, J. Lunine (University of Arizona), M. Geller (Harvard-Smithsonian Center for Astrophysics), and I. R. Little-Marenin (Wellesley College). Additional assistance was provided by J. M. Shull, L. Esposito, R. A. McCray, J. A. Tyson (Bell Laboratories), J. O. Burns (New Mexico State University), B. A. Goldberg (JPL), K. van Aachen (JPL), D. Malin (Anglo-Australian Observatory), P. Smiley (National Radio Astronomy Observatory), Marc Sher (William and Mary), S. V. Forgue (Ocala, Florida), G. D. Nelson (NASA and the University of Washington), R. Marcialis (University of Arizona), and E. Chaisson (Space Telescope Science Institute).

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A special debt is owed to those who wrote the Guest Editorials, for adding their thoughts and visions to my own less elegant discussions. Much of the excitement of astronomy lies in the pursuit of new revelations beyond the scope of current knowledge, and the essays written by leaders in this pursuit help immeasurably to impart this excitement to the reader. Those contributing new essays to this edition are France Cordova (Pennsylvania State University), Jonathon Lunine (University of Arizona), Stephen Strom and Suzan Edwards (Five Colleges Astronomy Department; Strom is located at the University of Massachusetts and Edwards is on the faculty at Smith College), and Margaret Geller (Harvard-Smithsonian Center for Astrophysics), who largely rewrote her article, originally included in the previous edition. Three essays written for earlier editions are also included here; their authors are Roger Culver (Colorado State University), Richard Larson (Yale University), and Robert Bakker (University of Colorado).

For all of these people, and to the students whose responses to my teaching philosophies have also helped to shape this book, I am grateful. With their continued input, I trust that this book will continue to evolve, as does our understanding of the dynamic universe.

Theodore P. Snow November, 1990

CONTENTS

Preface

SECTION I:

THE NIGHTTIME SKY AND HISTORICAL ASTRONOMY 1

Chapter 1: The Essence of Astronomy 3

What is Astronomy? 4

Astronomical Insight 1.1: The Philosophy
of Science 6

A Typical Night Outdoors 6

The View from the Earth 8

Astronomical Insight 1.2: What Is
an Astronomer? 10

From the Earth to the Universe: The Scale
of Things 11

Astronomical Insight 1.3: Astronomy
and Astrology 13

Perspective 14

Summary 15

Review Questions 15

Thought Questions 15

Problems 15

Additional Readings 15

Mathematical Methods: Powers-of-Ten Notation 16

Chapter 2: Cycles and Seasons: Motions in the Sky 17

Rhythms of the Cosmos 18

Daily Motions 18

Astronomical Insight 2.1: Keeping in Touch
with the Stars 20

Astronomical Coordinate Systems 22

Astronomical Insight 2.2: Celestial Navigation 23

Annual Motions: The Seasons 24

Calendars 27

The Moon and Its Phases 28

Eclipses of the Sun and Moon 30

Astronomical Insight 2.3: Chasing A Solar Eclipse 34

Planetary Motions 35

Perspective 37

Summary 37

Review Questions 38

Thought Questions 38

Problems 38

Additional Readings 38

Mathematical Methods: The Measurement
of Angles 39

Chapter 3: Early Astronomy 40

Babylonian Astronomy 42

The Early Greeks and the Development of
Scientific Thought 43

The Pythagoreans 44

Plato and His Followers 44

*The Geometric Genuis of Aristarchus
and Eratosthenes* 46



<i>Geocentric Cosmologies: Hipparchus and Ptolemy</i>	47	Chapter 4: The Renaissance	59
Astronomical Insight 3.1: The Mythology of the Constellations	48	Copernicus: The Heliocentric View Revisited	60
Early Astronomy in Asia	50	Tycho Brahe: Advanced Observations and a Return to A Stationary Earth	61
<i>Chinese Accomplishments</i>	50	Astronomical Insight 4.1: The Accuracy of Angular Measurements	63
<i>Hindu Astronomy</i>	51	Kepler and the Laws of Planetary Motion	66
Astronomical Insight 3.2: The Mysteries of Stonehenge	52	Galileo, Experimental Physics, and the Telescope	69
Ancient Astronomy in the Americas	53	Astronomical Insight 4.2: An Excerpt from the <i>Dialogue on the Two Chief World Systems</i>	73
Astronomy in the Dark Ages	55	Perspective	74
Perspective	56	Summary	74
Summary	56	Review Questions	75
Review Questions	56	<i>Thought Questions</i>	75
<i>Thought Questions</i>	56	<i>Problems</i>	75
<i>Problems</i>	57	Additional Readings	75
Additional Readings	57	Mathematical Methods: The Ellipse and Conic Sections	76
Mathematical Methods: The Geometry of Aristarchus	57		

