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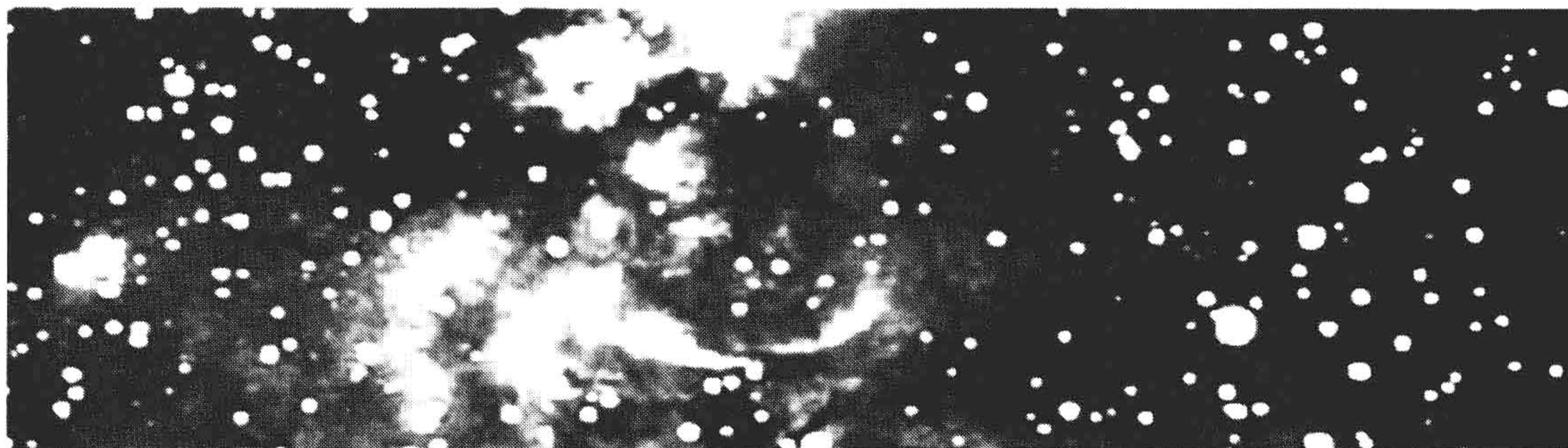
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# ASTRONOMY

*Second Edition*

99/00



## EDITOR

**David Dathe**

*Alverno College*

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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**1. Data-Gathering Techniques**

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**2. The Earth and the Moon**

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**3. The Solar System**

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**4. The Universe**

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**5. Making Sense of It All**

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## A. OPTICAL ASTRONOMY

1. **From Hipparchus to Hipparcos: Measuring the Universe, One Star at a Time**, Catherine Turon, *Sky & Telescope*, July 1997. 8  
The **satellite Hipparcos** (High Precision Parallax Collecting Satellite) was launched in 1989 as the first automated attempt to measure stellar positions, distances, and motions from space. Despite problems, the mission turned into a success as Hipparcos gathered data on distances to **stars**, brightness of variable stars, and positions within multiple-star systems.
2. **Mining the Heavens: The Sloan Digital Sky Survey**, Gillian R. Knapp, *Sky & Telescope*, August 1997. 15  
A telescope at Apache Point Observatory in New Mexico is being used in the **Sloan Digital Sky Survey (SDSS)**. The project will produce detailed color images of about a quarter of the sky using the telescope and **CCDs** (charge-coupled devices). CCDs are silicon chips that produce data in digital form but are up to 100 times as sensitive as photographic plates.

