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Astronomy

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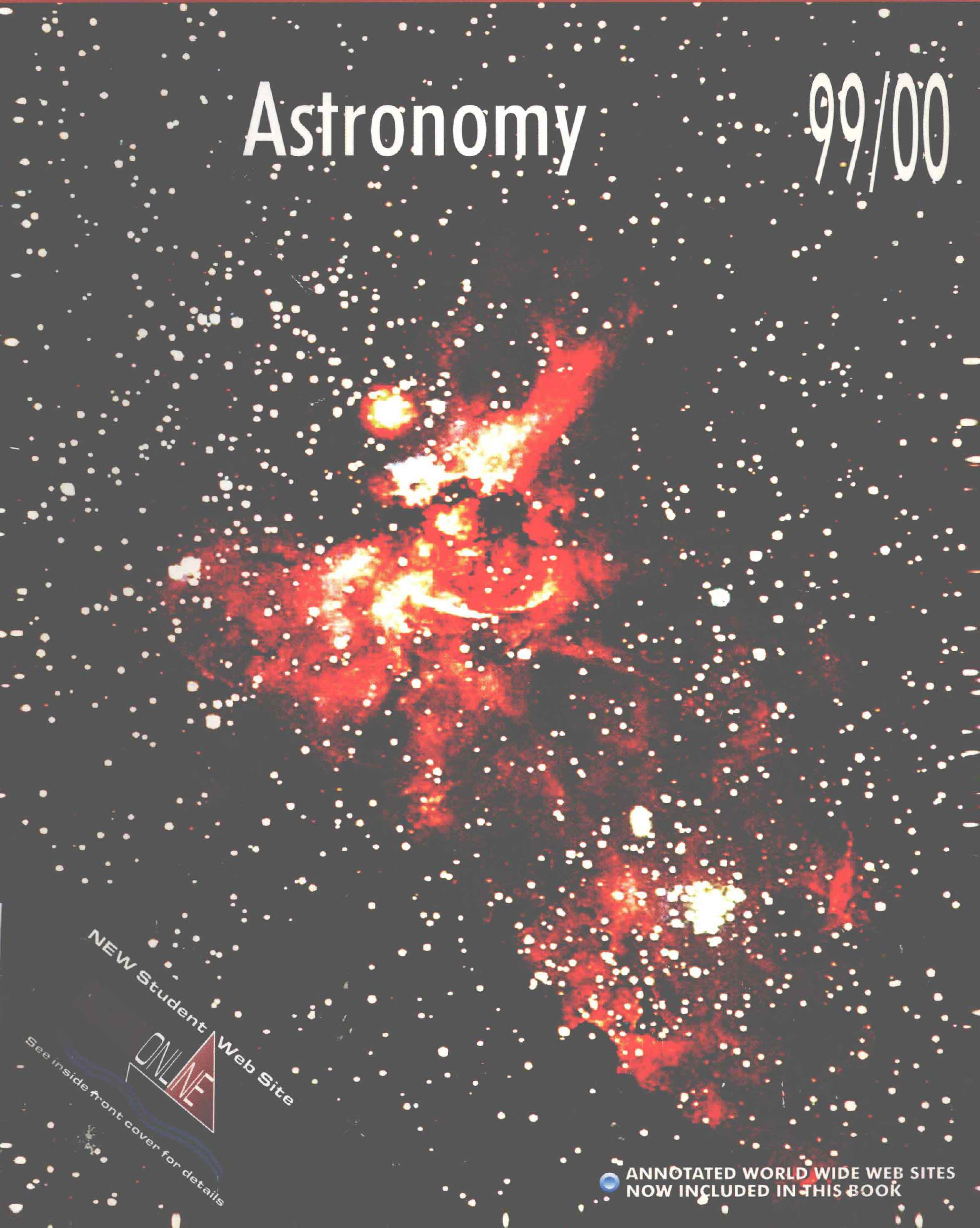

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ASTRONOMY 99/00

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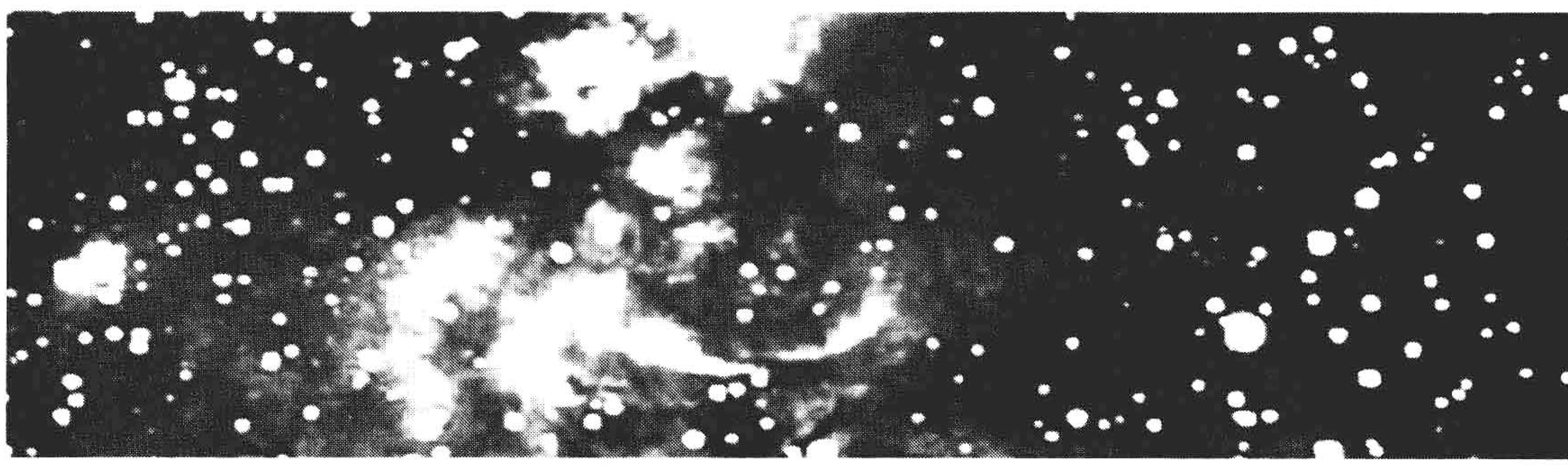

