SKY & TELESCOPE®

FOCAL POINT

The End of Dignity

THE AMERICAN MUSEUM of Natural History in New York City is tearing down the old Hayden Planetarium and replacing it with something snazzier: an 80-foot sphere in a glass box. The sphere's exterior will function as a giant projection screen, able to flash thousands of images simultaneously.

The museum wants to become interactive; it has already remade one of its galleries into what the *New York Times* described as a "miniature theme park." It's about time, too, according to the *Times*, which reported that the museum is "dogged by a reputation for stodginess" and known for its "musty corridors and dreary dioramas."

After all, the planetarium is a relic of the 1930s — and what can you say about an era that gloried in the old museum's measured, earnest educational tones? (Straight ahead for the Hall of Stodginess. Dreariness upstairs to your right.) Peter L. Rothholz, a former chairman of the Queens Museum, described one aspect of the 1939 New York World's Fair as "characteristic of the naiveté of that time." Most of us would agree. We are sophisticated; our predecessors were naive. Right?

Exactly wrong. The society of the planetarium's youth was the more sophisticated one, and the old building's death is part of a trend that has damaged American life.

In the 1930s, after all, you could please the public and command an audience without turning your museum into an amusement park, miniature or otherwise. When the planetarium opened in 1935, the *Times* was "enchanted" and declared that watching the sky show was "like seeing the splendors of the universe for the first time."

Behind these comments lies a now-discarded idea of a museum's function. Back then, a museum was for enjoyment and reflection, not thrills. "At last," *The Times* announced in evident relief when the planetarium opened, "the spectators understand what is meant by 'precession of the equinoxes.'"

According to a 1938 guidebook, the museum was "filled with the wonders of natural science from every known section of the globe." That alone made it noteworthy. The museum was a serious institution that addressed its audience with calm dignity.

Calm dignity used to be a valued commodity in public discourse. Listen to the 1930s holding forth on the advent of TV, which began its American career in 1939: "Television will contribute to the enjoyment of millions," read an RCA advertisement. "When it becomes a nation-wide service it should provide new opportunities for workers." David Sarnoff, the company's president, was only slightly more effusive. "It is with a feeling of humbleness," he said, "that I come to this moment of announcing the birth in this country of a new art so important in its implications that it is bound to affect all society."

Contrast those measured comments with modern journalism's fevered reaction to new technologies. *The Economist* announced that the advent of the information superhighway would be "a revolution in communications that is going to change the world." Lawrence J. Ellison, chairman of the California software company Oracle, said it is "going to forever change our lives."

The slow death of dignified public discourse echoes through our culture. In politics, it has meant the triumph of negative campaigning. In art, nuance and beauty are drowned out by the acid blare of the message. The public has become increasingly cynical about politics and art. It will become cynical about technology, too, when the actuality fails to live up to the advance billing. Our preference for the excessive in public discourse reflects one of the deepest trends in modern American life: the death of authority.

On March 17th workers began demolishing the Hayden Planetarium in New York City, the first step in an extensive three-year upgrade. When completed, the $135 million project will include a state-of-the-art sky theater and 50,000 square feet of exhibition space. Although generally endorsed, the plan has been opposed by a group called the Community Alliance for Responsible Museum Development. However, on February 26th the alliance's bid to halt the project was defeated in court, and the work began as scheduled.

On the Cover

Astronauts aboard the Space Shuttle *Discovery* visited the Hubble Space Telescope (HST) in February to make a high-flying service call on the venerable spacecraft. During five space walks the orbiting technicians performed above and beyond their repair schedule, replacing science instruments and upgrading several control systems. Upon completion, HST was boosted to a higher orbit and the old components were brought back home. Astronaut Joseph R. Tanner is shown here amid his first space walk — the second excursion of the flight — with Gregory J. Harbaugh (seen reflected in the helmet visor). Part of Hubble's solar-cell array is visible over Tanner's shoulder. The pictorial starting on page 34 presents the highlights of STS 82's 11-day mission. Courtesy NASA.

MARTIN KOZLOWSKI

The old American Museum of Natural History commanded a respectful audience without turning somersaults because it was an authoritative institution. David Sarnoff didn't need to proclaim a revolution in order to be heard; he was an authority, and people were predisposed to listen to him. Because authorities didn't need to shout, they had a calming (and often uplifting) influence on society.

Of course, authorities sometimes spoke nonsense too — an anti-Semite like Henry Ford had more credibility then than he would have today. But in democratic America, authority was an outstandingly democratic institution. For every institution like the American Museum of Natural History, ennobled by its long association with blue bloods like President Theodore Roosevelt, there was a David Sarnoff, who came to the U.S. as a 9-year-old Russian immigrant and worked as a self-taught telegrapher on his way to the top.

In itself, the proposed new planetarium does no harm. I'll miss the old building, but not because it was an architectural masterpiece. In a larger sense, though, those bulldozers are plowing calm dignity under and replacing it with glitz, hype, and somersaults, and we will all be worse off for it.

The democratic authority culture is gone, and we can't bring it back. But we can make sure that our children, as they stroll through the new glass box and the miniature theme park, interacting as they go, are aware that things used to be different — as an antidote to smugness, if nothing else.

Before all vestiges of the old Hayden Planetarium are gone, the museum might stage one last exhibit. Call it "On the wisdom of the society that built this condemned planetarium." Forgo just this once (as a special favor to children) the tendentious recitation of American sins that has turned so many contemporary history books, articles, and exhibits into sanctimonious rot. Tell us instead what our grandparents did right, which of their accomplishments we ought to treasure, what aspects of the society they built were noble — and are gone.

DAVID GELERNTER

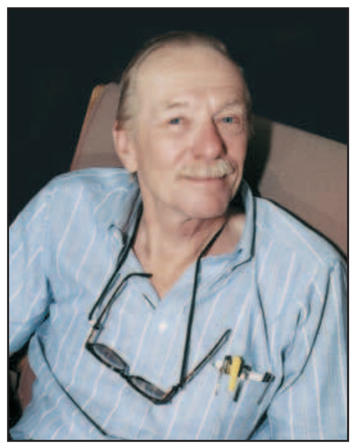
Gelernter is a professor of computer science at Yale and the author of 1939: The Lost World of the Fair. *This essay is copyright 1995 The New York Times Co.*

S&T: Bigger, Better

"C'MON IN!" a carnival barker in my head shouts. "C'mon in, and I'll show you a thousand wonders and give you a million goose bumps!"

That barker sounds off daily as I interact with our design department, led by Sandra Salamony, who joined our staff in December, to create a fresh, contemporary look for *Sky & Telescope*. Beginning with next month's issue you'll see a larger, more user-friendly, and greatly enhanced magazine. We're even cooking up a special surprise!

Magazines and their goals continually evolve — due to reader feedback, new technology, new needs. We've decided that *S&T* will benefit from greater flexibility. This will ensure that each article can be given all the space it deserves, and it will also extend our leadership in bringing you late-breaking news and observers' reports. We also want to better showcase our loyal advertisers, for these folks help make this hobby so exciting and dynamic. To accomplish all of these enhancements we will relocate some departments, add new ones, and redirect the mission of others.



To fulfill our new editorial vision, and to offer even better reader service, we will change our printer to take advantage of the very latest manufacturing technologies. This move will allow us to bring you sharper images with superior color and to deliver issues more quickly to your mailbox or newsstand. (I can't wait to see the July issue roll off the press on the new, whiter and brighter paper we've selected.)

Of course, the traditional mission of *Sky & Telescope* won't change. We'll still work overtime to provide you with the most comprehensive, readable, and elegant international magazine devoted to astronomy. Between the covers you'll find the same editorial quality and timeliness that we've delivered to amateurs and professionals for 56 years. Each issue will simply be bigger and packed with more good stuff.

Leif J. Robinson

Editor in Chief

50 & 25 YEARS AGO

June 1947

The funds for the erection of the giant 200-inch telescope on Mount Palomar in California have been supplied by three Rockefeller boards. . . . In 1946 the Foundation made a final grant of $250,000 to complete the project, bringing to a total of $6,250,000 the funds appropriated to the California Institute of Technology. . . .

What is the justification for this huge expenditure of money and effort? The answer, in general terms, lies in the unconquerable exploring urge within the mind of man. This new telescope will project man's sight into the universe . . . to a distance more than a thousand million light-years away.

This quaint quote was extracted from the Rockefeller Foundation report for 1946. The 200-inch, dedicated on June 3, 1948, has probably seen back some 8 billion light-years, depending on your pet cosmological model. Curiously, the foundation got the name of the site wrong — it's Palomar Mountain! That was a bad precedent, but it might help explain why so many people have persisted in using the misnomer ever since.

June 1972

Solar observers have discovered what they believe are large-scale sound waves in the sun's atmosphere. These appear as bright and dark rings which originate in the umbra (dark central part) of a sunspot, but become visible only as they expand into and across the penumbra (less dark outer part). . . .

"The undulations are some 1,600 miles from crest to crest, travel at 18,000 to 25,000 miles per hour, and follow each other about 270 seconds apart," [Big Bear Solar Observatory] director Harold Zirin reports. "They are visible only when the seeing is better than one arc second." . . .

Dr. Zirin suggests that the waves may be related to the unexplained phenomenon of umbral flashes discovered a few years ago at Sacramento Peak Observatory by Jacques M. Beckers and Paul E. Tallant. . . . "We believe the waves are sound waves carrying outward the energy generated by the umbral flashes."

The waves are now known as "running penumbral waves" and were independently discovered by Ronald Giovanelli. Later, Alan Nye and John Thomas interpreted them as being a byproduct of magnetic, pressure, and gravitational forces. Their association with umbral flashes is still unproved, but they may be related to pressure oscillations in the Sun's convection zone.

LETTERS

Sagan Remembered

I grew up in the same Brooklyn neighborhood that Carl Sagan did, and I've come to take some pride in that. When he died on December 20th, it affected me more deeply than I could have anticipated.

It is evident that Sagan was a special person — a learned and enlightened freethinker with a passionate sense of wonder that most of us lost long ago, if we ever had it. He was a brilliant communicator with a gift for conveying that sense of wonder, presenting physics, astronomy, and history like a poet. "We are all made of star stuff," he told us. If there were more people like Carl Sagan, how much saner our world would be.

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Largest Meteorite Shower

Descriptions of large meteorite falls usually make fascinating reading, and the article on the Sikhote-Alin shower is no exception (February issue, page 50). However, we are not certain that this fall represents the largest iron-meteorite shower on record. With less than 50 tons documented, it ranks second to the Cape York shower from Greenland, now totaling 58 tons.

Cape York became known primarily through the collections by Admiral Robert E. Peary in 1894, but in 1963 a new 20-ton member was spotted and subsequently brought to Copenhagen. The eight largest specimens were found mostly in a narrow strip of dry land, between the ice cap and Melville Bay; almost certainly more specimens remain under the ice cap and in the chilly waters of the bay. During our field trips there in 1992 and 1993 we searched areas that had been exposed by retreating ice, without success. However, we are confident that remote sensing techniques will one day locate additional fragments (and we invite readers to suggest ways to achieve this).

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Ambiguous Limiting Magnitudes

A few years ago the amateur community objected to manufacturers of commercial telescope mirrors making impressive claims about optical quality that were difficult to substantiate objectively. While that issue has, for the most part, been put to rest, a new quagmire has arisen involving the naked-eye limiting magnitudes at star-party sites (see the March issue, page 13). It may be entirely possible for a skilled observer who really works at it to detect magnitude 7.2 stars with the unaided eye from an excellent site under superb conditions, but a magnitude limit thus determined is meaningless to everyone but that observer. If we're going to start throwing numbers around, we had better decide to use standard equipment that varies less than the acuity and experience of observers' visual impressions.

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A Helpful Review

My thanks to Joshua Roth for his excellent review of three portable rich-field telescopes (March issue, page 55). I had been in the market for such a telescope, and after reading the article I knew exactly which one was best suited for me. Not only that, but the information was so thorough that for the first time I bought a telescope by mail.

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Radio Observing from the Moon

"Will the Sun Set on Radio Astronomy?" (April issue, page 40), is a well-documented warning about the future of this science, but it relegates lunar radio telescopes to the distant future and suggests that they be on the Moon's far side. This view may be somewhat shortsighted.

Productive microwave astronomy could be done from the side of the Moon facing Earth, preferably at a site near the lunar limb (*S&T:* September 1992, page 259). Distance alone will greatly reduce terrestrial interference. In addition, astronomers could simply point the telescopes away from Earth or put up an aluminum-foil shield. Furthermore, lunar radio telescopes need not resemble those of the Very Large Array in New Mexico. Using lightweight materials in the wind-free, low-gravity environment on the Moon, modest but effective instruments could be launched on a comparatively cost-effective Delta 2 rocket and erected robotically. The Apollo S-band antennas, easily set up by the astronauts, suggest what is possible with today's technology.

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A European Adventure

The San Francisco Sidewalk Astronomers are sponsoring public astronomy events throughout Europe during the three weeks following the total solar eclipse of August 11, 1999. We plan to bring telescopes and hold sidewalk star parties in the great cities of that continent. Anyone interested in helping us achieve our goal of sharing the wonders of the universe with the people of Europe should send a self-addressed, stamped envelope to the address below or contact the club through our World Wide Web home page at http://members.aol.com/raycash/sidewalk.htm.

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In Search of Maksutovs

Maksutov telescopes have many excellent features, including easily generated spherical optical surfaces, excellent image contrast, and freedom from internal tube currents, among others. With the Perry design (*S&T:* December 1995, page 74), most aberrations are eliminated. Despite the advantages of this instrument, I am not aware of many Maksutovs larger than 10-inch aperture. I would like to hear from anyone who owns or is aware of a Maksutov of this size. Please send information on the scope or contact information for the owner. Any reply will be acknowledged and greatly appreciated.

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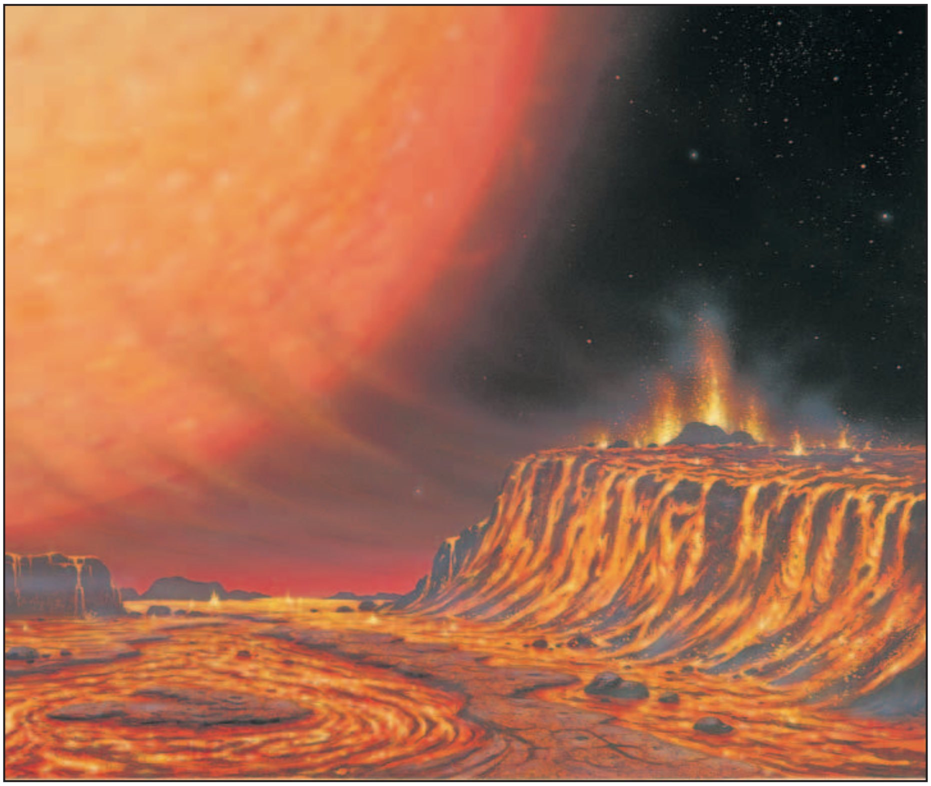

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The Earth's Fate Revisited

Generations of astronomy students have learned about the cruel fate that awaits our home planet some six billion years hence. Our Sun will swell toward red-gianthood, we have been told, engulfing the Earth in the process. But a few years ago three theorists pointed out that the Sun will shed a significant fraction of its mass as it evolves, and hence it will exert a lesser gravitational grip on the Earth (*S&T:* May 1994, page 12). The result: the Earth's orbit grows by roughly 70 percent and remains beyond the Sun's outer layers.

Or so things stood until last fall, when Frederic A. Rasio (MIT) and three colleagues studied tidal interactions between stars and their planets. Rasio's team got interested in the subject because of the planetlike companions recently found circling other Sun-like stars (February issue, page 12). While assessing those systems, the group also pondered the consequences of the tides that the Earth would raise in the swollen Sun.

While such tides are minuscule today, things change once the Sun starts to balloon outward because the tides induced in any body increase when that body gets bigger. Also, while the Sun currently spins much faster (25 days) than the Earth takes to orbit it, the situation will reverse after our star has swollen. Once that happens, any bulge induced in the Sun by the Earth will rob the Earth of orbital energy. Thus slowed, our planet will fall deeper into the Sun's gravitational grip.

As Rasio's team points out in the *Astrophysical Journal* for October 20, 1996, it's not a sure bet that this mechanism will actually pull the Earth into the swollen Sun's envelope. The outcome depends on how efficiently the Sun can shed the energy it absorbs from the tidal interaction.

Of course, such speculations are academic as far as the Earth's biosphere is concerned. Long before the Sun becomes a red giant, its luminosity, or total energy output, will increase, possibly triggering a runaway greenhouse in our atmosphere. And even if it manages to outrace the Sun's expanding envelope, the Earth won't escape its inexorably increasing luminosity, which will eventually melt the terra firma on which we live today.

Diffuse Interstellar Bands Explained?

The spectra of stars have been studied for more than 130 years and are the foundation of astrophysics. But they still hold secrets. Among the most perplexing are the diffuse interstellar bands (DIBs). These weak, vague absorption patterns appear in the spectra of all distant stars. They cannot be explained by any known atom or molecule. The first was discovered as early as 1921; more than 200 are known today.

Astronomers have hypothesized that complex carbon-based compounds are responsible. (A search for the cause of DIBs was what led to the discovery of the "buckyball" carbon-60 molecule, for which a Nobel prize was awarded last year.) But how could scores of unknown molecules all be distributed in the same proportions along the line of sight to every star?

Now two scientists are suggesting that the mystery compound is none other than the hydrogen molecule, H_2, the simplest and commonest molecule in space. Writing in the December 20, 1996, *Astrophysical Journal*, Peter Sorokin and James Glownia (IBM) propose that the bands result when an H_2 molecule simultaneously absorbs two photons, one ultraviolet and one visible. It works if the photons hit at essentially the same instant and their energies add up to match the difference between two of the molecule's energy levels. The theory has accounted for the wavelengths of about 70 observed DIBs.

But there's a problem. Two-photon hits are very rare. To get enough of them you need an extremely dense flux of ultraviolet light. Sorokin and Glownia, experts in laser physics and molecular spectra, suggest that ultraviolet photons of the right wavelengths can get trapped within sheetlike molecular clouds near hot stars, with a single photon ricocheting off H_2 molecules billions of times.

Astronomers remain skeptical. No sign of such intense, trapped ultraviolet radiation is observed. DIBs appear in the spectra of cool stars as well as hot, ultraviolet-emitting ones. And they actually seem to avoid nebulosity close to hot stars, where the proposed mechanism ought to work best. Still, the theory is tantalizing — and a reminder that decades after astronomy textbooks began saying that atoms and radiation are completely understood, some of their interactions are still beyond us.

Supernova Signs May Lurk in Ice

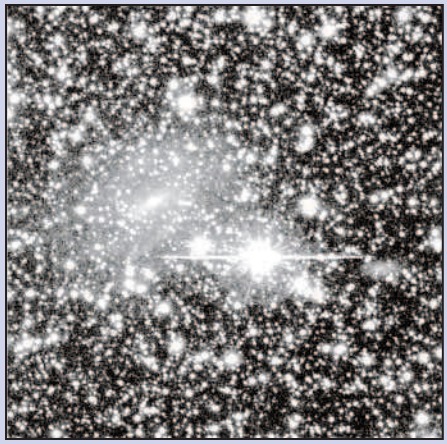
Astronomers typically look for evidence of supernovae in the sky, studying the collapsed cores and the nebulous residue they leave behind. However, signs of these stellar explosions may also lie deep beneath our feet.

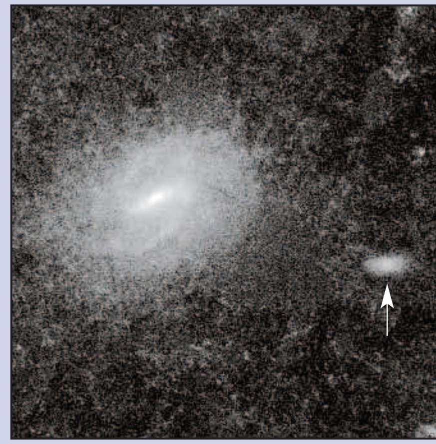
If a supernova were sufficiently close — about 130 light-years — high-energy particles could react with atoms in our atmosphere, producing anomalously high concentrations of certain isotopes (atoms of a given chemical element with differing numbers of neutrons). Furthermore, the Earth could pick up extrasolar material directly by moving through the supernova's debris cloud. The evidence for such events may be locked in layers in glacial ice sheets, deep-sea sediments, or other geologic strata. There is no definitive evidence that the Earth actually bears such isotopic debris. Nevertheless, John Ellis (CERN), Brian D. Fields (University of Notre Dame), and David N. Schramm (University of Chicago) examined what isotopes would be produced in a supernova and what would likely be swept up by the Earth.

Writing in the October 20, 1996, *Astrophysical Journal*, the researchers explain that the amount of supernova material deposited on the Earth would be strongly related to how close the exploding star was. One promising (but still undetected) candidate is the supernova that spawned Geminga, an enigmatic gamma-ray pulsar. Currently only 510 light-years away (*S&T:* June 1996, page 17), Geminga is believed to be about 300,000 years old. Any isotopes it spawned would therefore be relatively close to the Earth's present-day surface.

While isotopic evidence for Geminga's birth event has yet to be found, the physicists can point to an abundance of beryllium-10 in a sample of ice drilled from the Antarctic ice sheet. The aberrant concentrations, in two layers 35,000 and 60,000 years in age, could have originated in stellar blasts. The researchers note that if the beryllium-10 signatures are from supernovae, then other isotopes should show an increased abundance. Alas, such additional chemical analyses of ice cores have not yet been performed.

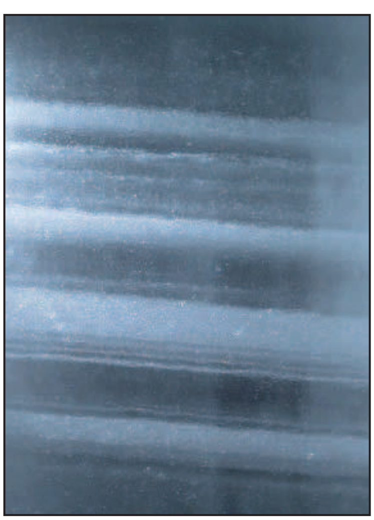
While ice cores go back only tens of thousands of years, deep-sea sediments extend the geological record by several hundred million years. It is believed that if a supernova occurred *too* close to the Earth, catastrophic effects to the biosphere might have resulted. The high-energy radiation from the explosion could break apart atmospheric ozone, allowing life-damaging ultraviolet light to reach the surface. Thus, examining yet older layers may turn up hints that one or more periods of mass extinctions resulted from supernovae.





Unmasking Galactic Neighbors

One of astronomy's ironies is that some of the galaxies nearest our own are among the least well known. Galaxies that happen to lie behind the Milky Way's dusty, starry disk are still being discovered today. The latest member of this growing family was winnowed by Marshall L. McCall (York University) and Ronald J. Buta (University of Alabama) from far-red (I-band) images they took with the 0.6-meter Burrell Schmidt telescope on Arizona's Kitt Peak. As explained in the *Astronomical Journal* for March, the scientists' computers painstakingly subtracted the foreground Milky Way stars from the image at left to better see Dwingeloo 1, a barred spiral in Cassiopeia that was originally spied with a Dutch radio telescope (*S&T:* February 1995, page 12). Their image also revealed a previously unknown dwarf elliptical galaxy (arrowed) 9 arcminutes to the west (right) of Dwingeloo 1. Another companion, Dwingeloo 2, lies beyond these frames to the northwest. The galaxies are believed to be members of the IC 342-Maffei 1 group, an assemblage roughly 10 million light-years distant. Courtesy McCall and Buta.



Anomalous concentrations of elements in ice cores from Antarctica may indicate periods when the Earth was irradiated by nearby supernovae — with possibly life-threatening effects. Courtesy Joan Fitzpatrick, U.S. National Ice Core Laboratory.

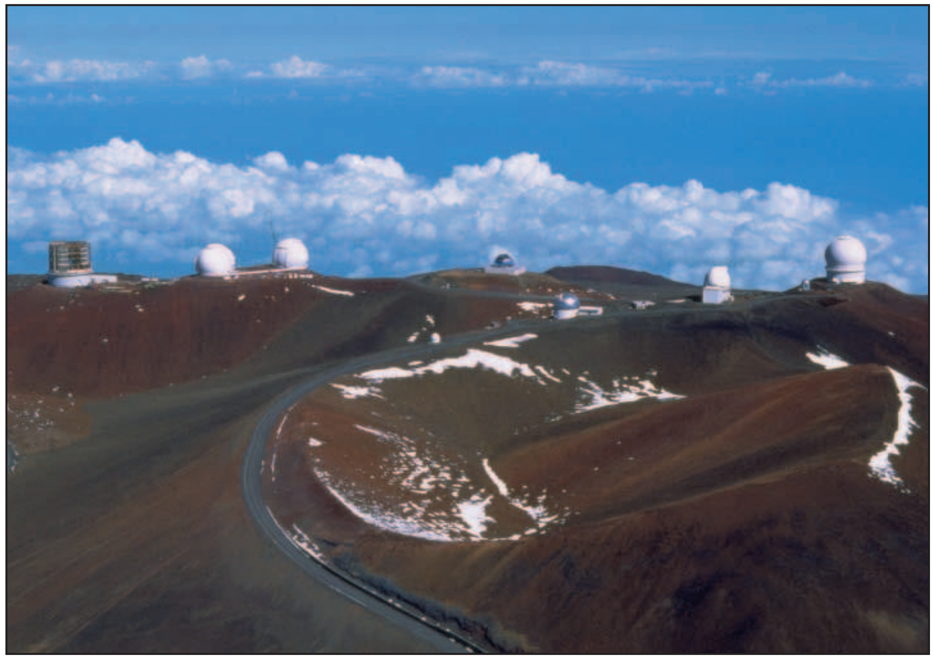
Crowded at the Top?

Have astronomers built too many telescopes at the summit of Mauna Kea? That's what Malama Solomon, a senator in the state of Hawaii, wants to know. Solomon has requested an audit for the entire management of the Mauna Kea Science Reserve, which is cooperatively administered by the University of Hawaii's Institute for Astronomy and the state's Department of Land and Natural Resources.

At the root of the controversy is whether the state government has allowed telescope construction to exceed limits on development agreed upon in 1982. By the year 2000, the dormant volcano was to be the home of no more than 13 telescopes. Currently, there are 11, a total that includes the 8-meter Subaru and Gemini facilities to be completed in 1999. A 12th telescope will be the Smithsonian Astrophysical Observatory's Submillimeter Wavelength Array — a sextet of 6-meter parabolic antennas expected to be finished at the end of this year. While astronomers maintain that this array counts as one facility since all antennas will work together, opponents argue that it should be counted as six separate telescopes.

The Sierra Club, which supports the audit on Mauna Kea's astronomical use, notes other concerns about the mountain's management. Among them are protection for the summit's historical and cultural value, as well as the habitat for a rare indigenous insect.

Donald Hall, director of IfA, explains that he welcomes public scrutiny of the management of the mountain. "We are in absolute compliance with the master plan," he says, and all telescopes have received proper public review and permits.



Has Mauna Kea become populated with too many telescopes too quickly? A Hawaiian legislator and an environmental group are leading the mission to question the intensive use of the volcanic peak. This aerial photograph by Richard Wainscoat was taken in February 1995.

Depleting Outer Asteroids

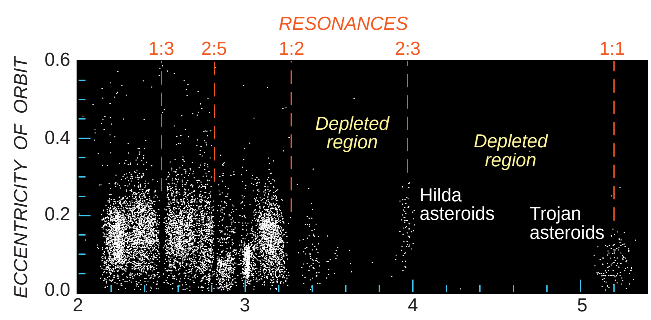
The asteroid "belt" between the orbits of Mars and Jupiter is hardly a flat, orderly disk. Over time the minor planets have been bullied by gravitational tugs from the giant outer planets (and one another) into a wide spread of orbital inclinations and eccentricities. Jupiter's influence is most noticeable within 1¼ astronomical units (200 million kilometers) of its orbit, which is virtually asteroid free, and at locations farther inward, called resonances, where an asteroid's orbital period forms a simple ratio with that of Jupiter. For example, gaps exist in the belt at the 1:2 and 1:3 resonances, as shown below.

However, dynamicists have puzzled over the dearth of asteroids in the region 3.5 to 3.9 a.u. (525 to 585 million km) from the Sun, which lacks strong resonances with Jupiter and is largely beyond the planet's gravitational control. Computer simulations have shown that about half of this region's original allotment of asteroids should still be there.

These studies assumed that Jupiter has always orbited 5.2 a.u. from the Sun. But that's probably not the case, assert Jer-Chyi Liou (NASA/Johnson Space Center) and Renu Malhotra (Lunar and Planetary Institute). "During the early history of the solar system," they write in *Science* for January 17th, "it is likely that the gravitational scattering of planetesimals by giant planets caused the orbits of Saturn, Uranus, and Neptune to migrate outward and the orbit of Jupiter to migrate inward." (Evidence for such shifting is found in Pluto's odd orbit and the distribution of Kuiper Belt objects farther out.) An inward Jovian shift of just 0.2 a.u. would have allowed higher-order resonances to sweep though the problematic region and force the asteroids there into unstable orbits that eventually sent them elsewhere.

One problem with this model, Liou and Malhotra admit, is its prediction that asteroids should have congregated at the 1:2 resonance (3.28 a.u. from the Sun). Instead a gap exists there now. One likely explanation, the scientists suggest, is that whatever accumulation occurred during Jupiter's inward drift has been gradually removed in the billions of years since the planets' migration ceased.

The asteroid belt is full of gaps. Much of its outer reaches has been swept clean by Jupiter's gravitational influence. Recent research suggests this process would have been much more efficient if the giant planet migrated inward early in the solar system's history. Adapted from *Science*.

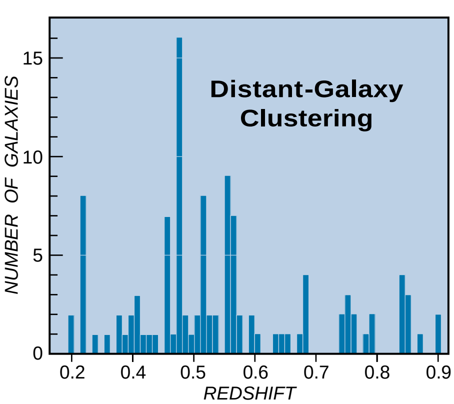


Large-Scale Clustering

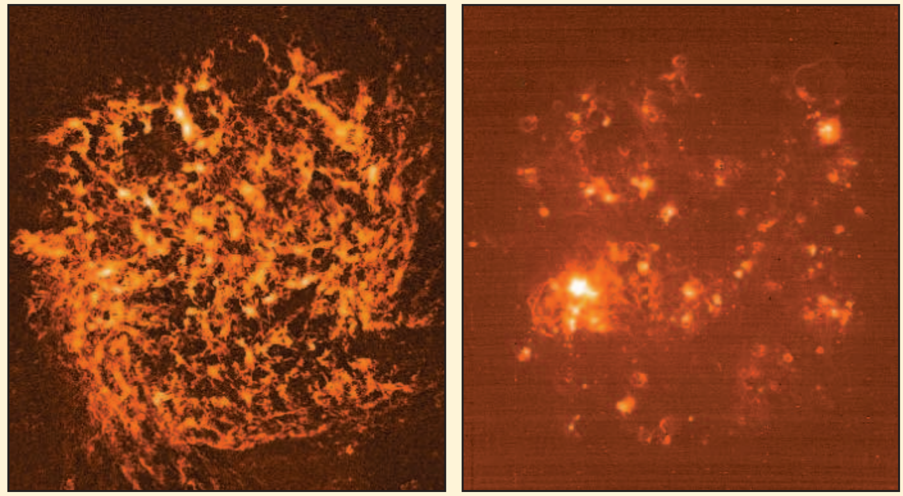
In the early part of this decade astronomers found conclusive evidence of large-scale structure in the "local" universe (at redshifts less than z = 0.2, which correspond to distances of about 3 billion light-years). Researchers suspected that the sheets, filaments, and walls of galaxies they found could not have existed in the earlier universe (at higher redshifts) since cosmological models suggest that such structures need a great deal of time to form. However, a recent study of galaxies with an average redshift of z = 0.5 hints that this may not be true.

Using the 10-meter Keck I Telescope, Judith G. Cohen (Caltech) and her colleagues found the redshifts of 140 extragalactic objects that fall within the Hubble Deep Field and in adjacent regions. Within that sample they detected six concentrations, all between z = 0.3 to z = 0.6. It may still be too early to say what these concentrations represent, since the sample was from such a small patch of sky. Cohen's team speculates in the *Astrophysical Journal Letters* for November 1, 1996, that it has found high-redshift counterparts to local large-scale structures, and it has already widened its redshift survey to see if these distant groupings extend to neighboring fields.

As if that weren't enough to confound cosmological models, astronomers at the University of Chicago have found evidence for superclusters of galaxies at even higher redshifts. Jean M. Quashnock, Daniel E. Vanden Berk, and Donald G. York took advantage of a recently compiled catalog of so-called "heavy-element quasi-stellar object absorbers." In effect, this catalog records extended objects that lie along the sight lines to distant quasars, absorbing portions of their spectra. Just what component of a quasar's spectrum is absorbed reveals the scale and redshift of these systems. The team's findings, reported in the *Astrophysical Journal Letters* for December 1, 1996, suggest that large-scale clustering exists out to redshifts as high as z = 3. This implies that galaxies (or the gas clouds from which they formed) were grouped together within a billion years of the Big Bang.



A recent survey of galaxies within the Hubble Deep Field reveals clustering at certain redshifts. These groupings may translate into large-scale structures similar to those seen within a few billion light-years of Earth. Adapted from the *Astrophysical Journal Letters*.



The Large Magellanic Cloud Through Radio Eyes

Do these two images look familiar? If your answer is no, it might be because human eyes weren't designed to view radio waves *(left)* nor to filter out the red glow of hydrogen-alpha emission *(right)*. You're looking at the Large Magellanic Cloud (LMC), a satellite galaxy of the Milky Way and, at visible wavelengths, a sight familiar to Southern Hemisphere observers. The radio image maps neutral hydrogen gas, which traces the structure of the LMC's interstellar medium. Made using the Australia Telescope Compact Array, it reveals large holes, called supergiant shells, that are telltale signs of violent explosions or tremendous stellar winds. The map of the LMC's H-alpha emission, produced using a 16-inch telescope at Mount Stromlo and Siding Spring Observatories, reveals sites of ongoing star formation. The bright region toward the left side of the H-alpha image is 30 Doradus, the Tarantula Nebula. By comparing these images, a team of astronomers led by Sungeun Kim (Mount Stromlo and Siding Spring Observatories) is developing a broad picture of the LMC's structure and dynamics. Radio and H-alpha images courtesy Sungeun Kim.

T Tauri's Magnetic Personality

Star formation, while ubiquitous, remains a mystery in many ways to astronomers. In part this is because the earliest stages of a star's development take place within an obscuring cloud of dust and gas. In one still dimly understood phase, magnetic fields are believed to play a crucial role in a star's growth, from facilitating the accretion of matter to shaping jets and outflows. But the existence of magnetic fields in stars being born has been difficult to establish conclusively.