## B. RADIO ASTRONOMY

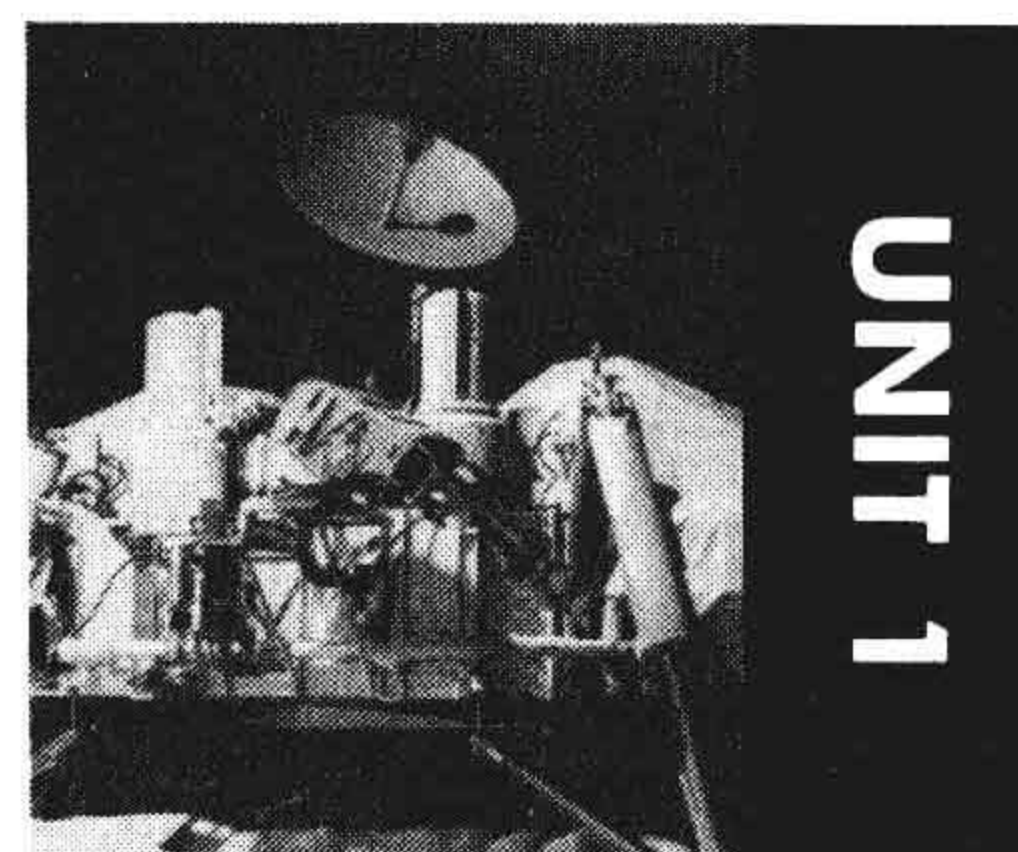
3. **Radio Astronomy in the 21st Century**, Kenneth I. Kellermann, *Sky & Telescope*, February 1997. 24  
**Radio waves** pass through Earth's atmosphere relatively unhindered and thus provide information on a variety of astronomical phenomena such as cosmic masers, beams of relativistic gas, **pulsars**, and radio bursts from the **Sun** and planets.
4. **A Radio Map of the Milky Way**, Paul W. Schuler III, *Sky & Telescope*, March 1994. 31  
Paul Schuler, an amateur astronomer, describes how he built a satellite dish to observe the **radio emissions from neutral atomic hydrogen**. Schuler presents a radio map of the Milky Way, and he explains how the radio signal is processed. His observations are then compared to those of a professional astronomer.

## C. INFRARED ASTRONOMY

5. **An Infrared View of Our Universe**, Ian Gatley, *Astronomy*, April 1994. 34  
**Infrared light waves** have longer wavelengths than visible light, which enables them to pass through gas and dust in space that block visible light. Detailed images of **nebulae** and **galaxies** made in the infrared thus provide information not otherwise available.