GUEST EDITORIAL:

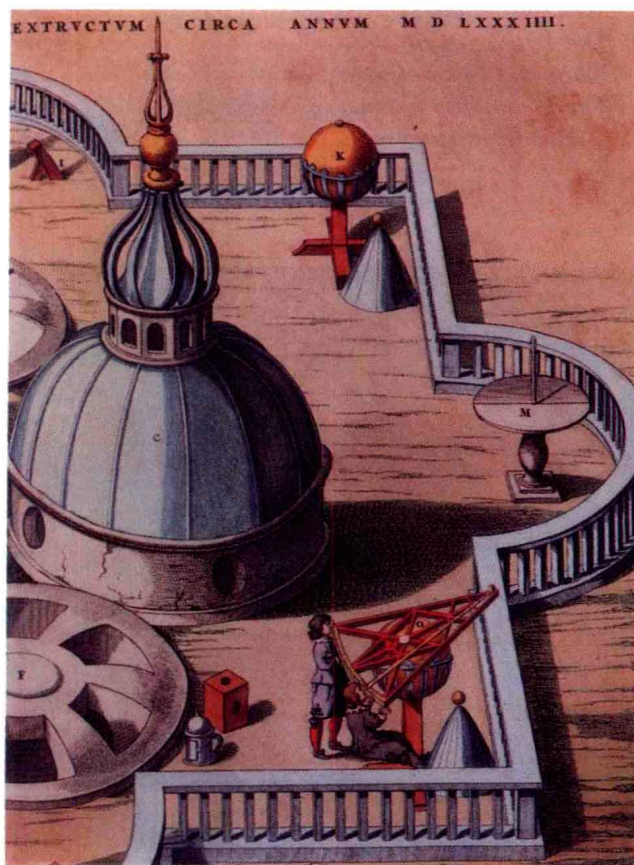
Astronomy on the Fringe, by Roger Culver	78
--	----

SECTION II:

THE TOOLS OF ASTRONOMY	83
-------------------------------	-----------

Chapter 5: Issac Newton and the Laws of Motion	85
---	-----------

The Life of Newton	86
Newton's Laws of Motion	87
<i>Inertia and the First Law</i>	87
<i>Force and Acceleration</i>	88
Astronomical Insight 5.1: The Forces of Nature	89
<i>Action and Reaction</i>	88
Gravitation and Orbits	90
Energy, Angular Momentum, and Orbits: Kepler's Laws Revisited	93
Escape Velocity and Gas Motions	95
Astronomical Insight 5.2: Relativity	97
Tidal Forces	98
Perspective	100
Summary	100
Review Questions	100
<i>Thought Questions</i>	100
<i>Problems</i>	100
Additional Readings	101



Mathematical Methods: The Use of Kepler's Third Law	101
---	-----

Chapter 6: The Nature of Light 103

The Electromagnetic Spectrum	104
<i>Particle or Wave?</i>	106
Astronomical Insight 6.1: The Perception of Light	107
<i>Polarization</i>	108
Continuous Radiation	108
Astronomical Insight 6.2: The Measurement of Wavelengths	110
The Atom and Spectroscopy	114
<i>Energy Levels and Photons</i>	118
<i>Ionization and Excitation</i>	119
<i>The Doppler Effect</i>	121
Astronomical Insight 6.3: Measuring the Speed of Light	122
Perspective	125
Summary	125
Review Questions	125
<i>Thought Questions</i>	125
<i>Problems</i>	126
Additional Readings	126
Mathematical Methods: Modeling the Atom	126

Chapter 7: Telescopes on Earth and In Space 128

The Need for Telescopes	129
Refractors and Reflectors	130
Astronomical Insight 7.1: A Night at the Observatory	132
<i>Auxiliary Instruments</i>	136
Astronomical Insight 7.2: The Magic of Modern Detectors	137
Choosing a Site: Major Observations	138
Telescopes in Space: Infrared and Ultraviolet Astronomy	138
The X-Ray Universe	142
Radio Telescopes	143
The Next Generation	146
SPECIAL REPORT: The Saga of the <i>Hubble Space</i> <i>Telescope</i>	150
Perspective	155
Summary	155
Review Questions	155
<i>Thought Questions</i>	155
<i>Problems</i>	156