EDITOR

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David Dathe received his undergraduate degree in geology from Winona State University, his M.S. in geology from Northern Illinois University, and he is completing a Ph.D. in geology, also from Northern Illinois University. Currently, he is assistant professor of physical science at Alverno College in Milwaukee, Wisconsin, where he teaches integrated science, earth science, and geology, and he also coordinates Problem Solving. He is author of *Fundamentals of Historical Geology* and coauthor with Dr. Carla Montgomery of *Earth: Then and Now.*

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3. The Solar System
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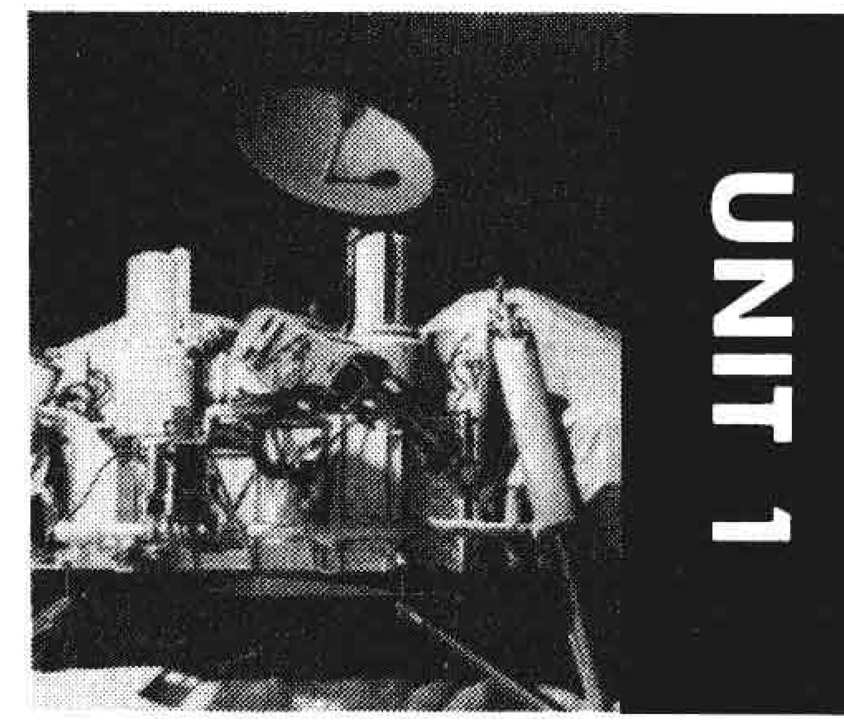
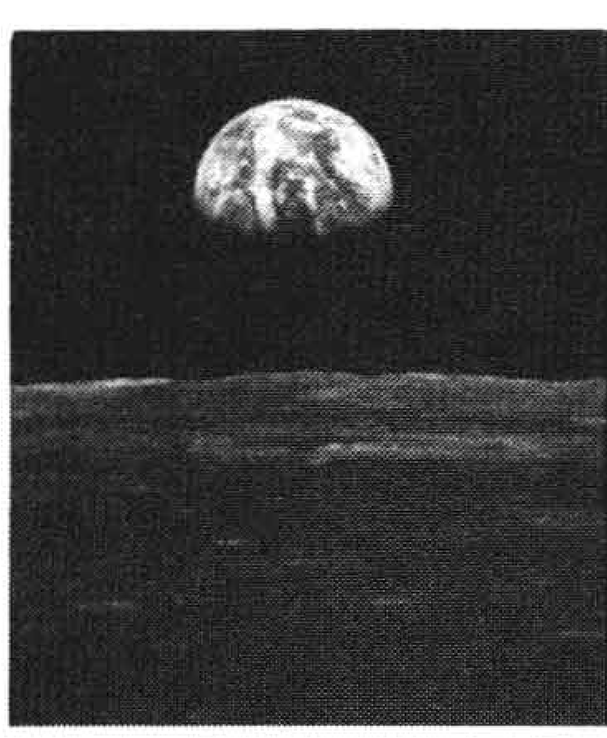
Contents



Data-Gathering Techniques

The nine articles is this section discuss how the space telescope, spectrum analysis, X-ray, gamma-ray, infrared, and radio astronomy are used in the gathering of celestial data.

The concepts in bold italics are developed in the article. For further expansion please refer to the Topic Guide and the Index.

