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DISAPPEARING SPOT
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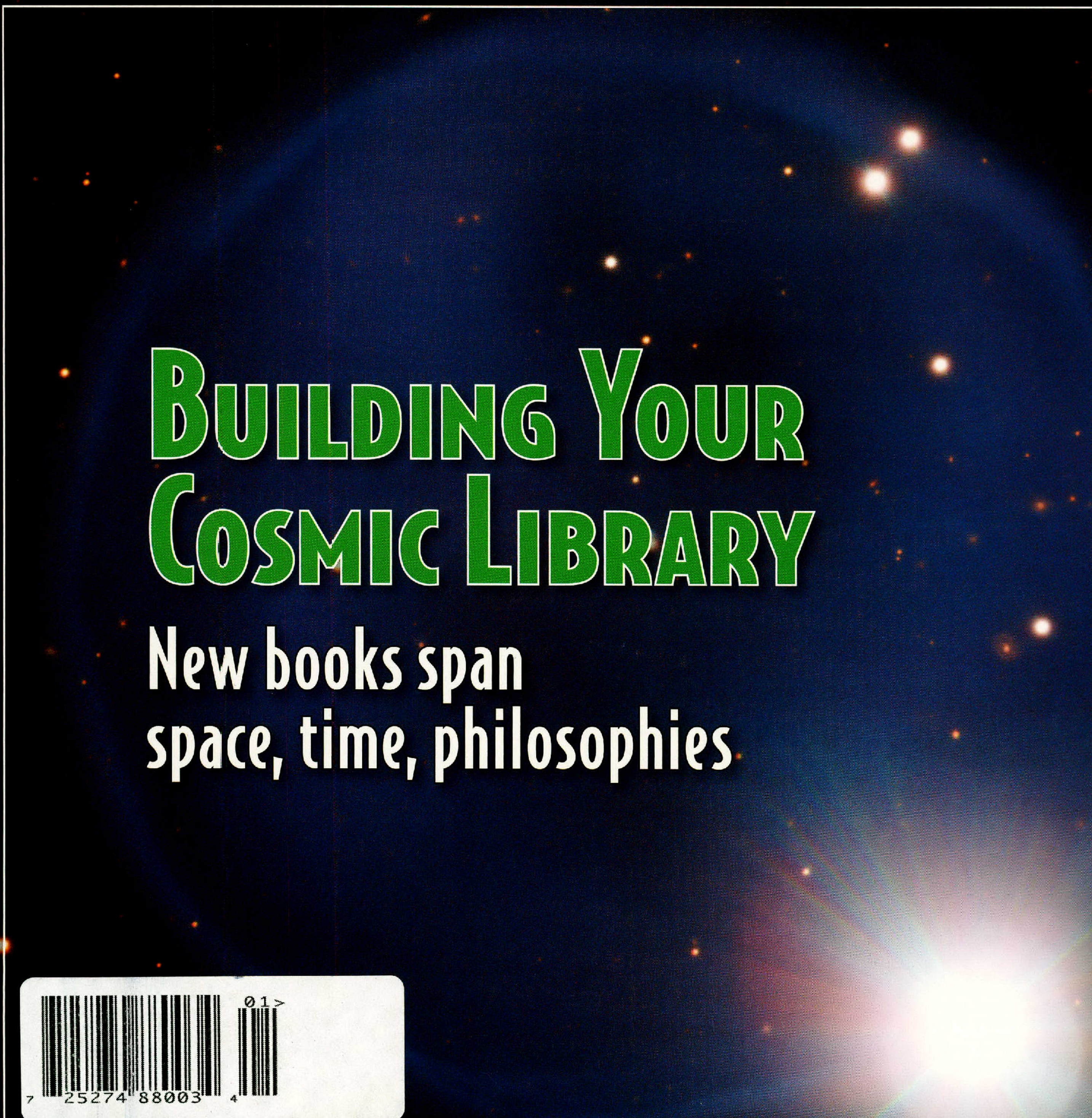

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StarDate

JULY/AUGUST 2014 • Vol. 42, No. 4

FEATURES

DEPARTMENTS

ESO

On The Cover
A cosmic coincidence allowed this alignment of planetary nebula Abell 33 (blue) and a foreground star (white, bottom right). The nebula resulted when an aging Sun-like star blew off its outer gas layers at the end of its life.

This Page
Astronomers weighed the 'El Gordo' galaxy cluster, seen here by Hubble Space Telescope, by measuring how much its gravity warps the images of galaxies behind it. It weighs up to 3 million billion times the Sun's mass. Hot gas (blue) moving between the cluster's hundreds of galaxies outweighs them. Giant clusters are thought to be rare in the early universe; this one is seen when the universe was only half its present age.

Coming Up
As autumn leaves start to turn, we'll bring you fall skywatching tips and charts. Plus we'll take a look at how migrating birds use the stars to find their way. Merlin answers your cosmic questions. And as always, we'll bring you the latest astronomy news.

NASA/ESA/J. JEE (UC DAVIS)

MERLIN

Dear Merlin,

I see a lot of TV specials and read a lot of articles about the search for planets orbiting around stars other than our own Sun. Scientists are looking at slight variations in the light intensity of a star. If there is a very slight dimming of the star on a regular interval, that could indicate something passing between that star and Earth.

If someone were looking at our solar system from a distant world, how would they see our Sun move about due to all the orbiting planets? How long would it take them to figure out how many planets are orbiting at what distances? Also, if their location was in line with our solar system's orbital plane, how long would it take them to figure out the orientation of all the planets?

Jim McCormick
Greenwood, Arkansas

Merlin recommends a comfortable chair, a stack of books, and a large pot of coffee for anyone trying to plot the planets of the solar sytem with this technique because it's going to take a while.

This technique looks for transits, which, as you aptly describe, occur when planets cross in front of their parent stars. The Kepler space telescope has discovered several thousand confirmed or possible planets with this technique, and ground-based telescopes have seen hundreds more.

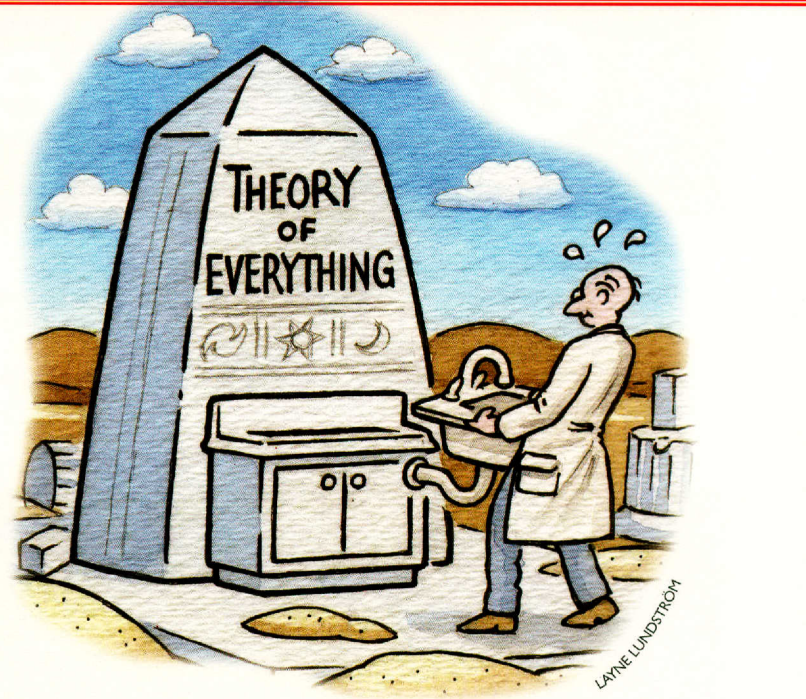
Transits require the orbital plane of the planets to align precisely with the astronomer's line of sight, so it works for only a tiny fraction of all the planetary systems in the galaxy.

If we assume that astronomers in other star systems have such a line of sight to the solar system, and that their technology is sufficiently advanced to detect very faint transits, then it still would take centuries for them to see and confirm all of the planets in the solar system. That's because an astronomer must see at least three transits to confirm the existence of each planet. One transit tells the astronomer that something has crossed in front of the star, but not when the object will return. Two transits could be from two different planets. Three transits, with equal gaps between them, confirms the planet's existence and reveals its orbital period.

That last parameter is why it would take so long to see all the planets in the solar system. It would take just two years to see Earth make three transits. But it would take a quarter-century to see giant Jupiter make three transits because it is much farther from the Sun, with a longer orbital period around the Sun. Neptune, the most distant of the eight major planets, takes 165 years to complete one orbit around the Sun, so it would take about 330 years to see three transits.

Other planet-finding techniques would allow distant astronomers to shorten that discovery time a bit. One technique reveals the gravitational pull of a planet, and it doesn't take two full orbits, although astronomers would like to see the better part of at least one orbit to be comfortable saying that a planet exists.

Any way you look at it, finding all the planets in a widespread system like the Sun's is a patience-testing task.



Dear Merlin,

What role does the Higgs particle play in the universe and how does it fit into the Standard Model theory?

Leonard C. Boucek
Monmouth Junction, New Jersey

The Higgs boson, which was discovered with the Large Hadron Collider, was the final piece of the Standard Model of particle physics, which breaks the universe into its tiniest building blocks — particles of matter, and particles that allow matter to interact.