## D. X-RAY ASTRONOMY

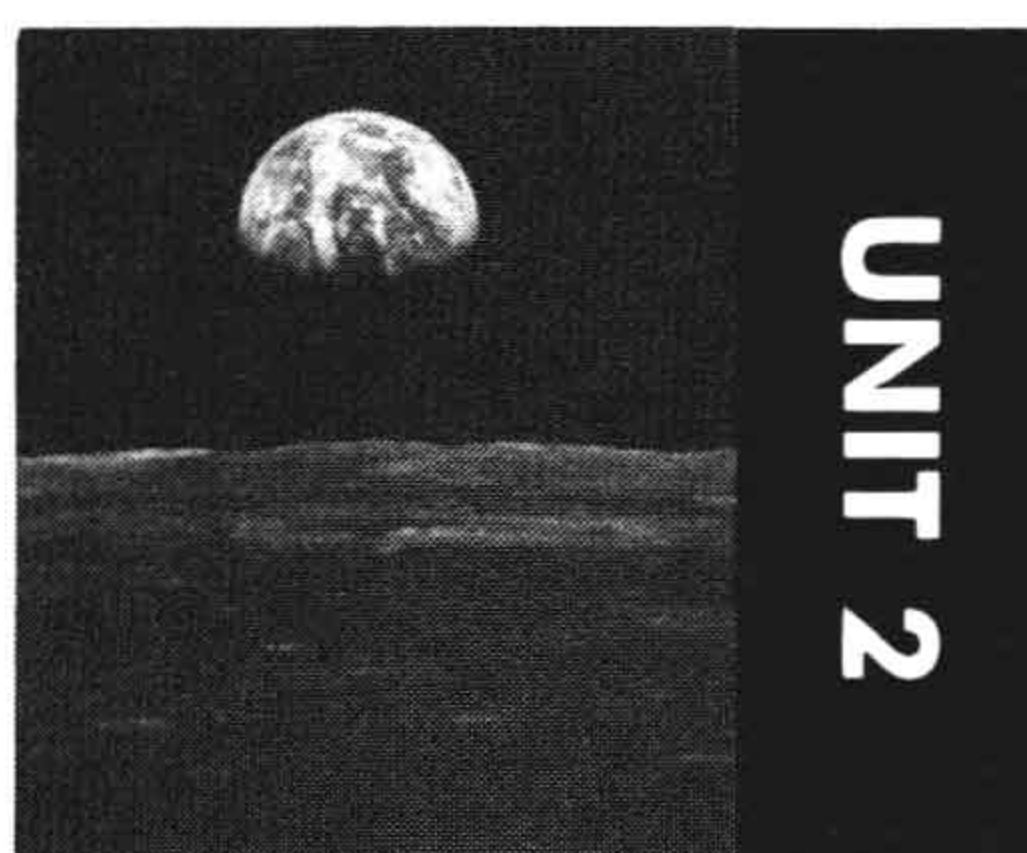
6. **Recent Advances of X-Ray Astronomy**, Yasuo Tanaka, *Science*, January 7, 1994. 38  
Because Earth's atmosphere absorbs cosmic X rays, astronomers were effectively blind in the X-ray astronomy wavelength band until satellite observations became possible. Important X-ray emitters in the galaxy include about 200 X-ray binaries. These include **neutron stars**, which appear as X-ray **pulsars**, and **black holes**. **Supernovae** are also strong X-ray emitters. Interstellar matter and the origin of the intense cosmic X-ray background have also been studied.



## Data-Gathering Techniques

The nine articles in 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 Earth and the Moon

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

### E. GAMMA-RAY ASTRONOMY

7. **Those Mysterious Cosmic Gamma Rays**, Stephen P. Maran, *The World & I*, April 1998. **41**  
The Compton Gamma Ray Observatory (CGRO), launched into Earth orbit by NASA in 1991, has collected data on a variety of unusual astronomical phenomena, including **gamma-ray bursts**, gamma-ray blazars, "fountains" of antimatter, and a gamma-ray halo around the **Milky Way galaxy**.
8. **Gamma-Ray Bursts**, Gerald J. Fishman and Dieter H. Hartmann, *Scientific American*, July 1997. **46**  
Gamma-ray bursts represent the most powerful explosions in the universe. In this article, the authors examine the history of **gamma-ray observations** and what implications they may have on the evolution of the universe.

### F. SPACE TELESCOPES

9. **In a Golden Age of Discovery, Faraway Worlds Beckon**, John Noble Wilford, *New York Times*, February 9, 1997. **52**  
More powerful telescopes on the ground and in space, especially the Hubble Space Telescope, and more sensitive electronic detection instruments are **sharpening the view of the cosmos**.