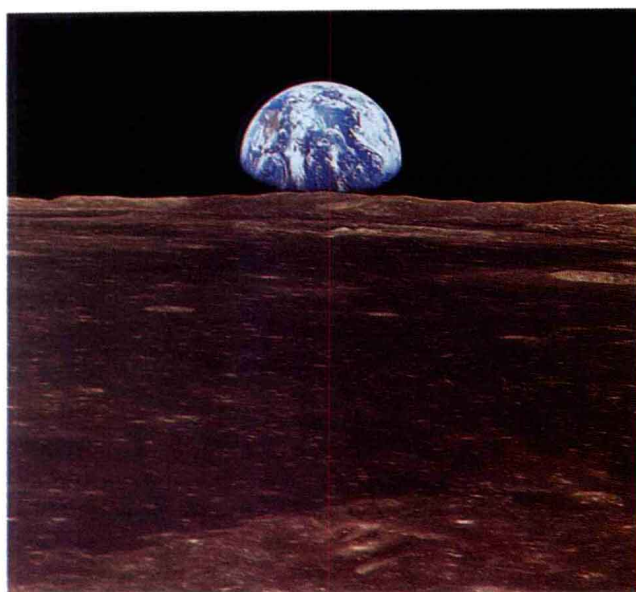
Additional Readings	156
Mathematical Methods: Resolving Power	157

GUEST EDITORIAL: Exploring the Universe at all Wavelengths, by France Córdova	159
--	-----

SECTION III: **THE SOLAR SYSTEM** 163

Chapter 8: Overview of the Solar System and Planetary Science 165

Overview of the Solar System	166
<i>Classifying the Planets</i>	168
<i>Observational Techniques</i>	170
Astronomical Insight 8.1: <i>Voyager's</i> Final Look Back	174
Planetary Science: The Process that Shapes the Planets	176
<i>Formation of the Planets</i>	176
Geological Evolution	177
<i>Tectonic Activity</i>	177
<i>Rocks and Surface Processes</i>	181
Planetary Atmospheres	182



<i>Atmospheric Circulation</i>	184
Tidal Forces	185
Perspective	186
Summary	186
Review Questions	187
<i>Thought Questions</i>	187
<i>Problems</i>	187
Mathematical Methods: Sizes and Shapes of Orbits	188

Chapter 9: The Earth As a Planet 190

The Atmosphere	191
<i>Heating and Atmospheric Motions</i>	192
Astronomical Insight 9.1: Technology and the Atmosphere	194
The Earth's Interior	196
Surface Terrain and Tectonic Activity	198
Rocks, Minerals, and the Age of the Surface	201
Astronomical Insight 9.2: The Ages of Rocks	202
The Magnetic Field	203
<i>Outer Structure and the Magnetosphere</i>	203
<i>Radiation Belts</i>	204
The Evolution of the Earth	205
Perspective	206
Summary	206
Review Questions	207
<i>Thought Questions</i>	207

<i>Problems</i>	207
Additional Readings	207
Mathematical Methods: Half Lives and Radioactive Dating	208

Chapter 10: The Small Terrestrials: The Moon and Mercury 210

Exploring the Moon	211
Astronomical Insight 10.1: Lunar Cartography	213
<i>A Battle-Worn Surface and a Dormant Interior</i>	214
<i>Origin of the Moon</i>	218
Astronomical Insight 10.2: Colonizing the Moon	219
<i>History of the Moon</i>	220
Mercury	222
The Earth-Based View	222
<i>The Orbital Eccentricity and Rotational Resonance</i>	223
Rendezvous with Mariner	224
Magnetic Field and Internal Conditions	225
Astronomical Insight 10.3: Visiting the Inferior Planets	226
Surface Features and Geological History	227
Perspective	230
Summary	230
Review Questions	230
<i>Thought Questions</i>	230
<i>Problems</i>	231
Additional Readings	231
Mathematical Methods: Particle Motions and Atmospheric Escape	232

Chapter 11: Venus: A Cloud-Covered Inferno 234

Observations from Near and Far	235
Astronomical Insight 11.1: Velikovsky and Venus	237
The Atmosphere of Venus	239
The Structure of the Atmosphere	239
<i>Atmospheric Motions</i>	240
The Surface and Interior	242
Earth and Venus: So Near and Yet So Different	245
Astronomical Insight 11.2: Volcanoes on Venus	246
Perspective	248
Summary	248
Review Questions	248
<i>Thought Questions</i>	248
<i>Problems</i>	249

Additional Readings	249
Mathematical Methods: Radar Measurements of Planetary Rotation	249