However, an active, young object in Taurus may have provided the first direct observational evidence of a developing star ejecting its magnetic field. In 1992 Tom Ray (Dublin Institute for Advanced Studies) and his colleagues observed T Tauri S (south), the visibly obscured component of a double (and perhaps triple) star, at a wavelength of 6 centimeters using the MERLIN network of radio telescopes. The astronomers discovered that the system had recently ejected two blobs of fast-moving gas, one from each side, and that energetic electrons within the blobs were emitting radio waves circularly polarized in opposite directions. As Ray and colleagues explain in *Nature* for January 30th, the most likely cause for such diametric polarization is a strong magnetic field. Ray's team plans to monitor the T Tauri S outflow as it expands away from the star, perhaps getting the chance to observe other aspects of the star-formation process.

In Brief

• An international team of specialists has found no evidence for a 50-meter-wide **impact crater in Honduras,** despite reports to the contrary following a spectacular bolide last November 22nd (March issue, page 12). According to Jiri Borovicka (Ondřejov Observatory) and María Cristina Pineda de Carías (National Autonomous University of Honduras), that fireball had a peak apparent magnitude of –19 to –21 — roughly a thousand times brighter than the full Moon! The event probably resulted in sizable meteorites near the Honduras-Guatemala border, though none has been recovered yet.

• The U.S. Naval Observatory plans to add a **leap second** to the world's clocks on June 30th at 23 hours 59 minutes 59 seconds Coordinated Universal Time (UTC). Since 1972, leap seconds have been added to the world's atomic clocks when needed to account for the Earth's slowing rotation. According to USNO, the last leap second was added in 1995.

• Further evidence for **intergalactic stars** has been winnowed from the Fornax Galaxy Cluster with the help of the New Technology Telescope in Chile. Tom Theuns (University of Oxford) and Stephen J. Warren (Imperial College of Science, Technology, and Medicine, London) have found what appear to be 10 planetary nebulae (the halos of dying, low-mass stars) between the cluster's galaxies. In the January 21st *Monthly Notices* of the Royal Astronomical Society, the researchers infer that as many as 40 percent of the cluster's trillions of stars lie between, rather than within, its galaxies. This parallels Hubble Space Telescope findings in the Virgo Cluster (May issue, page 18).

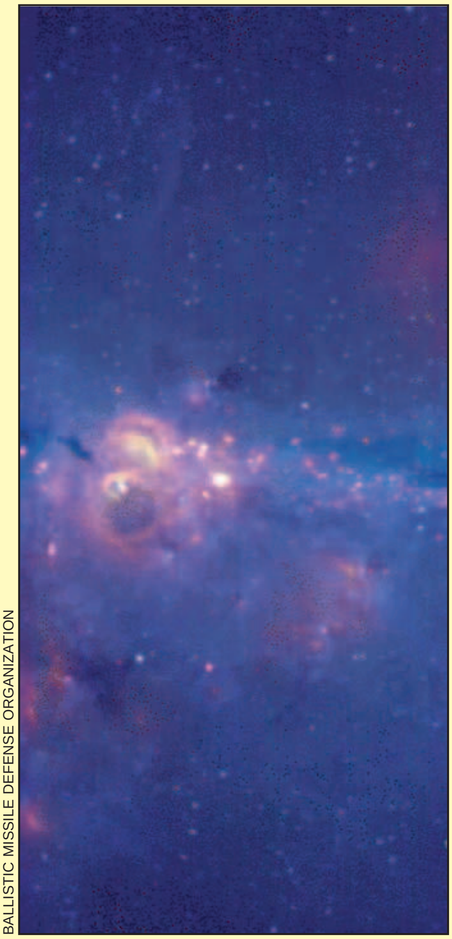
• Princeton University's **Robert H. Dicke** died at age 80 on March 4th. A multifaceted physicist who made fundamental contributions to the development of radio astronomy, Dicke was perhaps best known for formulating alternatives to Einstein's general theory of relativity.

MISSION UPDATE

By Jonathan McDowell

Midcourse Space Experiment

The infrared telescope aboard the Midcourse Space Experiment (MSX) has made a detailed map of the galactic plane. Stars and nebulae crowd together so closely in this region that the Infrared Astronomical Satellite was unable to tell them apart during its 1983 all-sky survey. MSX's higher-resolution observations thus provide our first comprehensive census of infrared objects along the plane of the Milky Way. In January, MSX scientists presented spectacular wide-angle views of the galactic center (see the example at right). Unfortunately the satellite's infrared observations have now come to a halt; the telescope's solid-hydrogen coolant ran out on February 26th.



BALLISTIC MISSILE DEFENSE ORGANIZATION

The MSX satellite made this 1°-wide map of the galactic center at infrared wavelengths between 6 and 20 microns. Emissions from stars, warm dust, and cool dust have been colored blue, green, and red, respectively. The brightest spot is the nucleus of the Milky Way.

Mars Global Surveyor

NASA's Mars Global Surveyor is now about halfway to its destination. The spacecraft will enter Martian orbit on September 12th, some two months after the July 4th landing of Pathfinder, also now en route to Mars. Surveyor's camera has passed several tests during its interplanetary cruise, taking pictures of the Pleiades and other targets.

Mir

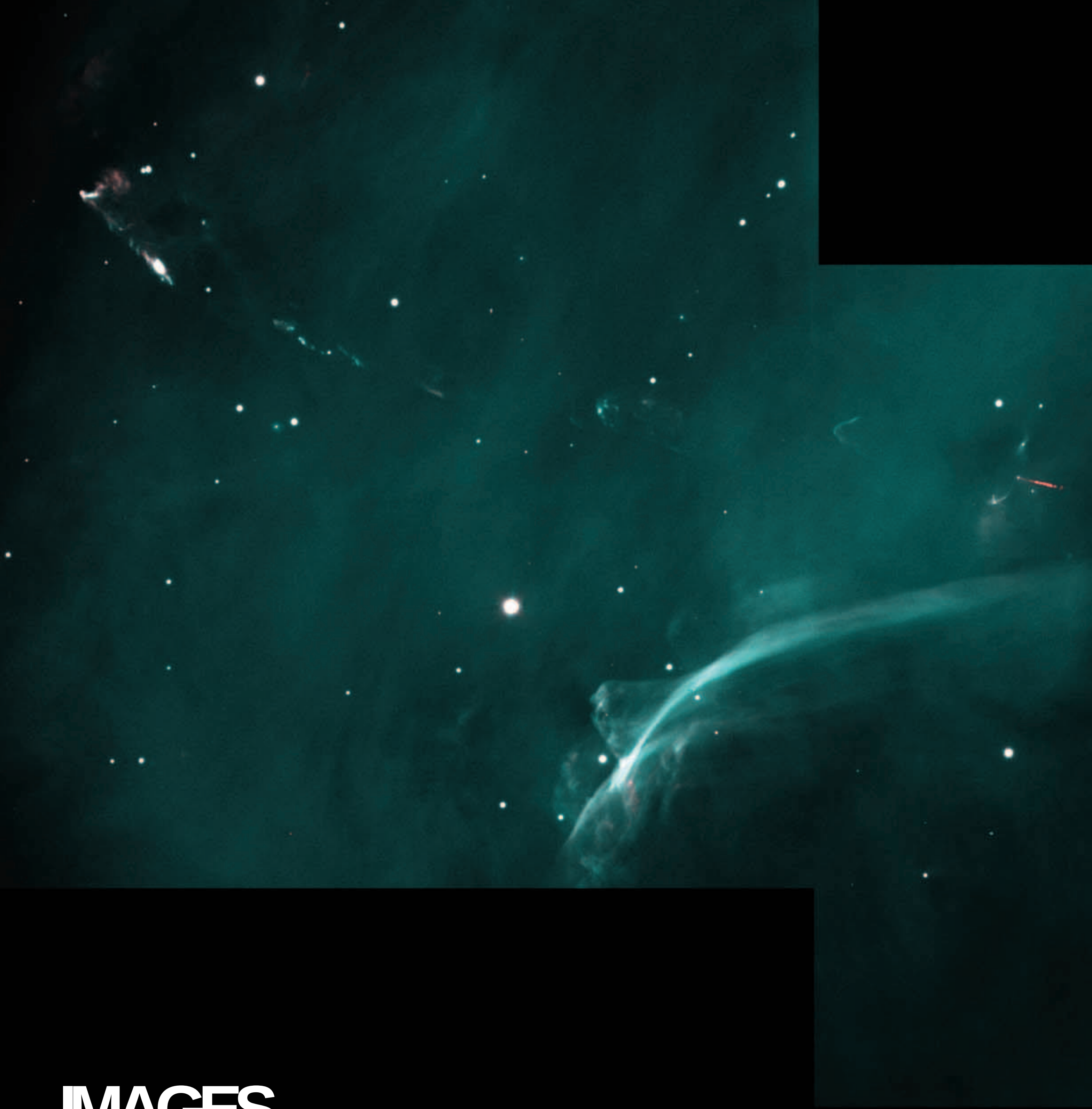
The Russian space station's 12th year in orbit got off to a shaky start in February when an oxygen generator caught fire in the Kvant ("Quantum") astrophysics module. Although the blaze was extinguished quickly, the cabin filled with smoke and the six Russian, American, and German crew members had to don oxygen masks temporarily. Then, in March, other life-support equipment broke down and a robotic supply ship failed to dock with the station. All these problems forced the crew to breathe oxygen from their reserve supply as they awaited the arrival of another cargo ship in April.

Galileo

NASA has extended Galileo's tour of the Jupiter system for another two years. After its primary mission ends in December, Galileo will concentrate on exploring icy Europa, with several close flybys planned.

Since last November, when the orbiter flew by Callisto, it has made almost monthly passes near the giant planet's moons. Galileo visited Europa for the first time on December 19th, swung around Jupiter in January, then encountered Europa again in late February. Ganymede was due for successive visits in April and May. After another flyby of Callisto in June, Galileo will head farther out to explore Jupiter's magnetotail before returning to the inner satellite system in September. The extended mission will end in 1999 with a close pass of Io.

An astronomer at the Harvard-Smithsonian Center for Astrophysics, McDowell writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).



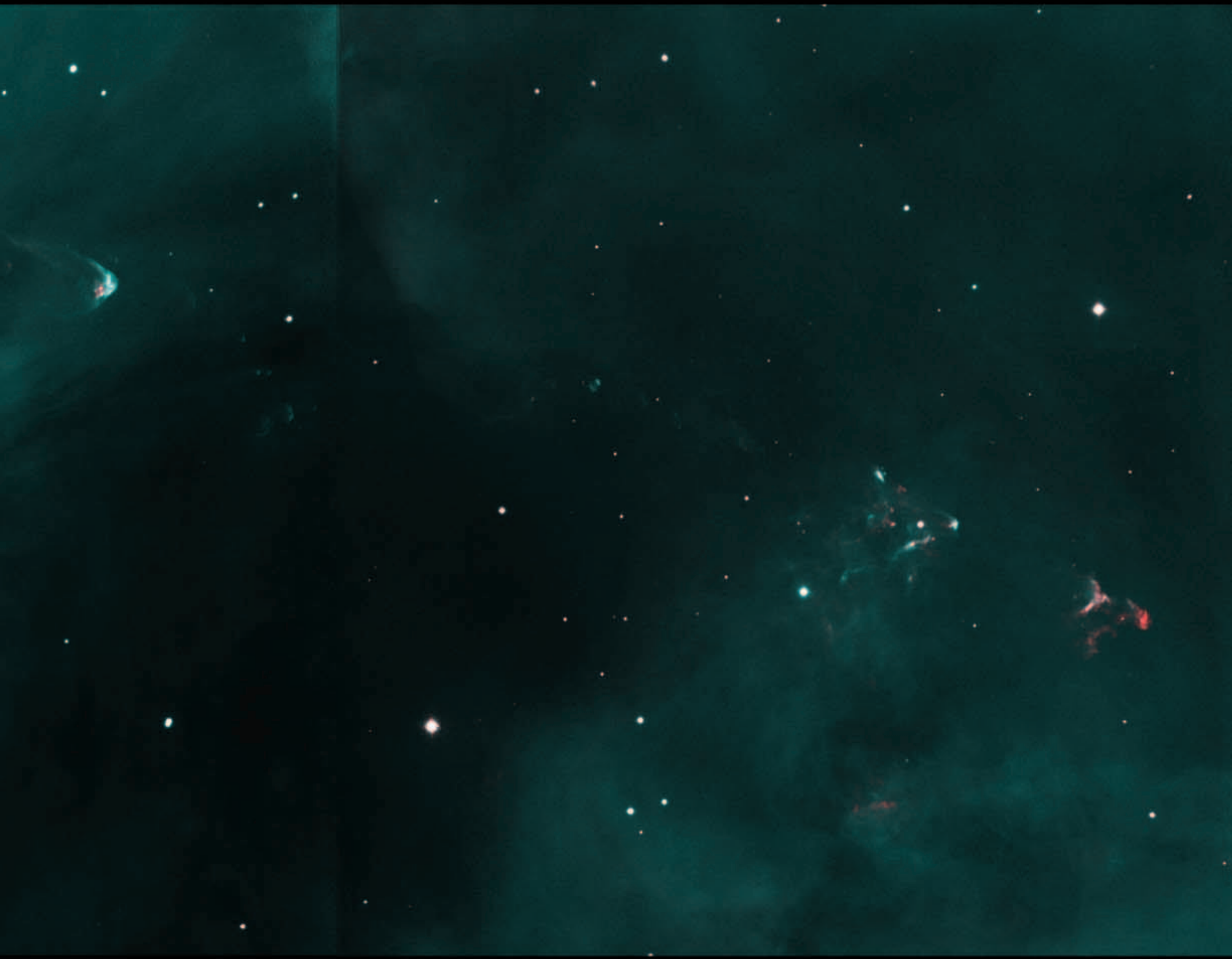
IMAGES

THE BIRTH of a low-mass star can drive spectacular jets of gas many light-years into the surrounding interstellar medium, culminating in bright nebulae called Herbig-Haro (HH) objects. These glowing rims are shock fronts produced where the supersonic jets plow into slower gas.

This image shows a chain of HH objects emerging from a young star about 1° south of the Great Orion Nebula. The star is still embedded in the molecular cloud from which it formed. Infrared observations locate it at the left end of the linear red feature near center — a jet emerging from the star at 300 kilometers per second. The very small reflection nebula near the jet's north (left) end is illuminated by the hidden star.

To the right the jet points directly at HH 34, the small, bright blue-green parenthesis south of the star. A similar but fainter feature is an equal distance north of the star. A long chain of more complicated HH objects extends 9 light-years toward both edges of the image. To the north the chain terminates in a bright complex containing HH 33 and HH 40. A group of highly fragmented objects (HH 86, 87, and 88) marks the opposite end of the outflow.

Comparison of images made about five years apart show that these HH objects are moving away from the young star at

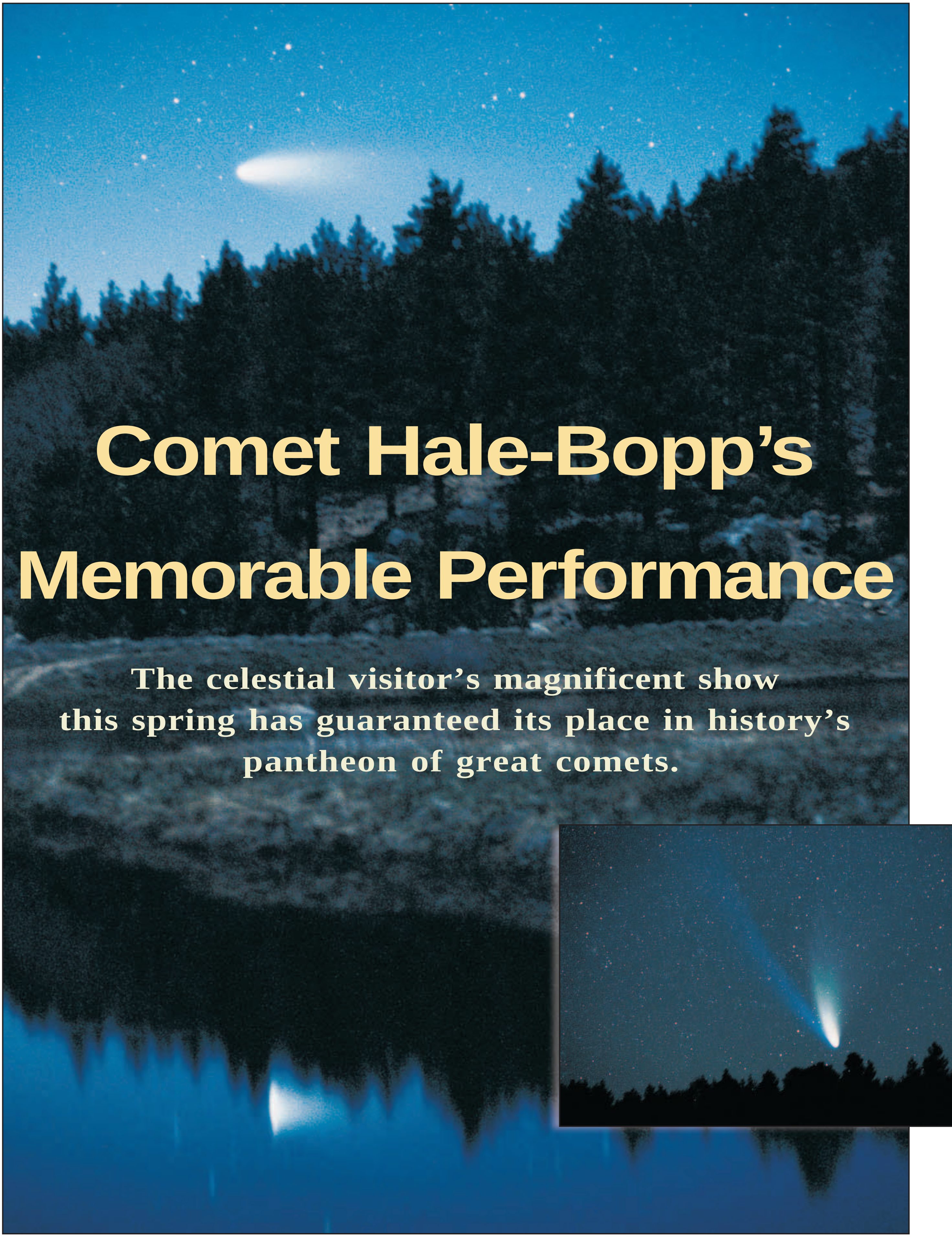


speeds ranging from 50 km per second for the most distant (and therefore oldest) knots to about 300 km per second for those near the source. Investigation of such flows may provide a glimpse into the ejection, and therefore the accretion, history of young stars. The slight misalignment of the HH objects most distant from the young star may have been produced by precession of the jet axis on a time scale of 10,000 to 100,000 years.

The bright blue-green arcs of nebulosity at lower left are HH 222, not related to the HH 34 outflow. The fainter wreaths of nebulosity lacing the entire image may be outlying portions of the Great Orion Nebula.

This image was obtained in January 1994 with a 2,048-pixel-square CCD camera on the European Southern Observatory's 3.5-meter New Technology Telescope on the summit of La Silla in Chile. Narrowband filters were centered on hydrogen-alpha emission (colored here blue-green) and singly ionized sulfur (red). The three mosaicked fields cover 22 arcminutes (10 light-years) in the north-south direction and about 8 arcminutes (3 light-years) east to west. Courtesy David Devine, John Bally (University of Colorado, Boulder), and Bo Reipurth (European Southern Observatory).

JOHN BALLY



Comet Hale-Bopp's Memorable Performance

The celestial visitor's magnificent show this spring has guaranteed its place in history's pantheon of great comets.

NOT SINCE 1957, when comets Arend-Roland and Mrkos blazed across the heavens less than four months apart, have astronomy enthusiasts enjoyed such back-to-back cometary spectacles. And those two were only 1st magnitude. Comets Hyakutake (C/1996 B2) and Hale-Bopp (C/1995 O1) gave their greatest performances exactly a year apart. Peaking at about magnitudes 0 and –1, respectively, they outshone everything in the night sky except the Moon and the brightest planets and stars.

For anyone who has gotten into astronomy later than 1976, Hyakutake and Hale-Bopp presented the first opportunities to see a bright comet at all. They were a study in contrasts. Unlike Hyakutake's naked-eye show, which lasted only a few weeks, that of Hale-Bopp has already spanned several months and as of early May could still be going strong.

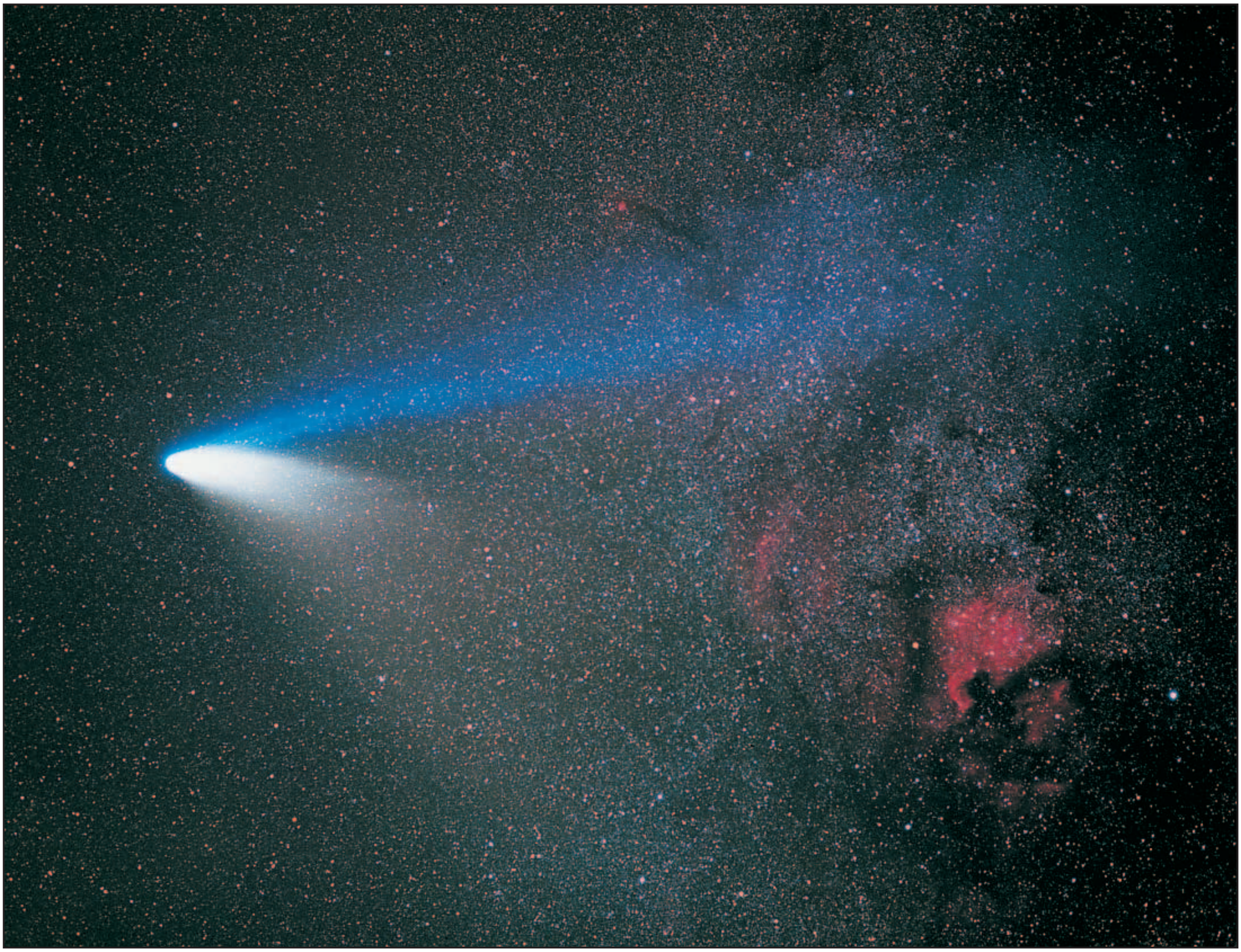
By April Fool's Day Hale-Bopp had reached magnitude –0.8 as it finally passed through perihelion 0.914 astronomical unit (137 million kilometers) from the Sun. The comet was then traveling at its fastest — more than 158,000 kilometers (98,000 miles) per hour.

And we just missed a bigger spectacle. "If C/1995 O1 had passed perihelion exactly four months earlier," noted Daniel W. E. Green (Central Bureau for Astronomical Telegrams), "it would have been visible all night long for Northern Hemisphere observers during early January, at a distance from Earth of only 0.11 a.u. and shining at a visual magnitude

By Edwin L. Aguirre

Left: **The Great Comet of 1997. Hale-Bopp's tail was oriented quite differently with respect to the horizon at dusk and at dawn, as shown in this pair of photographs by Jerry Schad in California's Laguna Mountains. The larger image shows the comet setting in the northwest after dusk on March 17th, while the smaller one on the right has it rising in the northeast the following morning. Schad used an 85-mm f/1.7 lens and Kodak P1600 film for the 30- and 60-second exposures, respectively. Note Hale-Bopp's reflection on the lake surface at lower left.**

Above: **Loke Kun Tan captured this view of Hale-Bopp on March 19th from California's Joshua Tree National Monument. Tan used an 8-inch f/1.5 Schmidt camera and gas-hypersensitized Kodak Ektar 25 film for this 6-minute exposure. The comet then was 141 and 198 million kilometers from the Sun and Earth, respectively. According to David G. Schleicher (Lowell Observatory), in late March Hale-Bopp was releasing approximately 1,000 metric tons of dust and 130 metric tons of water every second. North is to the upper right in this 2½° by 4½° field.**



Comet Hale-Bopp's blue ion tail extends more than 12° across the Cygnus Milky Way in this wide-field shot by Tony Hallas from Mount Pinos, California, last March 8th. Hallas combined two 5-minute exposures taken with a 165-millimeter f/4 lens and hypered 120-format Kodak Pro 400 PPF film to create the final image. The bright star at lower right is Deneb; the brightest red patch to its left is the North America Nebula. IC 5146, the Cocoon Nebula, is the tiny scarlet glow above the ion tail. North is to the upper right.

brighter than –5, or about as bright as a crescent Moon." Hale-Bopp would have spanned the sky, cast shadows at night, and been visible with the unaided eye during the day!

Even so, Hale-Bopp remained a splendid naked-eye object throughout April, conveniently placed in the northwest to west-northwest after dusk. A large fraction of the human race undoubtedly witnessed it.

The first day of May finds a somewhat faded comet glowing very low at the end of evening twilight, more than $^{2}/_{3}$ of the way from Capella down to Aldebaran. It should still be shining at about 1st magnitude, but its elongation from the Sun has decreased to 32°, and it is descending into the glow of sunset. On May 8th, look for it 4° to 5° to the upper right of the two-day-old waxing crescent Moon. The pair may present a fine binocular sight in late dusk.

Hale-Bopp enters Orion on May 19th. Viewing it becomes a real challenge by then as the comet moves deep into bright twilight. By the last week of May observers at midnorthern latitudes will have lost it in the solar glare. Skywatchers somewhat farther south can follow it a bit longer.

> **"This comet has a good chance to be the best-observed comet in the history of mankind." — Daniel W. E. Green**

The comet show, however, is just beginning to get better for observers south of the equator. On June 1st observers in the tropics will find the comet setting in the west roughly an hour and 15 minutes after the Sun, while those at latitude 30° south will see it linger for about 15 minutes longer.

Hale-Bopp continues its southeastward trajectory throughout June, crossing from Orion into Monoceros on the 17th. By the end of the month the comet will be centered inside the Winter Triangle formed by Sirius, Betelgeuse, and Procyon. Its path through August 1st is plotted in the March issue, page 38.

Except for perhaps Halley, Hale-Bopp may be the most-photographed and best-studied comet to date. For more than a year *Sky & Telescope* has been receiving hundreds of images and observing reports from amateur astronomers, and these reached a crescendo in March and April. As the comet brightened to naked-eye prominence, media attention and public interest increased proportionately. Hale-Bopp received worldwide headline-news coverage from the press, radio, television, and the Internet. "Given all the media attention," says Green, "this should be the most widely observed comet in history, in terms of millions of people having a look at their first comet."

Hale-Bopp-related Web sites, such as SKY Online's Comet Page (http://www.skypub.com/comets/comets.html) and also Charles Morris's Comet Observation Home Page (http://encke.jpl.nasa.gov/), reached saturation levels as uncounted hundreds of thousands of browsers found themselves unable to get in through the logjams.

Greg Mort of Ashton, Maryland, sketched this closeup of Hale-Bopp on March 9th with a 6-inch Jaegers f/15 refractor at 80x. Note the barred spiral-like feature near the comet's pseudonucleus. (Compare this drawing with the electronic image at bottom left, which is oriented slightly differently.) North is to the upper left and the Sun to the lower right in this nearly ½°-wide field. Hale-Bopp's multiple dust shells reminded observers of Comet Donati's famous hoods as drawn by George P. Bond at the Harvard College Observatory in September 1858.

FOUNTAIN, SHELLS, AND BANDS

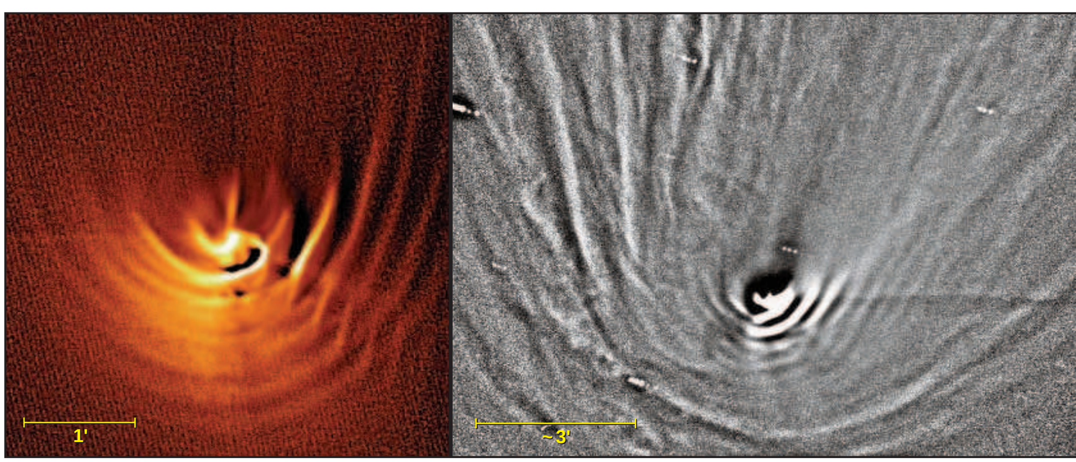
As Hale-Bopp neared perihelion, the comet awed its loyal observers with dramatic displays of its rapidly evolving telescopic features. The great fountain of material that came off the southwestern side of the pseudonucleus had faded from view by late March, though a bright streamer in the dust tail remained (see page 28 of last month's issue). At the same time, telescopes as small as 2½ inches showed at least three bright, evenly-spaced concentric shells or envelopes on the sunward side of the pseudonucleus. Some viewers described them as "like ripples in a pond of light."

Observing with a 16-inch reflector at 114× on March 24th, *Sky & Telescope* columnist John E. Bortle reported "three envelopes at estimated intervals of 75", 52", and 26" sunward of the pseudonucleus. The innermost is connected to the pseudonucleus by a short bar of bright material near its western end; on the opposite side of the pseudonucleus is another hook-shaped extension directed eastward. Overall, their appearance is very much like that of a barred spiral galaxy."

Contrary to popular belief, these shells were not bow waves or shock waves produced by Hale-Bopp's rapid motion, but rather the result of active vents on the comet's spinning, tumbling nucleus being periodically carried in and out of direct sunlight. When heated, they shoot tremendous amounts of gas and dust that gradually spread to form the envelopes. Their complex, asymmetric forms were due to the combined effect of the geometric positions of the vents, the ejection velocity of the material, the rotation and precession (wobbling) of the nucleus, and other factors.

Structure was also seen and imaged in Hale-Bopp's dust tail. Wide-field photographs taken with Schmidt cameras and medium telephoto lenses, such as the one on page 32, showed a set of nearly parallel bright streaks called *synchronic bands* in the tail. Their overall appearance resembled the famous banded dust tail of Comet West in 1976 (*S&T:* July 1996, page 33). Each synchrone represents an outburst of dust at a specific moment. The blob of material then becomes sorted by size to form a long, narrow streak, with the smaller or less dense particles being driven farther into space by solar radiation pressure.

H. Fukushima (Japan National As-



These computer-enhanced CCD images show the series of dust and gas shells or envelopes expanding radially from Hale-Bopp's nucleus. The shells are formed as active vents on the nucleus surface rotate in and out of direct sunlight. *Left:* This near-infrared image was made by James A. DeYoung on March 24th with the U.S. Naval Observatory's 0.61-meter reflector in Washington, D.C. A total of 150 2-second exposures were digitally combined for this composite view. The March 15th image *(right)*, taken in the light of ionized carbon monoxide (CO^+), was recorded by Stephen M. Larson and Carl W. Hergenrother (University of Arizona) with Steward Observatory's 2.3-meter telescope at Kitt Peak, Arizona. According to Larson and Hergenrother, the "complex, wavy outer structure is caused by CO^+ ions being driven back into the tail by the solar-wind magnetic field. The ion features change on a time scale of minutes." North is up and east to the left in both images.

tronomical Observatory) and his co-researchers first reported the detection of Hale-Bopp's synchronic bands on March 6th. "The characteristics of these bands are similar to those that appeared in the dust tail of several great comets, such as West 1976 VI, Ikeya-Seki 1965 VIII, Seki-Lines 1962 III, and Mrkos 1957 V, although these were observed when the comets' heliocentric distances were smaller than 0.5 a.u. It is remarkable that Comet Hale-Bopp shows synchronic bands at a larger heliocentric distance of 1 a.u."

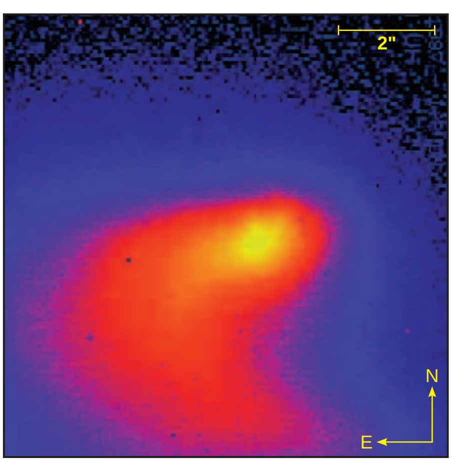
Gregory Terrance of Lima, New York, obtained this contrast-enhanced CCD image of Hale-Bopp on March 18th. Terrance used a 200-mm f/4 lens and a Finger Lakes Instrumentation IMG1300 camera for the 6-minute exposure. Note the multiple fine striations or *synchronic bands* in the comet's dust tail. The downward-pointing glow projecting from Hale-Bopp's head is an image artifact. North is up, and the field measures 5° wide.

A SCIENTIST'S COMET

Since its discovery in July 1995, Hale-Bopp has been observed with a wide array of ground-based and orbiting instruments. Its anatomy and chemical makeup have been examined in unprecedented detail at virtually all wavelengths, from radio to X-rays. "Comet Hale-Bopp is certainly meeting all our expectations," says Michael J. Mumma (NASA/Goddard Space Flight Center). "It is providing a scientific bonanza, and it is also a wonderful sight!"

David C. Jewitt (University of Hawaii), who has been observing the comet with the 15-meter James Clerk Maxwell Telescope atop Mauna Kea, Hawaii, agrees. "Comet Hale-Bopp is without doubt the brightest and most scientifically rewarding comet ever studied in the millimeter-to submillimeter-wavelength regime."

Hale-Bopp's brightness and size in March and April did pose some unusual problems for astronomers. By mid-March, as it brightened past the magnitude-0.0 mark, even experienced amateurs had difficulty finding appropriate comparison stars to judge Hale-Bopp's naked-eye brightness. Among the objects used for reference in late March and early April were Jupiter (magnitude –2.0), Sirius (–1.5), Mars (–1.2), and Mercury (–0.5 to 0.0).



Alan Tokunaga and Roland Meier (University of Hawaii) recorded this infrared (36,720-angstrom) image of Hale-Bopp at noontime last March 8th with NASA's Infrared Telescope Facility atop Mauna Kea, Hawaii. The false-color image "depicts heat emitted by the dust: the brighter the color the more dust is present."

Nor were their professional counterparts spared. "As a consequence [of Hale-Bopp's brightness] it is becoming difficult to obtain images of it with the large telescopes on Mauna Kea," said Alan Tokunaga and Roland Meier (University of Hawaii), who observed the comet with NASA's Infrared Telescope Facility (IRTF) in early March. "The detectors are saturated by this bright object, even when we are using the shortest possible exposure times. Moreover, it is now so extended that it will not fit in the small field of view of our instruments. At this point, anybody with small telescopes and even binoculars can get a more dramatic view of the comet than we can!"

A series of four Black Brant IX sounding rockets were launched by the U.S. Navy for NASA beginning March 25th at White Sands Missile Range near Alamogordo, New Mexico. The two-stage rockets carried spectrographs and polarimeters to observe Hale-Bopp in the ultraviolet for 5 to 10 minutes from an altitude of 300 to 400 km. (Preliminary results and images are posted on NASA's Hale-Bopp Web site at http://www.wff.nasa.gov/~web/comet.html.) To complement these suborbital flights, NASA will also fly an instrument package onboard the space shuttle *Discovery*'s STS 85 mission this July. Called the Southwest Ultraviolet Imaging System, the experiment will probe the comet more extensively during the shuttle's 11-day mission.