The particles of matter are further divided into two groups. Those in one group stick together to make bigger particles, such as the protons and neutrons in the nucleus of an atom, while those in the other group, such as the electrons outside an atom's nucleus, exist on their own.

These particles interact by exchanging other types of particles, known as force carriers. They act as the glue that holds atoms together, and the messengers that travel through the universe as light.

The Higgs particle, which was predicted in 1964, gives mass to all the particles of matter. Without it, those particles couldn't join together to form stars, planets, and people.

Yet the Standard Model has gaps. It doesn't incorporate gravity, it can't explain why there's more matter in the universe than antimatter, and it can't explain dark matter. Scientists are working on extending the model, however, to become a "theory of everything," which unites all the particles and forces in nature.

Merlin is unable to send personal replies. Answers to many astronomy questions are available through our web site:
stardate.org/astro-guide

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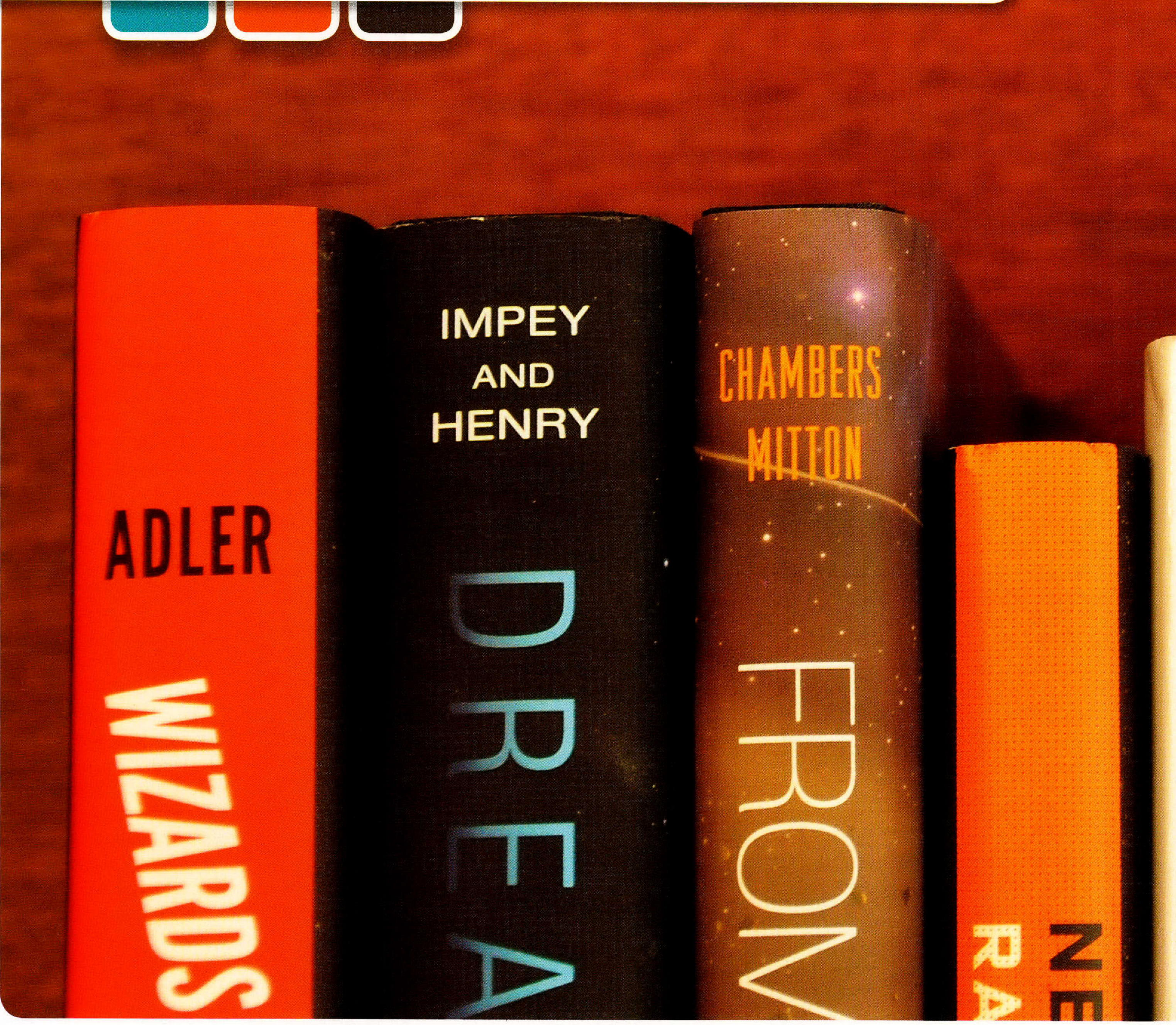
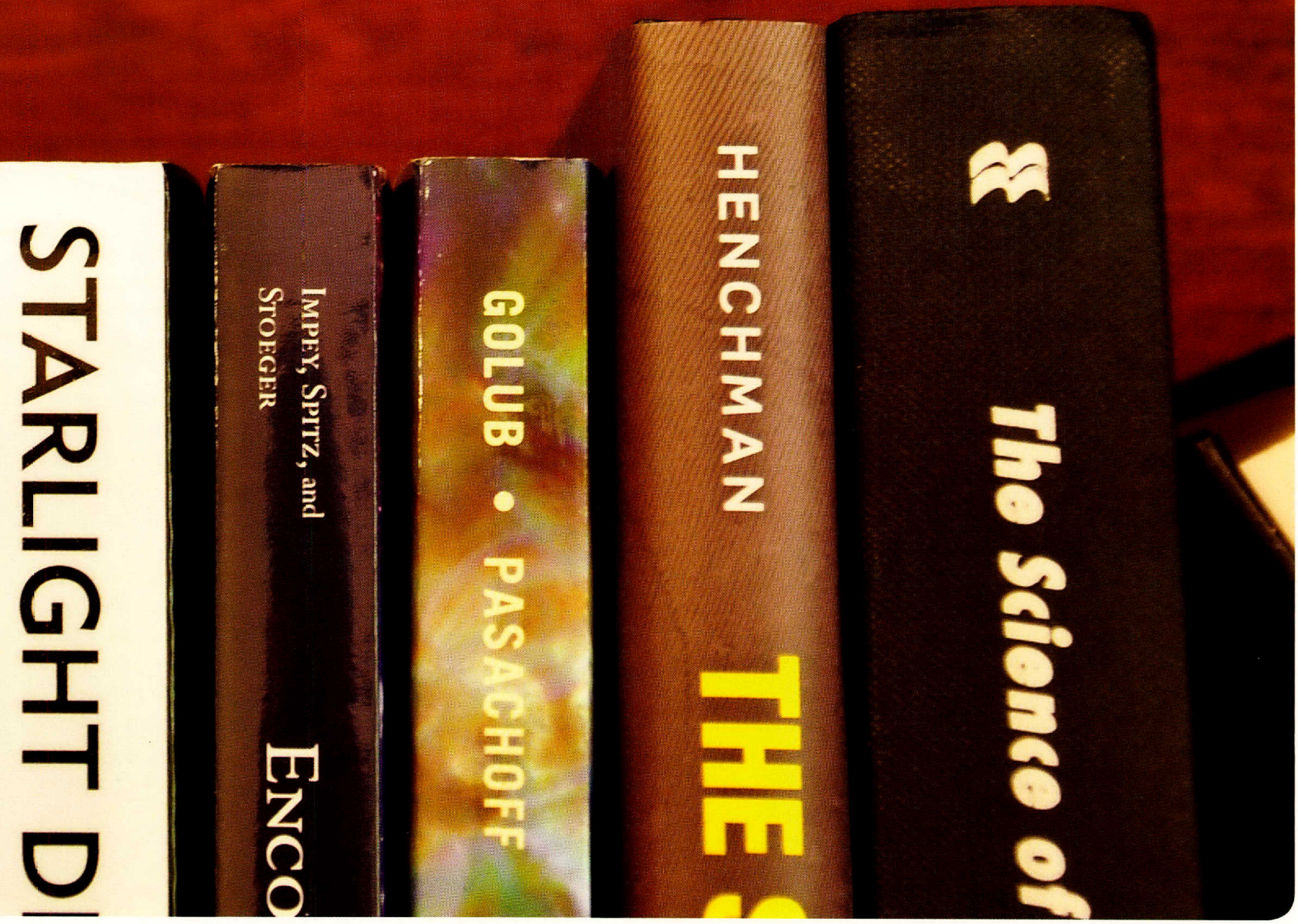
Centuries of Astron

From Hamlet to Martian bugs, books for your summer entertainment



C.J. DUNCAN

omical Reading



WRITTEN IN THE STARS

A wealthy amateur astronomer made some of the first observations of the chemistry of the stars, helping to prove that the Sun and distant stars are the same types of beasts

THE SETUP

Today, the study of the chemical make-up of stars of all types is the basis of understanding much about how stars are born, live, and die. More than a century and a half ago, though, scientists were just beginning to realize that we could deduce the contents of the stars — that their distances need not render them unknowable.

THE EXCERPT

In 1855, thirty-year-old English silk merchant and amateur astronomer William Huggins sold the family business, moved with his elderly parents to the upscale London suburb of Lambeth, and observed the night sky the way it had been done since Galileo's time: peering into the eyepiece of a telescope and letting the cosmic light flood his retina.