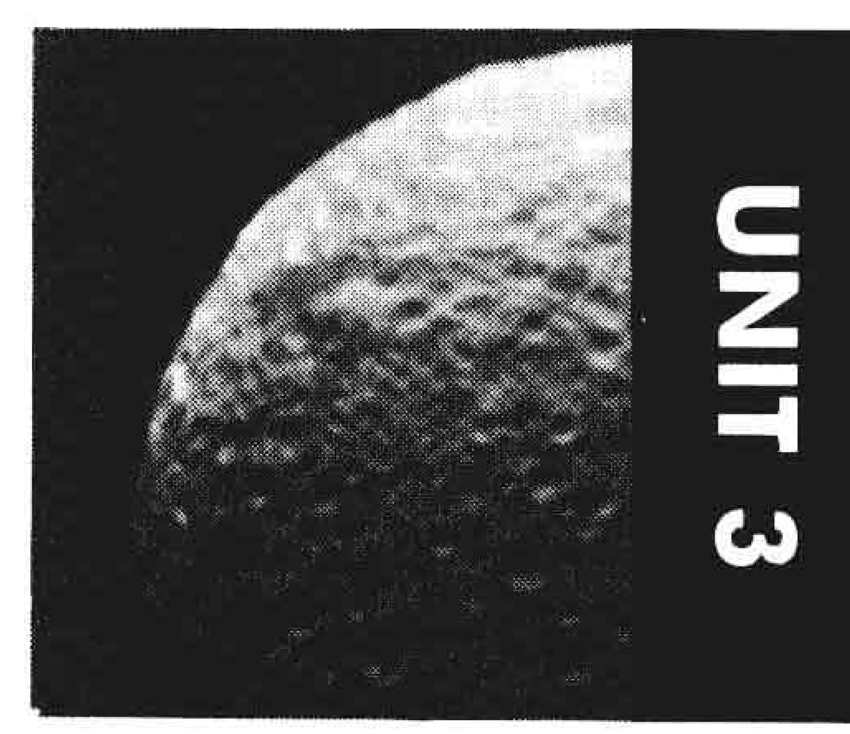


UNIT 2

The Earth and the Moon

The dynamics of Earth and our Moon are considered in the five selections in this section.

The concepts in bold italics are developed in the article. For further expansion please refer to the Topic Guide and the Index.

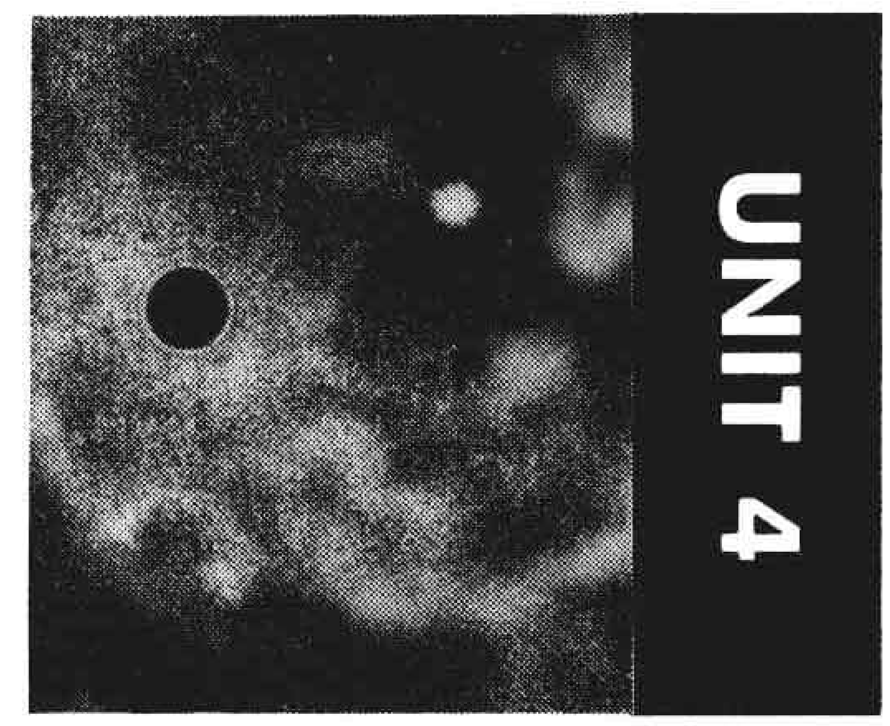


The Solar System

The 10 articles in this section focus on the makeup and interaction of our solar system: our Sun, the planets, comets, meteorites, and asteroids.

The concepts in bold italics are developed in the article. For further expansion please refer to the Topic Guide and the Index.

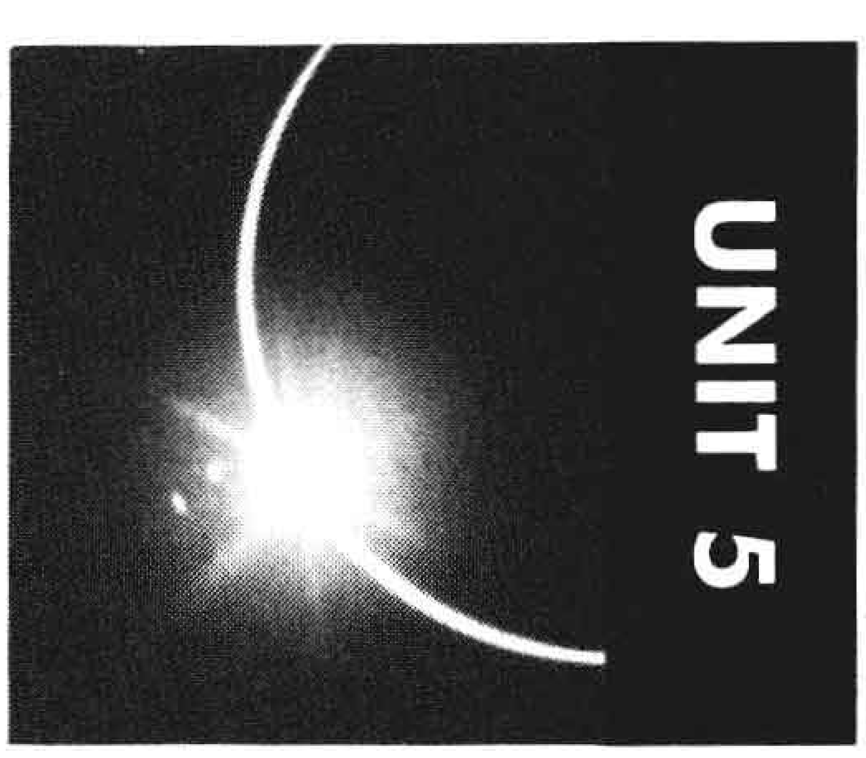
The concepts in bold italics are developed in the article. For further expansion please refer to the Topic Guide and the Index.