NASA's Hubble Space Telescope made a series of observations of the comet, particularly the nuclear region, from September 1995 to October 1996. "Unfortunately, HST will not be able to observe Hale-Bopp again until August 25th at the earliest," says Harold Weaver (Johns Hopkins University), one of the imaging scientists. "Observations with HST require that the comet-Earth-Sun angle (that is, the solar elongation angle) be at least 50° or more." This restriction is designed to prevent sunlight from damaging the telescope's ultrasensitive instruments. So Hubble missed out completely during Hale-Bopp's best months.

As Comet Hale-Bopp begins its long journey back into the outer fringes of the solar system, preparations are under way for a special session in the comet's honor during the 23rd General Assembly of the International Astronomical Union (IAU) on August 18–30 in Kyoto, Japan. Researchers are expected to unveil a slew of findings. (For details contact Toshio Fukushima, Japan National Astronomical Observatory, 2-21-1, Ohsawa, Mitaka, Tokyo 181, Japan; e-mail: iau97@tenmon.or.jp; World Wide Web: http://www.tenmon.or.jp/iau97/.)

A summary of Hale-Bopp's apparition, including the latest images, observations, and science results, will appear in next month's issue. For late-breaking news call Skyline, *Sky & Telescope*'s weekly three-minute recording at 617-497-4168, or access SKY Online's Weekly News Bulletin.

As Hale-Bopp's performance becomes a memory, astronomers agree that this visitor will go down in history as the Great Comet of 1997. Unless, of course, a more spectacular one is discovered between now and the end of the year!

House Call for Hubble

New science instruments and other assorted upgrades have rejuvenated the Hubble Space Telescope for three more years of astronomical service.

By Stuart J. Goldman

THE ASTRONAUTS aboard Space Shuttle *Discovery* last February were off to meet a familiar friend — the Hubble Space Telescope (HST). Astronomer-astronaut Steven A. Hawley had released the telescope into orbit in 1990, and commander Kenneth D. Bowersox had steered the shuttle during the first mission to service Hubble in 1993. And their crewmates who had not flown with the telescope before had trained so long and hard for this second round of equipment upgrades that they, too, felt as if they knew the spacecraft intimately.

During the 11-day mission of STS 82, as shown in the accompanying images, the anticipated tasks of installing new science instruments and other components were successfully completed in four planned space walks (February issue, page 42). But the astronauts also made a fifth excursion, to tidy up the telescope by repairing frayed insulation.

HST was sent on its way again on February 19th with improved capabilities for eager astronomers below. Only two weeks later scientific observations resumed, but not with the new instruments, which were still being checked and calibrated. On March 25th, NASA announced that the new Near Infrared Camera and Multi-Object Spectrometer (NICMOS) isn't working up to specs. One of the instrument's three cameras can't be focused — possibly because the solid-nitrogen coolant is warping its optical path.

Sky & Telescope will feature images and other results from HST's new instruments in upcoming issues.

Above: **Astronauts Steven L. Smith (left) and Mark C. Lee approach the Hubble Space Telescope to begin work. During each space walk, one astronaut rode the end of the shuttle's robotic arm while the other wore a tether to the spacecraft. All photographs courtesy NASA.**

Facing page, left: **NASA's repair schedule set the highest-priority maintenance for the first space walk: swapping two old refrigerator-size science instruments inside the telescope for two fresh ones. The Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) will deepen and widen Hubble's view of the universe. Here, Steve Smith grapples the Goddard High Resolution Spectrograph after removing it from the telescope. It and another of Hubble's original instruments, the Faint Object Spectrograph, were brought back to Earth in the shuttle's cargo bay.**

Facing page, right: **Joseph R. Tanner wields one of Hubble's original Fine-Guidance Sensors during the second space walk. In the background, Gregory J. Harbaugh examines the cavity where its replacement will be installed. The new instrument compensates for Hubble's misshaped primary mirror.**

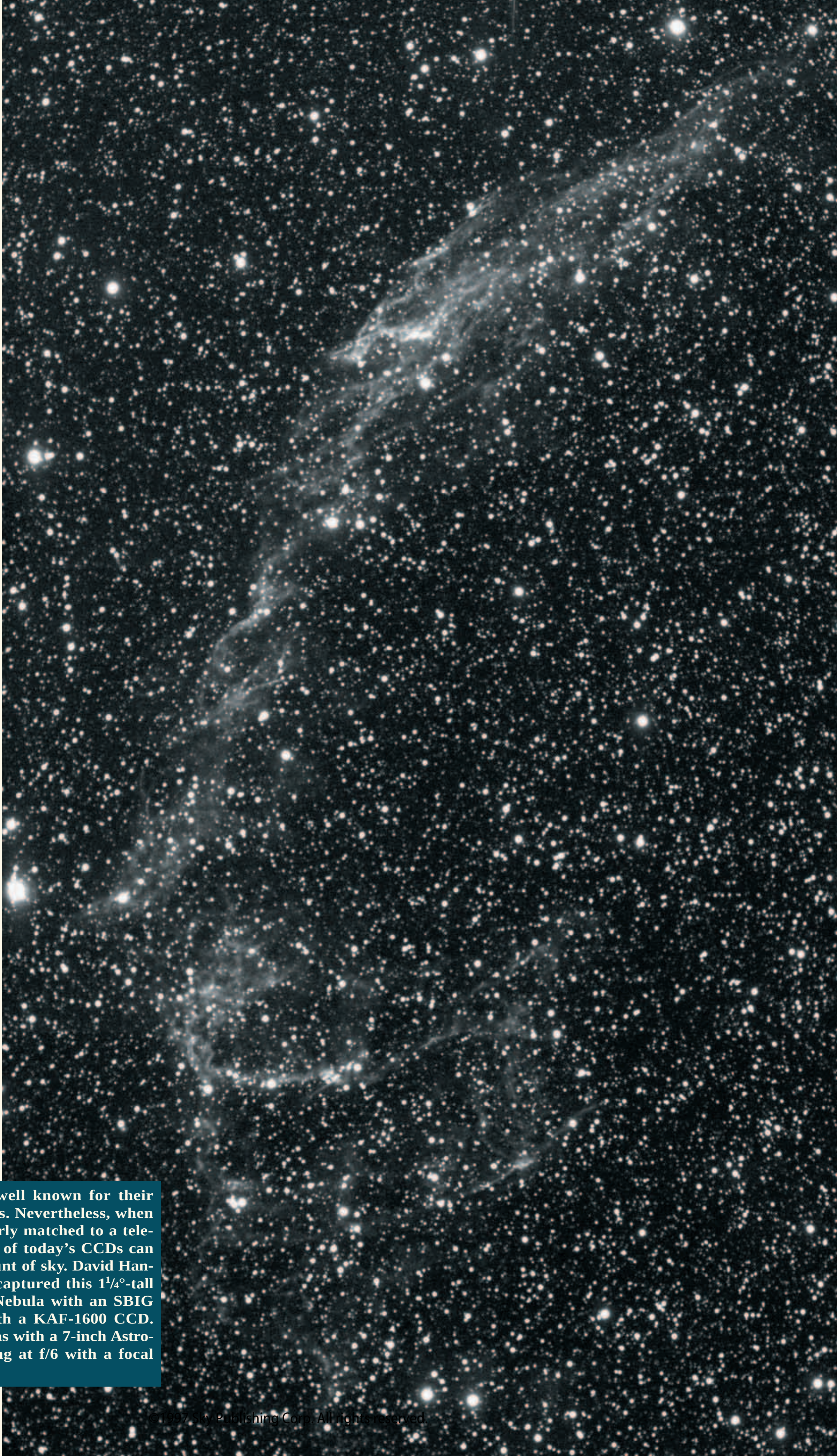
Right: **The crew of STS 82's 1997 Hubble tune-up team pose on *Discovery*'s flight deck. In the front row are (left to right) pilot Scott J. Horowitz, commander Kenneth D. Bowersox, and mission specialist Steven A. Hawley; in the back row are (left to right) mission specialists Steven L. Smith, Gregory J. Harbaugh, Mark C. Lee, and Joseph R. Tanner.**

Left: **Inspection of HST's surface revealed numerous tears in its protective insulation. Rather than wait until the next refurbishment mission in 1999, the astronauts embarked on an unplanned fifth space walk to patch the rips. They had to improvise the repairs using wire, foil, parachute cord, and other materials found aboard the shuttle.** ***Right:*** **Shuttle pilot Scott Horowitz uses a pocketknife to prepare one of the patches.**

With all planned and unplanned maintenance complete, the Hubble telescope is lifted out of *Discovery's* cargo bay to resume astronomical observations.

Before you purchase a CCD, weigh the options possible when focal reducers are added to the imaging system.

CCD ASTRONOMY



Digital cameras are not well known for their wide-field imaging abilities. Nevertheless, when a chip's pixel size is properly matched to a telescope's focal length, some of today's CCDs can cover a considerable amount of sky. David Hanon of Ringgold, Georgia, captured this $1\frac{1}{4}°$-tall view of the eastern Veil Nebula with an SBIG ST-8 camera equipped with a KAF-1600 CCD. His 20-minute exposure was with a 7-inch Astro-Physics refractor operating at f/6 with a focal reducer.

Of Pixel Size & Focal Reducers

THE SCENE PLAYED with the predictability of a well-rehearsed script. On a half dozen occasions last summer visitors stopped by while I was testing two high-end digital cameras. Each knew about the Kodak KAF-1600 and KAF-1000 CCDs in these cameras, but none had seen them firsthand. Handing each person the first camera, I would click the computer's mouse to snap open the shutter and reveal the Chiclet-size KAF-1600. With almost 20 times the imaging area of chips in early cameras marketed to amateur astronomers, this CCD impressed everyone.

Nevertheless, when the shutter clicked open on the KAF-1000 camera, jaws dropped. "Now *that's* a CCD!" exclaimed one guest. Measuring 1 inch square, this chip offers only slightly less imaging area than a frame of 35-millimeter film. While everyone was predictably fascinated by this expensive bit of silicon real estate, blank stares followed my comment that, at a given resolution, I could capture more sky with the KAF-1600 despite its substantially smaller size.

How can this be? Even a quick glance reveals the KAF-1000 to be considerably larger — 4.65 times, to be precise — than the KAF-1600. The key to this paradox, however, was my qualifying statement that *at a given resolution* the KAF-1600 covers more sky.

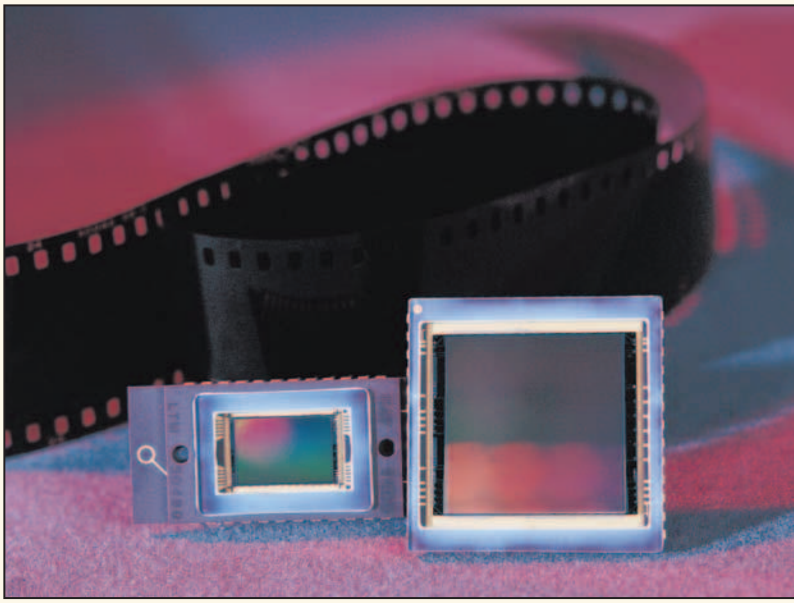
Most of us photographers never think much about resolution. Today's emulsions have relatively fine grain, and we use the same film with telescopes big and small. As such, the larger the piece of film, the more sky will be captured up to the point where optical or mechanical considerations limit the field of view.

CCDs, however, are a different story. Pixels — the individual, light-sensitive picture elements that make up the checkerboard array of a chip's imaging area — come in many sizes. The detectors found in today's popular cameras have square or slightly rectangular pixels ranging from about 7 to almost 30 microns (thousandths of a millimeter) across. The best results occur when a pixel's size is matched to a telescope's resolution under a given set of observing conditions. For example, conventional wisdom suggests that the astronomical seeing conditions experienced by a typical backyard observer will produce excellent deep-sky images with pixels that cover about 2 arcseconds (2") of sky.

With this criterion established, the paradox is quickly resolved. If you adopt a given pixel scale such as 2" for deep-sky imaging, then you need only remember that the more pixels a chip has the more sky it will cover regardless of the chip's physical size.

Consider the CCDs mentioned above. The KAF-1000 has 1 million 24-micron pixels arranged in an array measuring 1,024 pixels on a side. At 2" per pixel, the

By Dennis di Cicco



Even a glance reveals the dramatic difference in physical size between the Kodak KAF-1600 (left) and KAF-1000 chips. But, as explained in the text, at a given resolution the KAF-1600's 1.6 million pixels can cover 60 percent more sky despite having only about one-fifth the area of the KAF-1000.

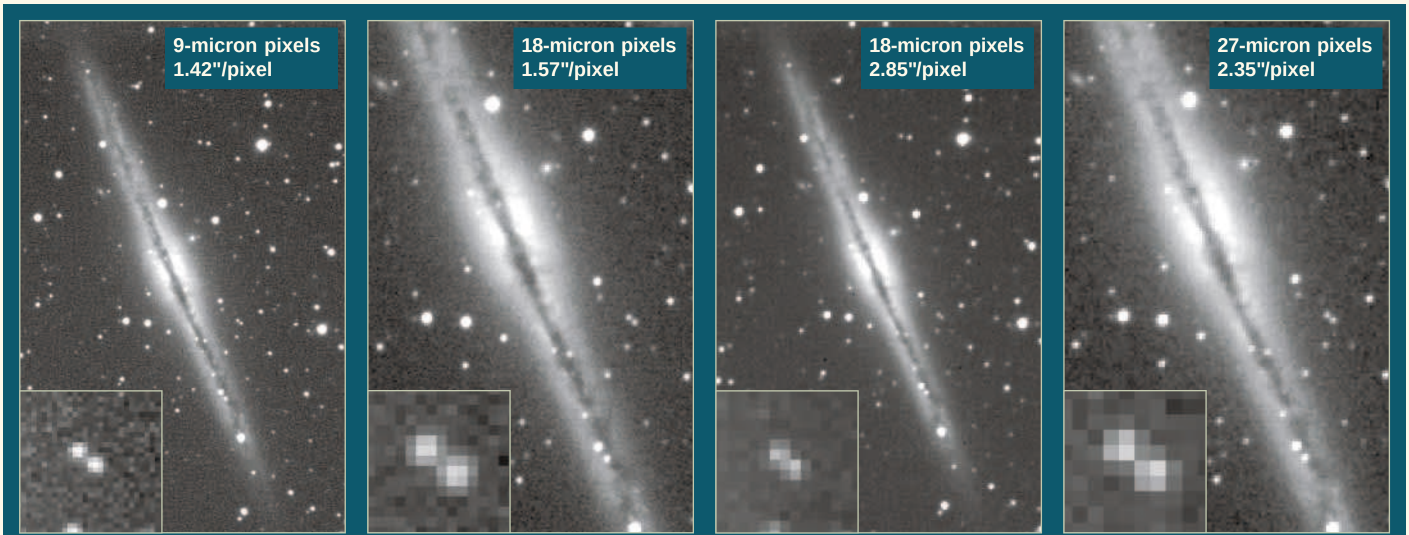


Image scale, not pixel size, controls the resolution of digital images. To illustrate this point, the author made these pairs of 3-minute exposures of the edge-on spiral galaxy NGC 981 in Andromeda with a Meade 16-inch LX200 Schmidt-Cassegrain telescope and SBIG ST-7 camera equipped with a KAF-0400 CCD. By changing focal reducers and binning pixels, roughly similar pixel scales were obtained at focal lengths of 1,303 and 2,365 millimeters (f/3.21 and f/5.85, respectively). Note that the resolution at a given scale is independent of pixel size. The shorter focal length covered about four times more sky than the longer one. *Insets:* A 5× enlargement of the double star to the lower right (southwest) of the galaxy's nucleus. The magnitude-16½ components are separated by 5.8".

detector covers a field 2,048" (about 34') square. The KAF-1600, on the other hand, has 1.6 million 9-micron pixels assembled in a 1,552-by-1,032-pixel array. At the same scale, this chip covers a field measuring 3,104" by 2,064" (about 52' by 34'). The KAF-1600 has 60 percent more pixels than the KAF-1000 and should therefore cover 60 percent more sky.

There is a catch, however. Obtaining the same 2"-per-pixel scale for these detectors necessitates very different effective focal lengths. Indeed, the KAF-1000's larger pixels require an effective focal length of 2,475 mm (about 97 inches), while the smaller KAF-1600 pixels need only 928 mm (about 37 inches). The nomogram on this page makes simple work of determining the relationships between pixel size, focal length, and a pixel's image scale.

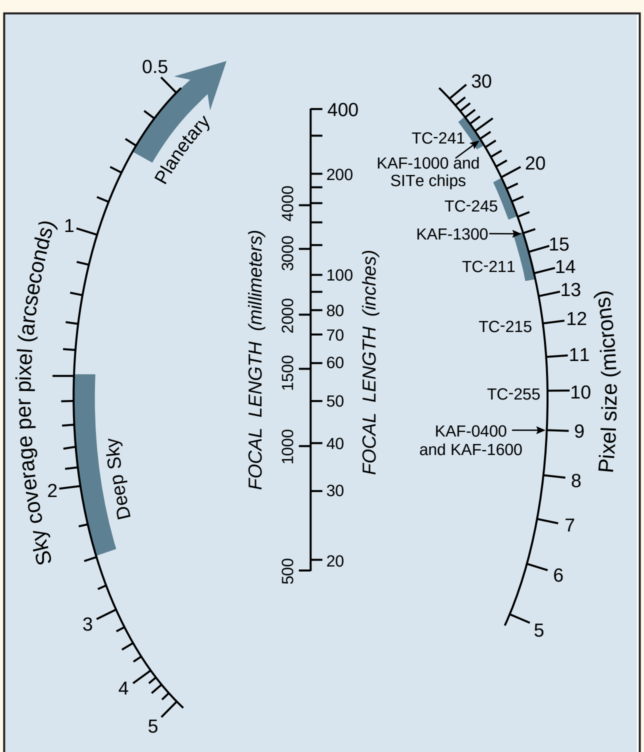
PIXEL BINNING

You might think that these parameters would be fixed for a given telescope and CCD camera. However, it is usually possible to vary both the focal length and pixel size within some limits.

Most cameras sold today offer what are called binning modes — the ability to electronically combine the signal collected by several adjacent pixels such that it appears to come from a single, larger pixel. There are several advantages of binning, including faster image readout, smaller file sizes, and greater CCD sensitivity for a given optical system. This technique is often used with long-focal-length systems, which deliver generous images scales. Unfortunately, binning also reduces a CCD's effective number of pixels.

Consider the example of 3×3 binning with the KAF-1600. The resulting 27-micron-square pixels are similar in size to those of the KAF-1000, and both chips will provide similar resolution when coupled to the same telescope. This binning, however, reduces the KAF-1600's effective number of pixels from 1.6 million to about 178,000, which is roughly one-fifth the number available with the KAF-1000 chip. In this situation the sky coverage of the KAF-1600 will be about one-fifth that of the KAF-1000, which is exactly what common sense tells us. When placed on the same telescope, the KAF-1000 covers about five times more sky than the KAF-1600 since physically it has about five times more area. Changing the binning mode of the KAF-1600 will change the resolution but not the total sky coverage.

If we want the greatest sky coverage from a given CCD, we should operate the chip in its full-resolution (unbinned)



Roger W. Sinnott developed this nomogram to show the relationship between image scale, effective focal length, and pixel size. A straight line connecting any two values passes through the third. For example, in order to have a 9-micron pixel cover 1½" of sky requires a focal length of about 50 inches. While experience ultimately dictates the best image scale for given conditions, conventional wisdom suggests that scales of 1½" to 2" are good for general deep-sky imaging, while lunar and planetary work can benefit from scales as small as ½" with apertures large enough to allow short exposures that "freeze" the astronomical seeing.

mode and select a focal length to produce the desired image scale. As mentioned earlier, for 9-micron pixels, a scale of 2" requires an effective focal length of about 37 inches. Traditionally such short focal lengths have been the domain of small apertures. While CCDs can deliver remarkably big performance with small telescopes, it's still desirable to use large apertures for deep-sky imaging. Besides, you probably want to work with your existing telescope. So from a practical standpoint the question becomes, what can be done to adjust its focal length? Fortunately, you can do a lot.

Focal reducers come in all shapes and sizes. The author feels they are one of the most important accessories for digital imaging since they are ideal for adjusting a telescope's effective focal length to a CCD's pixel size.

FOCAL REDUCERS

During the past 20 years numerous focal reducers have appeared on the market. Most observers think of these in terms of decreasing a telescope's f/number to make it "faster" photographically. But, as the name implies, these accessories work by reducing a telescope's effective focal length. They are excellent for helping match image scale and pixel size. This is especially useful for Schmidt-Cassegrain telescopes.

In the past the challenge was to design a system with high-quality images across a large field. But since CCDs are relatively small this tolerance can be relaxed, and many focal reducers suitable for digital imaging can be made from simple achromatic lenses such as those scavenged from a old pair of binoculars. (An excellent source of information about the design and function of focal reducers is an article by the late Alan Gee on page 367 of this magazine's April 1984 issue.)

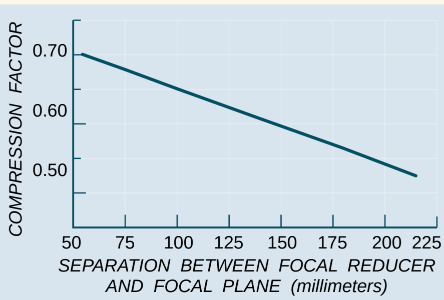
Today, however, designing a custom focal reducer is necessary only in unusual situations. Commercial units, particularly those for Schmidt-Cassegrain telescopes, offer many options — especially when the resulting focal length is tweaked by adjusting the spacing between the reducer and CCD.

Popular f/6.3 reducers sold by Celestron and Meade for their f/10 Schmidt-Cassegrains are designed to be used with a 105-mm separation between the back surface of the reducer and the detector (be it film, CCD, or whatever). As the accompanying graph indicates, altering this spacing changes the compression factor — great for fine-tuning a CCD system. Increasing the separation increases the amount of compression and thus reduces the effective focal length. Ideally we could increase the separation enough to accommodate small pixels. In practice, however, either image quality or, more likely, mechanical restrictions imposed by the telescope's focusing system will limit the amount of compression that can be obtained.

There is one notable exception. Optec's MAXfield unit is specifically designed to compress the field of an f/10 Schmidt-Cassegrain to a remarkable f/3.3 for CCD work. The spacing between the reducer and chip is critical, however, and changing it by even a millimeter degrades images. Also, the reducer has a maximum usable field about 11 mm across, too small for large chips.

There are also a few caveats for observers planning to use focal reducers with Meade's 8- and 10-inch f/6.3 Schmidt-Cassegrain telescopes. I have found that the MAXfield focal reducer, while in theory yielding an f/2 system when attached to these instruments, will not give satisfactory star images — it works only with f/10 telescopes. The f/6.3 focal reducers, on the other hand, will compress the f/6.3 telescopes to about f/4 with very acceptable results. But experience suggests that changing the spacing to obtain other compression ratios is not recommended and is the reason for the single focal-length entries in the table at left.

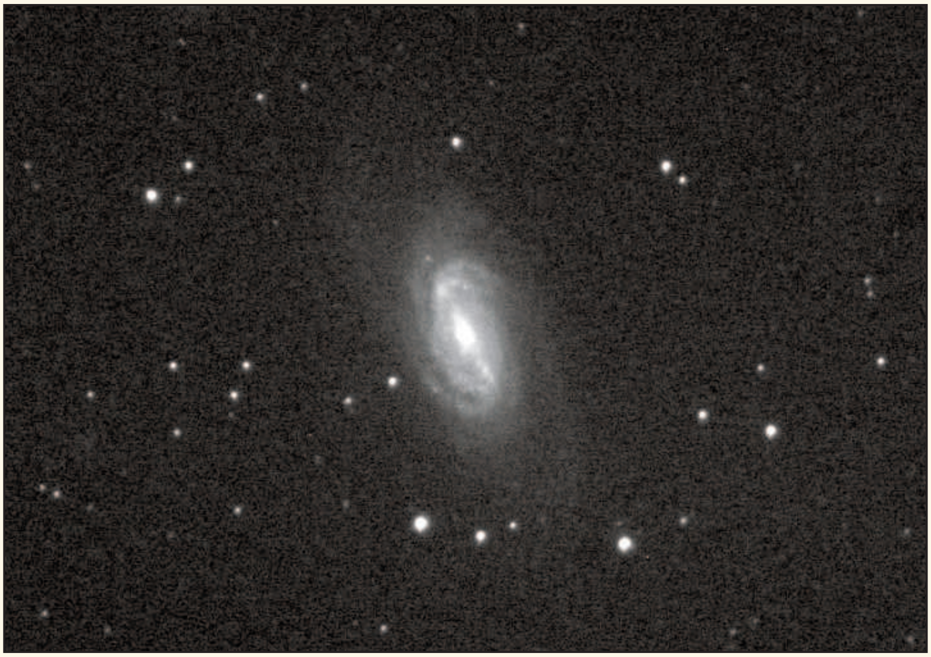
Of the many comments I've heard about focal reducers, no one has ever



The compression factor of popular focal reducers can be varied somewhat by adjusting the spacing between the reducer's back mounting surface and the CCD. The author derived this graph using Celestron and Meade f/6.3 reducers, which are designed for a spacing of 105 mm.

SCHMIDT-CASSEGRAIN FOCAL LENGTHS

Instrument	Focal length (millimeters)		
	Nominal	f/3.3 reducer	f/6.3 reducer
8" f/10	2,032	670	1,050–1,400
8" f/6.3	1,280	—	800
9¼" f/10	2,350	775	1,200–1,650
10" f/10	2,540	838	1,350–1,800
10" f/6.3	1,600	—	1000
11" f/10	2,800	924	1,500–1,950
12" f/10	3,050	1,005	1,600–2,100
14" f/11	3,910	1,290	2,050–2,700
16" f/10	4,060	1,340	2,100–2,850



Small telescopes can deliver big performance when properly coupled to today's CCDs with small pixels. This 10-minute exposure of the spiral galaxy NGC 2903 in Leo was made with a Celestron 5-inch Schmidt-Cassegrain and a focal reducer, yielding a effective focal length of 898 mm (about 35 inches). The camera's 9-micron pixels each covered 2.1" of sky, and the field is nearly ½° wide with north up.

mentioned their cost-saving benefit. Consider this example. I do much of my deep-sky imaging with a Meade 16-inch LX200 Schmidt-Cassegrain. The telescope's nominal f/10 (4,000-mm) focal length is long even for large pixels. Adding a f/6.3 focal reducer drops the effective focal length to about 2,500 mm — a good match for the 18-micron pixels available with a KAF-1600 chip binned 2×2. Such a setup would yield an image scale of 1.49" per pixel and a field of view measuring roughly 19 by 13 arcminutes.

By switching to the f/3.3 focal reducer, however, I can get nearly identical sky coverage and imaging performance from an unbinned KAF-0400 detector. This chip has the KAF-1600's same 9-micron pixels but is only one-quarter as large, with a 768-by-512-pixel array. What is really attractive about this arrangement, however, is that cameras equipped with the smaller chip cost about half as much as those with the KAF-1600, amounting to a savings of $2,500 to $3,000 depending on make and model! Similar results are possible with today's 12- and 14-inch Schmidt-Cassegrain telescopes.

SPECIFICATIONS FOR POPULAR CCDs

Manufacturer	CCD	Imaging area (millimeters)	Array format (pixels)	Pixel size (microns)	Total pixels
Kodak	KAF-0400	6.9×4.6	768×512	9×9	390,000
Kodak	KAF-1000	24.6×24.6	1,024×1,024	24×24	1,000,000
Kodak	KAF-1300	20.5×16.4	1,280×1,024	16×16	1,310,000
Kodak	KAF-1600	14.0×9.3	1,552×1,032	9×9	1,600,000
Philips	FT12	7.7×7.7	512×512	15×15	260,000
SITe	SI502A	12.3×12.3	512×512	24×24	260,000
SITe	SI003A	24.6×24.6	1,024×1,024	24×24	1,000,000
Sony	ICX027BLA*	6.4×4.3	500×256	12.7×16.6	130,000
Sony	ICX055AL*	4.9×3.6	500×256	9.8×12.6	145,000
Texas Instruments	TC-211	2.5×2.5	192×165	13.75×16	32,000
Texas Instruments	TC-215	12.3×12.3	1,024×1,024	12×12	1,000,000
Texas Instruments	TC-241*	8.6×6.5	375×242	23×27	91,000
Texas Instruments	TC-245*	6.4×4.8	378×242	17×19.75	91,000
Texas Instruments	TC-255	3.2×2.4	320×240	10×10	77,000

*An asterisk indicates the size and number of pixels as generally configured for astronomical use, since these chips actually have smaller, highly rectangular pixels originally intended for video applications.

MORE THOUGHTS

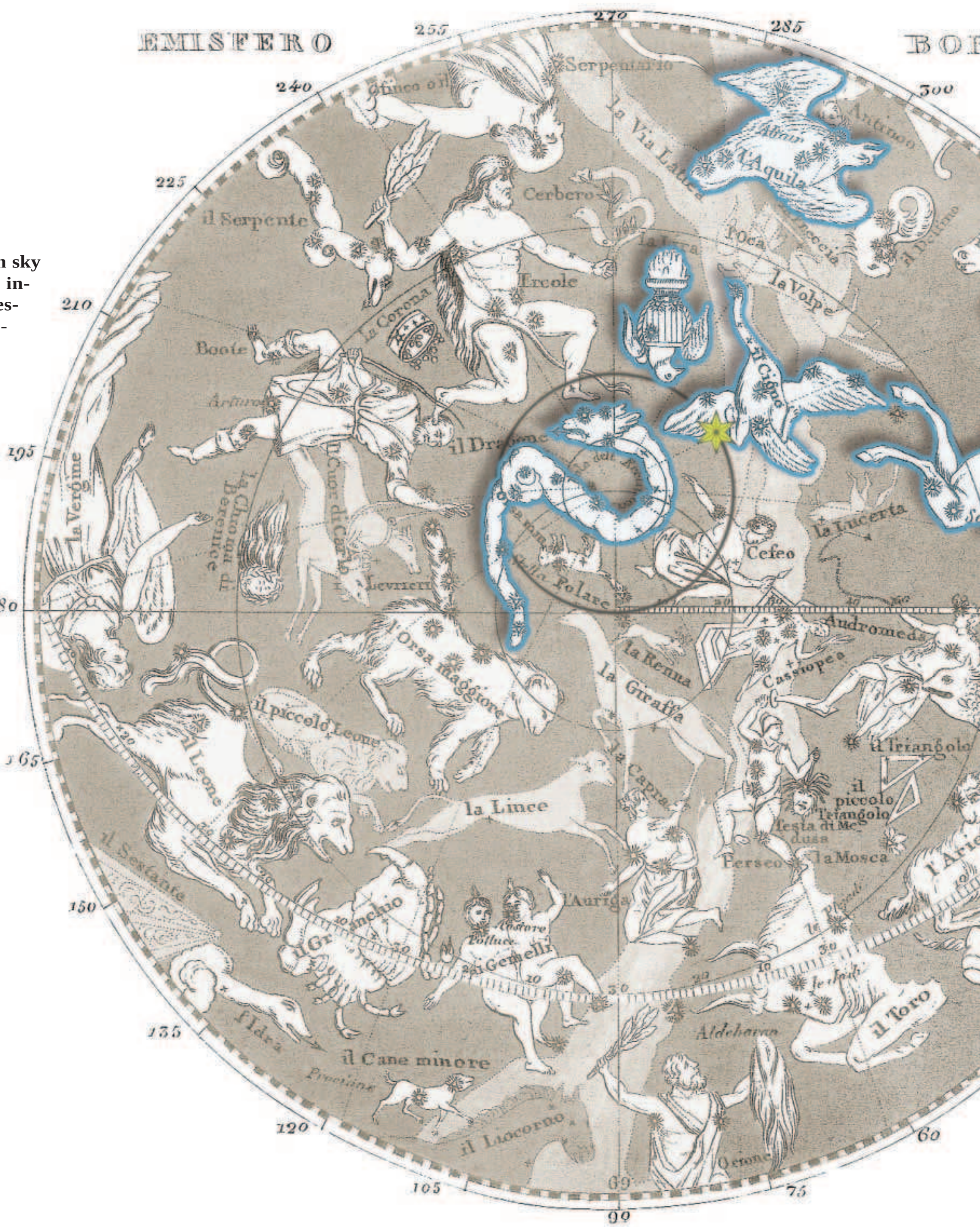
The previous discussion only highlights ways to maximize the field of view for deep-sky imaging with today's popular CCDs. There are many other considerations when it comes to matching telescopes and detectors. First, nowhere is it chiseled into stone that you must have an image scale of 2" per pixel. Anyone doing lunar and planetary imaging will get superior results with scales of ½" or less per pixel. Even for deep-sky imaging, any site with good seeing will benefit from scales of less than 2". Some image-processing techniques, especially those involving resolution-enhancing algorithms like maximum-entropy deconvolution, work better with images that have large image scales (so-called oversampled images).

Conversely, excellent deep-sky imaging has also been obtained with pixel scales of 4" or more, especially in the case of large, bright objects. Indeed, many stunning images are produced with conventional camera lenses attached to CCDs. The resulting image scales (tens or even hundreds of arcseconds per pixel) may not yield the best-looking stars, but they can render remarkable views of huge nebulae.

Another consideration is that some desirable features are found only on large-pixel chips. Take, for example, the back-illuminated SITe CCDs that are currently available in cameras manufactured by companies such as Apogee Instruments. Having 24-micron-square pixels in arrays with 512 and 1,024 pixels on a side, these chips have exceptional sensitivity, especially to blue light, compared to their front-illuminated cousins. The blue sensitivity alone makes these detectors very attractive to people who are interested in photometry and tricolor imaging.

The number and size of pixels in a detector are only two considerations when you are planning the purchase of a CCD camera. In the coming months we'll look at other important issues involved with getting the best performance from today's state-of-the art digital-imaging equipment.

IN SEARCH OF THE



In this 1842 map of the northern sky by Marmucchi, the dark circle indicates the path the north celestial pole traces during its 26,000-year precessional cycle. The yellow star indicates the pole's location 16,000 years ago, when the earliest constellations may have been created. Its position is roughly at the center of the "air stratum" — the band of ancient constellations associated with flying creatures.

Below: **Modern constellations in decreasing order of size (Argo is considered in its original form, before it was divided into Puppis, Pyxis, Vela, and Carina). Those colored brown comprised a constellation list dating from the third century B.C., and asterisks indicate zodiacal constellations.**

CONSTELLATION SIZES

	Area (square degrees)	Name
1.	1,667	Argo
2.	1,303	Hydra
3.	1,294	Virgo*
4.	1,280	Ursa Major
5.	1,231	Cetus
6.	1,225	Hercules
7.	1,138	Eridanus
8.	1,121	Pegasus
9.	1,083	Draco
10.	1,060	Centaurus
11.	980	Aquarius*
12.	948	Ophiuchus
13.	947	Leo*
14.	907	Boötes
15.	889	Pisces*
16.	867	Sagittarius*
17.	804	Cygnus
18.	797	Taurus*
19.	757	Camelopardalis
20.	722	Andromeda
21.	657	Auriga
22.	652	Aquila
23.	637	Serpens
24.	615	Perseus
25.	598	Cassiopeia
26.	594	Orion
27.	588	Cepheus
28.	545	Lynx
29.	538	Libra*
30.	514	Gemini*
31.	506	Cancer*
32.	497	Scorpius*
33.	482	Monoceros
34.	475	Sculptor
35.	469	Phoenix
36.	465	Canes Venatici
37.	441	Aries*
38.	414	Capricornus*
39.	398	Fornax
40.	386	Coma Berenices
41.	380	Canis Major
42.	378	Pavo
43.	366	Grus
44.	334	Lupus
45.	314	Sextans
46.	295	Tucana
47.	294	Indus
48.	291	Octans
49.	290	Lepus

FIRST CONSTELLATIONS

Could the earliest constellations predate the Ice Age?