Astronomy was the perfect hobby for Huggins, given his affinity for the sciences and his financial means. (It is said he dropped an interest in microscopy because of his distaste for dissection.) Huggins acquired his first telescope when he was eighteen. He replaced that instrument in 1853 with a pricey Dollond equatorial refractor of five-inches aperture. Like many neophytes, his observing runs were routine: peering at and sketching the Moon, planets, and the occasional comet. His drawings of Mars from April 1856 appear to be a hash of what he saw through the eyepiece plus what he had seen in existing illustrations. Although never formally trained in astronomy—what advanced academics he had came from private tutors—Huggins pursued his new avocation as an entrepreneur might a fledgling business: to gain one's market share of fame required hard work, self-belief, and persistence.

Huggins was elected in 1854 to the Royal Astronomical Society … . To his already substantial cottage on Lambeth's Upper Tulse Hill, Huggins added a twin-story, twelve-by-eighteen-foot observatory, whose iron columns raised the working floor above the surrounding trees. In 1858 … he swapped out his five-inch telescope for a top-quality, eight-inch Alvan Clark refractor. The telescope rested on a massive, pyramidal, brick pier, which was anchored in concrete at ground level. The original hemispherical dome, twelve feet wide at the base and sheathed in zinc, revolved atop three iron balls along a circular, iron channel. A door-way from the upper level of the house led straight into the observatory.

At the May 1856 meeting of the Royal Astronomical Society, Huggins presented a model and description of his new facility. He had fully entered the small army of independent amateur astronomers: men of means whose scientific aspirations superseded their more grounded ambitions in commerce or society. Often lacking the validation of an advanced degree, they delved into areas of research and invention spurned by their institutional counterparts. Over the next few years, Huggins received from these night-sky specialists a thorough education in the practical and theoretical aspects of astronomy. …

In January 1862, having marked time in desultory studies of planets and double stars, Huggins attended a lecture at London's Pharmaceutical Society by his neighbor, William Allen Miller, Chair of Chemistry at King's College. It was here, presumably, that Huggins learned of the momentous discovery by German scientists Robert Bunsen and Gustav Kirchhoff: the perplexing array of dark lines in the solar spectrum—the Fraunhofer lines—might be used to deduce the chemical constituents of the Sun. No longer did the Sun's remoteness place it frustratingly out of reach of laboratory-type scrutiny; to the contrary, its relentless stream of light delivers its chemical signatures right to Earth.

Miller's lecture was nominally about the science of spectroscopy, but was also a retort to Bunsen and Kirchhoff's claim of priority in spectrochemical analysis. Thus, Huggins heard the subject's entire time line of development, from Newton's seventeenth-century experiments to present-day research in England and on the Continent. The saga would no doubt have inspired the autodidact Huggins, who privately sought validation by his peers. How might one establish one's own research credentials among the crowded roster of visual observers?

Decades later, in a much-read retrospective titled *The New Astronomy*, William Huggins described in heroic prose his response to the genesis tale of cosmochemistry:

This news was to me like the coming upon a spring of water in a dry and thirsty land. Here at last presented itself the very order of work for which in an indefinite way I was looking—namely, to extend [Bunsen and Kirchhoff's] novel methods of research upon the sun to the other heavenly bodies. A feeling as of inspiration seized me: I felt as if I had it now in my power to lift a veil which had never before been lifted; as if a key had been put into my hands which would unlock the unknown mystery of the true nature of the heavenly bodies.

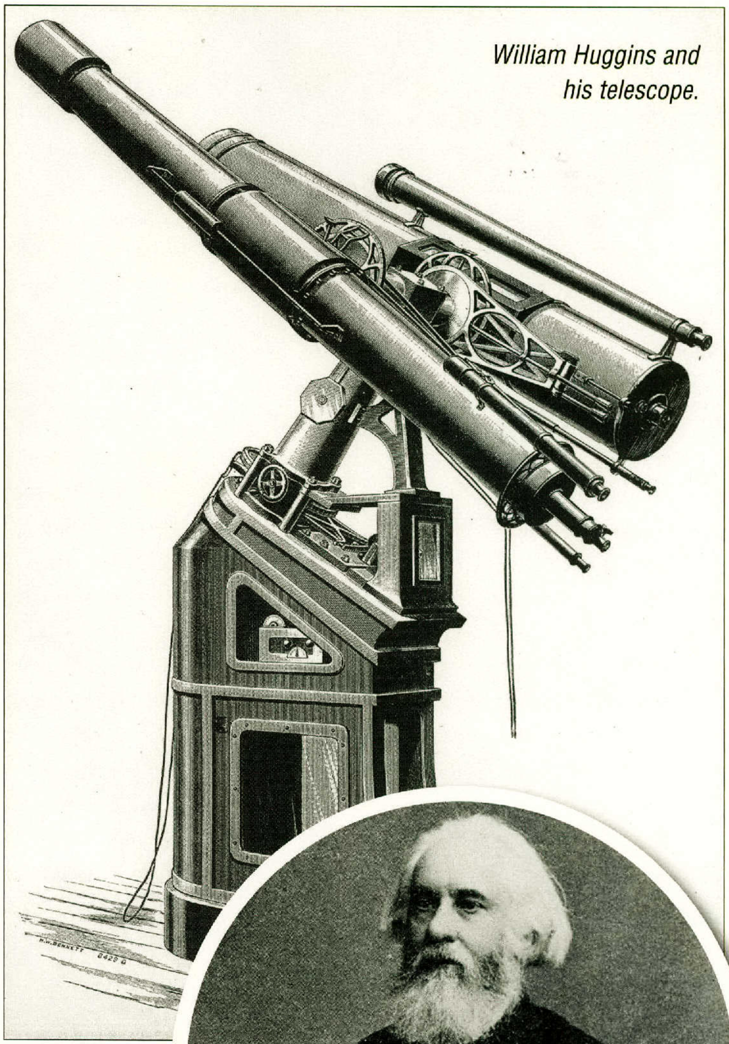
Whether this latter-day account portrays a genuine eureka moment or else the self-congratulatory embellishment of an aging man, Huggins did set his sights—and a spectroscope—on the stars. He stocked his household observatory with the trappings of the Victorian spectroscopist until it resembled a Frankenstein's laboratory: prisms, batteries, electrical spark coils, Bunsen burners, and chemical powders and fluids. And in William Allen Miller, his neighbor, Huggins found a close-at-hand and knowledgeable (if initially hesitant) collaborator.

Like their contemporaries Bunsen and Kirchhoff, Huggins and Miller were a complementary pair, whose collective productivity far exceeded the sum of what either might have accomplished on his own. Miller was the spectroscopic expert of decades standing, who provided the materials and the know-how to carry laboratory practice into the observatory. Huggins as the astronomer and inveterate maker, whose stamina, manipulative skill, and visual acuity secured results. Lacking the deep state and institutional pockets available [to Kirchoff and Bunsen at the university] at Heidelberg, Huggins bankrolled every aspect of his outsized hobby.

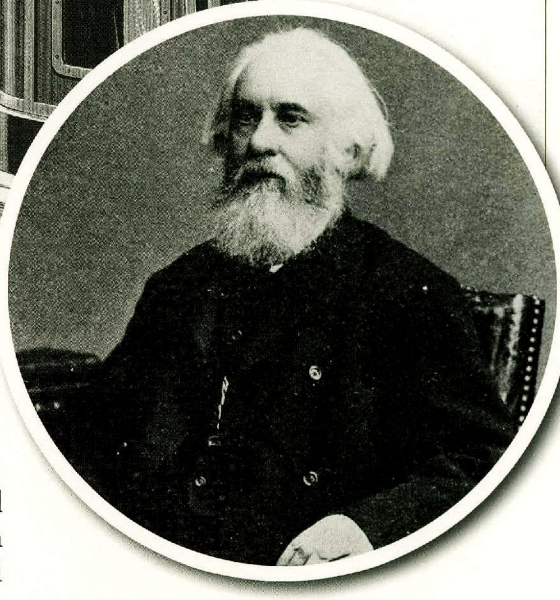
From the start, in early 1862, Huggins and Miller set themselves an ambitious agenda for a technology so new and so tangled. The spectroscope had proven its worth in the energy-lavish domain of the Sun, but was virtually untried on the dim luminal inflow of stars. Like other researchers, Huggins and Miller wished to cross-check the elemental composition of the Sun against those of the stars, based on coincidences of spectral lines. That meant building a spectroscope with sufficient dispersive power to portray the full complement of stellar lines, but not so dispersive as to dilute the already-faint spectrum to the point of invisibility.

They also needed to implement an effective framework of measurement, one that would fix the positions of stellar lines relative to an ironclad fiducial standard that all astronomers could use. Analogous to Bunsen and Kirchhoff's solar spectroscope, the new apparatus had to permit simultaneous viewing of a star's spectrum alongside a calibrated spectrum generated in real time within the observatory. And these parallel spectra must be identically scaled in wavelength, so as to "enable the observer to determine with certainty the coincidence or noncoincidence of the bright lines of the elements with the dark lines in the light from the star."

The completed spectroscope employed two flint-glass prisms and was bolted securely to the eye-end of the Clark refractor. The stellar spectra were observed through an auxiliary telescope fitted with crosshairs. For comparison, an external mirror-and-prism arrangement deflected light into the spectroscope from an incandescent source in the observatory. …



William Huggins and his telescope.