The Universe

In this section, 13 selections look at the universe: stars, stellar evolution, black holes, the Milky Way galaxy, dark matter, galaxy structure and evolution, and quasars.

The concepts in bold italics are developed in the article. For further expansion please refer to the Topic Guide and the Index.



Making Sense of It All

The six articles in this section consider the concepts of space and time, extraterrestrial life, and the Big Bang theory.

The concepts in bold italics are developed in the article. For further expansion please refer to the Topic Guide and the Index.

The concepts in bold italics are developed in the article. For further expansion please refer to the Topic Guide and the Index.

Topic Guide

This topic guide suggests how the selections and World Wide Web sites found in the next section of this book relate to topics of traditional concern to astronomy students and professionals. It is useful for locating interrelated articles and Web sites for reading and research. The guide is arranged alphabetically according to topic.

The relevant Web sites, which are numbered and annotated on pages 4 and 5, are easily identified by the Web icon (◎) under the topic articles. By linking the articles and the Web sites by topic, this ANNUAL EDITIONS reader becomes a powerful learning and research tool.

TOPIC AREA	TREATED IN
Asteroids	21. Bits of Mars and Pieces of the Moon 23. Day the Dinosaurs Died ◎ ***1, 2, 3, 4, 5, 19, 26, 29***
Atmosphere	11. Using the Solar Eclipse 12. How the Earth Got Its Atmosphere ◎ ***1, 3, 5, 12, 26***
Big Bang Theory	38. The Biggest, the Brightest, the Best 39. Nature of Space and Time 40. Life: A Cosmic Imperative? 41. Is Anybody (Like Us) Out There? 42. In Defense of the Big Bang 43. Everything You Wanted to Know about the Big Bang ◎ ***26, 27***
Binary Stars	27. How Planets Are Born ◎ ***3, 7, 11, 22, 23, 24, 25***
Black Holes	6. Recent Advances of X-Ray Astronomy 28. Life and Times of a Star 34. Evolution of Our Galaxy 36. What Makes Galaxies Change? 37. Galactic Engines 39. Nature of Space and Time ◎ ***1, 2, 3, 4, 5, 22, 26***
Charge-Coupled Device (CCDs)	2. Mining the Heavens ◎ ***6, 7, 8, 9, 10, 21, 22***
Comets	11. Using the Solar Eclipse 12. How the Earth Got Its Atmosphere 19. Jumping Jupiter 20. Kuiper Belt ◎ ***3, 4, 19, 25***
Cosmology	3. Radio Astronomy in the 21st Century 36. What Makes Galaxies Change? 39. Nature of Space and Time ◎ ***6, 21, 22, 23, 24, 25, 26, 27***
Dark Matter	30. Lives of Binary Stars 33. Dark Side of the Galaxy ◎ ***3, 7, 11, 21, 22, 23, 24, 25***
Earth	11. Using the Solar Eclipse 12. How the Earth Got Its Atmosphere ◎ ***4, 5, 11, 12, 29***
Europa	18. Planet in a Bottle 41. Is Anybody (Like Us) Out There? ◎ ***29, 30***
Extraterrestrial Life	37. Galactic Engines 40. Life: A Cosmic Imperative? 41. Is Anybody (Like Us) Out There? ◎ ***30***
Galaxies	3. Radio Astronomy in the 21st Century 5. Infrared View of Our Universe 28. Life and Times of a Star 31. New Findings Suggest Massive Black Holes 32. Milky Way 33. Dark Side of the Galaxy 34. Evolution of Our Galaxy 35. Before Galaxies Were Galaxies 36. What Makes Galaxies Change? ◎ ***6, 7, 8, 9, 10, 21, 22, 23, 24, 25, 26, 27***
Gamma-Ray Bursts	6. Recent Advances of X-Ray Astronomy 7. Those Mysterious Cosmic Gamma Rays 8. Gamma-Ray Bursts ◎ ***3, 4, 6, 7, 8***
Hertzsprung-Russell Diagram	22. Life from Ancient Mars? 25. Spectral Types of Stars 26. Stellar Magnitude System 28. Life and Times of a Star ◎ ***16, 17, 19, 20, 21, 22, 23, 24, 25***
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Jupiter	17. Crack in the Clockwork 18. Planet in a Bottle ◎ ***29, 30***
Kuiper Belt	19. Jumping Jupiter 20. Kuiper Belt ◎ ***3, 4, 19, 25***
MACHOs (Massive Compact Halo Objects)	30. Lives of Binary Stars 33. Dark Side of the Galaxy ◎ ***3, 7, 11, 21, 22, 23, 24, 25***