By Alexander A. Gurshtein

STARTLING CORRELATIONS materialize around us now and then. If you look at a map of the United States, you may notice that, on average, the later a state entered the Union the larger it is. Some historians of astronomy suggest that the converse is true for the 88 constellations recognized by modern astronomers: typically, the younger a constellation, the smaller its area. It is easy to understand why: the constellations delineated on the "empty" celestial sphere had more space available to them than those placed on a partially filled one. Furthermore, the relation appears valid for constellations contrived in historical times as well as for those with ancient origins. In "When the Zodiac Climbed into the Sky" (*S&T:* October 1995, page 28) I demonstrated that the age of the zodiacal constellations could be determined using this concept; here I propose that the idea can be taken a step further.

THE ARCHAIC SKY

The 88 constellations that fill the modern sky vary enormously in size, from about 1,300 square degrees (Hydra, Virgo, and Ursa Major) to about 75 square degrees (Crux, Equuleus, and Sagitta). Roughly half of them were introduced in historical times and have documented sources. Our "smaller implies younger" relation is easily confirmed for these recent additions. But what about constellations with unknown dates of origin?

The table below lists 85 modern constellations according to their areas — from largest to smallest. (Argo is represented in its original form, before it was replaced by four constellations.) What happens if we compare this modern list to an ancient one? Although scientists have made much progress deciphering cuneiform astronomical tablets from 700 B.C., we still have no complete and accurate map of the Babylonian sky. In contrast, we have *The Phaenomena*, by the Greek poet Aratus, from about 275 B.C. This poem, together with the *Almagest* — Ptolemy's star catalog of A.D. 150, provides a complete body of constellation data. These two sources include names, images, and locations that may hint at the archaic roots of the constellation-making process.

Aratus names 46 constellations, if we ignore the Pleiades and Orion's archaic Bow. The 18 largest modern constellations were known to him. Number 19 is Camelopardalis; then eight more Aratus constellations follow until we reach Lynx, which was introduced in the 17th century

50.	286	Lyra
51.	282	Crater
52.	270	Columba
53.	268	Vulpecula
54.	256	Ursa Minor
55.	252	Telescopium
56.	249	Horologium
57.	247	Pictor
58.	245	Pisces Austrinus
59.	243	Hydrus
60.	239	Antlia
61.	237	Ara
62.	232	Leo Minor
63.	210	Microscopium
64.	206	Apus
65.	201	Lacerta
66.	189	Delphinus
67.	184	Corvus
68.	183	Canis Minor
69.	179	Dorado
70.	179	Corona Borealis
71.	165	Norma
72.	153	Mensa
73.	141	Volans
74.	138	Musca
75.	132	Triangulum
76.	132	Chamaeleon
77.	128	Corona Australis
78.	125	Caelum
79.	114	Reticulum
80.	110	Triangulum Australe
81.	109	Scutum
82.	93	Circinus
83.	80	Sagitta
84.	72	Equuleus
85.	68	Crux

by the Polish astronomer Johannes Hevelius. Finally, after four more Aratus constellations, we find abundant non-Aratus items on our modern list.

THE OLDEST CONSTELLATIONS MAY REFLECT A KIND OF WORLD VIEW HELD BY OUR ANCIENT ANCESTORS.

When preparing a roster of the most archaic constellations, I feel it is better to err on the side of caution and omit a few that could be added rather than include ones that shouldn't be. Since many of the constellations smaller than 490 square degrees are not in *The Phaenomena*, let me take that number as a lower size limit. Following this approach, our best estimates of the oldest constellations are listed below.

THE THREE STRATA

The oldest constellations seem to fall into three groups: animals and objects associated with water, humans and other land-dwelling animals, and flying creatures. You may notice in the celestial map on the previous pages that the airborne beings are clustered near the north pole of the ecliptic, land creatures form a girdle around them, and water creatures are toward the south, mostly below the celestial equator. I propose that these strata reflect a kind of world view held by early humanity: a lower world existing as a water kingdom, a middle world for humans and animals, and an upper world populated by flying creatures. The symbolism on the sky, therefore, may be the manifestation of a sense of division developed by our ancient ancestors.

If the viewing location of our hypothetical constellation inventors is taken to be in midnorthern latitudes, the three constellation bands seem to have been logically arranged. Water constellations rose above the southern horizon for our ancient Greek or Babylonian observers, air constellations crossed the zenith, and land-bound constellations culminated between them. To be more precise, however, we must assume that at the time of their creation the three strata were symmetric with respect to the north celestial pole.

Precession makes the Earth's rotation axis appear to circle around the pole of the ecliptic every 26,000 years. The path (dark gray circle) the north pole of this axis takes has been traced on the map of the sky on page 46. The sky symmetry of the three strata we seek suggests the earliest constellations were created 16,000 years ago, with an uncertainty of not more than 2,000 years.

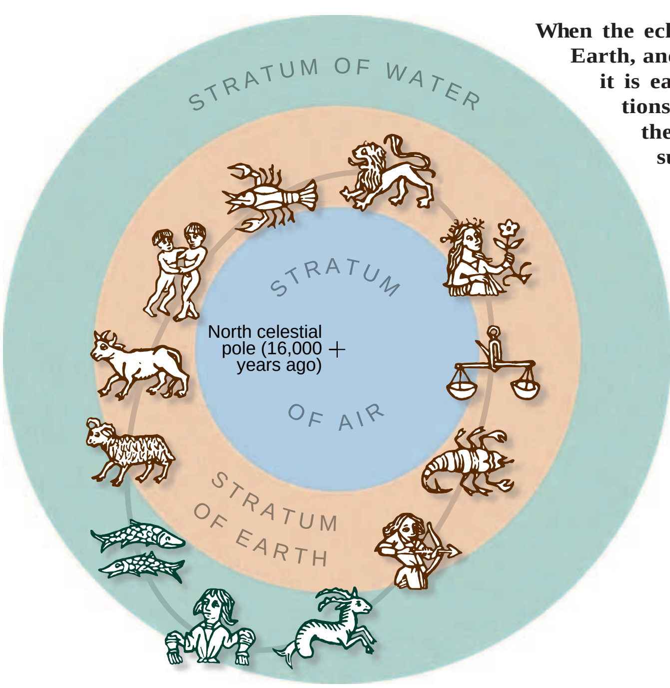
More than two-thirds of the small Aratus constellations, ones that I excluded from our "oldest" list, support the three-strata theory if we use similar analysis. Sagitta, the Arrow, flies through the air; Corona Borealis, the Northern Crown, and Ara, the Altar — important symbols of human activity — occupy the land; and Capricornus, the Goat (with a fish's tail), Delphinus, the Dolphin, and Piscis Australis, the Southern Fishes, swim in the waters. Only a few small Aratus constellations conflict with my concept.

Water constellations (with a mean area of 1,238 square degrees) are typically much larger than those in the land and air groups (mean area 819 and 915 square degrees, respectively). The three-strata theory, together with the constellations' proposed date of origin 16,000 years ago, may explain this difference.

To observers in midnorthern latitudes, a region of the sky around the south celestial pole remains invisible. If we exclude constellations partially or entirely inside this invisibility zone, the average size of water-associated constellations becomes smaller and is more in keeping with those in the other strata. But because the invisibility zone slowly changes position as a consequence of precession, from century to century observers saw new stars appear above the horizon. Perhaps they added them to an existing constellation and thereby created a "zone of accumulation." This could explain how Argo became the behemoth it was until being divided in the 18th century.

THE BABYLONIAN CONNECTION

The Greek custom for constellation naming has parallels with the presumably older Sumer-Akkadian tradition. Particularly, the three strata on the sky



When the ecliptic is shown in relation to the air, Earth, and water strata on the celestial sphere, it is easy to see why no zodiacal constellations, which trace the ecliptic, belong to the air stratum. The northern spring, summer, and autumn points along the ecliptic fall within the Earth stratum while the winter point lies in the water stratum.

The oldest constellations fall easily into one of three categories — water, Earth, and air. Here water constellations are colored green, Earth constellations tan, and air constellations blue.

THE THREE STRATA

	Area	Name
1.	1,667	Argo
2.	1,303	Hydra
3.	1,294	Virgo
4.	1,280	Ursa Major
5.	1,231	Cetus
6.	1,225	Hercules
7.	1,138	Eridanus
8.	1,121	Pegasus
9.	1,083	Draco
10.	1,060	Centaurus
11.	1980	Aquarius
12.	948	Ophiuchus
13.	947	Leo
14.	907	Boötes
15.	889	Pisces
16.	867	Sagittarius
17.	804	Cygnus
18.	797	Taurus
19.	722	Andromeda
20.	657	Auriga
21.	652	Aquila
22.	637	Serpens
23.	615	Perseus
24.	598	Cassiopeia
25.	594	Orion
26.	588	Cepheus
27.	514	Gemini
28.	497	Scorpius

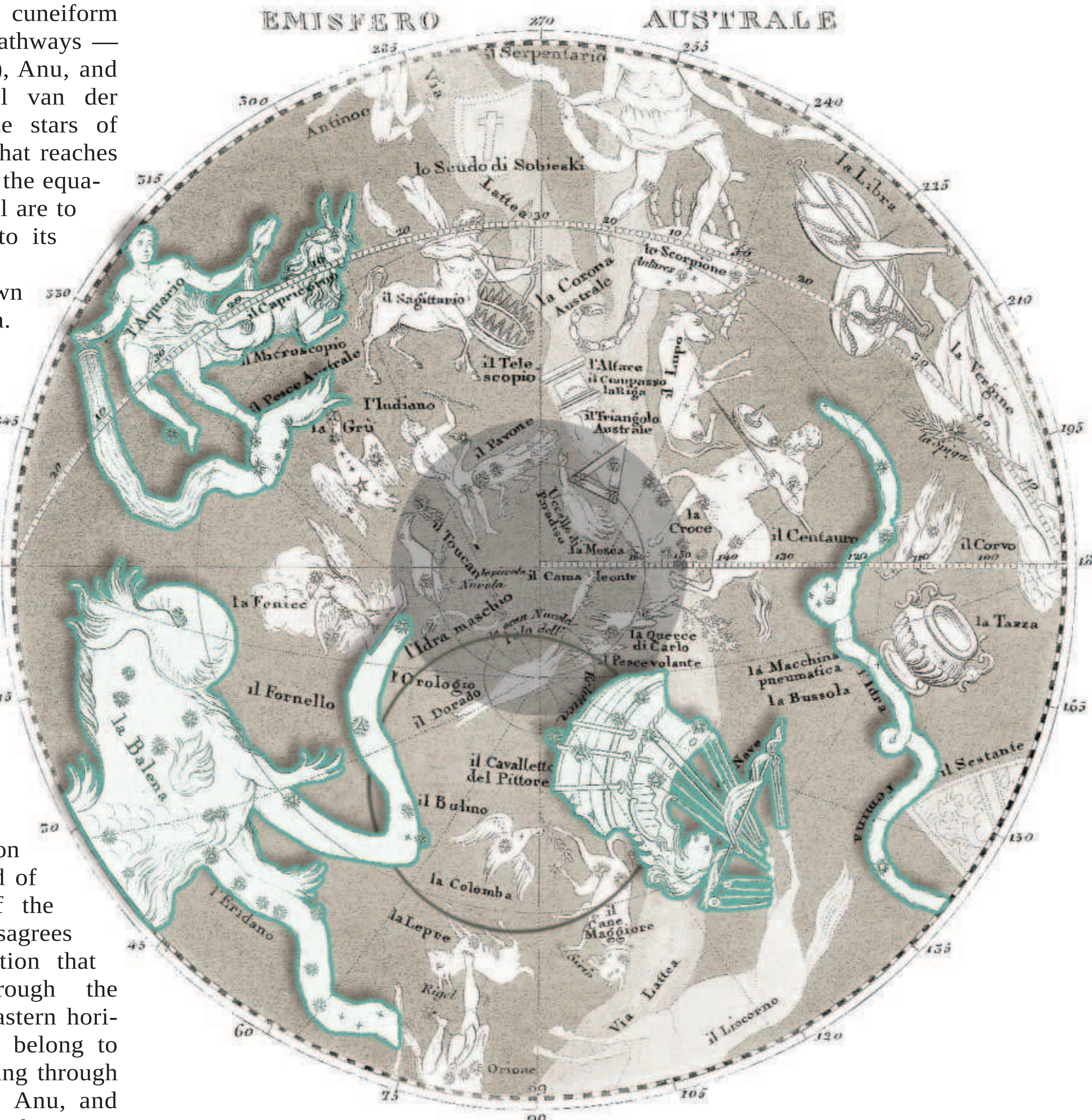
seem to be identifiable in cuneiform texts. Many mention three pathways — those of the gods Ea (Enki), Anu, and Enlil. Mathematician Bartel van der Waerden suggested that the stars of Anu are all within a girdle that reaches about 17° north and south of the equator, and that the stars of Enlil are to its north and those of Ea to its south.

It is not easy to pin down these Sumer-Akkadian strata. Parallels with the Greek sky are noteworthy, but no simple relationship is obvious. Historian David Pingree, author of the *Astronomical Commentary* in the recent English translation of the mulAPIN cuneiform text (from about 700 B.C.), tried to discover links between the different strata systems but failed. He concluded: "Most of the deities who are represented by constellations do not fit into any sort of evident scheme at all."

But Pingree's construction assumed that Anu is the god of the sky and Enlil that of the Earth. Such an approach disagrees with the mulAPIN description that constellations passing through the northernmost gates of the eastern horizon (and circumpolar ones) belong to the path of Enlil, those passing through the central gates belong to Anu, and those passing through the southernmost gates belong to Ea. So Enlil must rule the northern sky, Ea the southern-horizon kingdom, and Anu between them. This sequence agrees with the order of gods on a circular table from the Library of Assurbanipal and many other so-called astrolabes: the stars of Enlil lie at the center of the disc, those of Anu surround them, and those of Ea form the outskirts. The Mesopotamian astrolabes may be considered schematic celestial planispheres.

In further support of this idea, historian and linguist Samuel N. Kramer proposed that Ea was the deity of water, Enlil of atmospheric phenomena and storms, and Anu, the supreme god of gods, of the middle world. These Babylonian godly pathways, as well as their locations and order, concur with the strata decoded on Aratus's sky.

The strata concept also answers the question of why zodiacal constellations are represented only by land and water creatures, and those in a three-to-one ratio. When the ecliptic — the path of the Sun among the stars — was discovered around the 6th millennium B.C., it was located against the background of the land and water strata. It never reached the stratum for airborne beings. Furthermore, three distinctive points on the ecliptic (marking the northern spring and autumn equinoxes and the summer solstice) lay on the land stratum; only one (the winter solstice) lies on the water one.



To observers in the middle latitudes of the Northern Hemisphere a zone around the south celestial pole remains invisible (shaded circle). However, this invisible zone was located elsewhere when the oldest constellations were being created (open circle). As the zone shifted position with precession, observers may have added newly revealed stars to already existing constellations, explaining why several of the "water stratum" constellations are so large. Southern hemisphere sky map by Marmucchi, 1842.

PUTTING IT ALL TOGETHER

The Cro-Magnon Aurignacian culture of Western Europe (30,000–26,000 B.C.) may have exhibited the first evidence of astronomical knowledge. This late Paleolithic culture is known for elaborate burial rituals, body ornamentation, subtle tool-making methods, decoration of objects, musical instruments, and symbolical notation. These hunters and gatherers were probably the first to recognize the four cardinal points of the horizon. Also, an engraved plaque with complex markings found in the Abri Blanchard Cave in southern France has been interpreted by scientists as a lunar calendar.

In the Solutrean period of the late Paleolithic (20,000–16,000 B.C.), when the art of flint-working was at its peak, the first constellations were established. Later, during the Magdalenian period (16,000–8,000 B.C.), the names of starry

P. M. E. ERWOOD

Ursa Major and the Number Seven

IF WE ACCEPT the idea of the three symbolic strata, the question remains: Which were the first constellations? Although we may never know the answer for sure, one constellation holds promise for being among the oldest.

Historians of astronomy have long believed that Ursa Major, the Great Bear, is one of the most archaic constellations. The distinctive outline of its seven brightest stars and its circumpolar location for observers at midnorthern latitudes make the idea plausible, but the strongest line of evidence comes from the name itself. The stars of Ursa Major are seen as a bear by many apparently unrelated cultures across the globe.

Owen Gingerich of Harvard University may have been the first to date Ursa Major to as far back as the Ice Age. He drew attention to the fact that the constellation is known to some native peoples of both Siberia and Alaska. Archaeological and geological evidence suggests that these peoples share a common cultural heritage dating from the last glaciation, when the two regions were connected by a land bridge. The opening of the Bering Strait occurred 15,000 years ago, providing a lower limit to the age of the Great Bear.

But where did the constellation get its name? Archaeological evidence suggests that a Paleolithic bear cult existed 50,000 years ago. A cave bear may have been seen as a kindred creature to the Paleolithic cave-dwelling peoples. The reverence accorded to the animal was reflected in a prohibition from pronouning its name. In Russian, for example, there is no direct name: *medve'd* means one who is eating honey. Throughout the ages many cultures have placed taboos on speaking the names of divine beings, and a representation on the sky is fitting for a revered deity.

That Ursa Major contains seven bright stars may also be significant. In the early 1970s Alexander Marshack in the United States and Boris Frolov in the (then) Soviet Union independently collected evidence that a lunar month as a calendrical unit appeared during the Upper Paleolithic era. Some data suggest this may have occurred in as much as 30,000 years ago. The seven-day week, a quarter of the lunar month, would have the same date of origin. The well-known correspondence between the names of the seven days and the seven "planets" known to the ancients (the Sun, Moon, and five naked-eye planets) may also date from the same epoch. Therefore the number seven probably played a meaningful role in Paleolithic culture. Taking this idea one step further, it can be argued that all of the earliest constellations (those in the list on page 48) first appeared as groups of seven bright stars.

ALEXANDER A. GURSHTEIN

groups were developed into three symbolic strata for the lower, middle, and upper worlds. Water, land, and flying creatures became the core of celestial representation.

Around 10,000 B.C. the Ice Age in Europe came to an end. A warming trend induced the replacement of European grasslands with forests, and soon the Neolithic Revolution was in full force. Farming supplanted hunting and gathering for many peoples during this time period, demanding that the Sun's yearly track along the starry background be accurately monitored. Around 5600 B.C., probably in ancient Babylon, four constellations were contrived to mark the equinox- and solstice-points at that time. These were the modern zodiacal constellations Gemini, Virgo, Sagittarius, and Pisces. Their names, and those of future constellations, continued to reflect the three previous symbolic strata.

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He wishes to thank James P. Rybak for his assistance, as well as many other colleagues, too numerous to list here, for their stimulating discussions.

Further Reading

Allen, Richard H. **Star Names: Their Lore and Meaning.** New York: Dover Publications, Inc., 1963.

Eliade, Mircea. **Myths, Dreams, and Mysteries.** Magnolia, MA: Peter Smith Publisher, Inc. 1992.

Gingerich, Owen. **The Great Copernicus Chase.** Cambridge: Sky Publishing Corp. and Cambridge University Press, 1992.

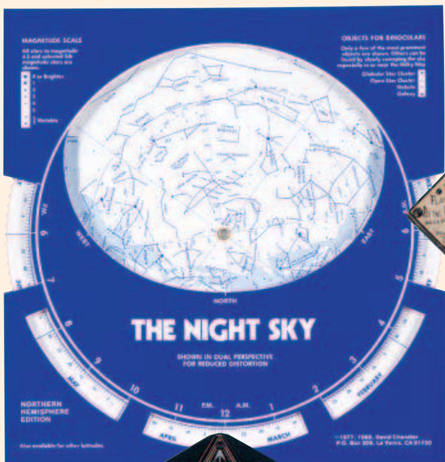
Gurshtein, Alexander A. **"Prehistory of Zodiac Dating: Three Strata of Upper Paleolithic Constellations."** *Vistas in Astronomy,* 39(1995): 347–362.

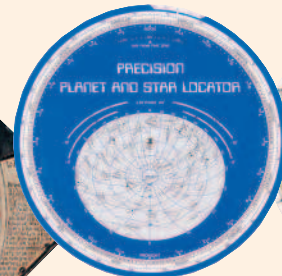
Gurshtein, Alexander A. **"When the Zodiac Climbed into the Sky."** *Sky & Telescope,* October 1995, 28–33.

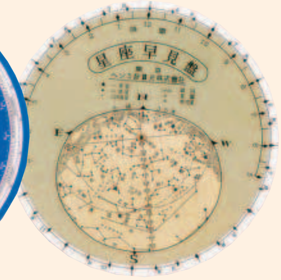
Marshack, A. **The Roots of Civilization,** 2nd ed. Mount Kisco: Moyer Bell, 1991.

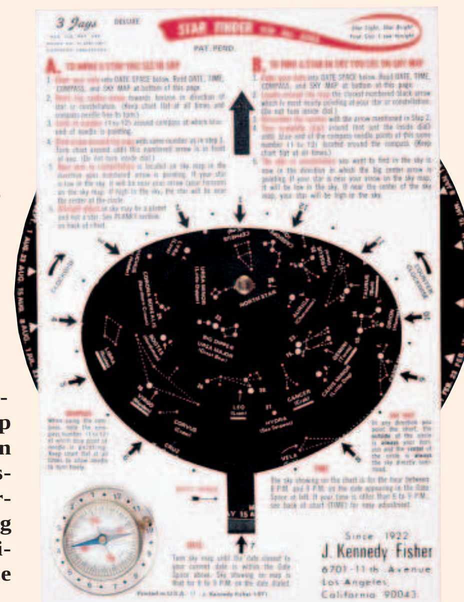
Sesti, Giuseppe M. **The Glorious Constellations.** New York: Harry N. Abrams Inc., 1991.

Waerden, Bartel L. van der. **Science Awaking II. The Birth of Astronomy.** Leiden & New York: Noordhoff International Publishers, Oxford University Press, 1975.









Planispheres of many styles. In each case you turn a disk to set your time against your date. The edge of the star map then represents the horizon all around you at that time. Some planispheres come with extra features. The large Precision Planet and Star Locator, for instance, includes settings to build in corrections for daylight saving time and your longitude, as well as a marker on the sky map that can be dialed to any right ascension and declination. The most important aspect of a planisphere, however, is the clarity and realism of its star map. Among those here, The Night Sky and the Precision Planet and Star Locator take the prize in this regard.

Star-Finding With a Planisphere

THE MOVEMENTS of the stars have taxed the human intellect throughout the ages — from ancient Babylonians seeking to predict sky events, to Greek philosophers wrestling with the structure of the universe, to beginning amateurs today trying to point a new telescope at the Andromeda Galaxy.

At first, the turning of the celestial sphere perplexes everyone who takes up skywatching. Sooner or later the picture snaps into place and the whole setup becomes obvious. But those who think the sky's motion is inherently simple should try explaining to a beginner why every star follows a different curved path across the sky at a different speed. And why do some stars move from west to east while most move east to west? Can you explain why some constellations turn somersaults during the night while others just tilt from side to side?

To bring the sky's motion down to Earth, astronomers for millenniums have built little mechanisms that duplicate it. A working model not only illustrates how the sky turns but can help locate objects at any given time. The simplest sky model is a planisphere.

Untold numbers of these star finders have been designed and produced in the last century. Even the most experienced observers rely on them, especially at unfamiliar hours of the night. The word "planisphere" simply means flat sphere. It incorporates a map of the sky that pivots at the celestial pole. As the map revolves around the pivot, it slides under a mask that represents your horizon. Turning the map mimics the apparent daily motion of the sky, complete with risings and settings at the horizon edges.

The basic idea was used in ancient Rome. The architect and engineer Vitruvius, writing around 27 B.C., described a star map engraved on a solid plate and a horizon mask that rotated over it to show the risings and settings of celestial bodies. A water clock turned the mask once a day to keep up with the sky. Nearly two centuries later, Claudius Ptolemy analyzed the map projections used for such devices in his treatise *Planisphaerium.*

By the fourth century A.D. a version known as the planispheric astrolabe was in use. Its star map was a skeletal metal framework sliding over a solid plate engraved with the observer's horizon. Medieval Arabs and Persians refined the astrolabe to a peak of versatility and beauty. Some of these ornate "mathematical jewels" made their way to Europe, where they were prized as almost magical. "All the conclusions that have been found, or might be found in so noble an instrument as an astrolabe, are not known perfectly to any mortal man in this region," wrote Geoffrey Chaucer in 1391. By the end of the Middle Ages astrolabes were the universal trademark of astronomers and astrologers.

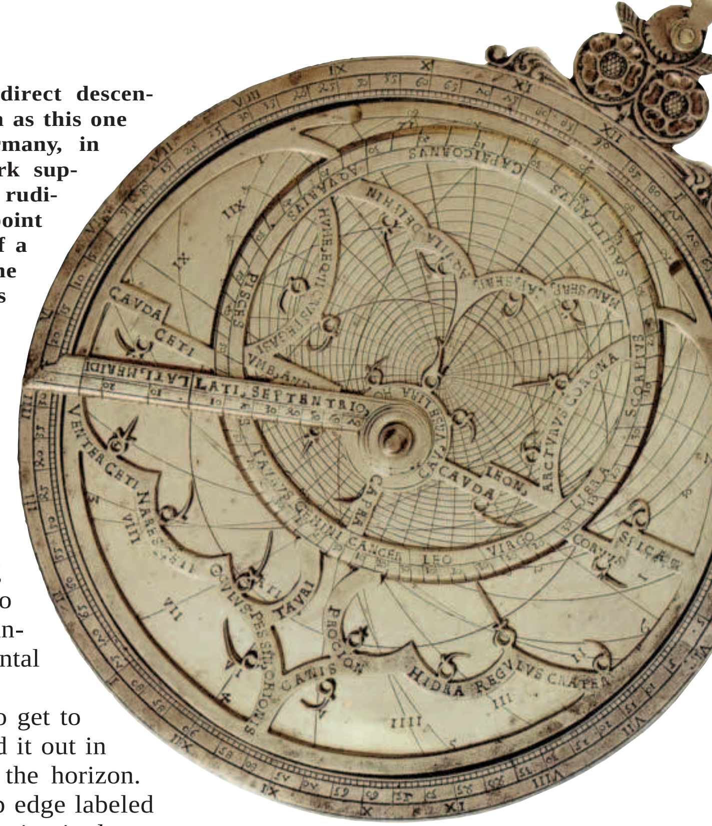
Astrolabes were commonly used to sight on the Sun and stars to tell time. The invention of accurate clocks allowed the procedure to be reversed. If you knew the time, you could use this kind of device to find stars. And that is how planispheres have been employed ever since.

USING A PLANISPHERE

In principle nothing could be simpler. You turn a wheel to put your time next to your date, and presto, there's a custom-made map of the stars that are above your horizon for that moment. The edge of the oval star map represents the horizon all around you, as you would see if you were standing in an open field and turned around in a complete circle. The part of the map at the oval's center represents the sky straight up — much like the all-sky constellation map in the center of each month's *Sky & Telescope*.

In practice, several complications can throw beginners off. The worst is that a planisphere's map is necessarily small and distorted. It compresses the entire celestial hemisphere above and around you into a little thing you hold in your hand. So star patterns appear *much* bigger in real life than on the map.

Moving your eyes just a little way across the map corresponds to swinging your gaze across a huge sweep of sky. The east and west horizons may look close together on a planisphere, but of course when east is in front of you west is behind your back. Glancing from the map's edge to center corresponds to craning your gaze from horizontal to straight up.



Modern planispheres are direct descendants of the astrolabe, such as this one made in Nuremburg, Germany, in 1532. The ornate scrollwork supports 27 points that form a rudimentary star map; each point is labeled with the name of a star or constellation. On the plate under them are lines marking the local horizon, altitude, and azimuth. The sky is portrayed backward, right for left.

There's only one way to get to know a map like this. Hold it out in front of you as you face the horizon. *Twist it around* so the map edge labeled with the direction you're facing is *down*. The correct horizon on the map now appears horizontal and matches the horizon in front of you. Now you can compare stars above the horizon on the map with those you're facing in the sky.

Then there's the distortion issue. On a planisphere designed for use in the Northern Hemisphere, constellations in the southern part of the sky are stretched sideways, taffy-like, making it hard to compare them with real star patterns. This problem does not exist on a well-designed map for fixed dates and times, such as the one in the center of each month's *Sky & Telescope*. Some planisphere designers have come up with a partial solution. David Chandler's planisphere *The Night Sky*, pictured at upper left on the facing page, presents a map on each side. One minimizes distortion north of the celestial equator, the other south of it. Just flip it over for the best view.

A further complication is that a planisphere works correctly for only one latitude on Earth. Most today are made in several editions, each for a particular latitude.

Then there's the matter of daylight saving or "summer" time. When this is in effect (from the first Sunday in April to the last Sunday in October in most of the United States), remember to "fall back" to standard time by subtracting an hour from what your clock says before you set the planisphere's dial.

Actually, planispheres don't employ standard time either, but rather local mean time. The difference, which depends on where you live in your time zone, can amount to a half hour or more. Instructions for finding your local mean time correction are in the text following the *Skygazer's Almanac* on page 76 of the January issue. The correction to apply *to* standard clock time in various cities before setting a planisphere is given below. Fortunately, even a half hour one way or the other doesn't really matter for most star finding.

In fact, if you just want to know which constellations are up and where they are, a planisphere's limitations can largely be overlooked. It's remarkable that such a simple working model of the sky can work so well.

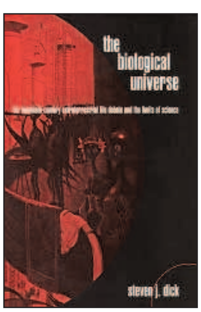
A. M.

LOCAL MEAN TIME CORRECTION

Anchorage	–60	Kansas City	–18
Atlanta	–38	Los Angeles	+7
Bismarck	–43	Memphis	0
Boise	–45	Miami	–21
Boston	+16	Minneapolis	–13
Buffalo	–15	New Orleans	0
Chicago	+10	New York	+4
Cincinnati	–38	Philadelphia	–1
Cleveland	–27	Pittsburgh	–20
Dallas	–27	Richmond	–10
Denver	0	Rochester, N.Y.	–10
Detroit	–32	St. Louis	–1
Durham	–16	Salt Lake City	–28
El Paso	–6	San Francisco	–10
Helena	–28	Santa Fe	–4
Honolulu	–31	Seattle	–10
Houston	–21	Tucson	–24
Indianapolis	–44	Tulsa	–24
Jacksonville	–27	Washington, D.C.	–8

Humans have long pondered the likelihood of life on other worlds. Is it limited to Earth, or do organisms thrive everywhere they possibly can? *The Biological Universe* explores the varied scientific aspects regarding life in the cosmos. Painting copyright 1991 David A. Hardy.

What Are the Chances for Life?



THE BIOLOGICAL UNIVERSE
Steven J. Dick (Cambridge University Press, 1996). 578 pages. ISBN 0-521-34326-7. $54.95.

STEVEN J. DICK has written a fascinating book, culling from a massive literature all the interesting ideas and facts relating to the extraterrestrial-life debate. Are we alone? Has intelligent life evolved in other solar systems? What is the best strategy for opening a channel of communication? What will be the consequences of contact with beings who may be older and more evolved than we are, and possibly superior not only in their science and technology but also in their moral and ethical values? *The Biological Universe* discusses these weighty matters in a lucid and engaging style. For those interested in the place of *Homo sapiens* in the cosmos, it is a mine of information and a delight to read.

Regarding the first question, recent reports of bodies circling other stars confirm the suspicion that planets probably are common in the universe. The evidence is indirect but quite robust, and we can now guess that a billion trillion families of planets — give or take a few powers of 10 — exist within the universe.

The book then turns to the question of life's origin: What is the probability that life has arisen out of inanimate matter on the trillions of these inferred planets? Opinions diverge widely. Dick cites an estimate by physicist Harold Morowitz that the probability of creating a bacterium — the simplest living organism — through random molecular collisions is 1 in $10^{100,000,000,000}$. Fred Hoyle raises this chance to a more optimistic 1 in $10^{40,000}$. Biochemist Robert Shapiro estimates that the probability of chance formation of a short strand of self-replicating RNA is considerably greater — as "large" as 1 in 10^{992}. All these numbers are so small that, even when multiplied by the vast number of planets probably present in the universe, they force us to conclude that the Earth must be the only planet bearing life.

But some astronomers argue that astrophysical findings on the cosmic distribution of the elements suggest a very different answer. They base their conclusion on the aptly named Principle of Mediocrity: The Earth is an ordinary planet, made of common materials that must be found in many solar systems. Why would the Earth alone — an undistinguished body among trillions of similar ones —

be chosen by nature or the deity as the only planet on whose soil the seeds of life have taken root? They conclude that many — perhaps nearly all — Earth-like planets circling Sun-like stars bear life.

What, then, can science say about the probability of life arising on other planets? Apparently not much, since scientific estimates of the number of inhabited planets vary from one (the Earth) to trillions.

Now we see why the recently reported and still-tentative evidence for fossilized life on Mars is so important. The fact that

What may be expected of a meeting between civilizations separated by a billion years? Will we survive the encounter? I see no grounds for optimism.

life appeared on our planet does not tell us whether this event is rare or commonplace; a probability cannot be estimated on the basis of a sample size of one. However, if independently evolved life or the remains of life are indeed found on Mars, we will know immediately that the creation of life out of nonlife is not an event of vanishingly low probability. If it were, we would certainly not find two of these very rare objects — a planet on which life has evolved — in one solar system. Confirmation of the Mars report will demonstrate that the universe is teeming with life.

There is much more to praise in this excellent book. Particularly intriguing are the discussions of the probable consequences of contact with intelligent extraterrestrials. Most thinking on this subject assumes implicitly that ETs have roughly a human level of intelligence, but perhaps we should expect something quite different. Astronomy sets the age of the universe at roughly 10 to 15 billion years, and planetary science sets the age of the solar system at 4.6 billion years. These two numbers tell us that somewhat more than half the intelligent beings in the universe are a billion or more years older than we are. Presumably they are correspondingly more evolved than *Homo sapiens*. What is the significance of a separation of a billion years of evolution?

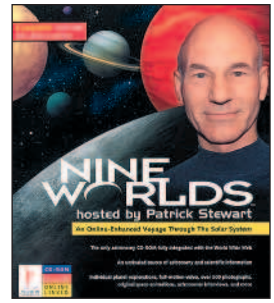
A hint of the answer comes from the fossil record, which reveals that a billion years ago the highest forms of life on Earth were wormlike creatures. What stands in relation to humans as we stand in relation to the worm? The human imagination fails in its attempt to grapple with this question.

And while many people look forward with pleasurable anticipation to contact with these presumably marvelous creatures, experience suggests that the outcome may not be pleasant at all (February issue, page 6). On this planet, contact between scientifically advanced civilizations and a primitive society — and "primitive" is the description we must apply to humans as they prepare to join the older residents of the cosmic community — typically results in the destruction of the less-developed culture.

Regardless of whether the intent of the technically advanced civilization is destructive or benign, the powerful forces at its command tear apart the fabric of the primitive society. Such was the fate of early Native Americans, Australian aborigines, and Polynesians. These have been the consequences of contact between two civilizations separated by only some tens of thousands of years of cultural evolution. What may be expected of a meeting between civilizations separated by a billion years? Will we survive the encounter? I see no grounds for optimism.

ROBERT JASTROW

Jastrow is director of the Mount Wilson Institute and wrote Red Giants and White Dwarfs *(W. W. Norton and Co., 1990).*



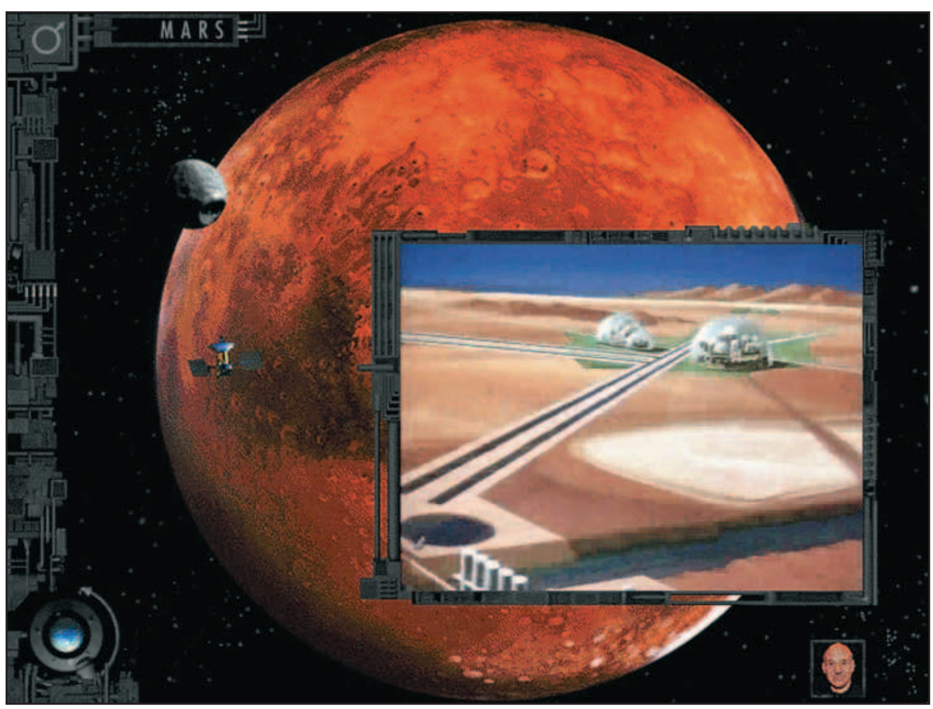
NINE WORLDS

Palladium Interactive, Inc., 900 Larkspur Landing Circle, Larkspur, CA 94939. CD-ROM for MacOS and Windows 3.1 and 95. $39.95.