### Overview **58**

#### A. THE EARTH

10. **Tilt-a-Whirl Astronomy: The Seasons Explained**, Jeff Kanipe, *Astronomy*, March 1996. **60**  
Jeff Kanipe concisely explains how the complex Earth-Sun relationship (distance from Earth to the Sun, the tilt of Earth's axis, the revolution of Earth around the Sun, and the rotation of Earth on its axis) produces the **seasons**.
11. **Using the Solar Eclipse to Estimate Earth's Distance from the Moon**, Mikolaj Sawicki, *The Physics Teacher*, April 1996. **63**  
Follow an intricate and beautiful piece of astronomical reasoning as the author shows how using the Moon's shadow on Earth's surface, produced during a **solar eclipse**, can be used to calculate the distance from Earth to the Moon.
12. **How the Earth Got Its Atmosphere**, Tobias Owen, *Ad Astra*, November/December 1995. **65**  
**Earth** retains its **atmosphere** because its mass is sufficient to produce a gravitational field that prevents most gases from escaping. Our abundant molecular oxygen is due to green plants. It is believed that other elements in our atmosphere may have been derived from **comets**.



B. THE MOON

13. **Moon Watching: An Experiment in Scientific Observation**, William P. Lovegrove, *The Physics Teacher*, February 1994.

William Lovegrove shows how students can incorporate the **scientific method** into astronomy observations. Generally, an astronomer, or any scientist, knows exactly what type of data to collect when the answer to a particular question is sought. However, this is not the case when confronting a new and unknown phenomenon.
14. **Age and Origin of the Moon**, Der-Chuen Lee, Alex N. Halliday, Gregory A. Snyder, and Lawrence A. Taylor, *Science*, November 7, 1997.

The authors use a newly developed isotopic chronometer (hafnium-tungsten) to study the age and origin of the **Moon**. Results indicate that the Moon formed about 4.5 billion years ago.

Overview78

A. THE SUN

15. **Unsolved Mysteries of the Sun—Part 1**, Kenneth R. Lang, *Sky & Telescope*, August 1996.

In the first of a two-part series, Kenneth Lang discusses the Sun’s energy-generating core, which presents the **solar neutrino** problem, as well as the unknown processes that heat the multimillion-degree **corona** and produce the **solar wind** in the Sun’s outer atmosphere.
16. **Unsolved Mysteries of the Sun—Part 2**, Kenneth R. Lang, *Sky & Telescope*, September 1996.

Kenneth Lang, in the second of a two-part series, examines **solar-oscillation** data. Sound waves that reveal motions of the Sun’s material are continuously studied. Currently, the Solar and Heliospheric Observatory (SOHO) spacecraft provides an ongoing “uninterrupted view of the Sun, 24 hours a day, 365 days a year.”

B. THE PLANETS

17. **Crack in the Clockwork**, Adam Frank, *Astronomy*, May 1998.

We have a tendency to think of the solar system as virtually eternal—no new **planets** gained, no current planets lost. However, chaos theory, a branch of mathematics that focuses on dynamic systems, shows that this view is wrong. Chaos theory indicates that a planet’s orbit around the Sun may be viewed as a tightly woven bundle of orbits. Some are stable, others are not. And it is possible that an unstable, chaotic orbit will doom a planet to ejection from a solar system.



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.



- 18. Planet in a Bottle**, Jeff Kanipe, *New Scientist*, January 4, 1997. **94**

Astronomers have been trying to construct physical models to explain the atmospheric dynamics of **Jupiter** in an attempt to explain both the atmospheric bands and the famous Great Red Spot. Astronomers also have been simulating winds on **Mars** in a wind tunnel.

- 19. Jumping Jupiter**, Richard Talcott, *Astronomy*, June 1998. **97**

The Galileo spacecraft has provided a wealth of data on **Jupiter** and its four largest moons: Io, Europa, Ganymede, and Callisto. **Europa** is covered with a thin ice crust, indicating the possibility of water. **Io** is highly volcanic. While all the moons have a thin atmosphere, Callisto's consists of hydrogen, oxygen, and carbon dioxide, while Ganymede's consists mainly of hydrogen.

### C. COMETS

- 20. The Kuiper Belt**, Jane X. Luu and David C. Jewitt, *Scientific American*, May 1996. **103**

The **Kuiper belt** is a region beyond the orbit of **Neptune** that contains a varied number of small bodies and marks the beginning of the outer extremities of our solar system. Some **comets** may have originated here, as well as the planet **Pluto**.