TOPIC AREA	TREATED IN
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Milky Way Galaxy	4. Radio Map of the Milky Way 6. Recent Advances of X-ray Astronomy 29. Lives of Stars 32. Milky Way 33. Dark Side of the Galaxy 34. Evolution of Our Galaxy ***6, 7, 8, 9, 10, 11, 21, 22, 23, 24, 25, 26, 27***
Moon	13. Moon Watching 21. Bits of Mars and Pieces of the Moon ***13, 28, 29***
NASA (National Aeronautics & Space Administration)	9. In a Golden Age of Discovery ***6, 7, 20, 22***
Nebulae	5. Infrared View of Our Universe ***6, 7, 8, 9, 10, 24***
Neptune	19. Jumping Jupiter 20. Kuiper Belt ***3, 4, 19, 25***
Neutron Stars	6. Recent Advances in X-Ray Astronomy ***22, 26***
Planets	16. Unsolved Mysteries of the Sun—Part 2 24. Target: Earth! 25. Spectral Types of Stars ***17, 18, 19, 20, 29***
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White Dwarfs	26. Stellar Magnitude System 28. Life and Times of a Star ***7, 11, 21, 22, 23, 24, 25***
WIMPS (Weakly Interacting Massive Particles)	30. Lives of Binary Stars ***3, 7, 11, 22, 23, 24, 25***
X-Rays	6. Recent Advances of X Ray Astronomy ***6, 7, 20, 22***

World Wide Web Sites

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Annual Editions: Astronomy

The following World Wide Web sites have been carefully researched and selected to support the articles found in this reader. If you are interested in learning more about specific topics found in this book, these Web sites are a good place to start. The sites are cross-referenced by number and appear in the topic guide on the previous two pages. Also, you can link to these Web sites through our DUSHKIN ONLINE support site at *http://www.dushkin.com/online/*.

The following sites were available at the time of publication. Visit our Web site—we update DUSHKIN ONLINE regularly to reflect any changes.

General Sources

1. American Astronomical Society Home Page
http://www.aas.org/
From this page you can reach the *Astrophysical Journal's* electronic edition, browse through the latest issues, and also access other astronomy links.

2. AstroWeb: Astronomy/Astrophysics on the Internet
http://www.stsci.edu/astroweb/astronomy.html
Basic site for all astronomical information, this is a collection of pointers to astronomy-related information available on the Internet. The AstroWeb Consortium, which maintains this database, also offers a search of its 2,501 distinct resource records.

3. SKY Online
http://www.skypub.com/
This extensive popular astronomy site allows anyone to explore the universe. Some unusual treats include Tips for Backyard Astronomers, SkyLinks, What's Up in the Sky?, and eclipse, occultation, comet, and meteor pages. This site is produced by Sky Publishing Corporation.

4. The Space, Planetary, and Astronomical Cyber-Experience
http://www.nss.org/space/home.html
This site is presented by the National Space Society and features a Site of the Week as well as links to NASA, international space agencies, the International Space Station, and many other sites.

5. Yahoo!—Science: Astronomy
http://www.yahoo.com/Science/Astronomy/
Basic search engine leads to much information and a multitude of sites in the field of astronomy. Add */pictures/* to the URL to reach the gallery of Messier Objects.

Data-Gathering Techniques

6. CADC HST Science Archive
http://cadcwww.dao.nrc.ca/hst.html
At this site you can *view* the HSA (HST Science Archive) data collected by the Hubble Space Telescope and maintained by the Canadian Astronomy Data Center. To retrieve the data, astronomers are requested to register.

7. Hubble Space Telescope
http://ecf.hq.eso.org/HST.html
The Earth-orbiting Hubble Space Telescope is explained and explored at this site. Also see the Guide Star Catalog, the world's largest astronomical star catalog, which contains coordinates and brightness for some 19 million objects. At *http://archive.eso.org/* you can now directly retrieve a list of HST Data Sets or search ESO (European Southern Observatory) and HST Databases.

8. Project CLEA
http://www.gettysburg.edu/project/physics/clea/CLEAhome.html
Project CLEA develops laboratory exercises that illustrate modern astronomical techniques using digital data and color images. Manuals, questionnaire forms, and lab software are readily available throughout this site. Featured also is an astronomy site of the day.

9. SIRTF (Space Infrared Telescope Facility) Home Page
http://sirtf.jpl.nasa.gov/sirtf/
Currently under design by NASA, this cryogenically cooled observatory to conduct infrared astronomy from space is planned to be launched December 12, 2001. SIRTF is expected to offer orders-of-magnitude improvements in sensitivity over previous IR missions. Read all about it at this site.

10. Telescopes
http://www.stsci.edu/astroweb/yp_telescope.html
This page will lead you to a long list of telescopes that can be accessed for retrieval data. Descriptions of projects are included. At *http://stdatu.stsci.edu/dss/*, the STScI Digitized Sky Survey is available.

The Earth and Moon

11. Observatory/NASA site
http://observe.ivv.nasa.gov/
NASA's Observatorium is a public access site for Earth and space data. Site uses satellite data (i.e., Landsat TD) and has excellent pictures of Earth, planets, stars, and other cool stuff, as well as the stories behind those images.

12. Welcome to Earth RISE
http://earthrise.sdsc.edu/earthrise/main.html
An easy graphical way to see 15 years of photos of Earth that were taken from space by astronauts out of the windows of the space shuttles can be found here. At Highlights, see the 500 best images.