Chapter 12: Mars and the Search for Life 251

Observations and General Properties	252
Astronomical Insight 12.1: Percival Lowell and the Martian Civilization	254
The Martian Atmosphere and Seasonal Variations	256
Water, Tectonics, and the Martian Surface	258
Astronomical Insight 12.2: Meteorites from Mars?	262
Surface Rocks and the Interior of Mars	263
Prospecting for Life: The Viking Experiments	264
The Martian Moons	266
Astronomical Insight 12.3: Primordial Life on Mars?	267
Perspective	268
Summary	268
Review Questions	269
<i>Thought Questions</i>	269
<i>Problems</i>	269
Additional Readings	269
Mathematical Methods: Planetary Energy Budgets	270

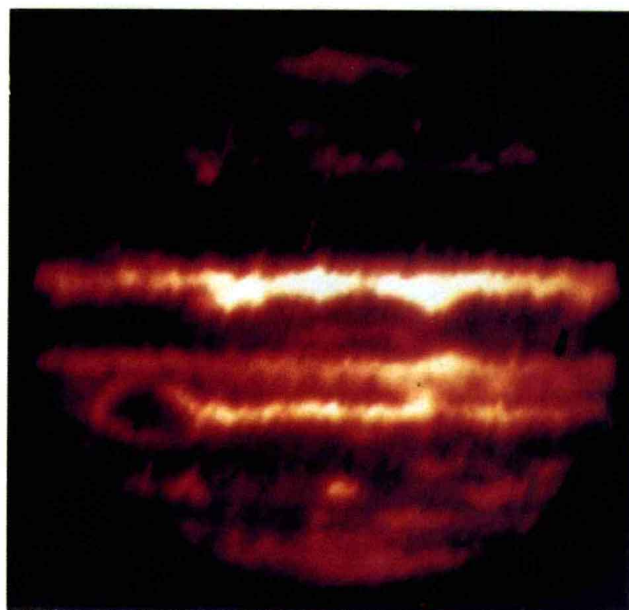
Chapter 13: The Gaseous Giants: Jupiter and Saturn 271

Jupiter	272
<i>Observation and Exploration</i>	272
Astronomical Insight 13.1: The <i>Galileo</i> Mission to Jupiter	275
<i>Atmosphere in Motion</i>	278
<i>Internal Structure and Excess Radiation</i>	279
<i>The Magnetic Field and Radiation Belts</i>	281
<i>The Satellites of Jupiter</i>	282
Saturn	286
<i>General Properties</i>	287
<i>Atmosphere and Interior: Jupiter's Little Brother?</i>	289
<i>The Satellites of Saturn</i>	292
<i>The Rings</i>	295
Astronomical Insight 13.2: The Elusive Rings of Saturn	298
Perspective	300
Summary	300
Review Questions	301

<i>Thought Questions</i>	301
<i>Problems</i>	301
Additional Readings	301
Mathematical Methods: Tidal Forces	302

Chapter 14: The Outer Planets 303

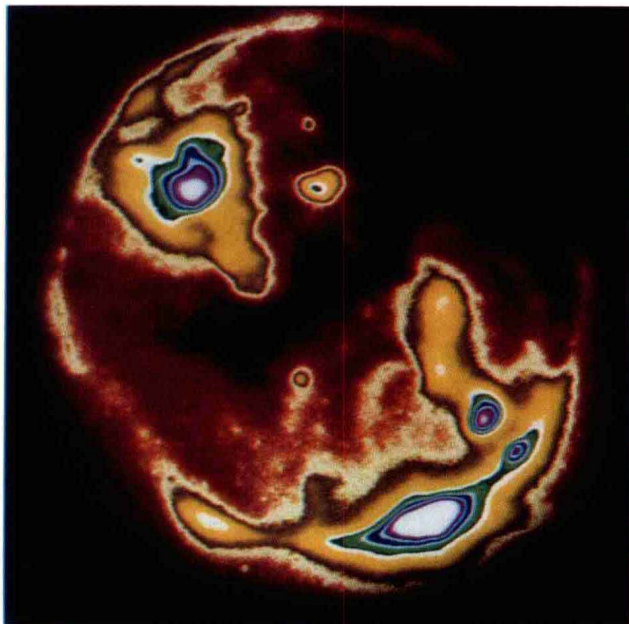
Uranus	304
<i>Discovery and Observations from Earth</i>	304
<i>Atmosphere and Interior</i>	306
<i>Satellites and Rings</i>	308
Neptune	312
<i>The Discovery: A Victory for Newton</i>	312
<i>The Voyager Encounter and the Properties of Neptune</i>	313
Astronomical Insight 14.1: Science, Politics, and the Discovery of Neptune	314
<i>Neptune's Moons and Rings</i>	317
Pluto	321
<i>Planetary Misfit</i>	321
Astronomical Insight 14.2: The Search for Planet X	323
Perspective	324
Summary	325
Review Questions	325
<i>Thought Questions</i>	325
<i>Problems</i>	326
Additional Readings	326
Mathematical Methods: The Roche Limit	327