### D. METEORITES

- 21. Bits of Mars and Pieces of the Moon**, *Geotimes*, June 1996. **109**

Recent studies have confirmed that some **meteorites** that are found on Earth come from the **Moon** and from other planets, such as **Mars**. For billions of years, inner solar system planets and their satellites have been "sharing bits and pieces" that are shorn off when meteorites or comets collide with them.

- 22. Life from Ancient Mars?** J. Kelly Beatty, *Sky & Telescope*, October 1996. **110**

Certainly no other science story of 1996 generated more interest than the announcement of the discovery of what appeared to be primitive life preserved in a **meteorite** from **Mars**.

### E. ASTEROIDS

- 23. The Day the Dinosaurs Died**, Ron Cowen, *Astronomy*, April 1996. **113**

Did an **asteroid** strike Earth about 65 million years ago? The evidence certainly tends to support the idea. Did the asteroid's impact and the resultant climate and environmental changes cause the extinction of the dinosaurs? The evidence is more problematic in this area.

- 24. Target: Earth!** David Morrison, *Astronomy*, October 1995. **119**

The possibility of a collision of an **asteroid** with Earth is small but real. David Morrison reviews the astronomical ideas behind such an event, including the analogies drawn from the impact of Comet Shoemaker-Levy 9 with Jupiter, risky asteroid sizes, impacts in Earth's history, the probability of such an impact, and possible solutions if we should find an asteroid heading toward Earth.



## Overview 126

### A. STARS

- 25. The Spectral Types of Stars**, Alan M. MacRobert, *Sky & Telescope*, October 1996. 128

What we know about stars is based, in large part, on information carried by their light. Therefore, the modern spectral classification system is of vital knowledge to every astronomer. Important concepts to understand are the dissection of starlight, the establishment of various **spectral classes**, the luminosity classes, and how spectral type is used to produce the **Hertzsprung-Russell diagram**.

- 26. The Stellar Magnitude System**, Alan M. MacRobert, *Sky & Telescope*, January 1996. 131

The **stellar magnitude system** is a mix of modern ideas and needs and historical frameworks. Two types of magnitude are needed: **visual magnitude**, the brightness of the star as we see it, and **absolute magnitude**, the actual brightness of the star.

- 27. How Planets Are Born**, Sharon Begley, *Newsweek*, May 4, 1998. 134

Early May 1998 was a time of great excitement as several teams of astronomers announced the discovery of dust rings surrounding several stars. The dust rings are a prelude to **planet** formation.

### B. STELLAR EVOLUTION

- 28. Life and Times of a Star**, Ken Croswell, *New Scientist*, November 26, 1994. 138

The **Hertzsprung-Russell diagram** is used by astronomers to study the tremendous diversity that exists among stars. The distribution of stars on such a plot reveals three types of stars: **main-sequence stars**, **supergiants**, and **white dwarfs**.

- 29. The Lives of Stars: From Birth to Death and Beyond (Part I)**, Icko Iben Jr. and Alexander V. Tutukov, *Sky & Telescope*, December 1997. 143

The life span of a **star** is covered in detail, from its birthplace in gaseous dust clouds, to the collapse of the dust cloud to form a protostar, and the subsequent "death" of the star, depending on its initial density, as a white dwarf, neutron star, or black hole.

- 30. The Lives of Binary Stars: From Birth to Death and Beyond (Part II)**, Icko Iben Jr. and Alexander V. Tutukov, *Sky & Telescope*, January 1998. 150

The second part of the lives of stars looks at the development and evolution of **binary stars**. The birth of an X-ray binary is discussed, low-mass binaries are explained, and how close two stars must be to be considered binaries is outlined.