13. Yahoo! Astronomy: Solar system: Moon, The
http://www.yahoo.com/science/astronomy/solar_system/planets/earth/moon/
At this site, in addition to searching on your own, find a list of interesting material on the Moon, from the Clementine Lunar Image Browser, to a new theory on the Origin of the Moon, to many other Moon links.

The Solar System

14. Center for Mars Exploration
http://cmex-www.arc.nasa.gov/
This is the starting place for an exploration of the history of Mars, with links to the Whole Mars Catalog and Live from Mars information about the Pathfinder mission and Global Surveyor.

15. Current Solar Images
http://solar.uleth.ca/solar/www/images.html
At this site you can click on recent solar imagery, hourly ionospheric maps, or a movie of Full-Disk Solar Xrays from

the Yohkoh Satellite (October–November 1992). There is always a host of images to view. See *http://umbra.gsfc.nasa.gov/images/latest.html* for more solar images.

16. Solar Data Analysis Center Home Page
http://umbra.gsfc.nasa.gov/sdac.html#ECLIPSES
Information collected by the SDAC at NASA's Goddard Space Flight Center includes frequent updates. See eclipses, the SUMER spectrum, the High Resolution UV Solar Atlas, and much more, plus links to other sources.

17. Solar System
http://www.geocities.com/CapeCanaveral/Lab/2683/
This excellent site enables you to navigate through the solar system to discover solar origins and planetary comparisons. View all the major solar bodies—click on Solar System, the Sun, or the Planets—and the Mars Pathfinder from here.

18. The Nine Planets
http://www.seds.org/nineplanets/nineplanets/
William A. Arnett's multimedia tour of the solar system is an overview of the history, mythology, and current scientific knowledge of each of the planets and moons in our solar system. There are references to other related information. Besides pictures, you can find a glossary and many appendices. The site is constantly updated.

19. Views of the Solar System
http://www.hawastsoc.org/solar/homepage.htm
This page, under the auspices of the Hawaiian Astronomy Society, connects you to Calvin Hamilton's multimedia adventure that unfolds the Splendor of the Sun, planets, moons, comets, asteroids, and more. Latest scientific information, history of space exploration, rocketry, early astronauts, space missions, and spacecraft are all available through a vast archive of photographs, graphics, videos, and words.

20. Welcome to the Planets
http://pds.jpl.nasa.gov/planets/
Collection of many of the best images from NASA's planetary exploration program. Other items of interest at this site include Contacts and Related Pages, Glossary, and What's New. Mariner 10, Vikings 1 and 2, Voyagers 1 and 2, Galileo, Hubble, and Space Shuttle—the Explorers—are also shown with histories of their missions.

The Universe

21. 2MASS Home Page
http://pegasus.phast.umass.edu/
The Two Micron All Sky Survey at the University of Massachusetts is shown and explained at this page. See Overview, Implementation, Images, and Status Report for more on this project, which will canvass the entire sky for stars and galaxies that are as much as 50,000 times fainter than the stars seen in the last survey, done 25 years ago.

22. Amazing Space Web-Based Activities
http://oposite.stsci.edu/pubinfo/education/amazing-space/
This site is offered by the Space Telescope Science Institute. It offers these activities: Star Light, Star Bright, Solar System Trading Cards, Hubble Deep Field Academy, Student Astronaut Challenge, Galileo to Hubble Space Telescope, and The Truth about Black Holes.

23. Harvard-Smithsonian Center for Astrophysics
http://cfa-www.harvard.edu/cfa-home.html
This site is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. The CFA's research mission is the study of the origin, evolution, and ultimate fate of the universe. Weekly Sky Reports, Images, and Astronomical Links are available here.

24. Infrared Processing and Analysis Center Main Page
http://www.ipac.caltech.edu/
Explore IPAC's current projects and archives of images from this page. IRAS Galaxy Atlas is a useful data retrieval service. Projects include Midcourse Space Experiment, NASA/IPAC Extragalactic Database (NED), Wide-Field Infrared Explorer, and more.

25. STARDUST Home Page
http://stardust.jpl.nasa.gov/
Find here live views of the STARDUST Spacecraft. Also drop in at the STARDUST Café, where you'll find details on the STARDUST Spacecraft, On Comet Wild 2, the target of the mission, the mission schedule through 2006, and projects and opportunities for students.

Making Sense of It All

26. The Astronomy Cafe
http://www2.ari.net/home/odenwald/cafe.html
Click on Ask the Astronomer and Dr. Sten Odenwald will provide information on black holes, the Big Bang, Blue Moons, and many other topics. This site contains an archive of 3,001 questions with answers.

27. Cosmology and Astrophysics
http://www.physics.upenn.edu/~www/astro-cosmo/
From this page explore the work and thoughts of the University of Pennsylvania's Astrophysics and Cosmology Group. Links to other related sites are available.

28. LunaCorp
http://www.lunacorp.com/
In partnership with the Robotics Institute of Carnegie Mellon University, LunaCorp plans to launch rovers to the Moon and to allow "netizens" to navigate the Lunar Surface through a technology called telepresence—that is, navigation of the Moon's surface with mouse and keyboard. Learn about the project at this site.

29. P.E.R.M.A.N.E.N.T.
http://www.permanent.com/
Projects to Employ Resources of the Moon and Asteroids Near Earth in the Near Term describes the plans to use materials in near-Earth space to establish settlements in orbit and beyond. Physicist Mark Prado acts as curator for the ideas of many engineers and scientists from around the world interested in the possibilities of the settlement of space.