Huggins and Miller found themselves competing with a host of researchers similarly inspired to apply a spectroscope to the stars … . Both Huggins and Miller were predisposed to claim priority over their cohorts: Huggins, the nonacademic newcomer, keen to make his professional mark; Miller, the aggrieved laboratory veteran, disenfranchised by his rivals in Heidelberg (at least, in his own view). … Whether or not Huggins and Miller began their spectroscopic work in early 1862 as they claim, one point is certain: In January 1863, spurred by a development on the Continent, the pace of their project accelerated from a canter into a full-fledged gallop. The Royal Astronomical Society released a translation of a paper by Florentine astronomer Giovanni Battista Donati, describing the dark "striae" or lines he had observed as early as 1860 in the spectra of fifteen stars. …

In the wake of Donati's paper, Huggins and Miller rushed a preliminary report to the Royal Society on February 19, 1863, outlining their spectroscopic studies of the stars Sirius, Betelgeuse, and Aldebaran. That very day, Huggins learned that Lewis M. Rutherfurd in New York had recently completed visual observations of the spectra of twenty-three stars, the results to be published in a forthcoming issue of the American Journal of Science. Huggins and Miller hurriedly appended a statement to their report informing the Royal Society that they had viewed the spectra of at least thirty stars over the previous twelve months; measurements of the lines of these stars were in progress.

A common complaint in this pre-photographic era of stellar spectroscopy was the extreme difficulty sighting the ghostly spectral lines. The dispersed glimmer of a star is barely sufficient to stimulate the retina, much less ease measurement of lacunae strewn along a spectral-smudge of light. "On any but the finest nights," Huggins and Miller wrote, "the numerous and closely approximated fine lines of the stellar spectra are seen so fitfully that no observations of value can be made. It is from this cause especially that we have found the inquiry … more than usually toilsome; and indeed it has demanded a sacrifice of time very great when compared with the amount of information which we have been enabled to obtain."

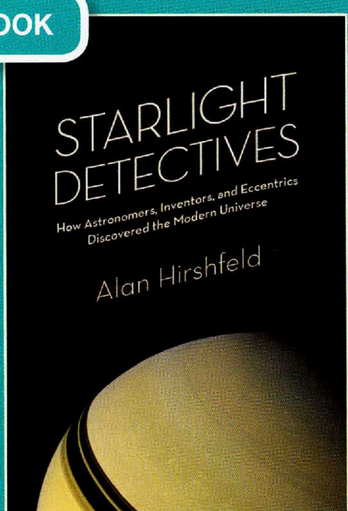
By mid-1864, Huggins and Miller had endured enough. Instead of the anticipated inventory of fifty stars, they had obtained detailed results for only four, of which a mere two, Aldebaran and Betelgeuse, had complete spectral-line maps. The spectrum of low-lying Sirius, the brightest star in the sky, had been muddled by turbulence in the air. (The atmospheric roiling had also foiled attempts in January and March 1863 to produce a wet-collodion photograph of Sirius's spectrum.) Other stars had received only cursory treatment. Yet what seems a meager outcome relative to what had been expected is, upon reconsideration, a veritable triumph of industry. With the fickle weather, seasonal cycling of the constellations, limited nightly observing times, and all manner of methodological complexities, the new science of stellar spectroscopy had proved to be a protracted venture. Complete investigation of even a single star, Huggins and Miller realized, would take months, if not years. Their accumulated observations, incomplete as they were, permitted inferences about the chemical nature of stars. Faced with the daunting prospect of more nighttime labor, they decided to publish.

"On the Spectra of Some of the Fixed Stars," read by Miller to the Royal Society on May 26, 1864, led off with a generous nod toward Gustav Kirchhoff as the discoverer of the connection between the dark lines of the solar spectrum and the bright lines of terrestrial flames. …

The symbolic core of the 1864 paper is its spectral-line maps of Aldebaran and Betelgeuse. Placed one above the other, each spans the width of three pages. Scores of fine lines crowd the graphical space, together as seemingly mundane as scratches in the dirt—until one notices the familiar Fraunhofer letters from the solar spectrum; and next, the assortment of italicized labels accompanying the stellar lines: H, for hydrogen; Hg, for mercury; Na, for sodium; Fe, for iron. Here, in what Huggins called the "strange cryptography of unraveled starlight," was science of the most profound order: visual confirmation of the chemical unity of the Sun and stars—and, by extension, of Earth and life. …

Extending the theme of cosmic unity to its logical conclusion, they suggest that the stars are not just structurally analogous to the Sun, but are "surrounded by planets, which they by their attraction uphold, and by their radiation illuminate and energize. And if matter identical with that upon the earth exists in the stars, the same matter would also probably be present in the planets genetically connected with them, as is the case in our solar system. … On the whole we believe that … at least the brighter stars are, like our sun, upholding and energizing centres of systems of worlds adapted to be the abode of living beings."

THE BOOK



Starlight Detectives

How Astronomers, Inventors, and Eccentrics Discovered the Modern Universe

By Alan Hirshfeld

ALL THE UNIVERSE IS A STAGE

William Shakespeare was a genius, but scholars disagree on his understanding of the scientific revolution he lived through

THE SETUP

Shakespeare understood the human mind and human relations so well that after almost half a millennium, his poems and plays still resonate with us. What's less certain is whether he understood the scientific changes wrought by Nicolas Copernicus, whose idea of a Sun-centered cosmos shook church and society just before Shakespeare's birth. Many literary scholars have said the bard either didn't know, or didn't pay much attention. One astronomer, however, argues the opposite — and uses Shakespeare's most famous play to illustrate his point of view.

THE EXCERPT

Did Shakespeare know about Copernicus's revolutionary idea? Did he care? History is so much clearer in hindsight: Looking back after four centuries, it's obvious *to us* that Shakespeare lived in a remarkable time. The medieval world—a world of magic, astrology, witchcraft, and superstition of all kinds—was just beginning to give way to more modern ways of thinking. Shakespeare and Galileo were born in the same year, and new ideas about the human body, the Earth, and the universe at large were just starting to transform Western thought. The first modern anatomy book, by the Flemish-born physician Andreas Vesalius, was published in 1543, the same year as *De revolutionibus*. Is it possible that Shakespeare was unaware of these developments—or that he was vaguely conscious of them, but uninterested?

For some literary figures, the impact of this new picture of the world is obvious: In a famous passage from *An Anatomy of the World* (1611), John Donne laments that "the new philosophy calls all in doubt. … The sun is lost, and th'earth, and no man's wit / Can well direct him where to look for it." A half century later, John Milton would devote lengthy passages in *Paradise Lost* to a debate over the structure of the cosmos; indeed, he refers to Galileo three times in the poem (once by name; the astronomer is the only living figure to warrant such a mention). Milton is even said to have met the Italian scientist in person, when Galileo was in his final years, under house arrest, in his villa outside Florence. By Milton's time, as one scholar puts it, the Copernican system was "a scientific force with which all thinking men had to reckon." But Milton went to Cambridge, and Donne studied at *both* Oxford and Cambridge. Shakespeare flourished a little bit earlier, and had only the benefit of his local grammar school; as Jonson famously quipped, his colleague had only "small Latin and less Greek."

The traditional view is that Shakespeare was unconscious, or barely conscious, of the "new philosophy." It's not that Shakespeare scholars, or historians of early modern science, have neglected to look at possible connections between Shakespeare's works and the ideas and discoveries that mark what we now call the Scientific Revolution: They've looked, and concluded—wrongly, I believe—that no such connections exist. …

But a reassessment may finally be at hand. In the last few years, a handful of scholars have begun to look closely at Shakespeare's interest in the scientific discoveries of his time—asking what he knew, when he knew it, and how that knowledge might be reflected in his work. …

It's the world's largest gathering of astronomers and astrophysicists: The American Astronomical Society meets twice a year, giving its members a chance to talk about their research and to announce the most noteworthy findings. I attended for the first time in January 1997, when, by luck, it was held in my home city of Toronto. As an aspiring science journalist, I was eager to take it all in: extrasolar planets, exploding stars, galaxies, black holes, the latest findings in astrophysics and cosmology—whatever was on offer. The AAS always picks out a handful of papers to publicize during the meeting, in the hope of garnering media attention, and one of these highlighted papers, titled "A New Reading of Shakespeare's *Hamlet*," caught my attention. What did Shakespeare have

Continued on page 16

SKY CALENDAR

by Alan MacRobert

There's a lot to see in the night sky in the late summertime. A pair of overlapping meteor showers rain down from different corners of the sky. The season also brings Mars, Saturn, and the summer Milky Way flowing between Sagittarius and Scorpius, with its attendent star clusters and nebulae.