### C. BLACK HOLES

- 31. New Findings Suggest Massive Black Holes Lurk in the Hearts of Many Galaxies**, John Noble Wilford, *New York Times*, January 14, 1997. 156

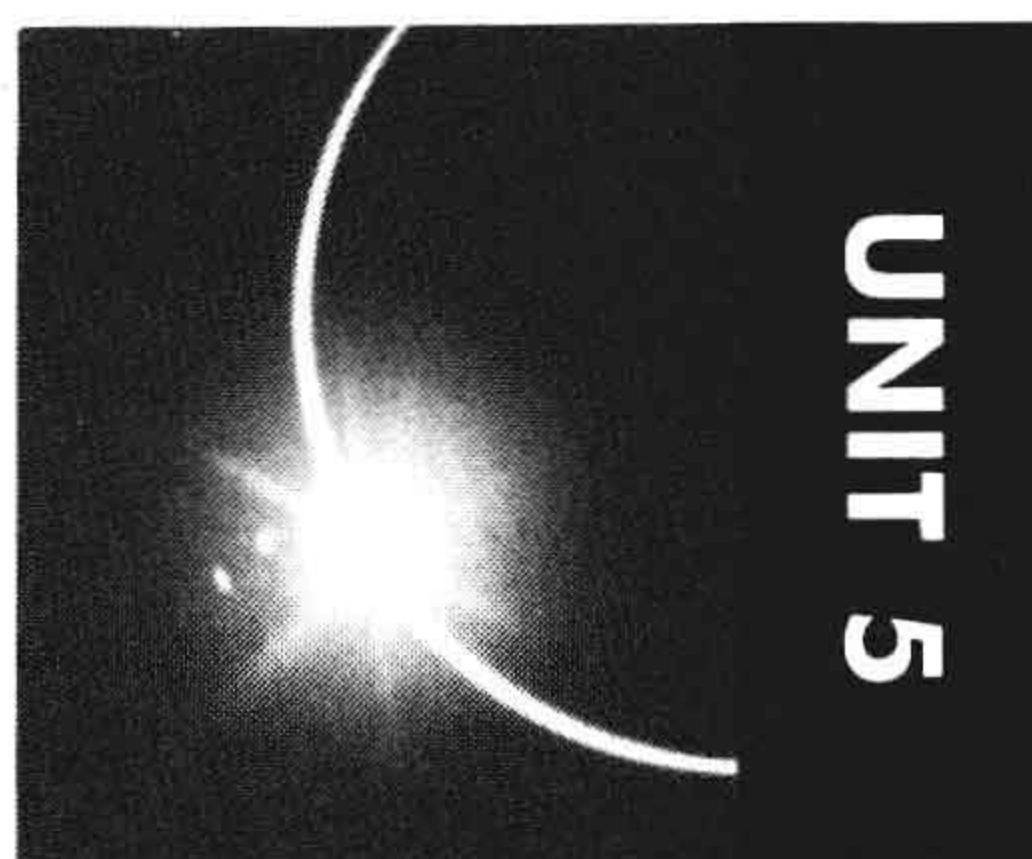
John Wilford examines new evidence that has emerged to indicate that supermassive **black holes** are located at the core of nearly all **galaxies**.



## 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.





## 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.

### D. THE MILKY WAY GALAXY

- 32. The Milky Way**, Ken Croswell, *New Scientist*, May 25, 1996. **160**

By mapping the **Milky Way galaxy**, plotting the distribution of stars within the galaxy, and classifying the types of stars that occur within the galaxy, astronomers are attempting to learn the origin and evolution of the Milky Way.

### E. DARK MATTER AND ANTIMATTER

- 33. The Dark Side of the Galaxy**, Ken Croswell, *Astronomy*, October 1996. **165**

Astronomers have narrowed the field of candidates for dark matter to two broad possibilities: **MACHOs** (Massive Compact Halo Objects) and **WIMPs** (Weakly Interacting Massive Particles).

### F. GALAXY STRUCTURE AND EVOLUTION

- 34. The Evolution of Our Galaxy**, James Binney, *Sky & Telescope*, March 1995. **170**

The study of the evolution of our **galaxy** is based both on observations within our galaxy and on studying other galaxies.

- 35. Before Galaxies Were Galaxies**, William Keel, *Astronomy*, July 1997. **176**

A question that has plagued modern astrophysics is, **How did galaxies form?** William Keel reviews some of the answers to this provocative question.

- 36. What Makes Galaxies Change?** Marcia Bartusiak, *Astronomy*, January 1997. **182**

Ideas about **galaxy evolution** are changing rapidly. Images from the Hubble Space Telescope have allowed astronomers to classify galaxies more accurately by size, type, and magnitude. A great understanding of what kinds of galaxies there are allows for more accurate models of galaxy evolution.