30. SETI@home
http://www.setiathome.ssl.berkeley.edu/
This is the main page of Search for Extraterrestrial Intelligence, whose experiment is to harness the power of Internet-connected computers in the search for extraterrestrial intelligence (SETI). The experiment is to launch in late 1998.

We highly recommend that you review our Web site for expanded information and our other product lines. We are continually updating and adding links to our Web site in order to offer you the most usable and useful information that will support and expand the value of your Annual Editions. You can reach us at: *http://www.dushkin.com/annualeditions/*.

Unit Selections

Optical Astronomy

1. **From Hipparchus to Hipparcos: Measuring the Universe, One Star at a Time,** Catherine Turon
2. **Mining the Heavens: The Sloan Digital Sky Survey,** Gillian R. Knapp

Radio Astronomy

3. **Radio Astronomy in the 21st Century,** Kenneth I. Kellermann
4. **A Radio Map of the Milky Way,** Paul W. Schuler III

Infrared Astronomy

5. **An Infrared View of Our Universe,** Ian Gatley

X-Ray Astronomy

6. **Recent Advances of X-Ray Astronomy,** Yasuo Tanaka

Gamma Ray Astronomy

7. **Those Mysterious Cosmic Gamma Rays,** Stephen P. Maran
8. **Gamma-Ray Bursts,** Gerald J. Fishman and Dieter H. Hartmann

Space Telescopes

9. **In a Golden Age of Discovery,** John Wilford

Key Points to Consider

❖ What are CCDs, and why have they revolutionized optical astronomy?

❖ What types of objects can be studied by radio waves?

❖ What type of information does infrared light provide astronomers that visible light does not?

❖ Why was X-ray astronomy developed only after the development of satellites?

DUSHKIN ONLINE Links

www.dushkin.com/online/

6. **CADC HST Science Archive**
   http://cadcwww.dao.nrc.ca/hst.html
7. **Hubble Space Telescope**
   http://ecf.hq.eso.org/HST.html
8. **Project CLEA**
   http://www.gettysburg.edu/project/physics/clea/CLEAhome.html
9. **SIRTF (Space Infrared Telescope Facility) Home Page**
   http://sirtf.jpl.nasa.gov/sirtf/
10. **Telescopes**
    http://www.stsci.edu/astroweb/yp_telescope.html

These sites are annotated on pages 4 and 5.

Data-Gathering Techniques

Astronomy is unique in science in two different respects. First, it is one of the few sciences where the scientist has virtually no direct contact with the subject. (No one has traveled into space farther than our Moon.) Second, it is one of two sciences, (paleontology is the other), where the amateur can still make important contributions.

Dealing with the first matter, astronomers are hardly at a loss because they cannot view stars, black holes, or quasars close up. Information about these phenomena arrive on Earth daily in the form of energy along the electromagnetic spectrum. This unit deals with this challenge of data gathering when the objects of interest may be at cosmological distances.

Visible light is one obvious source of data. The first two articles deal with two major advances in optical astronomy: the Hipparcos satellite and the Sloan Digital Sky Survey. The Sloan Digital Sky Survey makes use of a revolutionary technological advance, CCDs (charge-coupled devices), which are basically silicon chips. The chips produce data in digital form for analysis and are up to 100 times more sensitive than photographic plates.