Chapter 15: Space Debris	328
The Minor Planets	329
Kirkwood's Gaps: Orbital Resonances Revisited	331
The Origin of the Asteroids	332
Comets: Fateful Messengers	333
<i>Halley, Oort, and Cometary Orbits</i>	333
The Anatomy of a Comet	337
Astronomical Insight 15.1: Comets and Water	340
Meteors and Meteorites	342
<i>Primordial Leftovers</i>	343
<i>Dead Comets and Fractured Asteroids</i>	344
Astronomical Insight 15.2: The Impact of Impacts	345
Microscopic Particles: Interplanetary Dust and the Interstellar Wind	347
Perspective	350
Summary	350
Review Questions	351
<i>Thought Questions</i>	351
<i>Problems</i>	351
Additional Readings	351
Mathematical Methods: Orbital Resonance and Kirkwood's Gaps	352

Chapter 16: Formation of the Solar System: Disks, Rings, and Moons

A Summary of the Evidence	354
---------------------------	-----



Catastrophe or Evolution?	356
Astronomical Insight 16.1: The Explosive History of Solar System Elements	358
A Modern Scenario	359
Astronomical Insight 16.2: Catastrophe Revisited: Violent Origins of the Planets	362
Miniature Solar Systems: Rings and Moons	365
<i>Satellites of the Giant Planets</i>	365
<i>Rings and Moonlets</i>	367
Astronomical Insight 16.3: Resolving the Rings	372
Are There Other Solar Systems?	373
Perspective	374
Summary	374
Review Questions	375
<i>Thought Questions</i>	375
<i>Problems</i>	376
Additional Readings	376
Mathematical Methods: Angular Momentum	377
GUEST EDITORIAL:	
The Grand Tour of the Outer Solar System . . . and Coming Attractions, by Jonathan I. Lunine	387

SECTION IV:

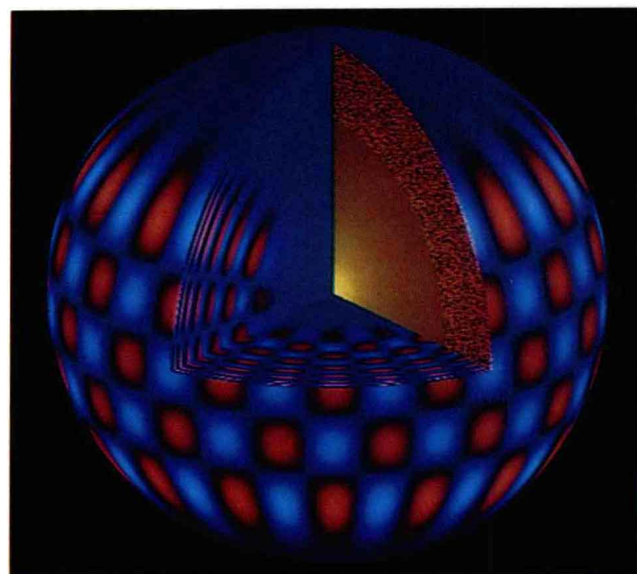
THE STARS	381
------------------	------------

Chapter 17: The Sun

Basic Properties and Internal Structure	384
Nuclear Reactions	386
Astronomical Insight 17.1: The Solar Neutrino Mystery	387
Modelling the Sun	388
Structure of the Solar Atmosphere	389
Astronomical Insight 17.2: Measuring the Sun's Pulse	390
The Solar Wind	396
Sunspots, Solar Activity, and the Magnetic Field	398
Perspective	405
Summary	405
Review Questions	406
<i>Thought Questions</i>	406
<i>Problems</i>	406
Additional Readings	406
Mathematical Methods: Surface Temperature, Solar Luminosity, and the Solar Constant	407

Chapter 18: Stellar Observations: Positions, Magnitudes, and Spectra 408

Positional Astronomy	409
Astronomical Insight 18.1: Star Names and Catalogs	411
Stellar Brightnesses	411
The Appearance of Stellar Spectra	414
<i>Normal Stars and Spectral Classification</i>	414
Astronomical Insight 18.2: Stellar Spectroscopy and the Harvard Women	417
<i>Peculiar Spectra</i>	418
Binary Stars	420
Variable Stars	423
Perspective	424
Summary	424
Review Questions	425
<i>Thought Questions</i>	425
<i>Problems</i>	425
Additional Readings	425
Mathematical Methods: Stellar Magnitudes	426