PATRICK Stewart is the grand host of this heavily illustrated introductory tour of the solar system, and he narrates passages throughout.

The "Orrery" is the first of three main sections. Click on the Sun or a planet for a tour that uses a sophisticated combination of photographs, diagrams, animations, and videos. Topics include surface features, satellites and rings if present, planetary structure, and the history of our concept of the body. All is nicely delivered, though without great depth and with uneven writing. A lively "Vacation Planner" tailored for children gives your age and weight on each planet.

The "Resource Explorer" is a grab bag that includes: a short introduction to amateur astronomy with hints on how to select a telescope; a quiz; names and addresses of astronomy organizations, ob-



Nine Worlds **combines photographs, diagrams, animations, and videos. Here Patrick Stewart narrates a video outlining our changing concept of Mars that is inset within larger graphics. Click on the moonlet for information on Phobos and Deimos (one picture and one paragraph each), or click on the spacecraft to create a NetProbe bookmark.**

servatories, and space places around the world; “This Day in Astronomy”; and more. A collection of shareware (which you copy from the disc to your hard drive) is especially interesting.

Caution: Use the Resource Explorer with care. Errors — and there are plenty — range from typos (“Griffith Obsevatory” is my personal favorite) to errors of fact (“Mariner 4 landed on Mars in 1965”) to absurdities (August 24th is the anniversary of Hipparchus’s invention of the magnitude system).

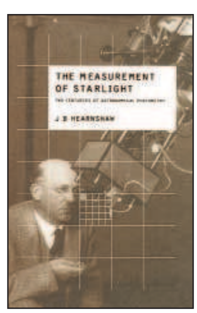
“Mankind’s View” is a time line of astronomical history with summaries of famous astronomers, major discoveries, and future space missions. As for the rest of the disc, the navigation system is cleverly designed and the graphics are superb, even if the information is elementary.

If you have access to the World Wide Web, the program links you to Palladium’s proprietary *Nine Worlds* site, where you’ll find pointers to Web pages, a biweekly astronomy news digest, and underused chat and discussion areas. If you flagged areas of interest while browsing the disc by creating bookmarks called NetProbes, the program creates a customized Web page that links you to other Internet sites. There is little you couldn’t find elsewhere, but it is nicely organized.

The disc is as attractively produced as any I’ve seen, and Patrick Stewart’s narration is a big plus. It’s a pleasant introduction to the solar system, but one marred by too many inexcusable errors.

JOHN E. MOSLEY

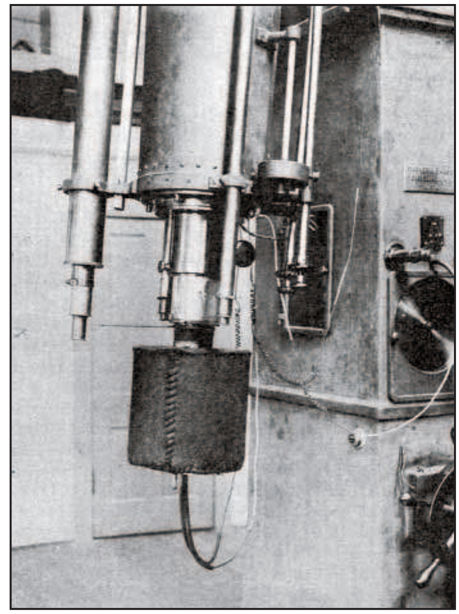
Mosley supervises the educational programs at Griffith Observatory in Los Angeles. He can be reached via e-mail at jmosley@earthlink.net.



THE MEASUREMENT OF STARLIGHT

John B. Hearnshaw (Cambridge University Press, 1996). 511 pages. ISBN 0-521-40393-6. $89.95.

PHOTOMETRY — the craft of measuring the magnitudes and colors of astronomical objects — is one of the cornerstones of modern astrophysics. Optical photometry formed the basis for the first reliable estimates of



Joel Stebbins’s pioneering work involved this photometer, incorporating a selenium photocell, attached to a 12-inch refractor at the University of Illinois. While initial tests were performed observing the Moon, Stebbins’s light curve of Algol in 1910 revealed a previously undetected secondary minimum for the eclipsing binary star. From *The Astrophysical Journal.*

the absolute dimensions of stars and the size of our galaxy. Samuel P. Langley used an infrared bolometer to measure the solar constant in the 1880s. Charles G. Abbot later derived the first stellar effective temperatures from radiometry spanning wavelengths between 0.44 and 2.22 microns. Current applications of precise brightness measurements range from determining the size and composition of objects in our solar system to studying the evolution of galaxies in the distant universe.

In *The Measurement of Starlight: Two Centuries of Astronomical Photometry* John B. Hearnshaw masterfully reviews the development of photometry up to the application of the charged-coupled device (CCD). After a brief summary of classical stellar magnitudes, he clearly describes the origin and development of visual, photographic, and photoelectric photometry. His comprehensive account includes fine, critical comparisons of the instruments built to measure stellar brightnesses as well as the various magnitude systems derived from these instruments.

The illustrations — of the instruments, the scientists who made them, and the landmark results they produced — are impressive and add to the richness of the story. The book contains an extensive set of references at the end of each chapter and excellent indexes.

Throughout the volume, Hearnshaw

describes how technological developments drove the main advances in the field and how each of these innovations fueled the expansion of modern astrophysics. Despite numerous technological challenges, the first photometrists successfully measured stellar brightnesses with an almost bewildering variety of tools, including bolometers, photovoltaic cells, radiometers, and thermocouples. Some of the early photographic and visual catalog projects rivaled the *Henry Draper Catalogue* of spectra in accuracy and scope and led directly to the discovery of the interstellar medium, the Cepheid period-luminosity relation, and precise maps of galactic structure. Smaller programs of systematic observations of eclipsing binaries and other variable stars yielded the first mass-luminosity relations for main-sequence stars and the first classifications of pulsating variables.

Hearnshaw's narrative includes a good mix of major accomplishments and historical vignettes that show both the cooperative and competitive aspects of modern science. Edward C. Pickering's haste to produce *Harvard Photometry* led to numerous misidentifications and unacceptably large photometric errors compared to the Potsdam group of Paul Kempf and Gustav Müller. The photographic observations of Harvard's North Polar Sequence were more careful. For example, Mary Hunt of Radcliffe College showed that tarnishing gradually decreases the ultraviolet reflectivity of a silver mirror.

These and other improvements in photometry came too late for Carl V. L. Charlier, who unfortunately attributed the first color-magnitude sequence for the Pleiades star cluster to an error in the visual magnitudes and hence missed developing the "Charlier diagram" 20 years before Ejnar Hertzsprung began work on the Hertzsprung-Russell diagram!

The Measurement of Starlight is a well-written and lively history of stellar photometry. The text is most appropriate for professional astronomers with a historical bent. Science historians should enjoy the close ties between detector development in astronomy and physics — sometimes by the same scientist — as well as those between photometry and astrophysics. Amateur astronomers should also appreciate the instrument histories now that many amateurs regularly compete with professional observatories at producing beautiful images and in detecting new solar-system objects and distant supernovae. Everyone should relish the rich history of astronomical photometry and Hearnshaw's skill in presenting it.

SCOTT KENYON

Kenyon is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics and is the author of The Symbiotic Stars *(Cambridge University Press, 1986).*

Briefly Noted

Earth Clock, Terry Koyn (Bradford Publishing Co., 16 Craig Rd., Acton, MA 01720). Software for MacOS (68030 processor or better). $88.

This nifty but overpriced program demonstrates to students one of the more difficult concepts in astronomy — how Earth's illumination by the Sun changes hourly and seasonally. View the Earth as a map or as a globe in orbit about the Sun (or as both simultaneously) and step through time to watch the pattern of day and night vary. A sundial shows how shadows change with time. Intended for schools, grades 6 to 9.

StarTrax, Paul Warme (120 S. Patterson St., State College, PA 16801; e-mail: pkwarme@twd.net). Software for Windows 3.1. $30 (enhanced version for $40).

This versatile yet simple star-charting program shows 39,600 stars, 5,438 deep-sky objects, constellation outlines, coordinate grids, and star names and designations, as well as the Sun, Moon, and planets as viewed from any geographic location. A trial version is available from online sources.

Jupiter: The Giant Planet, Reta Beebe (Smithsonian Institution Press, 1996). 265 pages. ISBN 1-56098-731-6; $29.95, cloth. ISBN 1-56098-685-9; $16.95, paper.

The second edition of this 1994 text (*S&T:* January 1995, page 59) has been revised to include concluding sections on the impact of Comet Shoemaker-Levy 9 and initial data from the Galileo spacecraft.

Astrology: What's Really in the Stars, J. V. Stewart (Prometheus Books, 1996). 156 pages. ISBN 1-57392-077-0. $19.95.

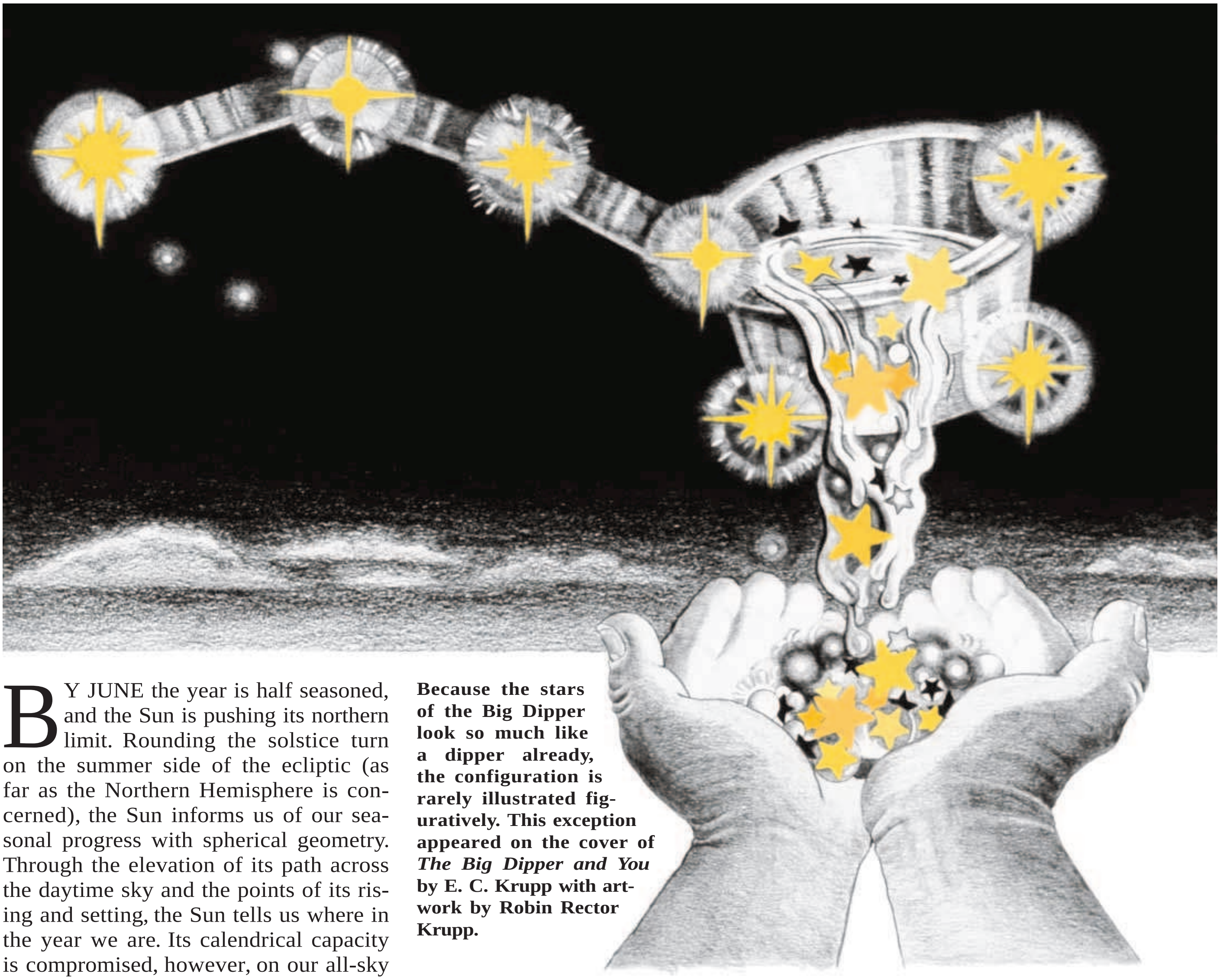
An emergency-room physician takes a detailed look at the foundations of astrology and compares it to what is touted as astrology today. Although he successfully questions surviving ancient myths, several errors of calculation confuse his results.

The Quest for Longitude, William J. H. Andrews, ed. (Harvard University Press, 1996). 437 pages. ISBN 0-9644329-0-0. $75.

The human drama of John Harrison's struggle to perfect his chronometer in the age of exploration was well told in *Longitude* by Dava Sobel (*S&T:* July 1996, page 60). On its heels comes this encyclopedic book that tells the story in a more scholarly fashion. The text, beautifully illustrated and packed with references, was produced by Harvard University's Collection of Historical Scientific Instruments. The contributions by historical experts pick up where Sobel left off.

By E. C. Krupp

A Dipper for All Seasons



Because the stars of the Big Dipper look so much like a dipper already, the configuration is rarely illustrated figuratively. This exception appeared on the cover of *The Big Dipper and You* by E. C. Krupp with artwork by Robin Rector Krupp.

BY JUNE the year is half seasoned, and the Sun is pushing its northern limit. Rounding the solstice turn on the summer side of the ecliptic (as far as the Northern Hemisphere is concerned), the Sun informs us of our seasonal progress with spherical geometry. Through the elevation of its path across the daytime sky and the points of its rising and setting, the Sun tells us where in the year we are. Its calendrical capacity is compromised, however, on our all-sky map on pages 70 and 71. The chart, after all, illustrates the pastures of heaven after the Sun has left the field. Fortunately, the swing shift has clocked in, and the Big Dipper is ready for duty.

The seven bright stars form a large and distinctive arrangement, looking like the long-handled cup that was a lot more common before running water, indoor plumbing, and sports-drink bottles let us kick the bucket back down the well. Not classified as an official constellation, the Big Dipper is an *asterism* — an informally recognized arrangement of stars — that really belongs to Ursa Major, the Great Bear. You can find it on our June star map to the right of the meridian (the blue vertical line that cuts through the middle of the map) and a short distance southwest of Polaris and the sky's north pole.

Because the Big Dipper is so hard to misplace, just about everybody has acknowledged its value as an astronomical utensil. Its seasonal dimension is not advertised, however, on a single map. You have to look at a series of monthly charts to see how its configuration at the same time of night varies through the year. Six months from now, in December, the early-evening Dipper will be marking time in the northeast, more or less on the opposite side of Polaris.

People all over the world have long been aware of the Dipper's seasonal displacement. This knowledge is reflected, for example, in the story the Micmac Indians of eastern Canada told about hunting the celestial bear. Events in the hunt are linked to the Dipper's ascent from the northern horizon, its culmination above the Pole Star, and its descent back to Earth. And the Dipper-tempered calendar kept by the Yi people of China's Yunnan Province reveals that the year begins in winter, when the Dipper is east of Polaris in the early evening with its Handle dangling toward the ground.

The menu of Big Dipper services, of course, is not confined to calendrics. North of the equator the most reliable recipe for finding north puts the Pointers to work. These two stars that front the Bowl of the Dipper point to Polaris and turn the asterism into a compass that indicates true north. No less an authority than my 1954 Boy Scout *Handbook for Boys* confirms the merits of this method.

Even though we have already inventoried a bowlful of Big Dipper benefits, this multipurpose tool also tells time. Turning on its axis, the Earth spins the entire sky around the north celestial pole every 24 hours, and in that time the Big Dipper runs a complete circle around Polaris. By monitoring the Dipper's progress around the pole, we can assess how much of the night has elapsed. William Tyler Olcott and Edmund W. Putnam explained how this works for several generations of readers in *Field Book of the Skies*. Turning the line that connects Polaris with the Pointers into the "hour hand of a clock," they asserted, "With a little practice the time of night can be ascertained to an approximate degree." In *Living Life's Circle*, anthropologist Claire R. Farrer reports how Bernard Second, a Mescalero

Although it is no surprise that people spotted a Big Dipper in the stars of the Great Bear, it is not so easy to say exactly when and how this happened.

Apache Head Singer and her collaborator, kept track of the time using the Big Dipper during nocturnal ceremonies.

Nearly everyone in the United States and Canada extracts a dipper from the stars of the Great Bear. Although it is no surprise that people spotted a Big Dipper there, it is not so easy to say exactly when and how this happened. Neither the North American Indians nor the colonizing Europeans knew the magnificent seven of Ursa Major as the Big Dipper. In fact, the seven stars are known sometimes as the Plough in Britain, identified as somebody's *Wain* (or wagon) throughout most of Europe, and officially assigned an ursine pedigree that reaches back through Ptolemy to ancient Greek sky lore. No reference, however, tells us how the Dipper habit got started on the western shore of the North Atlantic.

Asa Smith's *Illustrated Astronomy*, a 19th-century sky guide, describes the "Great Dipper." It was published in Boston without a date, though internal evidence places it in the late 1850s. Elijah H. Burritt's *Geography of the Heavens*

China's version of the Big Dipper is also a practical utensil. The Chinese picture it as the Northern Bushel, a ladle or scoop used to measure portions of grain. Here the Dipper is mapped on the great bronze celestial sphere on the rooftop observing platform of Beijing's Ancient Observatory. Courtesy E. C. Krupp.

(1835) preceded Smith's handbook, and its accompanying text refers to Ursa Major's seven bright stars as just "the Dipper." Burritt described Ursa Minor with dipper imagery, but he did not use the term Little Dipper. This implies our recognition of two northern Dippers is a later development.

The Big Dipper is another kind of kitchen utensil in southern France, where they sometimes call it Casserole, the Saucepan, presumably in deference to the lofty status of French cuisine. The Chinese called the Big Dipper *Pei tou*, which means Northern Bushel. It represented a container used to measure grain before it was stored. Taoist ritualists judged that this confederation of stars furnished the biggest helping of transcendental power they could harvest from the sky. Celestial spirits residing in the Big Dipper kept track of what people did and rewarded the just with longevity. Without mindful measure, there can be no equity, and so in the symbolism of imperial power the grain measure and the Northern Bushel stood for the emperor's justice.

Ancient Egyptians found a funereal implement in the Big Dipper. This tool was touched to a mummy's eyes and mouth to revive the spirit of the deceased. A hawk-headed god, perhaps Horus, the son and heir of the dying god Osiris, performs this ceremony on a mummy wrapped to look like Osiris. This detail is from Inherkau's tomb at Deir el-Medina. Inherkau led a work crew of royal tomb-builders in the 12th century B.C. Courtesy E. C. Krupp.

The ancient Egyptians also made a tool out of the Big Dipper, but for them its task was the magical revival of dead souls. They saw something like an adze in its stars, the long-handled chisel used by a priest officiating at a funeral. Phonetically interchangeable with the name the Egyptians assigned to the Big Dipper, the ceremonial utensil was equivalent to the bull's thigh they also saw in those stars and was included in the ritual paraphernalia for the "Opening of the Mouth" liturgy. Because the stars of the Big Dipper never rose and never set, the Egyptians regarded them as undying. The priest brushed the lips and eyes of the mummy with a talismanic Dipper and so simulated cutting open these apertures that had been sealed by death. In doing so, the priest rekindled the senses of the deceased and reactivated the conscious personality for the spirit's life after death. With the help of the Big Dipper, the dead sipped celestial immortality from imperishable stars.

In southern Arizona the Akimel O'odham (formerly Pima) and the Tohono O'odham (formerly Papago) reach the ripened fruit of the tall saguaro cactus with a long hook fabricated from a saguaro rib, and their name for this tool is the same as that for the Big Dipper. They begin harvesting the fruit about mid-June and ferment from it saguaro wine, which is consumed in the summer-solstice New Year ceremonies. In a ritual intended to season the world with fertility, renewal, and rain, the beverage is served with a Dipperful of seasonal power.

E. C. Krupp sips from the Dipper at Griffith Observatory in Los Angeles.

By Fred Schaaf

On June evenings the band of the Milky Way begins ascending in the eastern sky, starting a seasonal appearance that will crest overhead in late summer. Jerry Schad used a 24-mm wide-angle lens to capture this view of the southern end of the summer Milky Way rising in the southeast. When he took this photograph two years ago, Jupiter, the brightest "star" here, was just to the upper left of orange Antares. Starting from Antares you can trace out other stars and constellations using the map on the preceding two pages.

The Rise of the Summer Milky Way

IF YOU'VE just pulled this magazine out of your mailbox or just bought it after it arrived on the newsstand, Comet Hale-Bopp may still be putting on an exciting performance in your evening twilight sky, glowing low in the west-northwest.

By late May, however, we'll lose sight of the comet in the glow of sunset. (Presumably it will still be bright as it passes Betelgeuse and moves into Monoceros during June, but it will be almost directly behind the Sun from our viewpoint.) And Mars, brilliant during early spring, will be considerably faded and dwindled. What then to look at?

Just the entire rest of the universe, waiting each clear night for you to discover, or rediscover.

THE SKY AT THE ARCTURUS HOUR

Our all-sky constellation map on the previous two pages is drawn for 15:00 sidereal time: when the 15^h line of right ascension is on the sky's north-south meridian.

This "star time," and the entire sky scene that goes with it, occurs around 1 a.m. daylight saving time in early May, midnight in late May, 11 p.m. in early June, and at dusk (for midnorthern latitudes) in late June. The chief star of spring, Arcturus, is already a little past the meridian, as the map shows. But this still deserves to be called the Arcturus Hour.

What else could we call it? Few other notable stars or constellations are as close to the meridian now as Arcturus. Toward the south Libra, the Scales, balances almost on the meridian, but Libra is pretty dim. Overhead, the northern part of the constellation Boötes is on the meridian — but Boötes is dominated by Arcturus itself.

What about in the north? Right on the meridian is the second-brightest star of the Little Dipper, Kochab or Beta (β) Ursae Minoris. Moreover the Little Dipper's brightest star, Polaris itself, is barely past its "lower culmination" just under the north celestial pole. This happens almost when Kochab is at "upper culmination" above the pole. So it's a special time for Ursa Minor. The Little Bear now stands on its unnaturally long tail, and the Little Dipper (the asterism of the same stars) on its handle.

What's the Big Dipper doing? It's starting to decline into the northwest, its handle pointing along an arc toward . . . Arcturus.

Of course, we could name our sky hours for the sights that are rising into fresh view instead of those already on the meridian. What's rising on our map? On the southeastern horizon we find the Teapot of Sagittarius, but it's too low to see properly yet. Scanning the horizon from southeast to northeast, we find a remarkably dim strip of the heavens. This strip is thicker than we see on the map; more of it will keep rising without any bright stars for quite a while.

This dark strip is all the more noticeable in contrast to what's right above it, or ahead of it: the rich band of the summer Milky Way, with bright Cygnus and Aquila.

On the western (upper) side of this Milky Way strip is a line of bright Lyra, bigger but dimmer Ophiuchus, and sparkling Scorpius. It's interesting that such bright stars precede the Summer Milky Way across the sky but that nothing bright follows it.

As a matter of fact, the last 1st-magnitude star to rise was Altair in the Milky Way's edge, about an hour and a half before map time. When will the next 1st-magnitude star rise for observers at 40° north latitude? Not for five more hours! That's when Fomalhaut and Capella come up, around 3 a.m. daylight saving time in early June.

At least Jupiter rises to brighten things during that long period of no 1st-magnitude star-rises this year. And Saturn makes a late, late rising with Fomalhaut and Capella.

Take another look at the all-sky map. Turn it around so the eastern horizon is at bottom. Does this sky look familiar to you? If you were one of the bold and faithful out in the cold when morning twilight began back in early February, this is the sky scene you saw — framing Comet Hale-Bopp in the process of becoming magnificent. The Arcturus Hour occurs at different times of night (or day) all around the year.

There's one tempting alternative to calling this the Arcturus Hour, if you live far enough south. Only three stars in the heavens are brighter than Arcturus. But one of them is actually closer to the 15^h right ascension line. At mid-southern latitudes, skywatchers would doubtless want to call their sky scene the Alpha Centauri Hour. But of course that scene would look far different from the one portrayed on our map. You have to be as far south as latitude 29° (Florida, south Texas) just to see Alpha Centauri skimming the southern horizon.

On May and June nights as the hour grows late, the Milky Way looms like a great, glowing arch across the eastern sky — if you are blessed with natural, unspoiled darkness.

THE SUN, MOON, AND PLANETS IN JUNE

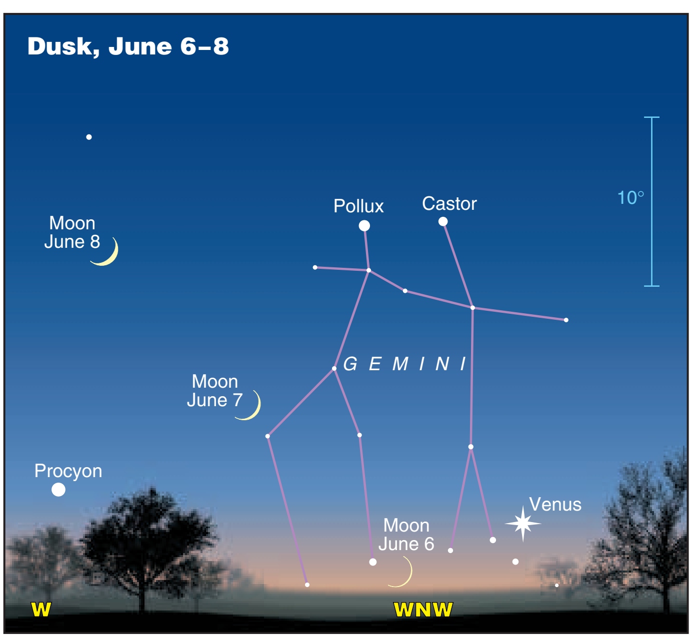
The comet's departure leaves nights of only moderately interesting planetary sights strung across the rather short gap between dusk and dawn. At dusk, Venus is still very low in the west-northwest during June. Mars is high in the southwest when darkness falls, an unmistakable golden orange point despite its faded and shrunken status. Late in the night Jupiter rises impressively. It shines highest in the south-southeast as dawn brightens, by which time Saturn is lower in the east-southeast.

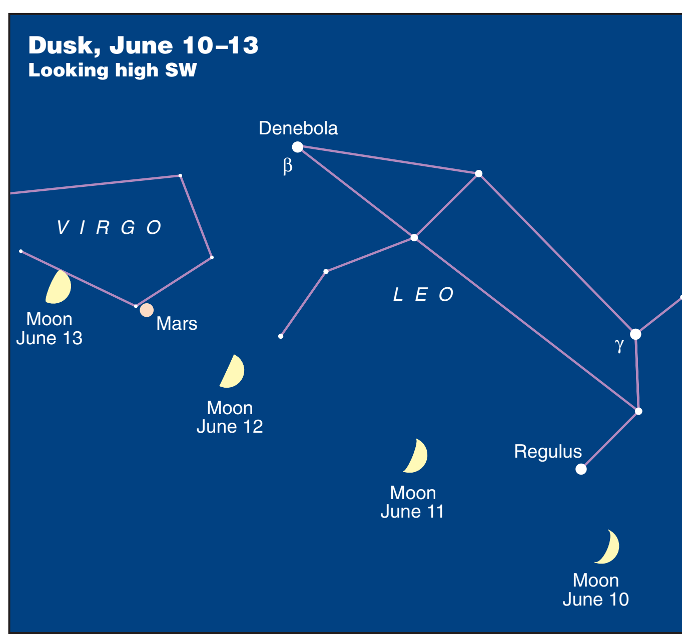
Venus is so bright that it can be spotted even through twilight very low in the west-northwest 45 minutes after sunset. But Venus is beginning the kind of evening apparition that tries our patience. It won't get much higher and more easily visible until autumn.

Mars remains prominent all evening, even though it fades from magnitude +0.2 to +0.6 during June. Look for the colorful world shining high in the southwest during dusk and lower in the west-southwest as night grows late.

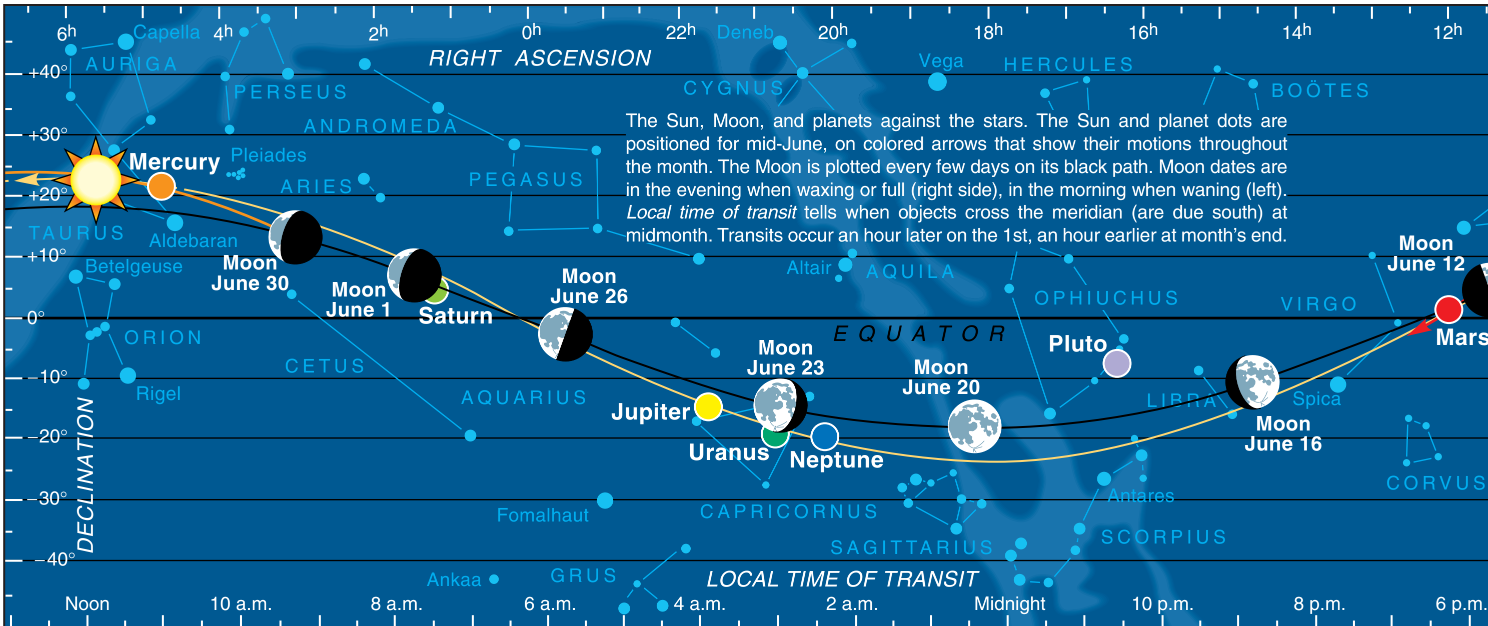
Mars's brightness in June is about midway between that of Arcturus and Spica. Its position is about midway between Spica and Regulus — but it's moving toward Spica and will pass less than 2° from it in the first few days of August. On the North American evenings of June 11th and 12th, Mars is within $\frac{1}{3}$° of 3.8-magnitude Beta Virginis.

Because Mars comes to eastern quadrature on June 23rd, it should appear

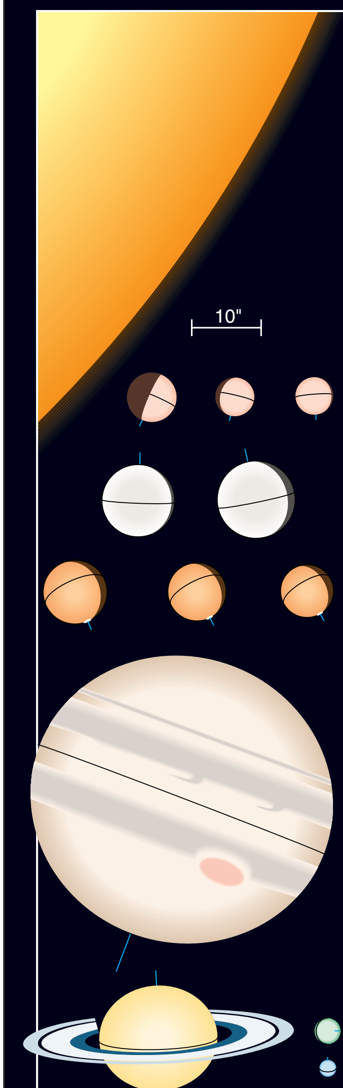




Venus can be spotted low in the west-northwest during twilight in June, while fainter, orange Mars shines higher in the southwest. The two planets will gradually converge on each other to meet in the twilight next October. These diagrams are drawn for one hour after sunset at latitude 40° north, but they can be used throughout the world's north temperate latitudes.

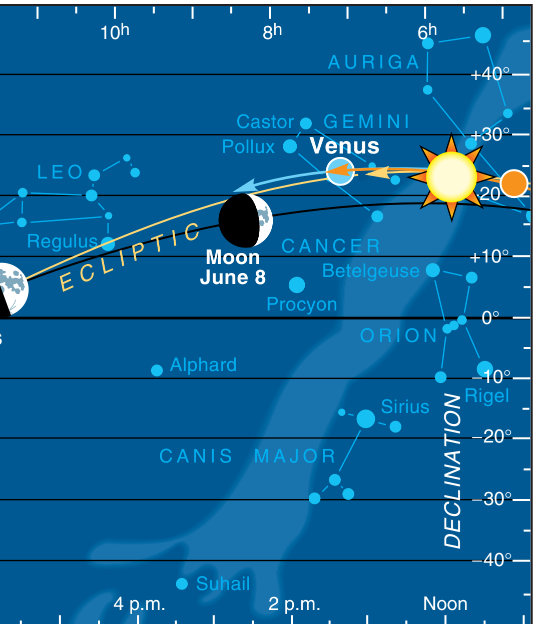


THE SUN AND PLANETS



		Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	June 1	4^h 35.8^m	+22° 02'	—	–26.8	31' 33"	—	1.014 a.u.
	16	5^h 37.8^m	+23° 20'	—	–26.8	31' 29"	—	1.016 a.u.
	July 1	6^h 40.1^m	+23° 07'	—	–26.8	31' 28"	—	1.017 a.u.
Mercury	June 1	3^h 03.2^m	+14° 17'	23° Mo	0.0	6.9"	56%	0.981 a.u.
	11	4^h 07.5^m	+19° 31'	17° Mo	–0.8	5.8"	78%	1.165 a.u.
	21	5^h 32.8^m	+23° 45'	6° Mo	–1.7	5.2"	97%	1.302 a.u.
	July 1	7^h 08.0^m	+24° 13'	6° Ev	–1.6	5.1"	97%	1.315 a.u.
Venus	June 1	5^h 42.9^m	+24° 10'	16° Ev	–3.9	10.2"	96%	1.642 a.u.
	16	7^h 03.3^m	+23° 55'	20° Ev	–3.9	10.5"	94%	1.590 a.u.
	July 1	8^h 21.5^m	+21° 05'	24° Ev	–3.9	10.9"	91%	1.525 a.u.
Mars	June 1	11^h 35.5^m	+3° 37'	102° Ev	+0.2	9.1"	89%	1.033 a.u.
	16	11^h 55.5^m	+1° 01'	94° Ev	+0.4	8.2"	88%	1.145 a.u.
	July 1	12^h 19.9^m	–2° 00'	86° Ev	+0.6	7.5"	88%	1.254 a.u.
Jupiter	June 1	21^h 37.7^m	–14° 55'	109° Mo	–2.5	42.2"	99%	4.668 a.u.
	16	21^h 38.1^m	–14° 57'	123° Mo	–2.6	44.2"	99%	4.455 a.u.
	July 1	21^h 35.6^m	–15° 13'	138° Mo	–2.7	46.1"	100%	4.274 a.u.
Saturn	June 1	1^h 07.4^m	+4° 41'	53° Mo	+0.8	16.5"	100%	9.999 a.u.
	16	1^h 12.1^m	+5° 06'	66° Mo	+0.7	16.9"	100%	9.784 a.u.
	July 1	1^h 15.7^m	+5° 24'	80° Mo	+0.7	17.3"	100%	9.547 a.u.
Uranus	June 16	20^h 43.3^m	–18° 49'	137° Mo	+5.7	3.7"	100%	19.068 a.u.
Neptune	June 16	20^h 06.1^m	–19° 51'	145° Mo	+7.9	2.3"	100%	29.309 a.u.
Pluto	June 16	16^h 16.3^m	–8° 12'	155° Ev	+13.7	0.1"	100%	29.058 a.u.