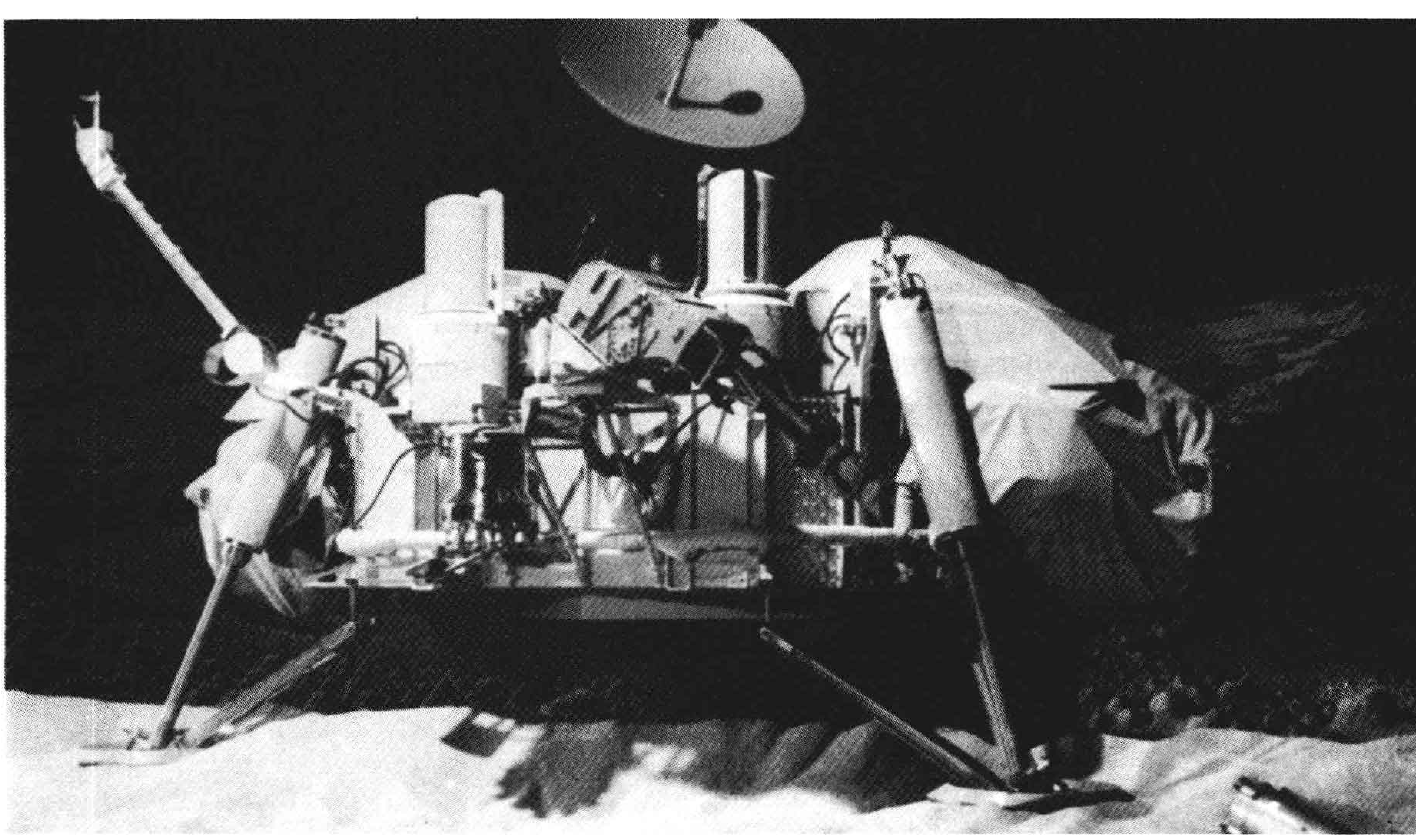
Radio waves have also been used to study celestial objects. The essay "Radio Astronomy in the 21st Century," by Kenneth Kellermann, gives a fairly complete view of the discipline, including suggestions for further advancements in the field. "A Radio Map of the Milky Way," by Paul Schuler III, was included specifically to show how amateur astronomers contribute to the field of astronomy.

On the lower end of the spectrum, infrared light has been used by astronomers to "see" galaxies and nebulae in ways that are impossible with visible light. The reason for this is that infrared light can pass through the gas and dust of space that block visible light. Ian Gatley in "An Infrared View of Our Universe," provides a sample of the remarkable images that are achieved using infrared light.

The article by Yasuo Tanaka, "Recent Advances of X-Ray Astronomy," looks at X rays from the high end of the spectrum compared to visible light. X-ray emitters are numerous in the galaxy, and the most familiar examples include supernovae and black holes.

Gamma rays, also on the high end of the electromagnetic spectrum, allow astronomers to infer the composition of objects such as supernovae. Two great puzzles concerning gamma rays are their source and nature. Stephen Maran's article, "Those Mysterious Cosmic Gamma Rays," lists some of the astronomical phenomena associated with gamma rays. Then, Gerald Fishman and Dieter Hartmann, in "Gamma-Ray Bursts," examine the history of gamma-ray observations. Observations tend to confirm that gamma-ray bursts do not occur within our galaxy but at cosmological distances.

The Hubble Space Telescope, a telescope in space and thus free from the interfering nature of our atmosphere, has opened up a whole new avenue of data collection. This has led to what John Wilford calls "a new golden age of astronomy" in which faraway worlds beckon.



FROM HIPPARCHUS TO Hipparcos

Measuring the Universe, One Star at a Time

By Catherine Turon

Hipparchus of Nicaea must have been an interesting fellow. He was a second-century B.C. mathematician, philosopher, and astronomer. Using the only astronomical instrument available to him—his eyes—Hipparchus took on the daunting task of measuring the positions of the stars and planets as they passed overhead each night. He came up with a catalog of 1,080 stars, each of which he described with terms like "bright" or "small."

Hipparchus wasn't the first astronomer to pursue the science of astrometry, as the astronomical discipline of positional measurement is now called. However, his star catalog was the first of many compiled over the centuries by astronomers using ever-better instruments and techniques. From those measurements—all made from the Earth's surface—astronomers have derived everything from basic stellar properties to estimates for the age of the universe.

On August 8, 1989, the science of astrometry took a long-awaited leap to the stars. Riding aboard an Ariane rocket was the *Hi*gh *P*recision *Par*allax *Co*llecting *S*atellite, otherwise known as Hipparcos. For the next three and a half years, Hipparchus's 20th-century namesake measured the parallaxes and brightnesses of more than a million stars—despite a potentially crippling accident that sorely challenged the project's architects.

From Desperation to Recovery

The Hipparcos mission was planned as the first automated attempt to measure stellar positions, distances, and motions from space—where instruments are free of the atmospheric blurring that plagues ground-based astrometry. Nevertheless, it would use the same principles as ground-based parallax measurements. Like its predecessors, Hipparcos would exploit the

Hipparcos	
Targets:	118,000 stars
Magnitude limit:	12.5
Astrometric resolution:	0.001 arcsecond
Photometric resolution:	0.002 magnitude

Tycho	
Targets:	1 million stars
Magnitude limit:	11.5
Astrometric resolution:	0.025 arcsecond
Photometric resolution:	0.06 magnitude

One arcsecond is 1/3600 of 1° and is the typical resolution of ordinary ground-based visible-light telescopes.
One magnitude corresponds to a 2.5-fold change in brightness. For historical reasons, smaller magnitude numbers indicate brighter stars.

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