JULY 1 – 15

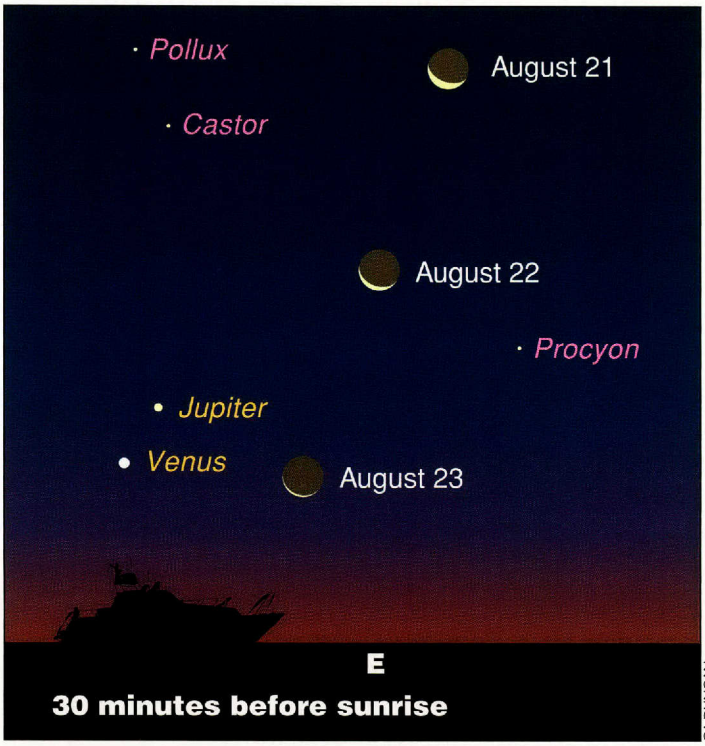
As July begins, take a look for Jupiter just above the west-northwest horizon in the afterglow of sunset. Jupiter has been sinking lower there for many weeks, and now it's saying goodbye for the season.

Mars is much higher in the southwest at nightfall. It's shining a lot more modestly now than it did when closer to Earth in April. But Mars puts on a special show in the first half of July. It draws closer to pale bluish Spica each day, then passes just over it (by 1.3 degrees, about a finger-width at arm's length) on July 12 and 13. Mars may have faded, but it still outshines Spica.

If you're out watching the fireworks at dusk on July 4, don't miss the waxing first-quarter Moon hanging to the right of Mars and Spica, and then between them on the evening of the 5th.

Moving left from Mars, we come to Saturn glowing in the south at nightfall. It, too, has a stellar companion, but a less assuming one: 3rd-magnitude Alpha Librae lies about $2^1/2$ degrees below it. The waxing Moon poses close to them on July 7.

Look high above Mars and Spica for Arcturus as the stars come out. Arcturus is a paler yellow-orange than Mars (ginger-ale colored, some say), but it's not quite as pale yellow-white as Saturn. How finely can you discern these subtle tints? Binoculars make star colors much easier to distinguish.



Arcturus outshines every other star on the western side of the sky. But it finds its match in Vega, shining about equally high toward the east at dusk. Vega is white with a trace of blue.

A star with nothing subtle about its color shines in the south after dusk, at roughly the height of Mars and Spica (depending on where you live). This is Antares, one of our two closest orange-red supergiants (the other is Betelgeuse in the winter sky). Like Betelgeuse, Antares is a topaz set among lesser blue-white diamonds, those giant stars that make up Scorpius.

JULY 16 – 31

Mars, still in the southwest at dusk, is now pulling away from Spica, heading eastward against the stars toward its next encounter: Saturn. Be patient. They won't pass each other until late August — almost back-to-school time.

Antares and the stars of upper Scorpius shine at their highest in the south in late twilight now, as soon as the stars come out. The rest of Scorpius curves down and left from there. If you have a good view low to the south, or if you live at a southerly latitude, look for the canted pair of stars in the tail of Scorpius known as the Cat's Eyes. You'll know them when you see them, though they're rather unequal (the one on the right is fainter). From left to right they are Lambda and Upsilon Scorpii, commonly known

Asteroid Hunting

Mars and Spica team up for a beautiful showing in the southwest on the evening of July 13. As night falls, bright orange Mars stands just above Spica.

If you draw a line from Spica to Mars and continue upward by less than the width of your fist, you'll come to two members of our own solar system that are staging an even closer encounter: Ceres and Vesta. They are not quite bright enough to see with the eye alone, however, so you need good strong binoculars or a telescope to spot them. They look like they're almost touching each other.

Ceres is the largest object in the asteroid belt — a ball of rock and ice about one-quarter the diameter of the Moon. A few years ago Ceres was classified as a dwarf planet — one of five objects to receive that designation so far.

Vesta is the second most-massive asteroid, after Ceres. Although it's only about half the size of Ceres, it's also closer to Earth and its surface is more reflective, so it's the brightest asteroid.

The Dawn spacecraft orbited Vesta for more than a year before departing in late 2012. It is headed toward Ceres, where it's scheduled to enter orbit in February, providing our first close look at any dwarf planet.

Meteor Watch

The Shower

Perseids

Named for the constellation Perseus, the hero, which climbs into view in the early morning hours.

Peak

Night of August 12

Notes

The waning gibbous Moon rises in early evening and remains in the sky all night, obliterating all but the brightest meteors.

as Shaula and Lesath.

Look a little to their upper left for two grand star clusters, Messier 6 and 7 (see chart, this page). They're a fine sight in binoculars or a low-power telescope, and if you have a dark sky and a good southern view, they're even apparent to the unaided eye.

The Teapot star pattern of Sagittarius lies to the left of all of these. It's now sitting almost level, and is about the size of your fist at arm's length. Its spout is on the right. Messier 8, the Lagoon Nebula, floats above the end of the spout. It looks like a hazy spot in the steamy-looking Milky Way, lying somewhat less than a fist-width above the spout's end star. M8 is the brightest nebula of the summer sky, filling the role for binocular and telescope users that the Orion Nebula, M42, does in winter. If you invite people to a summer evening star party to use your telescope, M8 is always a crowd pleaser.

AUGUST 1 – 15

Look southwest at dusk for Mars continuing its slow creep away from Spica (to its lower right) and toward Saturn (to its upper left). Mars is halfway there on August 4, just after the waxing Moon passes through the scene.

The summer Milky Way now arches high overhead — running like a broad, irregular river from Sagittarius and Scorpius in the south up and high across the eastern sky, where it contains a particularly bright star cloud along the Northern Cross of Cygnus, then down to Cassiopeia and just-rising Perseus in the north-northeast.

Perseus is best known to August skywatchers as the source of the Perseid meteor shower. This year the shower peaks late on the night of August 12-13. The shower actually lasts for many days. You're likely to notice a Perseid or two when you're out starwatching as much as a week or 10 days before the peak night. The shower drops off more quickly after the peak. Although the Perseid meteoroid stream has a relatively dense core, through which Earth passes over the course of just a day or two, the entire stream is quite broad, and Earth takes at least a couple weeks to get all the way across it.

The even broader Delta Aquarid meteor stream is also active in July and August. To tell Delta Aquarid meteors apart from Perseids, track the direction of each meteor's path backward far across the sky. Does this line cross northern Perseus, near Cassiopeia in the northeast? Then you've got a Perseid. Does the path instead cross dim Aquarius in the southeast? Then it's probably a Delta Aquarid.

In addition, after you've seen a few of each, you may notice that the Delta Aquarids appear slower than the swift Perseids.

AUGUST 16 – 31

Mars and Saturn glow together now in the southwest in early evening, moving a little lower each week. They're nearly the same brightness now, though bearing different colors. Watch Mars pass $3\frac{1}{2}$ degrees under Saturn from August 21 through 26.

Look to their left at dusk for Antares and the other stars of upper Scorpius. Mars is on its way to a rendezvous with Antares in late September.

Where are the other planets? The bright ones, Mercury, Venus, and Jupiter, are out of sight in the glare of the Sun. Uranus and Neptune are positioned in the east and southeast late at night but are too dim for viewing without binoculars.

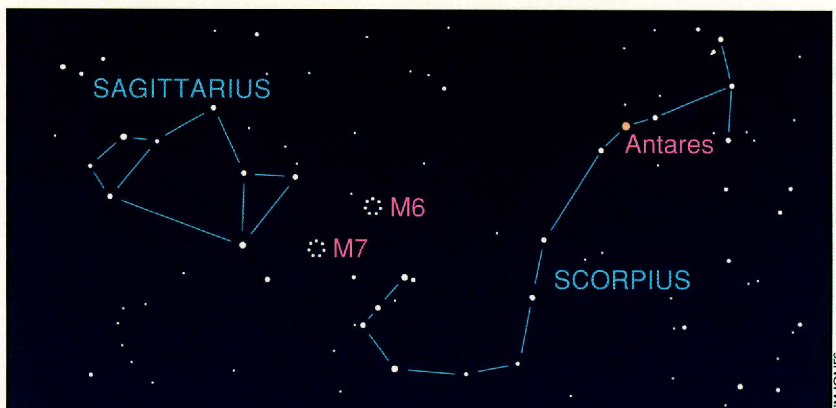
When Sagittarius is in the south, bright Vega is always passing overhead — for those of us in the world's mid-northern latitudes. Vega passes exactly overhead each night if you live at latitude 39 degrees north (Baltimore; Washington, D.C.; Cincinnati; Kansas City; and Lake Tahoe, California).

The Big Dipper is primarily a sign of spring; by now it's dipping well toward the northwest. The Dipper's opposite number, Cassiopeia, is already beginning its autumn rise at about the same height in the northeast. These two constellations turn eternally around the North Star, which is midway between them (actually just a bit higher).

Far off to Cassiopeia's right in the east these evenings, and probably somewhat lower, the big, dim Great Square of Pegasus is already climbing skyward. The Great Square is the signature star pattern of fall. Its looming up in the east at this time of year has long brought back memories for me of being shocked at this symbol of the impending back-to-school season making its foreboding appearance in summer vacation.