### G. QUASARS

- 37. Galactic Engines**, Neil de Grasse Tyson, *Natural History*, May 1997. **191**

At the center of **quasars** are **black holes** that provide them with the energy to produce their light. In order for a quasar to stay healthy, its central black hole must "consume" stars to obtain energy.

### Overview

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- 38. The Biggest, the Brightest, the Best**, Sally Stephens, *Astronomy*, June 1997. **196**

Sally Stephens's compilation of "a random sampling of astronomical record holders" includes everything from the largest meteorite to the fastest-moving star to the most distant object in the universe.

- 39. The Nature of Space and Time**, Stephen W. Hawking and Roger Penrose, *Scientific American*, July 1996. **201**

By discussing such concepts as quantum **black holes**, quantum theory, and quantum **cosmology**, two famous physicists define their own unique and differing views on quantum mechanics and the evolution of the universe.



A. EXTRATERRESTRIAL LIFE

40. **Life: A Cosmic Imperative?** Yvonne J. Pendleton and Jack D. Farmer, *Sky & Telescope*, July 1997. 208  
The authors explore the possibility of **extraterrestrial life** by considering the general physical and chemical conditions that must be present for life to exist. Possibilities within our solar system are listed: Venus, Mars, several of the moons of Jupiter, and Saturn.
41. **Is Anybody (Like Us) Out There?** Neil de Grasse Tyson, *Natural History*, September 1996. 213  
Neil de Grasse Tyson presents a philosophical discussion on the questions arising from the notion of **extraterrestrial life**. The two most likely places to begin the search are **Mars** and Jupiter's moon **Europa**.

B. THE BIG BANG THEORY

42. **In Defense of the Big Bang**, Neil de Grasse Tyson, *Natural History*, December 1996/January 1997. 217  
The **Big Bang theory** is still regarded as a leading candidate for explaining the origin of the universe. The theory is explored by Neil de Grasse Tyson, and the criteria that theories must meet are also listed. For example, astronomers (and scientists) would insist that a theory make mathematical sense but not necessarily common sense.
43. **Everything You Wanted to Know about the Big Bang**, Richard Talcott, *Astronomy*, January 1994. 220  
Richard Talcott addresses the 10 most common questions about the **Big Bang theory**. Some of the questions that are considered are: Is space expanding or are galaxies moving apart? and, How do astronomers know how old and how big the universe is?

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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.

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		<b>X-Rays</b>	6. Recent Advances of X Ray Astronomy ☉ <b>6, 7, 20, 22</b>



## 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://cadwww.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](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/](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 Observa-

tory. 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

- |                            |  |
|----------------------------|--|
| <i>Optical Astronomy</i>   | 1. <b>From Hipparchus to Hipparcos: Measuring the Universe, One Star at a Time</b> , Catherine Turon |
|                            | 2. <b>Mining the Heavens: The Sloan Digital Sky Survey</b> , Gillian R. Knapp                        |
| <i>Radio Astronomy</i>     | 3. <b>Radio Astronomy in the 21st Century</b> , Kenneth I. Kellermann                                |
|                            | 4. <b>A Radio Map of the Milky Way</b> , Paul W. Schuler III   |
| <i>Infrared Astronomy</i>  | 5. <b>An Infrared View of Our Universe</b> , Ian Gatley  |
| <i>X-Ray Astronomy</i>     | 6. <b>Recent Advances of X-Ray Astronomy</b> , Yasuo Tanaka  |
| <i>Gamma Ray Astronomy</i> | 7. <b>Those Mysterious Cosmic Gamma Rays</b> , Stephen P. Maran                                      |
|                            | 8. <b>Gamma-Ray Bursts</b> , Gerald J. Fishman and Dieter H. Hartmann                                |
| <i>Space Telescopes</i>    | 9. <b>In a Golden Age of Discovery</b> , 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?



## Links

[www.dushkin.com/online/](http://www.dushkin.com/online/)

6. **CADC HST Science Archive**  
<http://cadwww.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](http://www.stsci.edu/astroweb/yp_telescope.html)

These sites are annotated on pages 4 and 5.



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.