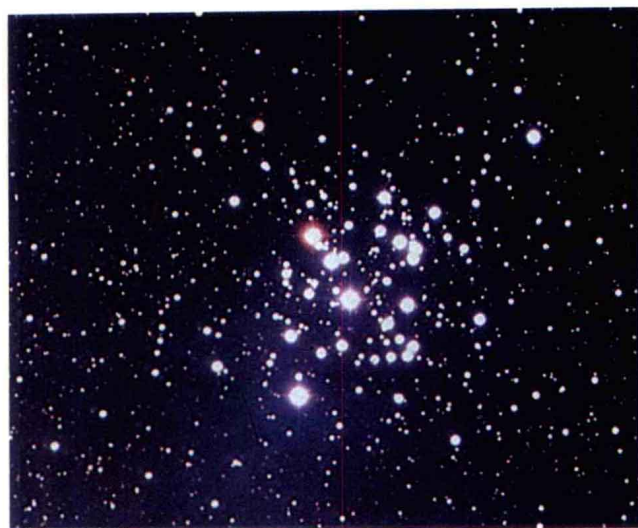
Heavy Element Enrichment	449
Stellar Chromospheres and Coronae	450
Stellar Winds and Mass Loss	451
Astronomical Insight 20.1: Stellar Pulsations and Mass Loss	452
Stellar Models: Tying it All Together	454
Astronomical Insight 20.2: Stellar Models and Reality	455
Perspective	456
Summary	456
Review Questions	457
<i>Thought Questions</i>	457
<i>Problems</i>	457
Additional Readings	457
Mathematical Methods: Energy Production in Nuclear Reactions	458

Chapter 21: Star Clusters and Observations of Stellar Evolution 459

Properties of Clusters	460
<i>The Assumption of a Common Distance</i>	462
<i>The Assumption of a Common Age</i>	464
The Main-Sequence Turnoff and Cluster Ages	464
Astronomical Insight 21.1: Star Tracks	465
Young Associations and Stellar Infancy	466
Star Formation	469
Astronomical Insight 21.2: Triggers of Star Formation	470
Astronomical Insight 21.3: Hyperactive Young Suns	472

Chapter 20: Stellar Structure: What Makes a Star Run? 443

What Is a Star, Anyway?	444
Nuclear Reactions and Energy Transport	446
Stellar Life Expectancies	448



Perspective	473
Summary	473
Review Questions	473
<i>Thought Questions</i>	473
<i>Problems</i>	474
Additional Readings	474
Mathematical Methods: The Jeans Length and Stellar Masses	475

Chapter 22: Life Stories of Stars 476

Stars Like the Sun	477
<i>The Helium Flash</i>	479
<i>Planetary Nebula to White Dwarf</i>	480
The Evolution of Massive Stars	482
<i>Nuclear Evolution of a Massive Star</i>	482
Astronomical Insight 22.1: The Missing	
Hypergiants	484
<i>The End of the Reactions</i>	484
<i>Formation of the Heaviest Elements</i>	488
<i>Supernova 1987A</i>	488
Evolution in Binary Systems	492
Astronomical Insight 22.2: The Mysteries of Algol	493
Perspective	494
Summary	494
Review Questions	495
<i>Thought Questions</i>	495
<i>Problems</i>	495
Additional Readings	495
Mathematical Methods: The Densities of Compact Stellar Remnants	496

Chapter 23: Stellar Remnants 497

White Dwarfs, Black Dwarfs	498
<i>White Dwarfs, Novae, and Supernovae</i>	500
Supernova Remnants	502
Astronomical Insight 23.1: The Story of Sirius B	500
Neutron Stars	505
Astronomical Insight 23.2: Reconstructing an Exploded Star	506
<i>Pulsars: Cosmic Clocks</i>	507
Astronomical Insight 23.3: Very Rapid Pulsars	508
<i>Neutron Stars in Binary Systems</i>	509
Black Holes: Gravity's Final Victory	511
<i>Do Black Holes Exist?</i>	514
Perspective	516
Summary	516
Review Questions	516
<i>Thought Questions</i>	516
<i>Problems</i>	516
Additional Readings	517
Mathematical Methods: Escape Speed and the Schwarzschild Radius	518
GUEST EDITORIAL:	
The Formation of Suns and Solar Systems, by Stephen E. Strom and Suzan Edwards	519

SECTION V:

THE MILKY WAY 525

Chapter 24: Structure and Organization of the Galaxy 527

Variable Stars as Distance Indicators	528
Astronomical Insight 24.1: The Invisible Milky Way	532
The Structure of the Galaxy and the Location of the Sun	534
Galactic Rotation and Stellar Motions	536
The Mass of the Galaxy	537
Astronomical Insight 24.2: The Shape of the Milky Way	538
Spiral Structure and the 21-Centimeter Line	539
The Galactic Center: Where the Action Is	541
Globular Clusters Revisited	542
A Massive Halo?	544
Perspective	545
Summary	545

Review Questions	546
<i>Thought Questions</i>	546
<i>Problems</i>	546
Additional Readings	547
Mathematical Methods: The 21-cm Emission Line of Hydrogen	547

Chapter 25: The Interstellar Medium 549

The Interstellar Dust	550
Observation of Interstellar Gas	553
<i>Clouds and Nebulae</i>	555
Dark Clouds and the Molecular Zoo	559
Astronomical Insight 25.1: Giant Molecules in Space	561
Interstellar Violence and the Role of Supernovae	563
Astronomical Insight 25.2: The Mysterious Cosmic Rays	565
Perspective	566
Summary	566
Review Questions	568
<i>Thought Questions</i>	568
<i>Problems</i>	568
Additional Readings	568
Mathematical Methods: The Effect of Extinction on Distance Measurements	569

Chapter 26: The Formation and Evolution of the Galaxy 570

Stellar Populations and Elemental Gradients	571
Astronomical Insight 26.1: A War Benefit	573
Stellar Cycles and Chemical Enrichment	574
The Care and Feeding of Spiral Arms	574
Galactic History	578
Astronomical Insight 26.2: The Missing Population III	580
The Age of the Galaxy	581
Perspective	582
Summary	582
Review Questions	583
<i>Thought Questions</i>	583
<i>Problems</i>	583
Additional Readings	583
Mathematical Methods: Orbital Velocities of Stars in the Galaxy	584

GUEST EDITORIAL:

Globular Clusters and the Evolution of the Milky Way, by Richard B. Larson	585
---	-----

SECTION VI:

EXTRAGALACTIC ASTRONOMY 588

Chapter 27: The Nature of the Nebulae 589

The Hubble Classification System	591
Astronomical Insight 27.1: The Shapley-Curtis Debate	595
Astronomical Insight 27.2: Infrared Galaxies	598
Galactic Distances	599
The Masses of Galaxies	603
Luminosities, Colors, and Diameters	604
The Origins of Spirals and Ellipticals	605
Perspective	607
Summary	607
Review Questions	607
<i>Thought Questions</i>	607
<i>Problems</i>	608
Additional Readings	608
Mathematical Methods: The Stellar Luminosity Function and Galactic Mass-to-Light Ratios	609

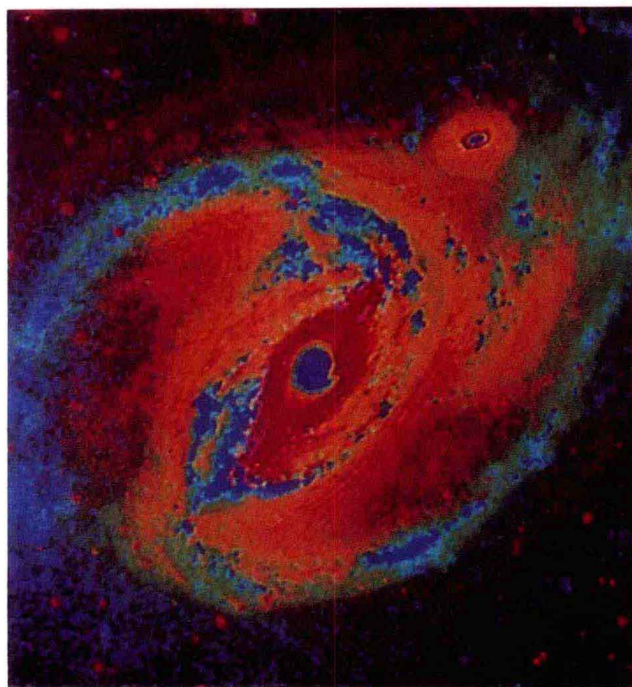


Chapter 28: Clusters and Superclusters: The Distribution of Galaxies 610

The Local Group	611
Rich Clusters: Dominant Ellipticals and Galactic Mergers	616
Masses of Clusters	617
Gravitational Lenses and Dark Matter in Clusters	619
Intercluster Gas and X-Ray Emission	621
Superclusters, Voids, and Walls	622
The Origins of Clusters and Superclusters	624
Astronomical Insight 28.1: Galaxies at the Edge of the Universe	625
Perspective	626
Summary	626
Review Questions	627
<i>Thought Questions</i>	627
<i>Problems</i>	627
Additional Readings	627
Mathematical Methods: Cluster Masses	628