The Great Square is currently tilted up on one corner, so for now it's really more like the Great Diamond of Pegasus. It's made of 2nd-magnitude stars and is somewhat larger than your fist at arm's length.

The brightest star shining in the southeast to south is Altair in Aquila, the eagle. The brightest star east of Vega overhead, by two or three fist-widths, is Deneb in Cygnus. Vega, Deneb, and Altair form the big Summer Triangle, which takes its rightful place straight overhead only as summer is coming to its end.



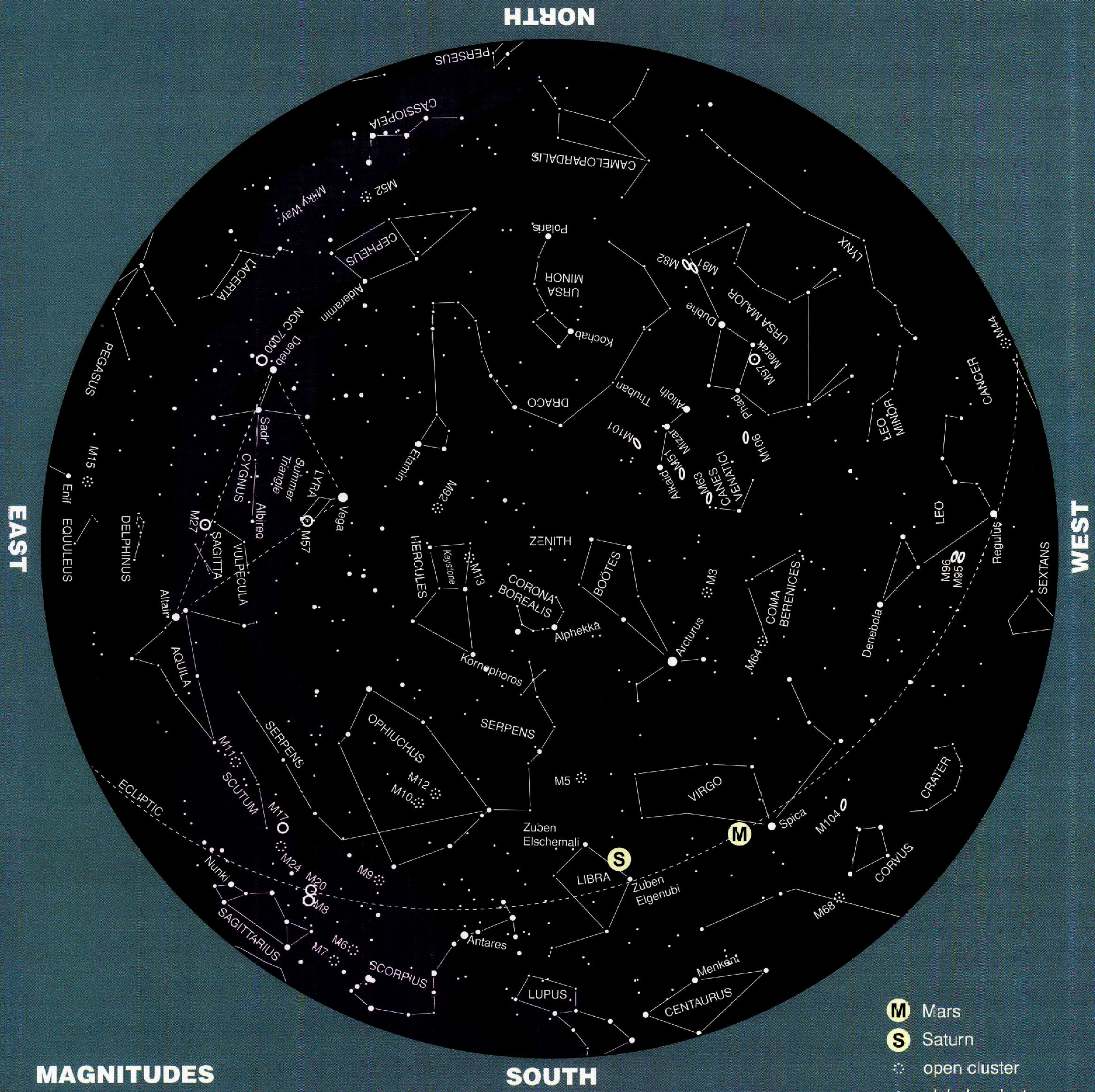
July and August nights are perfect for viewing a pair of open star clusters. About 90 minutes after sunset, use binoculars to look between the Teapot pattern of Sagittarius and the giant "J" of Scorpius in the south. You will spy Messier 6 and 7 (the Butterfly Cluster and Ptolemy's Cluster, respectively). About 1,600 light-years away, the Butterfly Cluster contains about 80 stars that are 50-100 million years old. Ptolomy's Cluster contains about the same number of stars, but is closer — 1,000 light-years — and older: 220 million years.

Alan MacRobert is a senior editor of Sky & Telescope *magazine.*

JULY

How to use these charts:
1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

June 20	**11 p.m.**
July 5	**10 p.m.**
July 20	**9 p.m.**



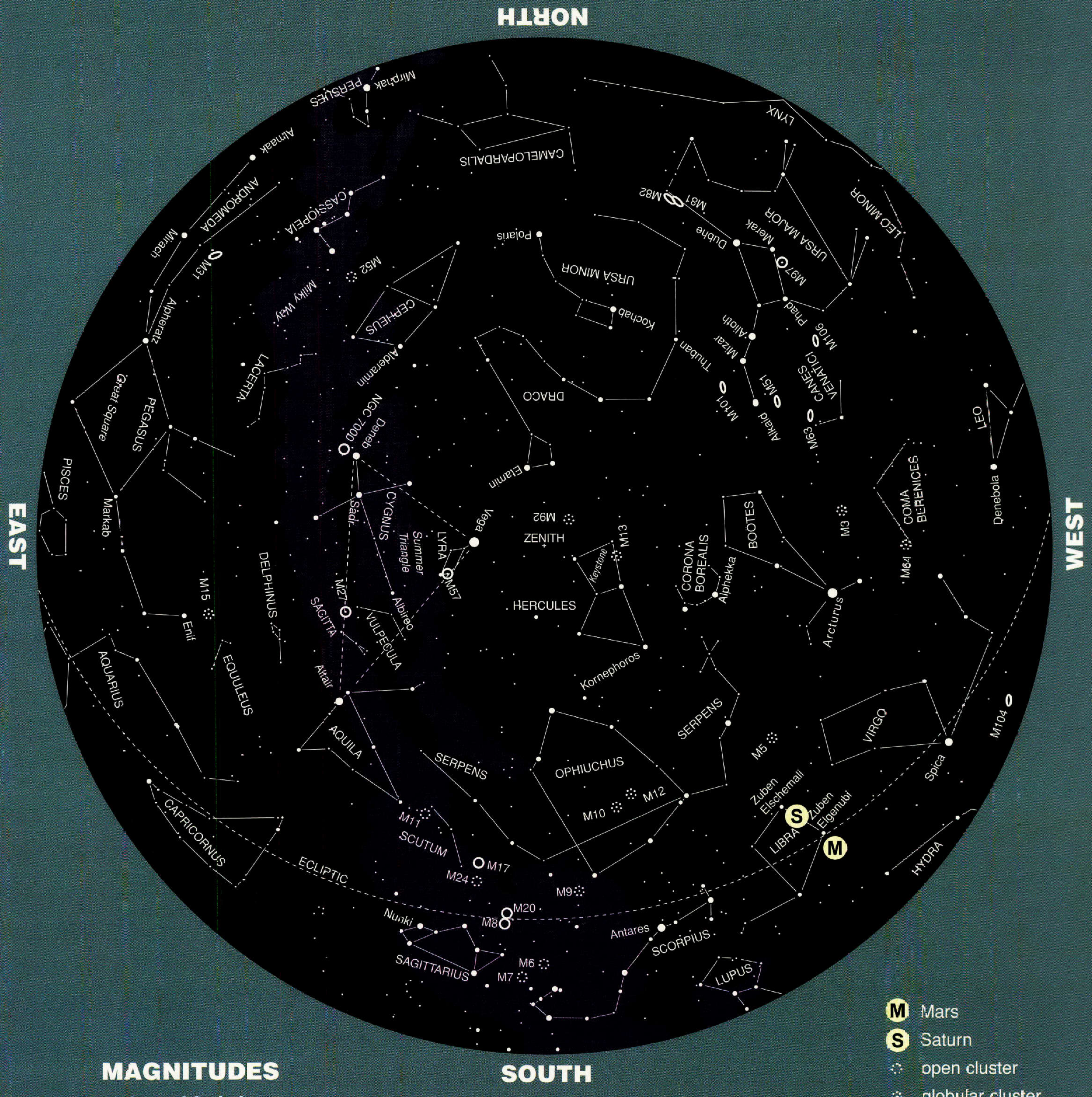
MAGNITUDES
- **0 and brighter**
- **1**
- **2**
- **3**
- **4 and fainter**

- M Mars
- S Saturn
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

AUGUST

How to use these charts:
1. Determine the direction you are facing.
2. Turn the chart until that direction is at the bottom.