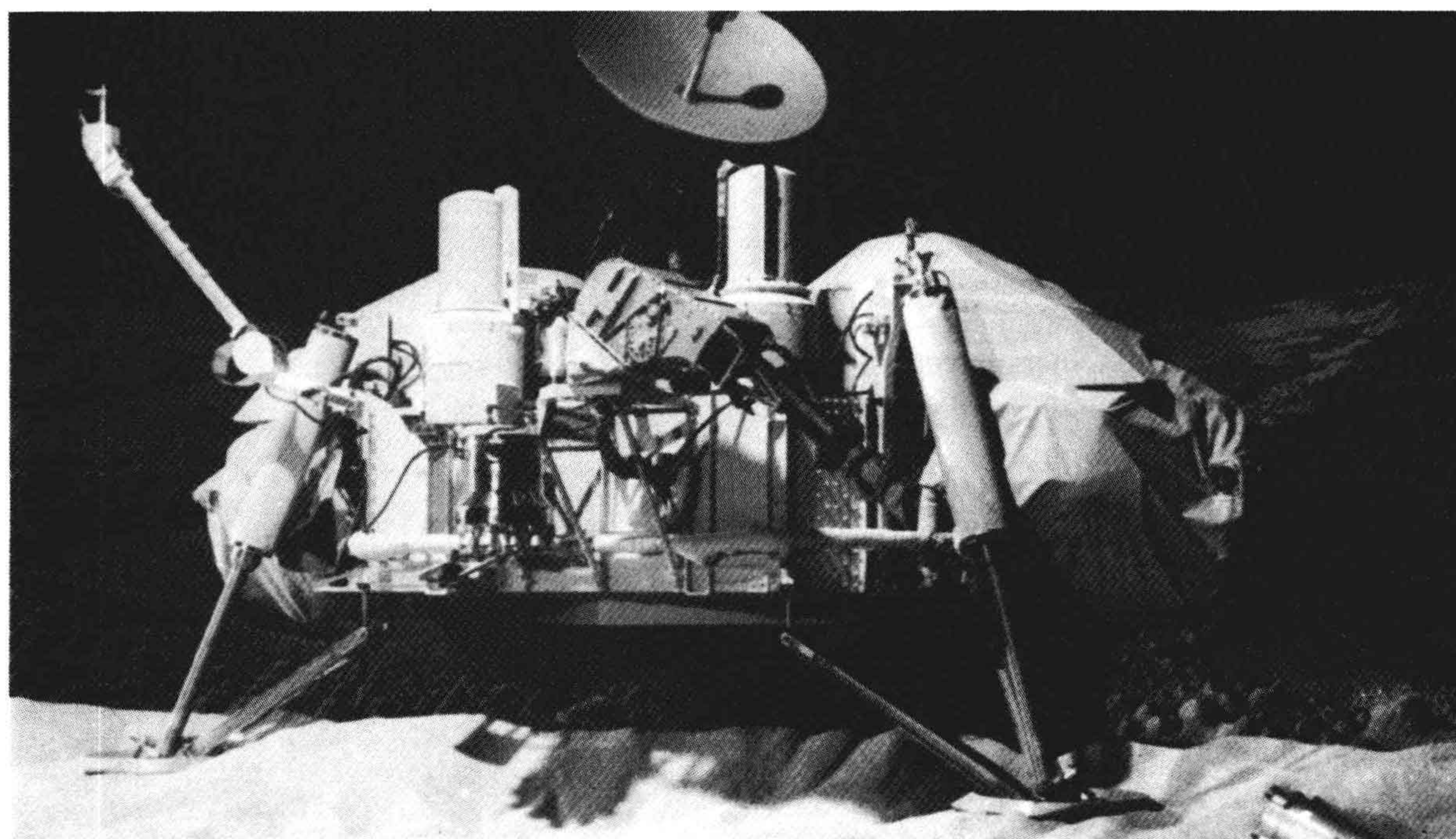
Radio waves have also been used to study celestial objects. The essay "Radio Astronomy in the 21st Century," by Kenneth Kellermann, gives a fairly complete view of the discipline, including suggestions for further advancements in the field. "A Radio Map of the Milky Way," by Paul Schuler III, was included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

**H**IPPARCHUS 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 *High Precision Parallax Collecting Satellite*, 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  $\frac{1}{3600}$  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.