Right ascension and declination (equinox of date) are given for 0^h Universal Time on selected days. *Elongation* is the angle between a planet and the Sun, in the morning (*Mo*) or evening (*Ev*) sky. Next are the object's visual magnitude and apparent equatorial diameter (neglecting phase). Next is the percentage of the disk diameter illuminated by the Sun. Finally, distances from Earth are given in astronomical units. One a.u. is 149,597,870 km, or 92,955,807 miles. The planet disk diagrams have south up. Sets of two or three disks show the beginning and end of the month, single disks midmonth.



THE MOON

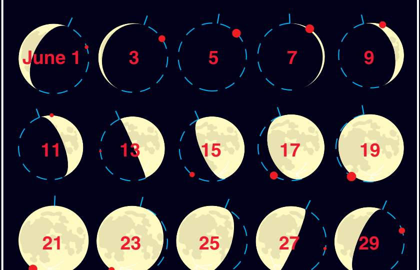
(Times and dates are Universal Time)

New Moon	May	6, 20:46
First Quarter	May	14, 10:55
Full Moon	May	22, 9:13
Last Quarter	May	29, 7:51
New Moon	June	5, 7:03
First Quarter	June	13, 4:51
Full Moon	June	20, 19:09
Last Quarter	June	27, 12:42

Greatest and Least Distances

Apsis		Distance	Diameter
Perigee	May 3, 11^h	366,626 km	32′35″
Apogee	May 15, 10^h	404,211 km	29′34″
Perigee	May 29, 7^h	369,788 km	32′19″
Apogee	June 12, 5^h	404,185 km	29′34″
Perigee	June 24, 5^h	366,494 km	32′36″

June Phases and Librations



The Moon's phase, orientation, and relative apparent size are shown for 0^h UT every two days in June. Celestial north is up, and a blue tick indicates the Moon's north pole. The red dot shows the point on the Moon's limb tipped into best view by libration; the dot's size indicates by how much. The maximum libration plotted is 8.5° on June 19th; the minimum plotted is 1.6° on the 13th. Adapted by Guy Ottewell from his *Astronomical Calendar 1997.* For more on libration see June 1992, page 670.

distinctly gibbous in even a very small telescope all month. Most amateur telescopes won't be showing any substantial detail on Mars, for its apparent diameter shrinks from 9.0" to 7.5" during June.

But at least the two spacecraft heading for the planet are now drawing near! Mars Pathfinder is due to land on July 4th; Mars Global Surveyor should go into orbit around the planet in September. See the December 1996 issue, page 24.

Pluto, at the Scorpius-Ophiuchus border, is well up in the south-southeast by late evening. If you have at least an 8-inch telescope, dark skies, and the finder chart on page 84 of last month's issue, consider taking on the challenge of finding this tiny, 14th-magnitude world discovered in 1930 by the late Clyde Tombaugh.

Jupiter rises around 1 a.m. daylight saving time at the beginning of June and 11 p.m. by month's end, a powerful brightness coming up from the eastern horizon. The –2.5-magnitude behemoth spends June essentially stalled out a few degrees north of Delta (δ) and Gamma (γ) Capricorni, the eastern tip of the boat shape of Capricornus. The giant planet will not be high enough to offer a steady telescopic image until dawn is nearing.

Uranus and **Neptune,** west of Jupiter near the Capricornus-Sagittarius border, are at their highest in the south around the time dawn gets under way. You can consult the map on page 84 of last month's issue to find them.

Saturn doesn't rise until early-morning hours, when it comes into view in the east in faint Pisces. Don't confuse it with decidedly dimmer Fomalhaut, which rises around the same time in the southeast. Even by morning twilight Saturn is not high enough in the east-southeast to look crisp in a telescope's eyepiece — but who can resist any view of the rings?

Mercury is essentially a lost cause for viewers at midnorthern latitudes in June. It has an apparition in the morning twilight from mid-May to mid-June, but it's very low in the bright dawn; look far to the lower left of Saturn. Mercury finally reaches superior conjunction with the Sun on June 25th.

The **Moon** is near Saturn before sunup on June's opening morning (parts of Asia and North Africa see an occultation). New Moon occurs on June 5th. After sunset on the 6th look for a slim crescent very low in the west-northwest, well to the left of Venus. On June 8th at dusk a line drawn through Castor and Pollux and extended far to the left hits the thicker Moon. The Moon is about half-lit as it slips past Mars between the North American nights of June 12th and 13th, occulting the planet for central Africa.

The full Moon pursues a low path across the southern sky on June 20th. A hefty waning gibbous Moon appears near Jupiter on the morning of June 24th, but it has dieted down to last quarter on the 27th. The Moon's second rendezvous of the month with Saturn takes place on the morning of June 28th, with the extreme southeastern U.S. getting an occultation in daylight.

The **Sun** is at the June solstice at 4:20 a.m. Eastern Daylight Time June 21st. This is the Sun's farthest-north point in our sky, marking the start of summer in the Northern Hemisphere and winter in the Southern Hemisphere.

Fred Schaaf welcomes mail at 681 Port Elizabeth-Cumberland Rd., Millville, NJ 08332 and e-mail at fschaaf@aol.com.

The Near Sky: Storms and Stars

WE SEE THE WONDERS of outer space through the often frustrating atmosphere — sometimes opaque with clouds, sometimes too much atremble to allow us a sharp telescopic view of Moon, planet, or double star. But sometimes the atmosphere's wilder manifestations can combine with astronomical views to produce scenes of rare splendor.

Long-exposure photographs of lightning sometimes show bright planets and stars above thunderheads in a clear sky. I recall a summer night in North Dakota when I was hiking to a weather radar installation. The thunderstorms were far away, but I got amazing views of lightning propagating many miles sideways, while just beyond the leading edge of cloud the sky was thick with 6th-magnitude stars and structured Milky Way. Occasionally very distant thunder rumbled in the cosmic silence — echoing in our imaginations across thousands of light-years or throughout the entire chamber of the universe itself. Another night, with the weather radar's help, we determined that we were hearing thunder from lightning 50 miles away!

F. S.

Mutual Events of Jupiter's Moons

EVERY SIX YEARS — twice in each orbit of Jupiter around the Sun — the orbital plane of Jupiter's four large moons turns edge on to the Sun and Earth. This event is similar to the way the rings of Saturn turn edge on to us twice in each Saturnian orbit, as happened last in 1995–96. But instead of seeing rings turn to a hair-thin line, we see Jupiter's four moons start to eclipse and occult each other as they shuttle back and forth on their way around the planet.

These "mutual events" of Jupiter's satellites, which last just a few minutes each, interest both amateur and professional astronomers. In some cases the satellites dim by enough for us to watch the change in a small telescope. Accurate photoelectric timings of the dimmings help to refine the precision with which the satellites' orbits are known. For centuries astronomers have tracked the orbits of the satellites by timing when they pass in and out of eclipse by Jupiter's own shadow. (Images from one such event, seen close up by the Voyager 2 spacecraft, are at right.) But Jupiter's shadow edge is hazy and variable, whereas the satellites' own profiles are sharp.

Above: ***Jupiter's satellites shuttle back and forth from our viewpoint as they orbit the planet. In most years, when two of them pass we see one going slightly above the other, as in this double pairing photographed by Jean Dragesco on April 16, 1984. But this year one satellite will often cross right over another.*** ***Left:*** **Europa being eclipsed by Jupiter's own shadow, as photographed by Voyager 2 in 1979.**

Listed in the table are the best mutual events of the satellites for the rest of Jupiter's apparition. More than 400 mutual eclipses and occultations are predicted in all. To make our short list, an event had to involve a drop in brightness of at least 47 percent (0.7 magnitude). This is enough change to be clearly noticeable to the eye. (The complete list with further details is on the World Wide Web at http://cdsweb.u-strasbg.fr/htbin/myqcat4?J/A%2bA/314/312.)

Events that happen when Jupiter is visible from at least part of North America are highlighted in boldface.

The first three columns give the date and time in Universal Time when an eclipse or occultation begins and ends. The *Event* column tells what happens. The satellites are numbered *1* for Io, *2* Europa, *3* Ganymede, and *4* Callisto. *O* stands for occults, *E* eclipses, *A* annularly, and *P* partially.

The next column gives the expected dimming as the percentage of light that will be lost. This is the change in one satellite's brightness in the case of an eclipse, or in the combined brightness of two satellites in the case of an occultation. The last column gives the distance of the event in Jovian radii east or west of the planet's center.

For example, the first line tells that from 23:03 to 23:10 UT May 5th, Europa occults Ganymede annularly for a 48 percent total light drop. (To change this value to magnitudes, use the formula $\Delta m = 2.5 \log(1–\Delta L)$, where Δm is the change in magnitude and ΔL is the light drop.) The last column in the table shows that Europa and Ganymede are six Jupiter radii from the planet, well removed from its glare.

You can use the wavy-line diagram at right to identify the satellites in your field of view at any time. Mark your calendar to try to catch one of these unusual events!

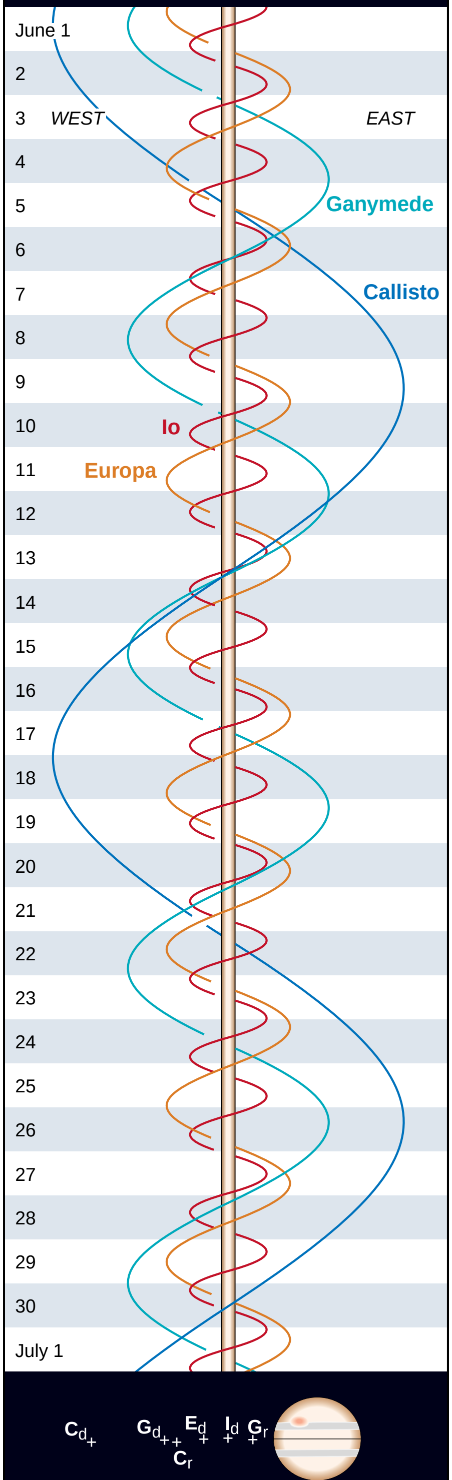
A. M.

BEST MUTUAL EVENTS

Date (UT)	Start (UT)	End (UT)	Event	Light drop (%)	Distance (Jup. radii)
May 5	23:03	23:10	2O3A	48	6.0
13	2:20	2:27	2O3A	48	5.6
18	**9:47**	**9:50**	**1E2P**	**49**	**5.5**
21	22:54	22:57	1E2P	61	5.6
25	**12:01**	**12:04**	**1E2P**	**72**	**5.7**
29	1:08	1:12	1E2P	81	5.8
June 1	14:16	14:21	1E2A	87	5.8
5	3:23	3:27	1E2A	88	5.9
7	**9:45**	**9:47**	**2E1A**	**50**	**3.9**
8	16:31	16:35	1E2P	85	6.0
10	22:51	22:54	2E1A	57	3.7
12	**5:39**	**5:42**	**1E2P**	**78**	**6.0**
14	11:57	12:00	2E1A	62	3.6
15	18:47	18:51	1E2P	68	6.0
18	1:03	1:06	2E1A	65	3.5
19	**7:55**	**7:59**	**1E2P**	**58**	**6.1**
21	14:10	14:12	2E1A	65	3.3
22	21:04	21:07	1E2P	47	6.1
25	**3:16**	**3:19**	**2E1A**	**64**	**3.2**
28	16:22	16:25	2E1A	60	3.0
30	**5:35**	**5:44**	**4E2**	**55**	**2.4**
July **2**	**5:28**	**5:31**	**2E1A**	**54**	**2.8**
6	22:26	22:40	3E4P	55	17.3

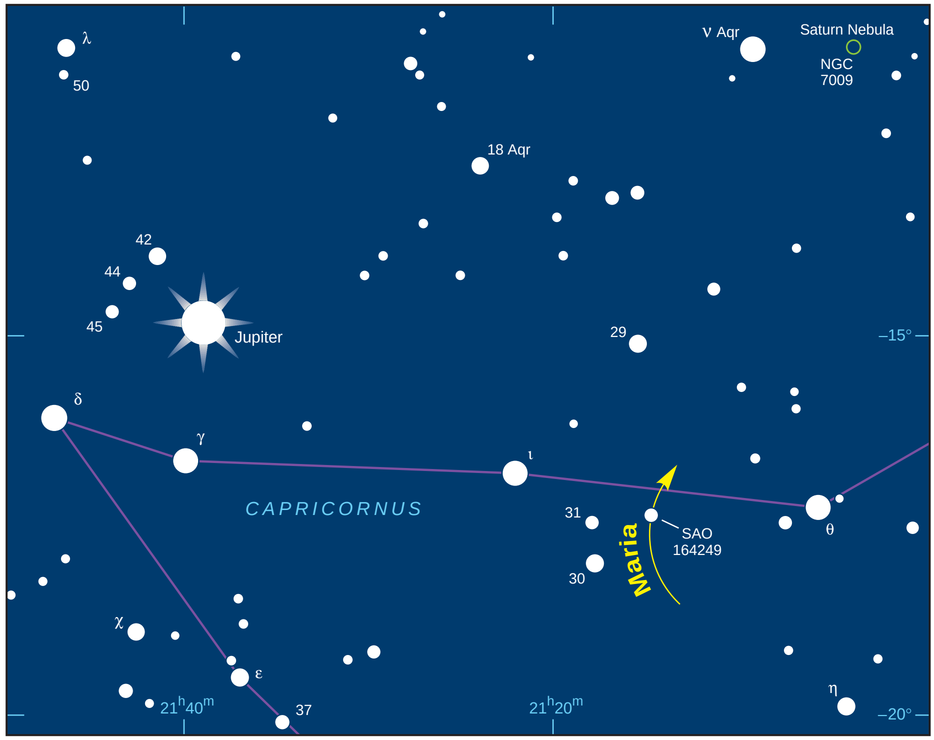
Date (UT)	Start (UT)	End (UT)	Event	Light drop (%)	Distance (Jup. radii)
17	14:17	14:21	4E2A	83	7.5
25	**8:58**	**9:08**	**1E4A**	**54**	**0.7**
Aug. 1	0:13	0:29	4E3A	60	14.9
3	0:03	0:07	4E1A	77	3.7
10	**11:15**	**11:19**	**3E4A**	**60**	**5.6**
20	**3:53**	**4:07**	**4E3**	**56**	**7.0**
24	**9:34**	**9:37**	**3E1P**	**57**	**0.3**
31	12:17	12:21	3E1P	82	0.6
Sept. **1**	**6:27**	**6:45**	**3E2P**	**72**	**9.3**
3	15:19	15:34	1E3A	49	4.5
7	15:01	15:04	3E1A	96	1.4
8	**10:56**	**11:12**	**3E2P**	**99**	**9.3**
14	17:45	17:48	3E1P	91	2.2
15	15:03	15:16	3E2P	99	9.2
18	19:32	19:38	1E3A	47	6.7
21	17:23	17:39	4E2P	85	0.4
21	20:30	20:33	3E1P	73	3.0
22	18:58	19:06	3E2P	67	9.0
28	**23:16**	**23:19**	**3E1P**	**48**	**3.7**
Nov. **4**	**6:23**	**6:55**	**3E1P**	**96**	**4.1**
4	11:03	11:25	3E1P	69	5.8
11	**4:24**	**4:43**	**3E1P**	**87**	**1.0**

Jupiter's Satellites



The curving lines represent Jupiter's four bright satellites: Io (I), Europa (II), Ganymede (III), and Callisto (IV). Jupiter itself is the center vertical bar. Each white or gray horizontal band represents a full day, from 0^h (upper edge of band) to 24^h Universal Time. The date is given at left, and 1 mm vertically is very nearly four hours. West is left and east is right to match the view from the Northern Hemisphere in an astronomical (inverting) telescope; binocular observers can just turn the page upside down. The bottom diagram shows where the satellites disappear (d) or reappear (r) during their eclipses by Jupiter's shadow nearest midmonth.

Calendar Notes



ASTEROID OCCULTS A BRIGHT STAR. A 6.2-magnitude star near Jupiter in Capricornus will be occulted by the faint asteroid 170 Maria on the morning of June 10th. Observers can try timing the star's disappearance with the smallest of telescopes or even tripod-mounted binoculars. The occultation path is predicted to run from Texas or Louisiana through Saskatchewan and Alberta between about 9:23 to 9:29 Universal Time. However, errors in the catalog position of the star or asteroid could move the occultation track many hundreds of kilometers east or west.

Maria is very small, only about 46 kilometers in diameter, but it is near the eastern end of its retrograde loop, so it will be moving slowly against the backdrop of stars. The occultation could thus last for up to 12 seconds. For more information see the map and table in the February issue, page 73. For late updates call the recording at 301-474-4945 a day or so before the event.

Moon occults Saturn. On the morning of June 28th telescope users in and around Florida can watch the waning Moon (two days past last quarter) occult Saturn in broad daylight. At Charleston, South Carolina, Saturn is covered by the Moon's bright limb at 8:11 a.m. Eastern Daylight Time and uncovered by the dark limb at 8:23. At Tampa Saturn is occulted from 7:42 to 8:33 a.m. EDT; at Miami, from 7:36 to 8:44 a.m. EDT. See the map in the January issue, page 90.

Variable-star maxima. May 10, R Reticuli, 0432**63**, 7.6; 11, V Coronae Borealis, 154639, 7.5; 13, V Cancri, 081617, 7.9; 16, U Ceti, 0228**13**, 7.5; 19, S Herculis, 164715, 7.6; 23, R Cygni, 193449, 7.5; 26, T Hydrae, 085008, 7.8.

June 1, R Carinae, 092962, 4.6; 1, W Lyrae, 181136, 7.9 (see chart, May 1990, page 524); 8, R Sagittarii, 191019, 7.3; 13, T Aquarii, 204405, 7.7; 22, R Normae, 152849a, 7.2; 29, W Andromedae, 021143a, 7.4 (see chart, October 1988, page 395).

The data above are, in order: the day of the month near which the star should be at maximum brightness; the star's name; its designation number, which gives rough right ascension (first four digits) and declination (boldface if southern); and the star's typical visual magnitude at peak brightness. The actual maximum may be brighter or fainter and many days early or late. All predictions are by Janet Mattei using recent data of the American Association of Variable Star Observers, 25 Birch St., Cambridge, MA 02138. Stars are listed if magnitude 8.0 or brighter at average maximum.

Easy sky measures. As a guide to judging angular distances on the sky, your wide-outspread hand at arm's length (from thumb tip to little fingertip) covers roughly 20°. Your fist at arm's length is about 10°, and your little fingertip is 1°.

An eyepiece's field of view. To find your way around with a telescope or finderscope, you need to match the star patterns you see in the eyepiece to star patterns on your charts. This means knowing the size of your eyepiece's field of view.

To find the field diameter, aim at a star within about 10° of the celestial equator and center it. Turn off the telescope's drive, if any, and time how many seconds the star takes to drift from the center to the edge. The number of seconds divided by two equals the field diameter in arcminutes.

Mirror images in telescopes. Any optical system with an odd number of reflections gives a reversed, or mirror, image. The usual culprit is a star diagonal used with a refractor or Cassegrain design. To obtain a correct image that can be compared with a map, remove the star diagonal and view straight through. Or use an Amici prism, which employs two reflections instead of an ordinary diagonal's one.

A mirror image has nothing to do with whether the view is turned upside down, as it is in most telescopes. The two effects are entirely separate. If the view is correct but upside down, you can simply turn a map upside down to match it. But you can't make a correct-image map match a mirror-image view no matter how you turn it.

However, you can flip the map over and shine a flashlight up through it to view a mirror image of the printing through the paper. Or trace the map and flip the tracing paper over. (A mirror-image Moon map is available from Sky Publishing Corp.)

Sunspot numbers. The following final American relative sunspot numbers are reported by Peter Taylor, chair of the AAVSO Solar Division, from observations by 88 contributors:

February 1, 9; **2,** 23; **3,** 27; **4,** 25; **5,** 20; **6,** 21; **7,** 22; **8,** 8; **9,** 7; **10,** 0; **11,** 0; **12,** 0; **13,** 0; **14,** 0; **15,** 0; **16,** 6; **17,** 7; **18,** 8; **19,** 7; **20,** 6; **21,** 0; **22,** 0; **23,** 5; **24,** 7; **25,** 7; **26,** 4; **27,** 3; **28,** 0.

The AAVSO's final mean for February is 7.9.

Below are provisional daily sunspot numbers derived by Pierre Cugnon of the Sunspot Index Data Center in Brussels, Belgium (http://www.oma.be/KSB-ORB/SIDC/):

March 1, 0; **2,** 0; **3,** 0; **4,** 0; **5,** 0; **6,** 8; **7,** 10; **8,** 19; **9,** 18; **10,** 12; **11,** 13; **12,** 15; **13,** 14; **14,** 13; **15,** 25; **16,** 11; **17,** 12; **18,** 12; **19,** 0; **20,** 12; **21,** 0; **22,** 0; **23,** 0; **24,** 0; **25,** 0; **26,** 0; **27,** 10; **28,** 14; **29,** 18; **30,** 20; **31,** 17.

Cugnon predicts the following classically smoothed monthly sunspot numbers: May, 13; June, 14; July, 14; August, 15.

Universal Time (UT). In *Sky & Telescope* many events are given in Universal Time. UT is used worldwide by all who need to avoid confusion between time zones. It is expressed in the 24-hour system, whereby 1:00 p.m. is called 13:00, 2:00 p.m. is 14:00, and so on.

To convert a UT time and date to a standard time and date in North America, subtract the following hours: to get Eastern Standard Time, 5; CST, 6; MST, 7; PST, 8; Alaska, 9; or Hawaii, 10. To obtain daylight saving time (currently in effect in most of North America), subtract one hour less than these values. If you get a negative number of hours, add 24; in this case the result is on the date before the UT date given.

For example, 6:45 UT on the 9th of the month is 1:45 a.m. on the 9th EST, and 10:45 p.m. on the 8th PST.

You may find it easier just to remember when 0:00 UT happens in your time zone. This is on the previous date at 7 p.m. EST, 6 p.m. CST, 5 p.m. MST, or 4 p.m. PST. When daylight saving time is in effect: 8 p.m. EDT, 7 p.m. CDT, 6 p.m. MDT, or 5 p.m. PDT.

Universal Time is sometimes expressed as a decimal of a day to simplify calculations. Thus, 12:00 UT June 9th is June 9.5.

A note on sky positions. In *Sky & Telescope,* descriptions of where things appear with respect to the horizon or zenith are written for the world's midnorthern latitudes. Descriptions that also depend on longitude are for North America, except where otherwise noted.

Skyline: our telephone news service. To provide all readers with access to fast-breaking news such as comet and nova discoveries, *Sky & Telescope* maintains Skyline, a dial-up news service. The three-minute voice recording is updated every Friday afternoon, or more often if news warrants. Call 617-497-4168. Only regular toll charges apply.

The Skyline text ("Weekly News Bulletin") and much more can be found at our World Wide Web site, http://www.skypub.com/.

An Optimized Newtonian Reflector

Gary Seronik's attention to design and construction resulted in a 6-inch f/9 Newtonian reflector that provides refractor-like views of the planets and deep-sky objects. The author's observing buddy Steve Ewald is seen here with the telescope. The squat mounting is highly stable and much lighter than that required for a refractor of equivalent aperture. All photographs are by the author.

THE GENERAL BELIEF among amateur astronomers is that obtaining the ultimate in planetary performance and pinpoint definition requires a refractor. Recent advances in lens design and the availability of new, exotic glass types have only served to reinforce this wisdom. What is less-well appreciated, however, is that the humble Newtonian reflector is capable of remarkably similar performance at a fraction of the cost.

But can a Newtonian, no matter how carefully designed and built, really match the views of an expensive apochromatic refractor? I say yes because I have made just such an instrument. I like to call it my Newtonian refractor.

DESIGN FIRST

I began my project by choosing design parameters that matched those typical of commercial apochromats. I settled on a 6-inch f/9 optical system. While smaller apertures can show a lot, I wanted the greater light grasp of a 6-inch telescope. Experience has shown that with this aperture planetary details become much more certain than with smaller scopes. A 6-inch also puts a truly astonishing number of deep-sky objects within reach.

There are good reasons for the popularity of the f/9 focal ratio among modern apochromatic refractors. The tube length is short enough to be manageable, while still retaining the benefits traditionally ascribed to long-focus instruments. These include a generous image scale, which yields high-magnification views with medium-focal-length eyepieces. Add a high-quality Barlow lens, and it is possible to minimize the need for short-focal-length eyepieces, which lack the adequate eye relief necessary for relaxed viewing.

Furthermore, the slowly converging f/9 light cone is much easier for simple eyepiece designs to handle. It is amazing how well the previous generation of orthoscopic, Erfle, and Plössl eyepieces perform with moderate and long f/ratios. These eyepieces lack the extra correcting lenses found in some modern eyepieces designed with fast-f/ratio telescopes in mind. Because less glass can be better than more, at least when the quest is for maximum contrast and light transmission, the use of simple eyepieces became part of my design criteria.

Comparing f/4.5 and f/9 Newtonian Optical Systems

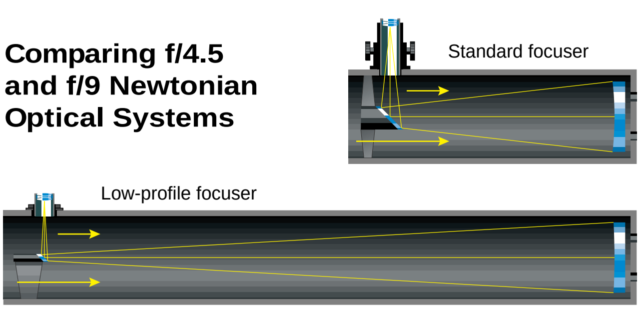


Image degradation due to the central obstruction in a Newtonian telescope is reduced to negligible levels when the obstruction is less than about 15 percent of the primary mirror's diameter. A long f/ratio and low-profile focuser make it possible to use a small secondary mirror.

Another important benefit of long f/ratios is the relatively lax collimation tolerances compared with faster mirrors. Rather then rendering an excuse for casual collimation standards, these tolerances provide the opportunity to colli-

Steve Ewald holds the tube extension, which prevents contrast-robbing stray light from reaching the eyepiece. This is especially important for telescopes having low-profile focusers that place the eyepiece's field lens close to the inside wall of the telescope tube.

mate with greater precision and the assurance that once adjusted, a telescope will remain collimated during use.

The principal limitation of the Newtonian design is often attributed to the secondary-mirror obstruction. Nevertheless, telescope experts such as Jean Texereau note that this image degradation can be greatly minimized. Because an f/9 light cone is very narrow where it meets the secondary mirror, a relatively small mirror can be used, thus reducing the size of the obstruction. An astonishing amount of literature has been devoted to this topic, and the range of opinions is wide, to say the least. One detailed discussion appears in Harold Richard Suiter's *Star Testing Astronomical Telescopes* (Willmann-Bell, 1994). After much deliberation, I settled on a secondary with a 3/4 inch minor axis. According to Suiter and Texereau, obstructions this small (only 12 1/2 percent of the aperture's diameter) degrade the image very slightly — certainly below the level that can be easily perceived in the eyepiece.

IT'S ALL DONE WITH MIRRORS

Without a doubt, the single most important aspect of building a high-performance Newtonian is the quality of the primary mirror. It has to be exceptionally well polished, accurately figured, and free of zones and surface roughness. Fortunately, here again the choice of a long f/ratio has important benefits. Many telescope makers are familiar with the Millies-Lacroix tolerance envelope (*S&T:* February 1976, page 127), which graphically illustrates the range of surface correction for a mirror of acceptable quality. The envelope is extremely narrow for short f/ratios but generously wide for long ones. This implies that long-focal-length mirrors can tolerate far greater figuring errors than those of shorter focal length. It is also easier to work a long-focus mirror toward a truly excellent figure and verify it with the simple Foucault test.

Since the degree of parabolization required is small for a 6-inch f/9 mirror, the time-tested method of first producing a good sphere and then proceeding to a parabola works very well. The benefits of this technique are as subtle as they are important. The Foucault test is a null test for spheres, and as such the slightest imperfections stand out in stark relief. Early on I decided that the sphere would be the battlefield on which I would fight zones and surface roughness.

Obtaining a smooth, zone-free sphere was considerably more demanding than

I had expected. It was easy, for example, to see differences produced by working the mirror using pitch of different hardnesses and subtly different polishing strokes. After much experimentation I found the combination of soft pitch and a slow, gentle, 1/3-diameter stroke with a full-size tool produced a smooth, zone-free surface. The experience also left me wondering just how much roughness can hide in the dark Foucault shadows of a short f/ratio mirror. Glass pushers sometimes become so fixated on a mirror's figure that surface roughness becomes a secondary issue, especially with fast mirrors where such defects are difficult to detect. Could surface roughness be one reason why so many Newtonians fail to produce high-contrast images?

I made several tries at parabolizing my mirror before arriving at the final figure. Because the overall correction was small, it was easy to return the mirror to a sphere if I didn't like how the figuring was progressing. Several pretty good figures were polished back to spheres in my search for perfection, and my notebook reads like the diary of a mad telescope maker. I recall the trepidation with which I took a 1/12-wave paraboloid back to a sphere, uncertain I could do better.

After much effort the primary mirror was finished. Although the final wave-error calculation implied a surface figure good to 1/29 wave, such measurement accuracy is beyond that possible with the Foucault test. I was, however, satisfied that the primary mirror was very good, and perhaps even excellent.

Simple modifications like this embroidery hoop, which prevents the tube from sliding longitudinally in its cradle when you are rotating it to place the eyepiece in a comfortable observing position, greatly enhance operation of the telescope in the dark.

FADE TO BLACK

The high-contrast images I sought from my telescope required more than just a smooth, well-polished mirror. The telescope's baffling system had to be optimized. For most Newtonian telescopes, baffling consists of a coat of flat black paint on the inside of the tube. This is obviously better than nothing, but it is far short of the complete baffling systems found in today's quality refractors. The principle behind baffling is simply to ensure that only the light coming to focus from the telescope's objective reaches the eyepiece.

Refractors usually accomplish this with a series of ring baffles spaced along the length of the tube, hugging the converging cone of light as it narrows to a focus. Some advocate a system of ring baffles for Newtonians, but these have drawbacks. Not only are they time consuming to make and awkward to install, but without the correct dimensions and spacing they either become ineffective or, worse, vignette the light path. A greater drawback is that, without elaborate modification, they will force air moving inside the telescope tube into the light path and thus degrade the image.

In my mind it is much simpler to rough up the inside of the tube — in effect creating many tiny baffles. I recalled a note in this magazine's telescope-making department that described sprinkling sawdust onto the first coat of black paint before it dried. A second coat of paint made the surface truly black. Rather than sawdust, I used crushed walnut shells (a product sold commercially as Slip-Not). The resulting roughness made for a tube that did an impressive job of soaking up stray light.

Complete baffling requires more than just a blackened tube, however. Looking into the focuser without an eyepiece in place revealed several possible sources of stray light. Openings at the mirror end of the tube needed to be blocked. Also, the edge of the secondary mirror and the miscellaneous screws and hardware on the mirror supports were all blackened with paint.

A final, but crucial, piece of baffling consisted of an extension at the top of the telescope tube. Without it, stray light could fall directly on an eyepiece's field lens. This is a significant source of glow, especially for telescopes equipped with low-profile focusers. A tube extension eliminates this and also helps prevent the formation of dew on the secondary mirror.

SUPPORTING THE SECONDARY

One refractor trait I particularly like is the beautifully clean star images free of diffraction spikes. To reduce these spikes in my Newtonian, I first tried a single stalk to support the secondary mirror. While it did minimize the total amount of diffraction, I soon grew tired of seeing a streak of light running through bright stars and planets. Recalling another article in this magazine, I set about making a curved secondary support, which is shown in the accompanying photograph. Because the single curved vane is made of thin steel, it creates less diffraction than a traditional four-vane spider made from the same thickness material. It also spreads the diffracted light into an invisibly faint halo around stars. Even the very brightest ones appear as intense, refractor-like, spike-free points of light.

Three of the telescope's important contrast-enhancing features are apparent in this view: the roughened inner surface of the tube, the curved spider, and the small, 3/4-inch-diameter secondary mirror. While the roughened tube cuts down light scattered into the field of view, the other two features work by reducing diffraction. The black drawer handle provides a convenient handhold when you are aiming the telescope.

So far I've described how I minimized the Newtonian's shortcomings. But the design in its own right has many advantages. For example, one of the refractor's irksome problems results from the eyepiece's placement at the bottom end of the tube, requiring a tall mount for comfortable viewing. Such mounts are prone to vibrate more than squat ones suitable for Newtonians, especially considering that, for a given aperture, refractors tend to be heavier than reflectors.

A Newtonian can reach thermal equilibrium with the night air more rapidly than a refractor. The stabilizing process is even faster if the reflector is actively cooled with a small fan. There are few dewing problems with a reflector, which is an important advantage for those of us observing in moist climates.

Perhaps the Newtonian's biggest advantage over refractors is its perfect color correction. While some of today's premium refractors have nearly eliminated color errors, I've yet to see one that was perfect. Having always used reflectors, I may be more sensitive to color errors than some observers, but to my eyes the pure colors of a Newtonian's planetary images are aesthetically more pleasing.

THROUGH THE EYEPIECE

So how does my Newtonian perform? Did my efforts to achieve high contrast and resolution pay off? Happily the answer is yes. I can say without hesitation that the views are the equal of any I've seen through a 6-inch instrument. The planets present a wealth of subtle detail. There have been nights of steady seeing in which Jupiter displayed more detail than I could draw.

While I expected this telescope to perform well on the planets, I didn't expect the performance I got on deep-sky objects. One particularly memorable morning when I was observing on Mount Kobau, I had a superb view of the Orion Nebula. Delicate tendrils of nebulosity contrasted with a startlingly black sky. The clear demarcation of the nebulosity reminded me of views I'd had through my 12 1/2-inch reflector equipped with an ultra-high-contrast (UHC) nebula filter. The 6-inch performed as if it had a full-time UHC filter that worked on objects not typically helped with conventional filters, such as star clusters and galaxies.

In retrospect, the deep-sky performance should not have been a surprise. After all, the very properties that make a great planetary scope also result in a fabulous deep-sky instrument. My experience with the Orion Nebula helped me understand why refractor owners often report deep-sky views that seem out of line with the telescope's aperture — it's all a matter of contrast.