July 20	**11 p.m.**
August 5	**10 p.m.**
August 20	**9 p.m.**



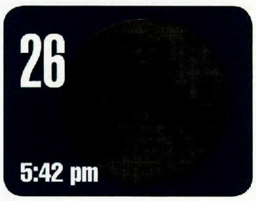
- **M** Mars
- **S** Saturn
- open cluster
- globular cluster
- nebula
- planetary nebula
- galaxy

MAGNITUDES
- 0 and brighter
- 1
- 2
- 3
- 4 and fainter

SKY HIGHLIGHTS

by Damond Benningfield

JULY



Moon phase times are for the Central Time Zone.

1 Regulus, the bright star that represents the heart of Leo, the celestial lion, lines up close to the upper right of the Moon as night falls.

3 Earth is at aphelion, its farthest point from the Sun for the year, about 1.5 million miles (2.4 million km) farther than the average distance of 93 million miles (150 million km).

5 The Moon, Mars, and Spica stage an impressive conjunction this evening. Orange Mars is quite close to the upper right of the Moon. From some locations, in fact, it's less than one degree away, which is less than the width of your finger held at arm's length. Spica is a little farther to the left or lower left of the Moon.

7 The planet Saturn stands close above the Moon at nightfall, with the star Zubenelgenubi, which represents the scorpion's southern claw, a little farther to the Moon's right.

8/9 Antares, the heart of the scorpion, stands close to the lower left of the Moon at nightfall on the 8th, and to the lower right of the Moon on the 9th.

12 The planet Mercury stands farthest from the Sun for its current morning appearance. It looks like a moderately bright star to the lower left of Venus, the brilliant "morning star."

Su	M	T	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

13/14 Mars passes by Spica on these evenings. At their closest, they will be separated by about the width of a finger held at arm's length. Mars is slightly brighter than Spica and passes just above the star.

22 Aldebaran, the brightest star of Taurus, stands quite close to the lower right of the Moon at first light.

24 Venus stands to the left of the crescent Moon at first light.

AUGUST

1-4 The Moon slides past a star and two planets on these evenings. On the 1st, Spica, Mars, and Saturn line up to the upper left of the Moon (in that order from the Moon). The Moon is closer to Mars on the 2nd, between Mars and Saturn on the 3rd, and to the left of Saturn on the 4th.

5 Antares, the heart of Scorpius, is below the Moon at nightfall.

11/12 The Perseid meteor shower peaks on these nights. The just-past-full Moon, however, will overpower most of the fireworks.

Su	M	T	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

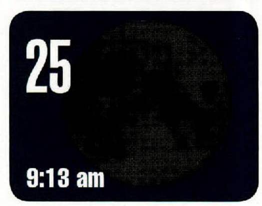
17-19 Venus and Jupiter, the most brilliant objects in the night sky other than the Moon, slip past each other in the dawn sky. Venus, the brighter of the two planets, is higher on the morning of the 17th. They almost appear to touch each other on the 18th, and Jupiter climbs above Venus on the 19th.

18 Aldebaran, the orange eye of Taurus, the bull, snuggles to the lower left of the Moon at first light.

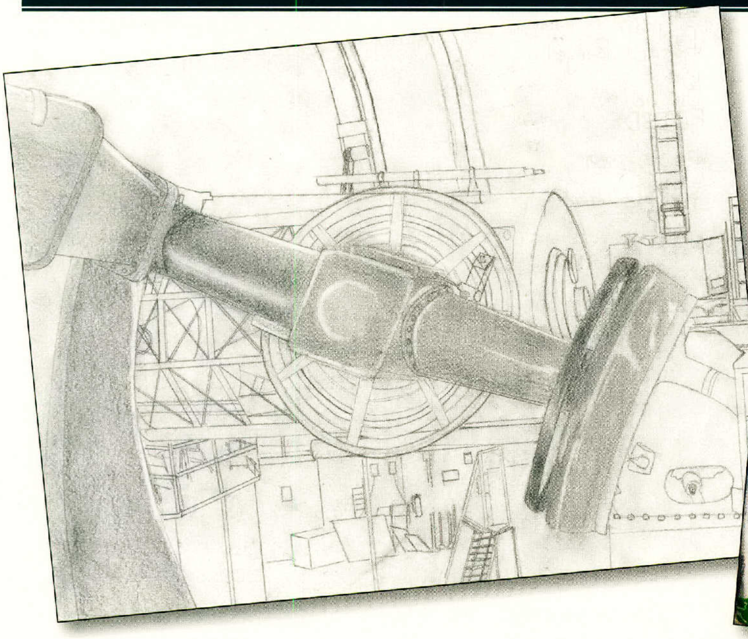
22 The planet Saturn, which shines like a golden star, stands just above the orange planet Mars at nightfall. They are low in the southwest.

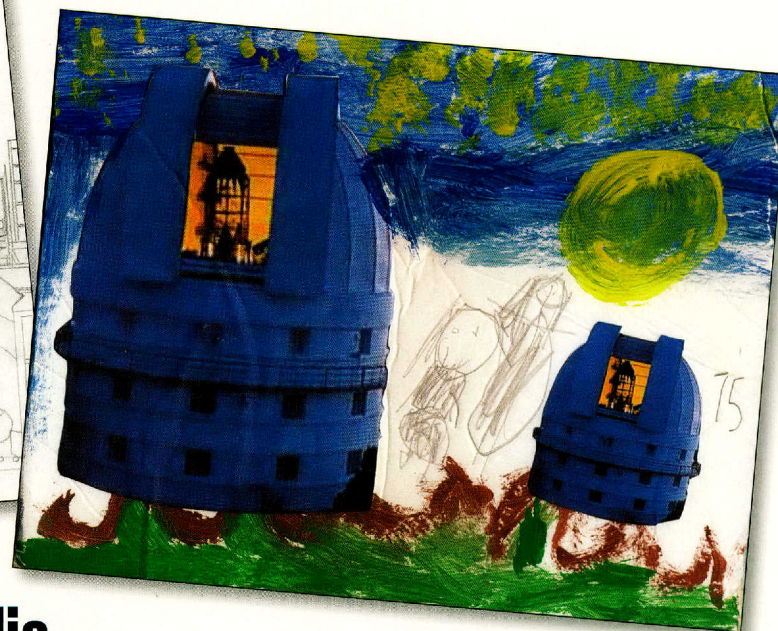
23 Jupiter is to the upper left of the Moon at first light, with brighter Venus to the lower left.

31 Saturn stands to the lower right of the Moon, and Mars to the lower left, at nightfall. Zubenelgenubi, the second-brightest star of Libra, is to the lower right of Saturn.



by Rebecca Johnson and Damond Benningfield





Impressions of a Golden Oldie

McDonald Observatory's original telescope and dome are commemorated in the winning entries in a student art contest held in connection with the Observatory's 75th-anniversary celebration in May. The colorful college at top right was created by Charlotte Browning, a kindergarten student at the Marfa Montessori School, who won best in show for the elementary division. Rafael Riegel, a sophomore at Fort Davis High School, won the junior high/high school division with the pencil drawing at top left. Other winners in the elementary division: Bowen Corbin, second grade; Anita Bailon, fourth grade; and Haden Wetzel, fourth grade. Other junior high/high school winners: Kylie Glidewell, junior; Cristian Zubia, seventh grade; Troy Hernandez, eighth grade.

Hubble Begins Quarter Century

Launched April 24, 1990, Hubble Space Telescope recently began its 25th year in space as a workhorse telescope. Its amazing astronomical images have fired the public imagination.

Over the years, five servicing missions fixed Hubble's optics and replaced instruments. Two instruments brought back to Earth are now on display in the National Air and Space Museum: COSTAR (Hubble's first pair of "glasses") and the camera that took many famous photos, WFPC2.

airandspace.si.edu/exhibitions/space-race

Hubble by the Numbers

3 BILLION Miles logged orbiting Earth

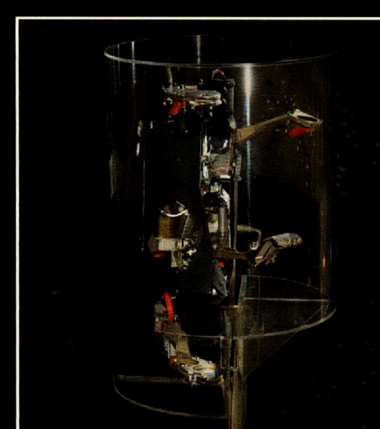
1 MILLION+ Observations made

38,000 Celestial objects targeted

11,000 Scientific papers

4,000 Astronomer users from around the world

100+ Terabytes of data produced



NASA; ERIC LONG/NASM/SMITHSONIAN INSTITUTION

Released from the space shuttle after a 2009 servicing mission, Hubble flies over Earth. Inset: COSTAR on display.

Continued from page 9

to do with astronomy?

According to the presenter, quite a lot. His name was Peter Usher, an astronomer from Penn State University, and his paper made some bold claims: "I argue that as early as 1601 Shakespeare anticipated the new universal order and humankind's position in it." The journalists at the press briefing listened attentively, if skeptically, as Professor Usher outlined his new interpretation of *Hamlet*; afterward, the professor answered a handful of questions. It is perhaps not surprising that the reporters from the British newspapers showed the most interest; after all, Shakespeare is "one of theirs." "Astronomer discovers cast of stars hidden in Hamlet" was the headline when the story ran in the next day's London *Times*.