Chapter 29: Universal Expansion and the Cosmic Background 629

Hubble's Great Discovery	630
Hubble's Constant and the Age of the Universe	633



Redshifts as Yardsticks	635
Astronomical Insight 29.1: The Distance Pyramid	636
A Cosmic Artifact: The Microwave Background	637
Astronomical Insight 29.2: Overlooking the Cosmic Background	638
The Crucial Question of the Spectrum	638
Isotropy and Daily Variations	639
Results from the Cosmic Background Explorer	641
Astronomical Insight 29.3: Falling Galaxies	643
Perspective	645
Summary	645
Review Questions	646
<i>Thought Questions</i>	646
<i>Problems</i>	646
Additional Readings	646
Mathematical Methods: Doppler Shifting the Cosmic Background	647

Chapter 30: Peculiar Galaxies, Active Nuclei, and Quasars 648

The Radio Galaxies	649
Seyfert Galaxies and Active Nuclei	654
The Discovery of Quasars	655
The Origin of the Redshifts	656
Astronomical Insight 30.1: The Redshift Controversy	657
The Properties of Quasars	658
Galaxies in Infancy??	662
Perspective	664
Summary	664
Review Questions	665
<i>Thought Questions</i>	665
<i>Problems</i>	665
Additional Readings	665
Mathematical Methods: Quasar Luminosities	666

Chapter 31: Cosmology: Past, Present, and Future of the Universe 667

Underlying Assumptions	668
Astronomical Insight 31.1: The Mystery of the Nighttime Sky	669
Einstein's Relativity: Mathematical Description of the Universe	670
Open or Closed: The Observational Evidence	673
<i>Total Mass Content</i>	673
Astronomical Insight 31.2: Dark Matter in the Universe	675

<i>The Deceleration of the Expansion</i>	676
The Inflationary Universe	678
The History of Everything	680
Astronomical Insight 31.3: Particle Physics and Cosmology	681
<i>Possible Heavy Element Formation in the Big Bang</i>	683
What Next?	684
Perspective	685
Summary	685
Review Questions	685
<i>Thought Questions</i>	685
<i>Problems</i>	686
Additional Readings	686
Mathematical Methods: Making Particles from Radiation	687

GUEST EDITORIAL:

Patterns in the Universe, by Margaret J. Geller	688
---	-----

SECTION VII:

LIFE IN THE UNIVERSE 693

Chapter 32: The Chances of Companionship 695

Life on Earth	696
Could Life Develop Elsewhere?	699
The Probability of Detection	701
Astronomical Insight 32.1: The Case for a Small Value of N	703
The Strategy for Searching	703
Astronomical Insight 32.2: The Complexity of UFO's	707
Perspective	707
Summary	708
Review Questions	708
<i>Thought Questions</i>	708
<i>Problems</i>	708
Additional Readings	709
Mathematical Methods: Travel Times for Interstellar Voyagers	709

GUEST EDITORIAL:

Dinosaur Die-Offs: A Bolt from the Blue, or Death by Earthly Causes, by Robert T. Bakker	711
--	-----

APPENDICES

<u>APPENDIX 1:</u> Symbols Commonly Used in this Text	A1
<u>APPENDIX 2:</u> Physical and Mathematical Constants	A1
<u>APPENDIX 3:</u> The Elements and Their Abundances	A2
<u>APPENDIX 4:</u> Temperature Scales	A3
<u>APPENDIX 5:</u> Radiation Laws	A3
<u>APPENDIX 6:</u> Major Telescopes of the World (2 meters or larger)	A6
<u>APPENDIX 7:</u> Planetary and Satellite Data	A7
<u>APPENDIX 8:</u> Stellar Data	A9
<u>APPENDIX 9:</u> The Constellations	A11
<u>APPENDIX 10:</u> Mathematical Treatment of Stellar Magnitudes	A12
<u>APPENDIX 11:</u> Nuclear Reactions in Stars	A14
<u>APPENDIX 12:</u> Detected Interstellar Molecules	A16
<u>APPENDIX 13:</u> Clusters of Galaxies	A17
<u>APPENDIX 14:</u> The Relativistic Doppler Effect	A18
<u>APPENDIX 15:</u> The Messier Catalog	A19
Glossary	G1
Index	I1