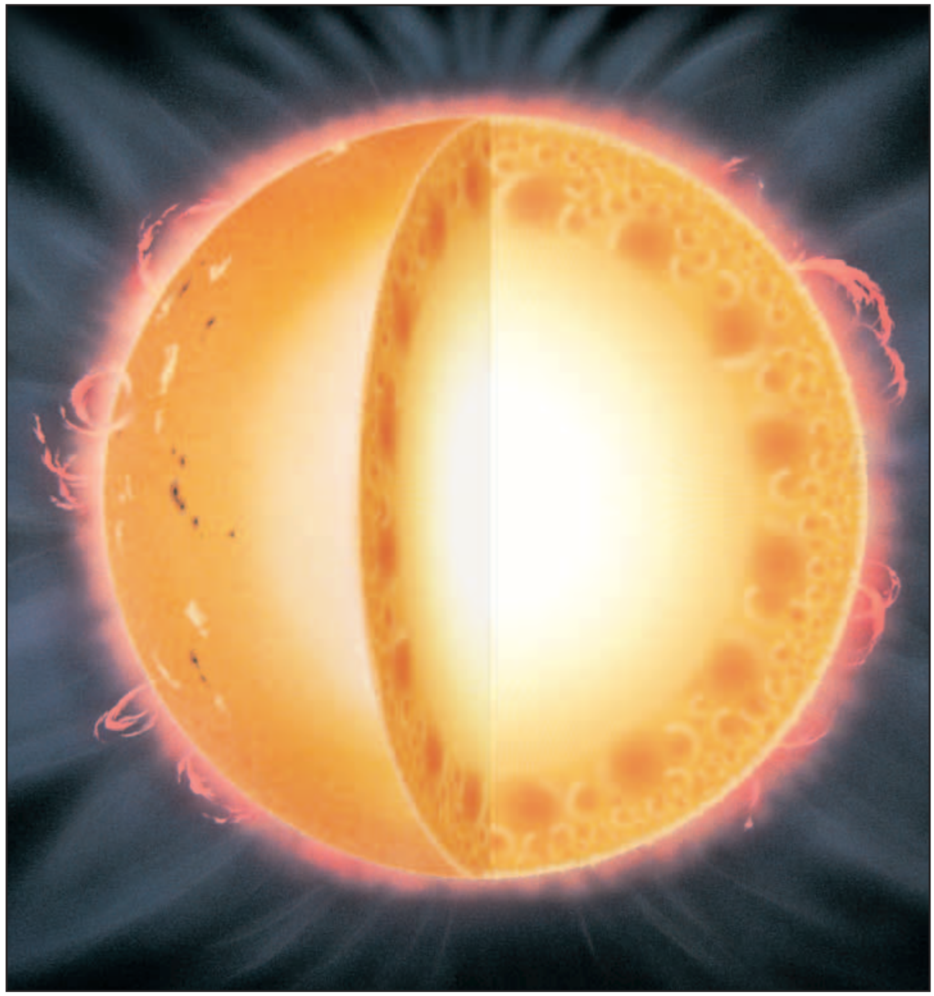
GARY SERONIK

Long-time amateur astronomer Seronik writes and presents programs at the H. R. MacMillan Planetarium in Vancouver, British Columbia.

Seeing Under the Sun's Skin

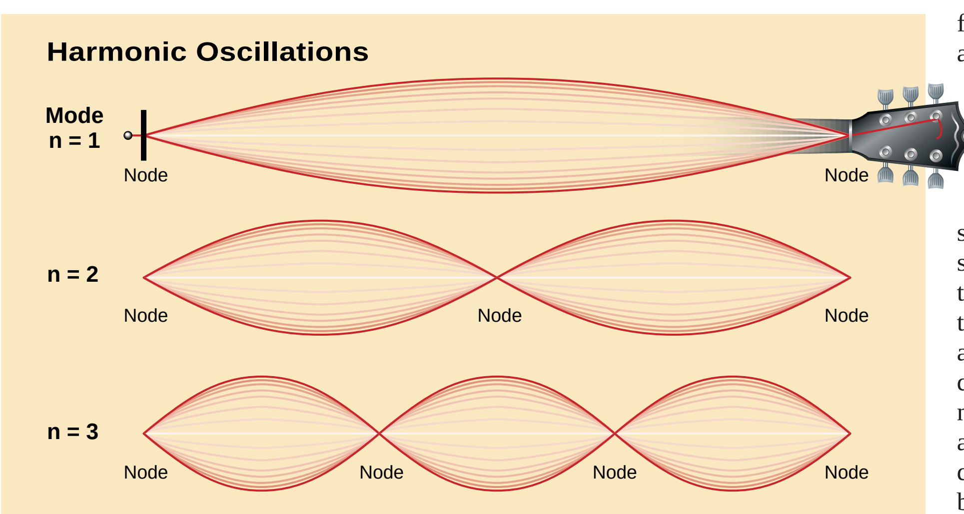
EVER SINCE GALILEO turned his telescope toward the Sun, astronomers have been confined to looking at the surface of our nearest star. Although we have learned a great deal in the course of these four centuries, there are still many facets of solar activity that we only dimly perceive. For example, we have great difficulty predicting the occurrence and extent of solar flares, a common astronomical phenomenon that can produce adverse consequences on the Earth (April issue, page 37).

Much of what we observe on the luminous solar disk (called the photosphere) is undoubtedly due to what happens beneath the surface. While studies of magnetic fields have helped explain many areas of solar physics, we really need to uncover what goes on below the photosphere. A burgeoning solar science called helioseismology has come to the rescue and is now starting to yield some of the Sun's secrets.



THE QUIVERING SUN

Two new observing programs — the ground-based Global Oscillation Network Group (GONG) and the Solar and Heliospheric Observatory (SOHO) spacecraft — are generating large amounts of data for study (*S&T:* September 1996, page 24; October 1996, page 20). These projects watch the Sun for extended, uninterrupted periods and allow astronomers to measure precisely the frequencies of millions of oscillations. The strongest shakings move the solar surface up and down about every 5 minutes.



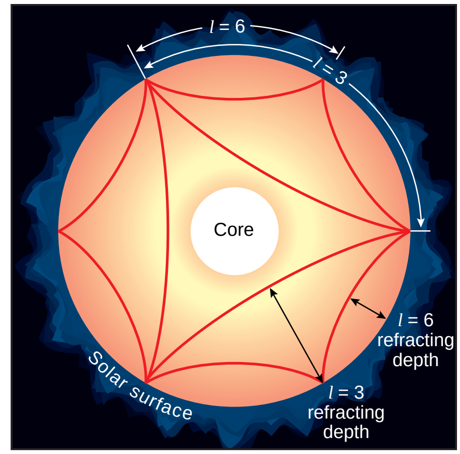
The Sun's three-dimensional oscillations are analogous to the one-dimensional vibrations of a plucked string. Waves bounce back and forth, reflected by the fixed endpoints (nodes). Higher-frequency vibrations produce intermediate nodes. Each set of nodes represents a different oscillation mode.

These undulations are the visible result of an incredibly large number of sound waves propagating throughout the solar interior. As the waves move through gas at different depths, they are affected by the changing temperature, density, composition, rotation, and magnetic fields they encounter. Detailed analyses of the frequencies can help us deduce these properties throughout the body of our star.

To understand why the Sun vibrates, let's look at simpler oscillating systems. A guitar string is a one-dimensional oscillator. When it is plucked, the string has two stationary points, called nodes, where the string is anchored at both ends. The string can have additional nodes for higher-frequency vibrations. These "standing waves" are illustrated in the diagram on the previous page. For each additional node, the string is said to oscillate in a higher "mode." In general the modal frequencies are given by $f = nf_0$, where f_0 is the fundamental frequency and n is the mode number. Our string will vibrate with up to a few dozen modes.

In two dimensions (say, for a drumhead), many more modes of vibration are possible. In such cases, there will be two mode numbers, n and m. A vibrating surface has frequencies related to multiples of its linear dimensions.

A three-dimensional body — the Sun — allows for even more modes. As we might expect, these are specified by three integers: n, m, and l. The result is a resonance occurring in a cavity defined by the surface of the Sun and a spherical lower edge located somewhere below. The first mode number, n, is called the radial order of the mode. It determines how many nodes exist on a line from the center of the Sun to its surface. It, however, does not influence the surface appearance of the mode. To characterize the surface motion we need only specify



Sound waves in the Sun do not travel in straight lines but are refracted by changing gas density. Here are ray paths for two fundamental oscillation modes marked with their *l* values. The lower the *l* value, the deeper a wave penetrates.

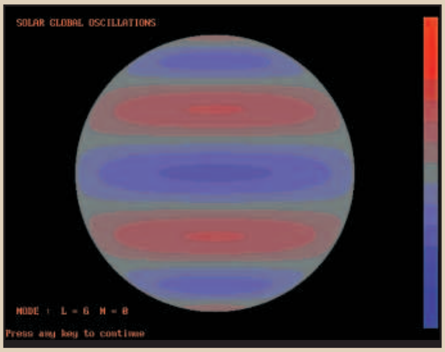
l, the degree of the mode, and m, the azimuthal order.

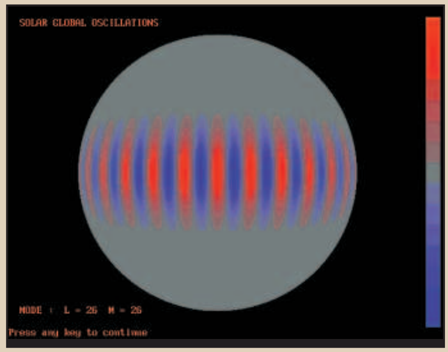
We view only a very limited part of the Sun's oscillations — the motions of the surface, which forms the outer boundary of each vibrating cavity. The inner boundary of the shell within which a given mode is confined depends on l (see the diagram above). Lower-degree modes resonate in larger cavities; that is, their lower boundary is located deeper

```
10 REM Solar Surface Oscillations
20 REM SOLAROSC.BAS by John Kennewell
30 DIM P(200)
40 SCREEN 12: PH=1.570795: MX=0
50 RD=1: GN=256: BL=65536!
60 PRINT "Solar Oscillation Modes"
70 INPUT "Degree L [0 to 28]";L
80 INPUT "Order M [0 to L ]";M
90 REM Generate Legendre function
100 FOR XI=0 TO 200
110 X=(XI-100)/100: D=SQR(1-X*X)
120 P1=D^L: P2=0
130 FOR LI=1 TO (2*L-1) STEP 2
140 P1=P1*LI: NEXT LI
150 IF M>=L OR P1=0 THEN 200
160 FOR MI=L-1 TO M STEP -1
170 PM=2*(MI+1)*X*P1/D-P2
180 PM=PM/(L-MI)/(L+MI+1)
190 P2=P1: P1=PM: NEXT MI
200 P(XI)=P1: MT=ABS(P1)
210 IF MT>MX THEN MX=MT
220 NEXT XI
230 CLS : COLOR 1: LOCATE 2,3
240 PRINT "Solar Global Oscillations"
250 LOCATE 28,3
260 PRINT "MODE : L ="; L;" M =";M
270 REM Show color palette
280 FOR I=1 TO 15
290 LINE (600,-15+30*I)-
         (620,15+30*I),I,BF
300 RC=RD*INT((15-I)*4.5)
310 BC=BL*INT((I-1)*4.5)
320 GC=GN*INT((7-ABS(8-I))*4.5)
330 PALETTE I,RC+BC+GC: NEXT I
340 REM Plotting
350 FOR CT=-1 TO 1 STEP .005
360 ST=SQR(1-CT*CT)
370 PM=P(CT*100+100)/MX
380 FOR SF=-1 TO 1 STEP .005
390 CF=SQR(1-SF*SF)
400 FI=PH*SGN(SF)
410 IF CF<>0 THEN FI=ATN(SF/CF)
420 S=PM*COS(M*FI)*ST*CF
430 X%=300+200*SF*ST
440 Y%=240-200*CT
450 PSET (X%,Y%),8-7*S
460 NEXT SF: NEXT CT: END
```

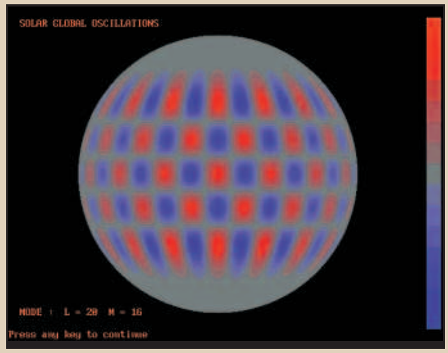
Program Listings Online

The BASIC listing in this article is available for downloading from SKY Online, *Sky & Telescope*'s site on the World Wide Web. Direct your browser to http://www.skypub.com/ and select "Astronomy Software for Your Computer."





The author's program on the opposite page illustrates the field of helioseismology by demonstrating a myriad of solar oscillation modes on your home computer. Entering values for the mode degree *l* and the azimuthal order *m* produces a disk showing where the solar surface is approaching (blue) and receding (red). These sample screens illustrate the general classes of modes: zonal *(upper left)*, sectoral *(upper right)*, and tesseral *(right)*. Astronomers are observing these fluctuations to gain a better understanding of the solar interior.



inside the Sun. Higher-degree modes tend to be shallow.

Solar modes exist with l ranging from zero to more than 1,000. For each value of l, m may range from $-l$ to l. Those, multiplied by more than a decade of values for n, produce more than one million separate modes of vibration.

HELIOSEISMIC SIMULATOR

The accompanying BASIC program (at lower left) will allow you to visualize some of the lower l modes. Upon execution, it asks for only two inputs: the mode degree l and the azimuthal order m. The program is written for IBM PC and compatible computers with a VGA or higher graphical display. It uses SCREEN MODE 12 to display the solar surface's velocity oscillations with a 640-by-480-pixel resolution in 16 colors. (This setting is not available with all BASIC interpreters; however, it will work with *QuickBasic*, which is included with the Windows operating system.) The neutral (nonmoving) surface of the Sun is depicted in gray-white. Points on the surface approaching the observer are colored blue while those receding are red. The hues are more intense for greater velocities.

After you have entered the two mode numbers, there is a slight delay while the program computes the Legendre function (lines 90 through 220). The screen is then cleared for the solar-surface plot. A color palette is drawn along the right-hand side of the screen. If the program is being run on a computer with a 386 processor that lacks a math coprocessor, it may take 15 minutes or so to complete. A Pentium processor will finish the task in seconds.

It is instructive to observe the different modal structure as l and m are varied using the program. In essence l determines the total number of nodal (stationary) planes. These planes may be either longitudinal (passing through the Sun's polar axis) or latitudinal (parallel to the equatorial plane). The m number determines how many longitudinal planes there are, while $l - m$ is the number of latitudinal planes.

For the general case when m is not equal to l, we have what are called tesseral modes. When $m = l$ sectoral modes are produced, and $m = 0$ creates zonal modes. To understand how they are named, just examine the images for these specific cases shown above.

When $l = 0$ the solar surface moves in and out equally all over (it could be termed a "breathing" mode). Although this scenario would look similar to the plot for $l = m = 1$, the two modes are quite different. The latter sectoral mode is such that when one side of the Sun moves out, the other side is moving in. The reason that the $l = 0$ mode features shading near the limb is that the motion is essentially radial and the program shows the line-of-sight component as actually observed by a terrestrial observer. This effect is apparent for all modes.

The program has its limitations. Unpredictable results may occur if m is specified to be greater than l — the program does not check for this condition. Values of l greater than 28 will cause an arithmetic overflow. This restriction may be bypassed by declaring the variables double precision. However, computational time will, of course, increase.

As a final note, helioseismology recently made headlines in the ongoing search for extrasolar planets. A Canadian astronomer suggested that sectoral oscillations of an $l = 2$, $m = 2$ mode, and not a Jupiter-mass planet, are responsible for the line-of-sight velocity variations in the Sun-like star 51 Pegasi (May issue, page 24).

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Bargain Hunting

FOR MORE than a decade, *The Starry Messenger* has offered a monthly publication devoted to classified advertisements for the amateur astronomer. The major aspect setting its contents apart from "normal" ads appearing in *Sky & Telescope* is that instead of payment upfront, the publication fee is a 4 percent commission once the item is sold, bought, or traded. *The Starry Messenger* can now be found on the World Wide Web (http://www.starrymessenger.com/), though in a limited capacity. You cannot read current ads at their Web site (that's reserved for subscribers), but the previous month's issue is available for downloading. You can also post an ad for the next issue by completing the online form.

Astronomy Online
By Stuart J. Goldman

However, there's competition out there. For several years, Robert Fields has been operating a classified-ad service called AstroMart (http://www.astromart.com/). The ads are available via an electronic mailing list and on the Web site. The systems are complementary: you'll receive ads quickly by e-mail, and you can search the entire collection on the Web. The site's information is updated every two hours.

A similar service is provided by the Students for Exploration and Development for Space (SEDS) at the University of Arizona. Among the vast astronomical riches on that Web site are Astro Ads (http://www.seds.org/Astro-Ads/). Like AstroMart, the no-cost classifieds are available on their Web site and as a mailing list. Similarly, The On Line Astro Trader (http://members.aol.com/EPSweb/olat.htm) is a relatively new service that pitches the searchability of the ads. However, effective with the May listing, posting is no longer free of charge.

The World Wide Web offers amateur astronomers an online marketplace.

Other than these astronomy-specific routes, you have several alternatives for buying and selling. For wider readership, there are more general classifieds on the Web, such as Classifieds2000 (http://www.classifieds2000.com/). For narrower reach, some local astronomy club Web sites have ad sections.

And finally, while it may seem enticing to post an ad to the sci.astro and sci.astro.amateur Usenet newsgroups, don't. There are specific newsgroups for ads, though none are dedicated to astronomical equipment. Most readers of the discussion newsgroups do not appreciate the ads. The people who feel most strongly will certainly let you know personally, should you post one anyway.

Amateur Astronomers

Edited by Edwin L. Aguirre

Floating more than 600 kilometers (375 miles) above the Earth, NASA's 2.4-meter Edwin P. Hubble Space Telescope is the world's premier orbiting observatory. Since 1992 15 amateurs have had the opportunity to use HST for observations ranging from observing frost on Jupiter's innermost moon to hunting for extrasolar comets around exploding stars. This photograph was taken during Hubble's servicing mission by astronauts aboard the space shuttle *Discovery* last February (see page 34). Courtesy NASA.

The Demise of the HST Amateur Program

ALL GOOD THINGS must come to an end. Take, for instance, the Hubble Space Telescope's amateur astronomy program. Following a much-publicized launch in April 1992, the program quickly set sail with high hopes and expectations before it sank into obscurity. This August James P. Flood, a chemist and amateur astronomer from Scotch Plains, New Jersey, will use the $1.5 billion orbiting observatory to probe the enigmatic nucleus of the galaxy NGC 1808 in Columba. But his will mark the 12th and final observation in the revolutionary, somewhat controversial, program. The question that immediately comes to mind is, What happened?

Former Space Telescope Science Institute (STScI) director Riccardo Giacconi conceived the program, which he made public on August 7, 1986. That day Giacconi said he wanted to reward amateurs for their contributions to astronomy by devoting $^1/_4$ of 1 percent of his discretionary observing time with HST to amateur programs. All United States citizens were eligible to apply. But the proposals had to pass the screening of the Amateur Astronomers Working Group (AAWG), a team of seven amateur and professional astronomers established to administer the selection process.

> ***"The program required so much manpower that I had to terminate it."***
> ***— Director Robert Williams, Space Telescope Science Institute***

Giacconi honored his promise, and on April 20, 1992, James J. Secosky, a high school science teacher in Bloomfield, New York, became the first amateur to use the world's premier telescope (*S&T:* August 1992, page 154). News of his historic observation rippled through the astronomical community and paved the way for a homemaker, an electrical engineer, a mathematician, and an electronics technician to follow in Secosky's footsteps (*S&T:* January 1990, page 30).

But HST's flawed primary mirror soon caused massive technical problems, affecting the scheduling of professional, as well as amateur, observations. By the time Hubble was repaired in 1993, the amateur program had lost momentum. Although the future looked bright for the space telescope with its corrected optics, winds of change had rattled STScI and, in turn, the foundation of the HST amateur program.

One major setback was Giacconi's departure from the institute in 1994 to direct the European Southern Observatory in Chile. Ray Villard, who spearheaded

Above: New York high school science teacher James J. Secosky _(far left)_ gazes intently at the computer screen as he and staff members of the Space Telescope Science Institute (STScI) in Baltimore, Maryland, review his observing run. In April 1992 Secosky made history as the first amateur astronomer to use HST. Photograph courtesy John Bedke, STScI. _Right:_ Secosky breaks into a wide grin as the first image of Jupiter's moon Io is displayed on the monitor. _Sky & Telescope_ photograph by Stephen James O'Meara.

public relations for the amateur program, was transferred to another department, and Eric J. Chaisson, a key STScI technical-support scientist, left to join the faculty of Tufts University in Massachusetts. Meanwhile, the institute's new director, Robert Williams, was faced with impending budget cuts; these, he says, forced him to make some difficult decisions. He had to downsize his staff by 60 people — and that included astronomers, technicians, and programmers.

"We lost a lot of capability to help amateurs with their proposals," says Williams. "We tried cutting back the number of amateurs using HST, but still, the program required so much manpower that I had to terminate it. The problem was not the telescope time but the amateurs, and I say that sympathetically. They don't have the technical background necessary to write a professional proposal, or to analyze their results. They needed a lot of help from our staff."

To the amateur astronomers already immersed in the program, William's decision hit hard. "I feel bad about it," Secosky says. "A piece of my life has been chopped away." Secosky, who had the honor of using HST twice, was a public-relations machine for NASA. He, like all the successful candidates, appeared on local television and radio shows, wrote letters to newspapers in support of HST when it was hobbled by bad optics, spoke to community groups about the benefits of the space telescope, and stressed the upside of NASA.

Indeed, public outreach was arguably the program's greatest achievement. And that was one of Giacconi's principal reasons for bringing amateurs onboard. He said he wanted the HST amateur experience to become part of the popular-science culture, and it did. He expected the participants to become local heroes and role models for the youth and spread the gospel about HST, and they did.

Take for instance Nancy K. Cox, a nurse and an HST amateur from San Francisco, California. Cox fought for the prestige of NASA when a myopic HST became the "butt of all the jokes." She says, "I hope [the institute] realizes the benefit of having had amateurs available at such a critical time, because we knew how to communicate the problem without talking over people's heads."

Cox did sense the amateur program wouldn't last. The halls of STScI were reverberating with talk of budget cuts and mass layoffs. "We had to have been taking up a lot of staff time," she says, "and that seemed ominous." Secosky concurs: "I knew the program had to be expensive, and we *did* need a lot of hand-holding. I feel bad about the outcome, but I'm really grateful for the once-in-a-lifetime opportunity I had."

THE SILENT MAJORITY

As far-reaching as Giacconi wanted the HST amateur program to be, it fell short of expectations. When the call for proposals went out, the review committee didn't know how the amateur community would respond — would they be deluged with tens of thousands or just a handful? Out of the estimated 300,000 amateur astronomers in the U.S. at that time, only about 500 submitted nearly 200 proposals during the first cycle; the second cycle produced 30, while the last one saw only 6.

The decline was due partly to a lack of publicity, claims AAWG chairman Stephen J. Edberg, especially when STScI was experiencing changes in management. But one other problem was clear: "There are *not* a lot of amateurs who could have presented the level of documentation necessary to apply," Edberg admits. He says it would have taken several weeks to draft a proposal, to prove the observation's worth, and to demonstrate its feasibility. The proponent had to be thoroughly familiar with related research in professional journals, HST's instrumentation, and other technical data. "Furthermore," Edberg emphasizes, "the Working Group took its job seriously. The amateurs had to know what they were doing. The proposals had to be really innovative and be really good."

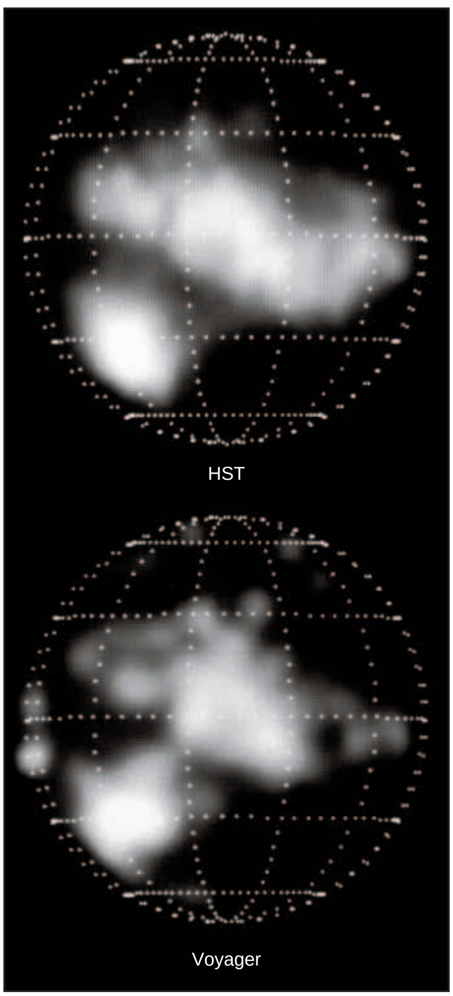
Edberg's estimate on the amount of time needed to prepare a proposal is conservative. HST amateur George R. Lewycky of Milltown, New Jersey, says his required seven *months* of research. "Being an amateur in a professional setting is quite difficult," he reveals. "I chose to do a project requiring spectroscopy. I had no idea what was in store for me. Using HST was a great opportunity, and I'd do it again. But I'd do imaging the second time around and not spectroscopy. Heck, I couldn't even pronounce 'spectroscopy' a few years ago. I wish I had known then what I do now."

Most everyone in the program agrees that, as an activity, the program did not offer enough amateurs a realistic opportunity to use HST — a few people used the telescope, and a lot did not. Furthermore, few of the amateur observations went smoothly, and some had to deal with the worst. "The amateurs were expecting perfection, but the unexpected happened," Edberg confesses, alluding to the telescope's mirror defect. "Some amateurs got distressed, and rightly so. It took time to try to find solutions to their problems, and not always with success."

For instance, because Hubble could not perform at its optimum level, HST amateur Ana M. Larson of Seattle, Washington, never got a chance to use the telescope; her program to search for extrasolar protoplanets required pushing HST to its optical limits, which was impossible given its astigmatic mirror.

"Just about every amateur had technical problems," Lewycky reveals, "and I can tell you we weren't ready for technical problems, and there were lots of them. These were the same problems professionals would have encountered, but we didn't have an army of graduate students to help solve them."

Lewycky is very grateful for the institute's technical support, but he believes some outside help in the proposal process could have saved some valuable time down the line. For example, his



Io as seen through HST's Wide Field/Planetary Camera *(top)* on April 20, 1992, and by Voyager 1 in 1979. The HST image is a composite of three ultraviolet (3577-angstrom) images, while the Voyager one was taken through a filter centered at 3500 angstroms. Courtesy James Secosky.

HST Amateur Observations

AMATEUR CYCLE 1 (1992)

Proposal: Sulfur Dioxide Concentration and Brightening Following Eclipses of Io

Investigator: James J. Secosky, science teacher, Bloomfield, New York

Overview: Use HST's Wide Field/Planetary Camera (WF/PC) in Planetary Mode to image Jupiter's moon Io in April and May, to see if temporary accumulations of sulfur dioxide (SO_2) frost cause the previously observed brightening of the moon when it emerges from the planet's shadow.

Results: Secosky did not see any brightening after three attempts. He did, however, find some minor, post-Voyager changes on Io's surface. The results appeared in *Icarus*, Vol. 111, 1994, pages 73–78.

Proposal: Imaging the Arc in the Galaxy Cluster 2244-02

Investigator: Raymond E. Sterner II, mathematician, Woodbine, Maryland

Overview: Use the WF/PC to determine whether the mysterious luminescent arc around CL 2244-02 in Aquarius is a gravitational-lens mirage or massive stars that formed along the shock wave generated during the collision of two galaxies.

Results: Because of HST's flawed optics, the resulting images were fuzzy and could not be deconvolved. Thus, the results are inconclusive.

Proposal: Magnetic Field of a Peculiar Type-A Variable Star

Investigator: Peter J. Kandefer, electrical engineer, New Hartford, Connecticut

Overview: Use HST's Goddard High Resolution Spectrograph (GHRS) to record the activity of Epsilon Ursae Majoris for one cycle of variation. In particular, study the intensity changes in the spectral signatures of rare-Earth elements in the star's atmosphere and make inference as to its magnetic-field strength.

Results: Kandefer did detect changes in the spectra of the rare-Earth elements, confirming the existence of a weak magnetic field around Epsilon Ursae Majoris.

Proposal: Search for the Oort Comet Cloud UV Emission, Suitable Nova of Opportunity

Investigator: John Hewitt, electronics technician, Berkeley, California

Overview: Use the outburst of a bright galactic nova (in this case Nova Cygni 1992) as a "probe" to search for evidence of an Oort Cloud of comets surrounding the erupting star. This is done by taking high-resolution, near-ultraviolet images with the WF/PC in Planetary Mode, and trying to detect the cloud's hydroxyl (OH) emission following the passage of the nova's light pulse through the cloud's inner regions.

Results: Saturated image; results inconclusive.

Proposal: Detection of Collapsing Extrasolar Protoplanets

Investigator: Ana M. Larson, homemaker and student, Seattle, Washington

Overview: Use the WF/PC in the near-infrared to search the star-forming regions in Taurus and Auriga for massive protoplanets undergoing gravitational contraction.

Results: Spherical aberration in Hubble's primary mirror prevented Larson from using the telescope.

AMATEUR CYCLE 2 (1993)

Proposal: Transition Comets: UV Search for OH

Investigators: Harald Schenk, civil engineer, Sheboygan, Wisconsin, and James Secosky

Overview: Use HST's Faint Object Spectrograph (FOS) to search asteroids 182 Elsa, 224 Oceana, 899 Jokaste, 944 Hidalgo, and 2201 Oljato for OH emission indicating weak cometary activity.

Results: No sign of OH emission.

Proposal: Investigation of the Dynamics of Binary Asteroids

Investigator: Benjamin P. Weiss, college student, Amherst, Massachusetts

Coinvestigators: Winslow Burleson and Rukmini Sichitiu, college students

Overview: Use the WF/PC in Planetary Mode in attempting to resolve the companions of suspected binary asteroids 18 Melpomene, 216 Kleopatra, 532 Herculina, 146 Lucina, and 624 Hektor.

Results: Did not discover any obvious asteroid satellites at the expected distances, but a few of the asteroids remain suspect.

Proposal: Titan's Atmosphere and Evolution Through Disk-Resolved Spectroscopy

The HST Cycle 2 amateurs pose for posterity at the STScI in October 1992. ***Front row (left to right):*** **James Secosky, Rukmini Sichitiu, George Lewycky, and Nancy Cox.** ***Middle row:*** **Lewis Thomas and STScI director Riccardo Giacconi.** ***Back row:*** **Benjamin Weiss, Winslow Burleson, Karl Hricko, Harald Schenk, and Joseph Mitterando. Photograph courtesy STScI.**

Investigator: George R. Lewycky, computer programmer, Milltown, New Jersey

Overview: Use the GHRS to search Titan's atmosphere for formaldehyde (CH_2O) which, when combined with hydrogen cyanide (HCN), can produce simple, precursor organic molecules necessary for DNA formation. (HCN was already discovered by Voyager 1 in Titan in 1980.)

Results: Data analysis is 90 percent complete. Preliminary results look promising. A few mysterious or unexpected absorption lines in the spectrum are under investigation. Updates can be found on Lewycky's Web site at http://soho.ios.com/~lewycky/hubble.html.

Proposal: WFC Observations of NGC 4319-Markarian 205: High-Resolution Morphology of a Galaxy-Quasar Association Displaying an Anomalous Redshift

Investigator: Karl J. Hricko, high school teacher, Carteret, New Jersey

Coinvestigators: Lewis Thomas, college teacher, and Joseph Mitterando, high school student

Overview: Use the WF/PC in Wide Field Mode to study the nature of the "bridge" of material linking the galaxy NGC 4319 (about 80 million light-years distant) and the quasar Markarian 205 (nearly 1 billion light-years away) in Draco.

Results: HST's uncorrected optics resulted in fuzzy images. Data analysis is still ongoing, but preliminary results are inconclusive.

Proposal: The Ultraviolet Emission Spectrum of an HII Region

Investigator: Nancy K. Cox, nurse, San Francisco, California

Overview: Use FOS to obtain ultraviolet spectra of M8, the Lagoon Nebula, in Sagittarius. Also use the WF/PC in Planetary Mode to look for filamentary structure and young, hot stars forming in the Lagoon's Hourglass region.

Results: The UV spectra did not reveal anything new. (The chemical abundances fell in line with other H II nebulae in the area like those in M17, the Omega Nebula.) Until recently, Cox's optical images showed more filamentary detail than any previous image. She was hoping newborn stars would appear in the images, but none did.

AMATEUR CYCLE 4 (1994–96)*

Proposal: UV Spectroscopic Determination of the Deuterium-to-Hydrogen Ratio Along the Line of Sight Toward Epsilon Indi and Lambda Andromedae

Investigator: William R. Alexander, chemist, Huntington, West Virginia

Overview: Use the GHRS to try to measure the abundance of deuterium left over from the Big Bang in the local interstellar medium.

Results: HST's spectral images along the line of sight toward the two target stars clearly separate the primordial deuterium from hydrogen. The observed deuterium-to-hydrogen ratio is about 1.65×10^{-5}. Alexander also discovered walls of hot, compressed hydrogen gas around the two stars he surveyed. These "hydrogen walls" are regions where the stellar wind interacts with the interstellar medium. The results were presented at the January 1996 American Astronomical Society meeting in San Antonio, Texas, and were published in the *Astrophysical Journal*, Vol. 470, 1996, pages 1157–1171.

Proposal: Lyman-Alpha Spectra of Discordant Redshift Systems

Investigator: R. Dennis Tye, computer programmer, San Francisco, California

Overview: Use the FOS to examine the Lyman-alpha forest absorption lines in the spectra of the galaxy MCG 03-34-085 and its associated quasar PKS 1327-206 in Virgo.

Results: Due to time constraints on HST, Tye could make only one observation of the quasar and none of the galaxy. His preliminary results show about 28 absorption lines in the observed spectral range. After eliminating those associated with the galaxy, there were still six to seven lines which might arise from clouds of neutral hydrogen (H I) in an object between the galaxy and the quasar. His results support the 1986 ground-based studies of the galaxy by French researchers; they too attribute the excess absorption lines to an intermediate system. Thus, the quasar is probably a background object and not related to the galaxy itself.

AMATEUR CYCLE 6 (1997)*

Proposal: Morphology of the Active Nucleus and Radial Filaments of NGC 1808

Investigator: James P. Flood, chemist, Scotch Plains, New Jersey

Overview: Use HST's new Wide Field and Planetary Camera 2 (WFPC2) to examine the core of the Seyfert galaxy NGC 1808 in Columba and hopefully reveal the nature of the half-dozen energetic "hot spots" residing there. (These spots could be circumnuclear starbursts, massive supernova remnants, or black-hole accretion disks.) Also study the pronounced radial dust filaments streaming from the galaxy's core. These are associated with large, gaseous polar outflows, suggestive of galactic fountaining.

Results: Was supposed to use HST in July 1996, but was bumped because of the servicing mission last February. Now slated to observe in early August.

S. J. O.

*Cycles 3 and 5 were cut short due to the HST repair and servicing missions in 1993 and this year, respectively.

project required comparing the spectral data he got from Saturn's moon Titan with spectral data from the Sun. The problem was that he couldn't point HST to the Sun. But no one at STScI thought of taking spectral images of Saturn's moon Rhea and reading the signature of reflected sunlight. "I got that advice from outside astronomers," Lewycky laments. "But the advice came a little too late — the observation had already been completed." The program could have been better, he believes, if professional astronomers had been more involved in the preparation of the proposal rather than just in the data reduction.

HST amateur Raymond E. Sterner II of Woodbine, Maryland, looks at the dilemma this way: "Everyone at the institute was nice to us, and we loved working with them. But they were learning too. The problem was that most of the amateur projects were long shots, but that's what they wanted." Sterner's project called for imaging a mysterious luminous arc in a galaxy cluster. Unfortunately, because of light loss arising from Hubble's defective mirror, the images couldn't be deconvolved — but no one knew that at the time. So his final images remain fuzzy.

"In a sense, we were guinea pigs," John Hewitt, an HST amateur from Berkeley, California, exclaims. "Our observations took place before many of the bugs in the postobservation process had been fully realized or resolved." Hewitt says his emotions went from elation, once he learned he would use Hubble, to despair, after he used it. His project was a longshot: it required using HST's Wide Field/Planetary Camera to detect the ultraviolet hydroxyl (OH) emissions in an extrasolar Oort Cloud. But he had to wait not only for a bright nova to occur, but for its light pulse to collide with the hypothetical comet cloud.

Surprisingly, a bright nova did erupt in the constellation Cygnus in time for him to use HST, and Hewitt carried out his observations — but not when he wanted to. "Ideally, the planned observation should have occurred about a week after the nova's peak luminosity, but I didn't get telescope time until *two months* after the event! This meant the loss of an opportunity to image the suspected circumstellar cloud. The name of the game was for the nova to provide 'illumination' of the Oort Cloud's inner region. The farther the nova's light pulse, the lesser the irradiance. So each day I waited meant a very rapidly decreasing possibility of detecting the hypothetical cloud."

HST Cycle 4 amateur William R. Alexander of Huntington, West Virginia, at the STScI in October 1994 doing his data reduction and analysis. Like other successful candidates, he became an advocate and ambassador of goodwill for NASA and STScI, promoting the cause of the HST amateur program to the public, the media, and the professional community. Courtesy William Alexander.

Despite the problems, Hewitt believes using Hubble was the greatest experience of his life. "There will be another nova someday," he says, "and my dream would be to reapply for HST time. The greatest miracle is that the telescope has been repaired and making stunning observations. I'd like another chance to do my observation right. In fact, I wish more people would have an opportunity to take up the challenge of using Hubble, to be a part in a continuing series of original, innovative observations made by the amateur community."

BUT WAS THE PROGRAM REALISTIC?

"The amateurs came up with good ideas," says Edberg, "and that's what they were asked to do. But was it realistic to expect that amateurs could use a professional instrument without outside help? The answer is, No!"

Villard shares Edberg's view: "The amateurs who used HST certainly followed the spirit of the program, but did the program accomplish its goals? There weren't any real scientific breakthroughs. But I don't think anyone was expecting any. The amateurs fulfilled their part of the bargain by asking new questions in their proposals and for involving the public. We loved working with them, and that was the greatest part of the experience. It's just that something was fundamentally wrong with the existing program."

So, this August the HST amateur experiment will have run its course. And, as with any experiment, the time has come to assess the results. The question now is, how can Hubble be linked with the amateur community without giving observing time to amateurs? That problem is in the hands of the STScI's Education Group, where Villard now works. Villard and Williams have already discussed new ways for amateurs to become involved with HST. "The amateur community is important for astronomy," Williams stresses. "In fact, I still consider myself one. Yet, ironically, I'm the one who killed the program."

Williams says he wants amateurs to be part of Hubble's scientific activities, but he doesn't think giving telescope time is the answer. He would have a hard time justifying that, especially in the face of budget cuts. "Besides," he asks, "what's more important — having three or four people use the telescope, or sending those same persons into schools? I'd have to say the schools. The thing most beneficial to society is education. I would love to send amateurs into the classroom with materials from the institute and have them communicate the findings of HST. Having amateurs *use* HST, however, would be last on my list."

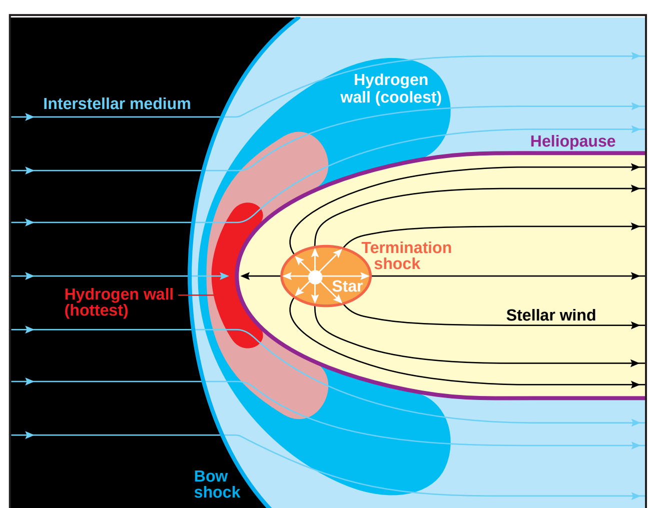
Williams would also like to make Hubble's archival data available for research. Such a program, he says, would reach a greater fraction of amateurs. His idea is to create some software, so that amateurs could start tackling the wealth of data in the archives. "Professional astronomers are going ga-ga over it," he says. "Why not the amateurs? And the data is free. Amateurs can get this stuff over the Internet." (Interested amateurs, teachers, and students can visit the HST Web sites at http://icarus.stsci.edu/~mutchler/HSTamateur.html and http://quest.arc.nasa.gov/livefrom/hst.html.)

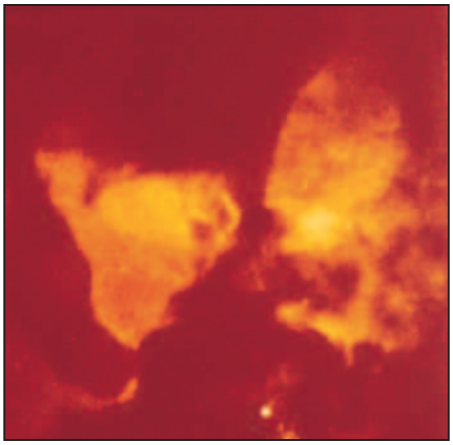
While the idea of a new amateur program is being considered at STScI, the HST amateurs are continuing to analyze their own data. And some important discoveries have already appeared on the horizon. For example, William R. Alexander, who was the first amateur to use HST after its optics were corrected, also became the first person to separate the absorption lines of deuterium from those of hydrogen along the line of sight toward the stars Epsilon Indi and Lambda Andromedae. "Not even the Copernicus or International Ultraviolet Explorer satellites have done that," Alexander exclaims. He gave a poster talk on his results at the January 1996 American Astronomical Society meeting in San Antonio, Texas.

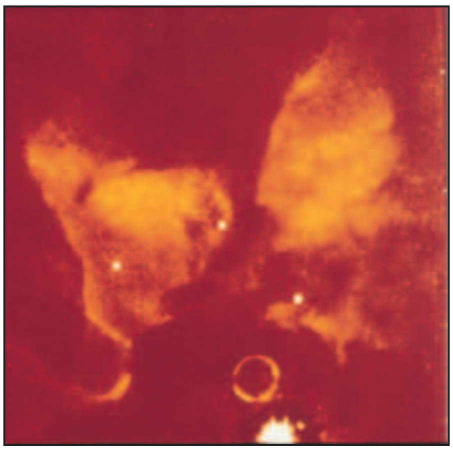
According to cosmological models the amount of deuterium observable at present was left over from the time of the Big Bang. The ratio of this primordial deuterium to hydrogen can be used to determine whether the universe is "open" or "closed." That ratio, as measured toward the two stars Alexander targeted, is about 1.65×10^{-5}, which, according to current Big Bang models, suggests that the universe is open and could expand forever. However, he admits that more research is needed to prove this theory.

Alexander also found some interest-

William Alexander used the HST to measure the abundance of deuterium left over from the Big Bang. But his results also led to the serendipitous discovery of gigantic "hydrogen walls" around the stars Epsilon Indi and Lambda Andromedae. A similar wall around our Sun had been found earlier by other professional HST researchers. Diagram courtesy Brian E. Wood and Jeffrey L. Linsky (University of Colorado) and Alexander.







These HST views of the Hourglass region of M8, the Lagoon Nebula, in hydrogen-alpha light *(top)* and sulfur (S II) were obtained by Nancy K. Cox. Compare them with the image on page 57 of the May issue.

ing features in his spectra, suggesting the existence of cup-shaped walls of hot, compressed hydrogen gas around the stars he studied. These "hydrogen walls," mark the boundary where the stellar wind interacts with the interstellar medium. (A similar wall around our Sun had been detected earlier by other professional HST researchers.) "Until this observation," Alexander says, "no one has been able to detect solar-wind-like outflows beyond our solar system."

The success of Alexander's program is testimony to the amateur vision. Certainly the amateur program as a whole would have been more successful had Hubble's optics been perfect from the start. Of the 13 amateur programs selected, only three will have utilized HST with corrected optics. How could the vast majority of HST amateurs be expected to make scientific breakthroughs when the telescope they hoped would lead them to discovery couldn't perform as promised? Unfortunately, right now, it appears there's little hope for many of these pioneers to get another chance to prove themselves.

Then again, consider the plight of Larson. Last September she earned her Ph.D. in astronomy from the University of Victoria in British Columbia, Canada. Her original HST research project called for the search for protoplanetary systems around young stars. "I actually did end up hunting for planets after all," she exclaims. "And I'm still looking for planets, like I dreamed in my HST proposal, but I'm doing it in a different fashion."

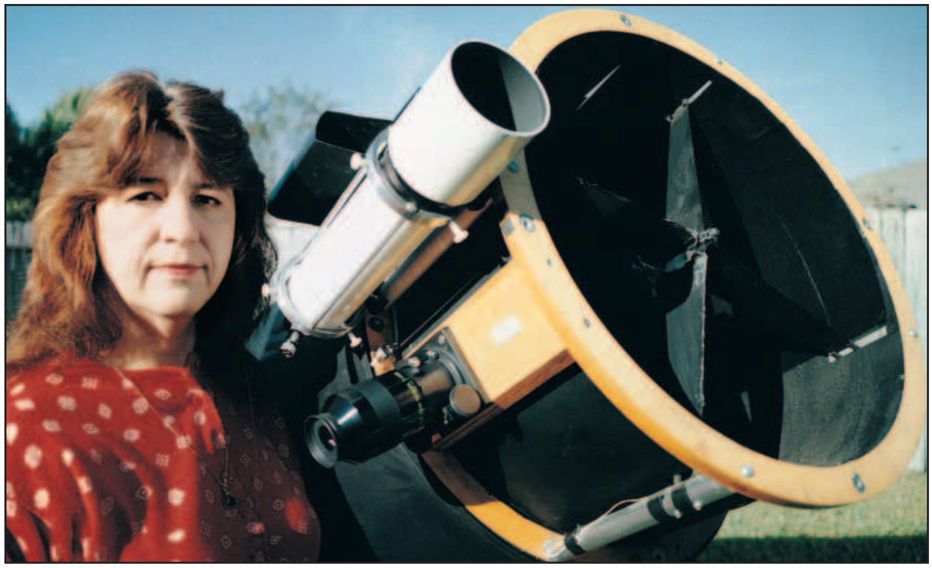
Larson became a member of the Canadian planet-search team that used data from the Canada-France-Hawaii Telescope atop Mauna Kea, Hawaii, in trying to detect planets around solar-type stars. Her current research at British Columbia's Dominion Astrophysical Observatory in Victoria is hunting for planets around red-giant stars.

"The fact that I didn't get a chance to use HST didn't lessen the experience," Larson explains. "Talking to people at STScI was a real encouragement for me — a mother of two kids — to enter graduate school. To think that you can come out of nowhere, get an opportunity to use HST, get guidance from professional astronomers, and then share your experience with the world — well that just really bolstered my confidence level. Imagine, the homemaker from Seattle finally made good!"

Although Ana M. Larson didn't get a chance to use the HST, this homemaker from Seattle, Washington, obtained her Ph.D. in astronomy from the University of Victoria, British Columbia, last fall. *Sky & Telescope* photograph by the author.

STEPHEN JAMES O'MEARA

Contributing editor O'Meara has covered the HST amateur program since it was first announced to the public in August 1986.



Amateur astronomer Barbara Wilson is an observing powerhouse. She enjoys hunting down deep-sky objects to the limits of her 20-inch f/5 Dobsonian. Photograph taken by Barbara's husband, Buster Wilson, from their suburban home in Houston, Texas.

STAR TRAILS

From Sixth Magnitude to Seventh Heaven

By David H. Levy

ONE of the top deep-sky observers of our time, Barbara Wilson was introduced to astronomy one evening in 1956 while taking down laundry from the clothesline at her family home in Green Bay, Wisconsin. "What is that bright orange thing in the east?" 9-year-old Barbara asked her father innocently. That "thing," her father explained, was the planet Mars at one of its best oppositions of the century.

Born to a military family, Barbara spent her youth moving all over the world, from Italy, Austria, and finally to Texas. Reading about the lives of great scientists like comet finder Maria Mitchell and physicist Marie Curie, Barbara felt inspired to study science. So she began a systematic study of the constellations, an endeavor later enhanced by her marriage to Buster Wilson in 1976.

In 1982 Buster brought home a vintage Criterion RV-6 Dynascope, a 6-inch f/8 reflector that was popular during the 1960s and 1970s. Since then life at the Wilson household in Houston has become focused on the stars. "I'd wake up at 4 in the morning and Buster would be outdoors with his RV-6!" says Barbara. By 1984 they were observing together, watching events like eclipses and conjunctions in the wee hours of the night.

The following year Buster bought his wife a 13-inch Coulter Odyssey Dobsonian. Barbara was shocked at the big, lanky heap of cardboard tubing and plywood box. "You're not going to bring that ugly thing inside the house," she insisted. "I want something with shiny knobs and gears and stuff coming off it."

Buster persuaded her to give the new scope a try. He set it up just inside the doorway of the front porch, where Barbara could see the clear skies beckoning. Peering skeptically through the eyepiece, she caught sight of an artificial satellite that happened to be moving slowly in the middle of the field. Mesmerized, Barbara nudged the telescope to follow the point of light as it passed from one field to the next. The journey ended abruptly when the telescope tube hit the carpet. That session changed everything. In an instant, Barbara recalls, "I was in love with that 13-inch!"

During the 1986 Texas Star Party she decided to give up her leisurely trek through the constellations to embark on an ambitious project of trying to observe the faintest deep-sky objects visible in amateur instruments. "From sixth magnitude to seventh heaven," is how

Barbara describes her shift from learning the constellations to collecting the bounty of the deep sky.

Barbara threw her energy into that effort with a single-minded intensity that went beyond books and star atlases. She watched her more-experienced colleagues in action at star parties. "I would watch how they observed, the way they used their scopes, and I'd ask lots of questions." For three years she logged observations of progressively fainter objects, including globulars and galaxies that offered her only fleeting glimpses at the limits of her telescope. Soon the 13-inch wasn't big enough.

One evening at the Texas Star Party in 1987 she happened to gaze at NGC 4631, a beautiful edge-on spiral a full quarter degree across, through a 20-inch Dobsonian. Laced with a series of bright knots, this galaxy in Canes Venatici was an amazing sight in such a large aperture. "This galaxy stretched from one edge of the field to the other; it was as big as life!" she exclaimed. "That's it. I gotta have a telescope like this."

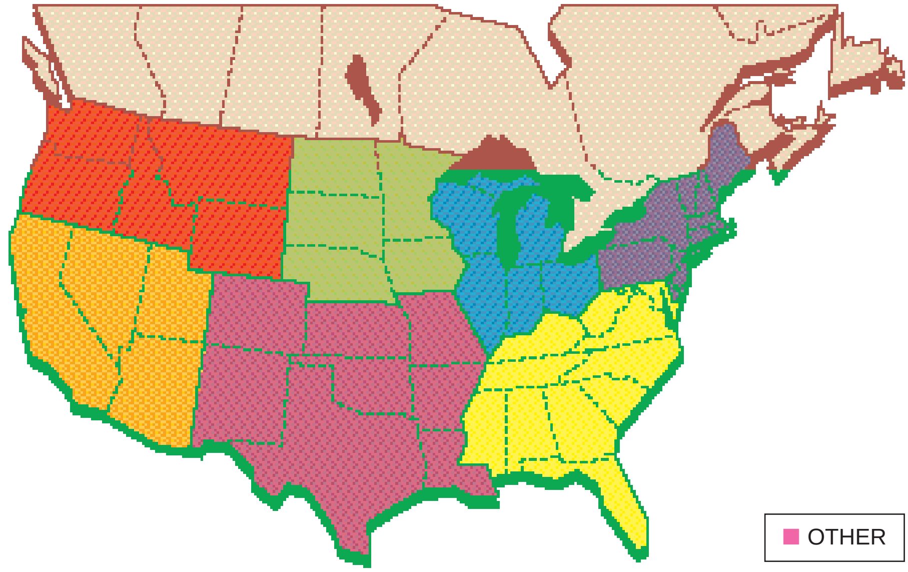
The following year Barbara arrived at TSP with a new 20-inch f/5 Dobsonian. Its primary mirror was handcrafted by the then-fledgling Galaxy Optics. With the 20-inch, Barbara extended her list of must-see objects to include the faintest globular clusters, including the seemingly impossible Palomar globulars (*S&T:* October 1991, page 423, and October 1994, page 97).

In 1986 some ten thousand people clogged the approaches to the Brazos Bend State Park where telescopes were set up to observe Halley's Comet. Although many were turned back, the sheer interest in the sky shown by Houstoners led to the construction of a permanent public observatory at the site. Involved in fundraising and other activities from the start, Barbara helped turn the project into reality with the opening of George Observatory in 1989. Her dedication eventually paid off. Burned out from being a real estate broker, in 1993 she happily accepted a teaching job at the observatory.

When Barbara sees a faint galaxy appear and disappear at the limits of her vision, she is living her dream. "Each session I try to push back the edge of the deep sky a little more. It's a thrill to imagine that these things, so distant and so faint that they offer me just a few photons, have now been seen by human eyes. Whatever lurks out there, there is some warmth to them."

An avid deep-sky enthusiast himself, author David Levy likes to observe at the limits of his 16-inch telescope from his home in Arizona.

Calendar of Events



■ **June 8–13** (New Mexico). The first annual Observational Astronomy Retreat will take place at the Lama Foundation near Taos (elevation 8,600 feet). Bring your own telescopes or use the site's 20-inch Dobsonian and 7-inch refractor. Camping facilities only. Cost is $250 per person. For details contact the Lama Foundation at 505-586-1202 or -1269; e-mail: 76375.2726@compuserve.com.

■ **June 10–14** (Florida). The Southeastern Planetarium Association's annual conference, hosted by the Space and Science Theatre of Pensacola Junior College, will be held at the Hampton Inn in Pensacola Beach. For more information contact Clint Hatchett, Science and Space Theatre, 1000 College Blvd., Pensacola, FL 32504, or call 904-484-2516; e-mail: chatchett@pjc.cc.fl.us.

■ **June 13–14** (Ohio). The Dayton Museum of Natural History in Dayton will be the site of the 27th annual Apollo Rendezvous convention. Call Terry Mann at 937-678-5032, or send e-mail to starsrus@infinet.com; WWW: http://www.mvas.org/.

■ **July 4–6** (Canada). The Royal Astronomical Society of Canada's Regina and Saskatoon Centres will host the Saskatchewan Summer Star Party at Cypress Hills Provincial Park (elevation 1,200 meters). Contact Erich Keser, RASC Saskatoon Centre, P.O. Box 317, RPO University, Saskatoon, SK S7N 4J8, Canada, or call 306-374-4262; e-mail: keser@duke.usask.ca.

■ **July 14–15** (West Virginia). The Society of Amateur Radio Astronomers (SARA) will hold its annual conference at the U.S. National Radio Astronomy Observatory in Green Bank. For details call Hal Braschwitz at 212-252-8177, or write to Vince Caracci, 247 N. Linden St., Massapequa, NY 11758; phone: 516-798-8459; e-mail: vinhell@juno.com.

■ **July 25–26** (Canada). The 15th annual telescope-making contest of the Montreal Planetarium and the Société d'Astronomie de Montreal will be held at the Parc des Iles de St-Timothée in Québec. For details contact Yvan Prégent at 514-377-2493; e-mail: ypregent@rocler.qc.ca; or Patrice Gérin-Rose at 514-257-9613; e-mail: pgr@cam.org.

■ **July 25–August 3** (Massachusetts). All are invited to the sixth annual Summer Star Party & Family Camping Vacation at Shady Pines Campground in Savoy. Contact the Rockland Astronomy Club, c/o Don Urban, 73 Haring St., Closter, NJ 07624; e-mail: durban1@aol.com.

■ **July 28–August 18** (Germany). The 33rd International Astronomical Youth Camp, open to anyone between age 16 and 24, will be held at the Jugendgastehause Mortelgrund hostel near Sayda, 50 kilometers from Dresden. The cost for the entire program is DM790 (approximately $520). Contact Gwendolyn Meeus, Parkstraat 91, B-3000 Leuven, Belgium; e-mail: gwendolyn@ster.kuleuven.ac.be.

An expanded version of this listing, including active links to e-mail addresses, is available on our World Wide Web home page. Point your browser to SKY Online at http://www.skypub.com/calendar/calendar.html.

Edited by Edwin L. Aguirre

Although small in size, Delphinus contains a variety of targets for backyard telescopes. The constellation's distinctive diamond-shaped asterism (left) at the Dolphin's head is easily located near the eastern edge of the Milky Way near the brilliant star Altair (below center), which marks the southern tip of the Summer Triangle. Australian astrophotographer Luke Dodd prepared this view from a pair of 20-minute exposures on 120-format Fujicolor 400 film. His Pentax 6×7 camera was fitted with a 105-millimeter f/3 lens. The negatives were sandwiched together before printing to enhance contrast and color saturation.

The Dolphin's Deep-Sky Delights

DELPHINUS is a small constellation. The celestial dolphin covers just 189 square degrees of sky, and only 19 of today's 88 officially accepted constellations are smaller. Nevertheless, Delphinus's distinctive diamond-shaped asterism is easily identified near the southeast edge of the prominent Summer Triangle. Despite its diminutive size, the Dolphin contains many interesting objects.

Delphinus's two brightest stars form the western edge of the diamond. While you won't find them printed on modern star charts, the names once attributed to these suns have a fascinating history. In Giuseppe Piazzi's *Palermo Catalogue* of 1814, Alpha Delphini was labeled Sualocin while Beta Delphini was Rotanev. The derivation of these names posed a mystery throughout much of the 19th century until Thomas William Webb pointed out that the monikers spell out Nicolaus Venator in reverse. This was the latinized name of Piazzi's assistant, Niccolo Cacciatore. The advertising hyperbole of today's private star registries not withstanding, Niccolo Cacciatore is one of the few people to ever get away with "officially" attaching his name to a star, at least for a while.

Delphinus offers something for every deep-sky appetite, be it double stars, nebulae, star clusters, or galaxies.

Alpha and Beta Delphini are both multiple stars. *Sky Catalogue 2000.0* lists four companions for Alpha and three for Beta. The main components (the so-called AB pair) of Alpha are difficult to split. Although they enjoy a generous 30 arcsecond (30") separation, the 13thmagnitude companion is often lost in the glare of the 4th-magnitude primary. Placing the bright star just outside the field of a high-power eyepiece can help show the secondary, which is located to the southwest.

The AB pair of Beta Delphini is a difficult double for another reason. These stars are of 4th and 5th magnitude, and they orbit each other with a 26.6-year period. They are difficult to split because their maximum separation is 0.7". Currently they are 0.5" apart and widening to the maximum, which occurs just after the turn of the millennium. The duplicity of this tight pair was discovered in 1873 by the famous double-star observer Sherburne Wesley Burnham with a 6-inch Alvan Clark refractor.

Not all of Delphinus's many multiple stars are difficult targets. Gamma Delphini is an easy pair notable for its color contrast. The primary is a 4.5-magnitude subgiant of spectral classification *K*2, while the secondary is a 5.5-magnitude *F*8 main-sequence star located some 10" due west of the primary. Although the spectral classification of the companion suggests a yellow-white star, many observers see it as bluish or greenish in contrast with its golden yellow primary.

Delphinus contains a star that is of special interest because of its position. Writing in the January 1992 issue of *Sky & Telescope*, page 83, Roger Sinnott points out that the 5th-magnitude star Rho Aquilae has crossed the border into Delphinus due to the slow drifting of its proper motion. It is the first naked-eye star with a Bayer designation to have suffered this fate since the constellation boundaries were officially established earlier this century. There will not be another such crossing until the southern star Gamma Caeli moves into Columba about 400 years from now.

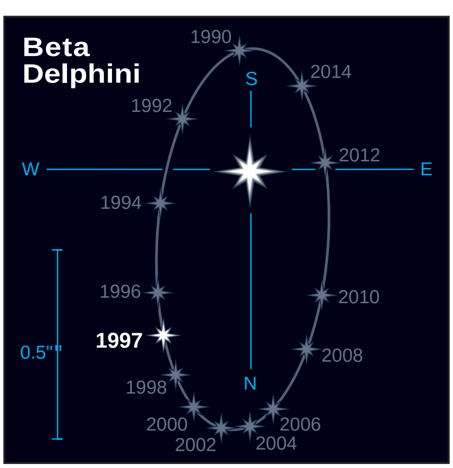
For observers who are amused by telescopic asterisms, there's a noteworthy group of stars between 9th and 11th magnitude that looks like a neat little toadstool. It's about 12' across and centered at right ascension $21^h\ 7^m$, declination +6° 18' (epoch 2000.0 coordinates).

There are two easily observed planetary nebulae in Delphinus. **NGC 6891** is very tiny but has a high surface brightness. Of visual magnitude 10.7, it can be seen in telescopes as small as 4-inch aperture, but medium to high powers are needed to distinguish the tiny 12"-diameter disk from those of nearby stars. An 8-inch scope reveals the nebula's 12.4-magnitude central star, while larger instruments may show glimpses of the faint, 74"-diameter outer halo and the bluish color of the central disk. NGC 6891 lies at an estimated distance of 7,200 light-years.

Somewhat closer is **NGC 6905,** which has an estimated distance of 4,200 light-years. With an apparent diameter of about 40", it is visible in a 4-inch scope. Through an 8-inch instrument this planetary appears slightly oval and a little brighter near the center. It lies along one side of a small triangle of faint field stars. A 10-inch aperture is usually needed to pick up the 14th-magnitude central star as well as the bluish color.

Two nice globular star clusters are found within the borders of the Dol-

Top pair: **Delphinus contains two interesting globular star clusters. NGC 6934 *(left)* is within reach of large binoculars, but resolving individual stars will require an aperture of at least 8 inches. NGC 7006 *(right)*, on the other hand, is a very remote object that will defy resolution with apertures of less than about 16 inches. Virginia amateur Preston Scott Justis recorded these views with a 10-inch f/5 Newtonian reflector. South is up, and the fields are each 10 arcminutes wide. *Bottom pair:* Two planetary nebulae in Delphinus are within easy reach of modest telescopes. At low magnifications the small disk of NGC 6891 *(left)* can be mistaken for that of a star, while NGC 6905 *(right)* is more easily identified as a planetary. Martin Germano of Thousand Oaks, California, captured both objects with a Celestron 8-inch f/10 Schmidt-Cassegrain telescope. South is up, and both fields are 4 arcminutes wide.**



Forming the southwestern tip of the diamond asterism, Beta Delphini is a challenging double star with 4.0- and 4.9-magnitude components that orbit each other in a 26.6-year period. It was discovered by the legendary double-star observer Sherburne W. Burnham with a 6-inch Alvan Clark refractor. This orbit diagram shows that the pair are presently separated by 0.5 arcsecond. Splitting them will test the caliber of an 8-inch telescope.

DELPHINUS DELIGHTS			
Name	Type	R.A. (2000.0)	Dec.
NGC 6891	Planetary nebula	$20^h 15.2^m$	+12° 35'
NGC 6905	Planetary nebula	$20^h 22.4^m$	+20° 07'
NGC 6928	Spiral galaxy	$20^h 32.8^m$	+9° 56'
NGC 6934	Globular cluster	$20^h 34.2^m$	+7° 24'
β Delphini	Double star	$20^h 37.5^m$	+14° 36'
α Delphini	Double star	$20^h 39.6^m$	+15° 55'
NGC 7006	Globular cluster	$21^h 01.5^m$	+16° 11'

phin. **NGC 6934** is 48,000 light-years away, yet it is visible in a pair of 14×70 binoculars as a tiny, fuzzy patch that grows brighter toward the center. It forms a nearly isosceles triangle with two stars of about 6th and 7th magnitude, and there is a faint star at the western edge of the cluster. In an 8-inch scope equipped with a high-power eyepiece, the cluster appears small, round, and slightly mottled around the edges. Increasing the aperture to 10 inches shows the 3-arcminute-diameter globular to be slightly oval and partially resolved into individual stars at a magnification of 218×.

The second globular, **NGC 7006,** is immensely distant, and it was once thought to be drifting independently among the galaxies. Recent measurements, however, suggest that NGC 7006 is some 113,000 light-years away and a remote member of the Milky Way. Even at this great distance, NGC 7006 can be spotted in a 4-inch scope. Mottling shows up when you are viewing it with apertures of 12 to 13 inches. Still larger instruments are needed to show any resolution.

The brightest galaxy in Delphinus is **NGC 6928** at magnitude 12.6. Through a 10-inch scope it looks like a spindle 1 arcminute (1') long and a third as wide. It is very faint, a little mottled, and brighter in the center. Two very faint companions lie nearby. NGC 6930 is a 13th-magnitude, elongated galaxy some 4' south-southeast of NGC 6928, while NGC 6927 is of similar brightness but located 3' to the west.

Small constellations are easily overlooked, especially if they contain no showpiece targets. But enthusiastic deep-sky observers will find many objects of interest in Delphinus. Those mentioned here are only a sample of what awaits you in the realm of the Dolphin on a clear, dark evening.

SUSAN C. FRENCH

Sue French and her husband, Alan, are long-time amateurs living in central New York. They are well known at gatherings of telescope makers and observers in the United States.

The Moon's northern limb juts into sunlight during the partial lunar eclipse on March 23rd. This mideclipse view was obtained by Dennis di Cicco. The 6-second exposure on 120-format Kodak Lumiere 100X film was made at the f/10 focus of a Meade 16-inch LX200 Schmidt-Cassegrain telescope.

OBSERVER'S NOTEBOOK

Eclipse Tales and Comet Tails

ASK ANY ASTRONOMER who hasn't witnessed a solar eclipse to describe one, and you're sure to hear how the Moon blots the Sun from the daytime sky to reveal the dramatic solar corona. But ask the same question of someone who's made the quest to stand in the Moon's shadow, and you're more likely to find the event itself buried in a long narrative of exotic travel punctuated with the intimate details of local weather conditions.

For those hardy souls who ventured into the Moon's shadow last March 9th there was no shortage of eclipse adventure. With a shadow track spanning the frigid winter wastelands of Mongolia, northern China, and Siberian Russia, this event crossed some of the world's most sparsely populated areas.

Many Western observers opted for sites near Darhan, Mongolia, or Chita, Russia, where the corona was seen through varying amounts of clouds. "Second contact was breathtaking, with the dark wall of the Moon's shadow racing towards us," writes German amateur Daniel Fischer, who trekked to eastern Siberia. His observations, as well as those of other eclipse chasers, will be summarized in a future issue.

On the night of March 23–24, two weeks after the solar eclipse, the Moon drifted through the northern half of Earth's shadow. This nearly total lunar eclipse was visible from much of the Western Hemisphere and western Europe. Although 8 percent of the lunar diameter remained outside Earth's umbral shadow, several observers commented on how remarkably similar the Moon looked to recent total eclipses that displayed a bright limb during totality. This event will also be detailed in a future issue.

Observers in western North America had a double treat during the lunar eclipse, since Comet Hale-Bopp had yet to dip below the northwest horizon.

With the full Moon fading from magnitude –12 to perhaps –5 during maximum eclipse, the sky darkened and afforded a better view of the comet. Alan Whitman of Okanagan Falls, British Columbia, writes that the Moon's waning light allowed "the stars and Milky Way to come out and the two tails of the great comet to lengthen." He could trace the gas and dust tails for 11° until they became lost in the glow of the Milky Way.

Arizona Earthshine. In the April issue, columnist Fred Schaaf commented on the varying visibility of Earthshine — the weak illumination on the dark portion of the crescent Moon from a brilliant, nearly "full" Earth suspended in the lunar night sky. Schaaf had once thought that Earthshine could not be seen on crescent Moons less than 28 hours from new because the subtle glow would be overwhelmed by bright twilight. But his own Earthshine sightings argued otherwise. He then asked readers what were the thinnest and thickest lunar phases at which the feeble light could be seen.

Jim Marrin of New York City was quick to reply. He was vacationing in Scottsdale, Arizona, when he caught sight of the Moon on the evening of March 9th between 7:00 and 7:30 p.m. Mountain Standard Time. The Moon was exactly 25 hours old at the midpoint of his observations. "I first noticed the Moon's thin, copper arc against the orange background of twilight," he writes. "Then I was able to trace the rest of the circle of the Moon. It was fainter than the sunlit portion, but definable. The face of the Moon appeared as a gray disk, however, and no surface features were apparent."

Possible new meteor radiant. Veteran meteor watcher George W. Gliba of Greenbelt, Maryland, sends a report of unusual meteor activity. He was observing under the tropical skies of the Winter Star Party held each year in the Florida Keys. Between February 6th and 9th he monitored the sky for a total of seven hours. In addition to logging 61 sporadic meteors, he counted several belonging to weak showers. The latter included 8 Virginids and 5 Alpha Centaurids.

Of special note, however, were 26 meteors that streaked outward from a point near the 4.5-magnitude star Xi Boötis. He saw a dozen during two hours on the 6th, as well as two more that he caught when he wasn't "officially" logging meteors. After that the numbers declined, with two hours of observing on both the 7th and 8th yielding six and four meteors, respectively. Two more were caught during an hour-long vigil on the 9th. All of his sightings were made between 7:30 and 10:30 Universal Time. The meteors were typically between 3rd and 4th magnitude, mostly white or blue-white, and traveling at medium speed.

ALPO at 50

This year marks the 50th anniversary of the founding of the Association of Lunar and Planetary Observers (ALPO). Inaugurated with a membership of fewer than two dozen, the organization today boasts nearly 1,000 members, including many prominent amateur and professional astronomers.

The annual ALPO conference is scheduled for June 25–28 in Las Cruces, New Mexico, and will serve as a celebration of the past as well as a look toward the future. All present and former members are invited to attend. Highlights include a tour of the Very Large Array radio telescope and a special session in honor of the late Clyde Tombaugh, discoverer of Pluto. Information is available from Elizabeth Westfall, 2775 39th Ave., San Francisco, CA 94116; 415-566-5786; e-mail: ewestfal@sfsu.edu.

GALLERY

Right: **This bright and colorful aurora borealis over Glenallen, Alaska, was recorded by David E. Cartier Sr. on January 14, 1996. He used a 24-millimeter f/2.8 lens and Fujicolor 400 film exposed for 20 seconds. Auroras are produced when gusts of solar wind buffet the Earth's magnetic field, inducing electric currents of charged particles to flow down the magnetic-field lines. The current excites the gases in the upper atmosphere and causes them to glow. The green and red are mainly emissions from oxygen atoms.**

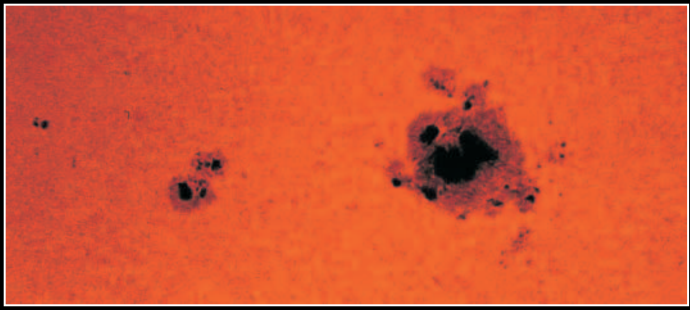
Above: **A rocket launched from the White Sands Missile Range near Alamogordo, New Mexico, on the morning of March 6th left this iridescent, spiraling contrail over the eastern horizon, visible for hundreds of miles. The view at left was snapped by Joshua Vaughan from Prescott, Arizona, while the one on the right was by Detrick Demond Branston in Tucson. The rainbow colors are sunlight refracted by water or ice particles condensing on the rocket's exhaust. The plume's chaotic pattern is caused by high-level winds.**

Straddling the Cepheus-Cassiopeia border is Cederblad 214, a complex of emission and reflection nebulae that measures 50' by 40'. The tiny, compact open cluster at lower right of center is Berkeley 59. Michael Stecker prepared this image from two 45-minute exposures on Fujicolor HG 400 film made with an 8-inch f/4 Takahashi reflector. To boost contrast and color saturation, he scanned the negatives and combined the resulting digital files using *Adobe Photoshop.* North is to the lower right.

Above: **NGC 1499, the California Nebula in Perseus, is a challenge to observe visually in any telescope, and long exposures are required to photograph it in its entirety. The bright star below it is 4th-magnitude Xi Persei, which causes the nebula to glow. George Greaney combined two 60-minute exposures taken with a 6-inch f/7 Astro-Physics EDF refractor and hypered 120-format Fujicolor Super HG 400 film (see page 116 of the April issue). North is up.**

Giovanni Dal Lago of Carrè, Italy, assembled six CCD images to create this mosaic of the Pleiades. Alfred, Lord Tennyson made one of poetry's finest references to the starry heavens when he wrote that the Pleiades "glitter like a swarm of fireflies tangled in a silver braid." Each of Dal Lago's frames is a composite of six 1-minute exposures made with a Starlight Xpress SL-8 camera attached to a Takahashi CN-212 (8.3-inch) reflector. North is up in this 1.3°-wide view.

Right: **David E. Cartier Sr. captured this luminous auroral band above the Alaska Highway Visitor Center at Tok Junction on January 3, 1996. He used a 24-mm f/2.8 lens and Fujicolor 1600 film for this 4-second exposure. As we approach solar maximum, due around 2000 or 2001, a dramatic rise in auroral displays can be expected as the Earth's magnetosphere gets bombarded by gusts of solar wind from eruptions on the Sun.**



Above: **Pierino Delvo' of Milan, Italy, photographed this sunspot group in February 1993. He used a 75-mm refractor working at f/40, a yellow filter, and Agfaortho 25 film. He made a color slide from the black-and-white print using an orange filter.**

Above: **From his home in Blanc-Mesnil, France, Gérard Therin made this CCD image centered near the smooth-bottomed crater Stöfler when the Moon was waning gibbous. Stöfler is roughly 125 kilometers (80 miles) in diameter. The smaller crater, Faraday, overlays Stöfler's southeast (upper left) rim, while large Maurolycus is prominent at upper left. Therin made this 0.04-second exposure with a Hi-SYS 22 camera and Takahashi 9¼-inch Schmidt-Cassegrain telescope operating at f/30. South is up.**

NGC 2237-39, the Rosette Nebula, is a famous emission nebula and star-forming region in Monoceros that surrounds the open cluster NGC 2244. The nebula measures about 80' by 60'. George Greaney obtained this view using the same setup and technique as his California Nebula shot on page 111. The exposure times were 50 minutes each. North is up.