* * *

Peter Usher became a Shakespeare enthusiast by accident. Born in South Africa, he taught astronomy for many years at Penn State, where he still holds the title of Professor Emeritus in astronomy and astrophysics. Often, while teaching introductory astronomy, he sought to engage his students by looking for connections across disciplines—for example, by connecting physics and astronomy with music or literature. Eventually he turned to Shakespeare, poring through the canon in search of astronomical references, and looking, in particular, for anything that might hint at the "new astronomy" of Copernicus.

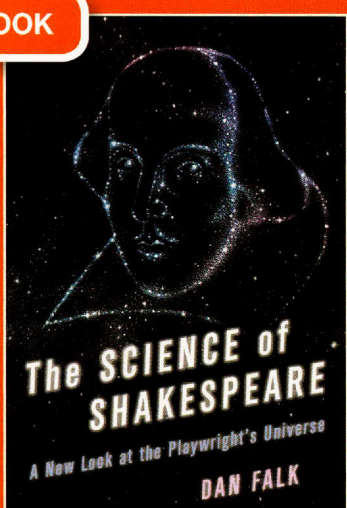
At first, Usher came up empty-handed. It's not that there weren't any astronomical references in the canon; in fact they seemed fairly common in Shakespeare's work. As Usher has pointed out, happenings in the sky were simply a "bigger deal," so to speak, in Elizabethan England than they are now, partly because there was less light pollution, and partly because many of the trappings of our perennially distracted information-drenched culture hadn't yet been invented. But most of these astronomical references seemed to either reflect the medieval, Ptolemaic view of the cosmos, or to be phrased in such a way as to render them ambiguous. There didn't seem to be anything that pointed directly to the Copernican model of the heavens. This left Usher somewhat puzzled, given the profundity of the new discoveries unfolding at the time, and Shakespeare's obvious curiosity about the world. "It seemed to me that someone who lived through the beginning of the Scientific Revolution would have *something* a little more strongly to say about it, because this was a major upheaval in the worldview," he says. Or, as he puts it in the preface to his book *Shakespeare and the Dawn of Modern Science* (2010), "It is simply not credible that a poet of this stature could remain ignorant of the cultural impact that the New Astronomy was having during his lifetime—or that he would refrain from using the literary devices at his command to address the topic if he was not ignorant of its significance." He spent his spare time "hunting through the canon, to find whether Shakespeare did or didn't have any knowledge of heliocentrism." Once he began his search, there was no turning back.

Usher, now retired, lives in a leafy neighborhood a few miles east of downtown Pittsburgh. He is tall, slim, and sports wire-rim glasses; when he was a bit younger, he may have borne a passing resemblance to the actor Ed Harris. His knowledge of astronomy and its history served as a starting point for his literary question. Soon he had read Leslie Hotson's account of the connections between Shakespeare and the Digges family, including the reference to Tycho Brahe's portrait with its "Rozencrans" and "Guildentsteren" crests; and of course he considered the possible cosmological significance of Prince Hamlet's reference to "infinite space." Soon he was scrutinizing Shakespeare's most famous play scene by scene, line by line. Whatever Shakespeare might have known about the "new astronomy," he reasoned, *had to be in there somewhere*; it was, after all, his most ambitious play and certainly his longest and most complex work. The "aha moment" came as Usher pondered the name of Hamlet's villainous uncle, Claudius. Could the name be an allusion to Claudius Ptolemy, the Greek astronomer who had worked out the mechanics of the geocentric system? Soon, Usher was finding what seemed like other correspondences in the text. Gradually, he began to see the entire *dramatis personae* of Shakespeare's masterpiece in a new light. The play, he says, can be interpreted as an allegory about competing cosmological models.

The Play Within the Play

In Usher's interpretation of *Hamlet*, nothing is quite what it seems—or, rather, nobody is quite who they seem to be. Nearly everyone in the play, he says, can be seen as "standing in" for an astronomer from Shakespeare's time,

THE BOOK



The Science of Shakespeare
A New Look at the Playwright's Universe

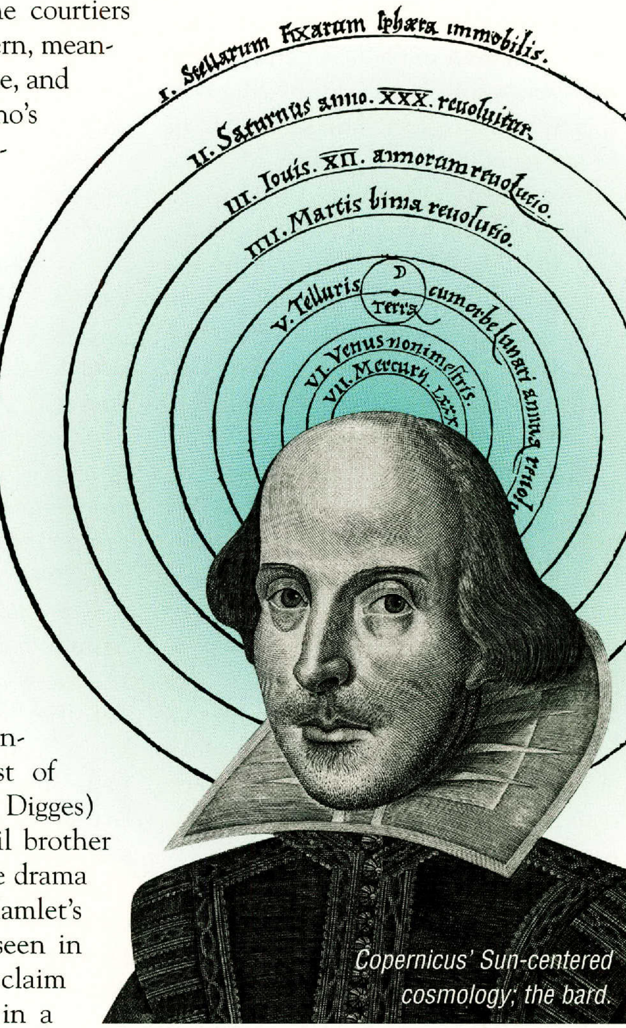
By Dan Falk

or from the annals of the history of astronomy—figures who, in one way or another, had a stake in the competing descriptions of the cosmos that were battling for acceptance in Renaissance Europe. According to Usher's interpretation, Prince Hamlet, the play's hero, represents the true picture of the universe—the heliocentric (sun-centered) model proposed by Copernicus and championed in England by the astronomer Thomas Digges. The correspondence applies also to the previous generation: The deceased king, Hamlet's father, is Leonard Digges, father of Thomas Digges—the man who, according to his son, may have invented a telescope-like device in the mid-sixteenth century, and whose work was continued by his son. ("Thomas and Hamlet are both compelled by the spirits of their deceased fathers to finish the job," Usher says.") The courtiers Rosencrantz and Guildenstern, meanwhile, represent Tycho Brahe, and serve as a surrogate for Tycho's "hybrid" model of the universe (in which the planets revolve around the sun, but the sun, in turn, revolves around the Earth. ... In all, Usher finds such correspondences for twelve characters in the play (a list that includes all of the main characters except for the two women, Gertrude and Ophelia).

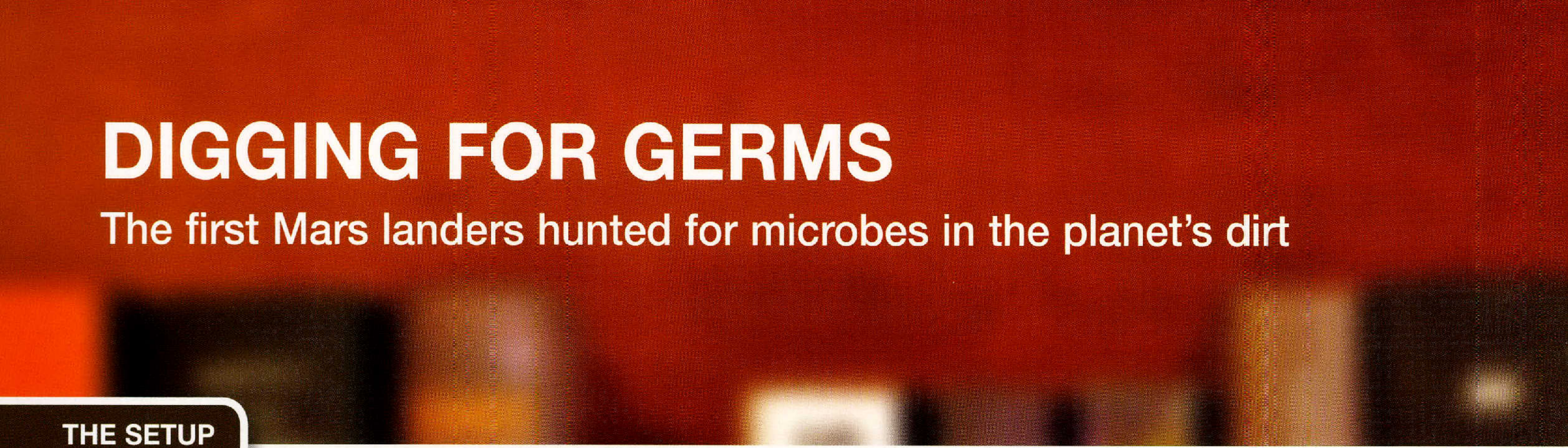
As Usher sees it, the battle between the worldviews gets under way right from the play's famous opening scene, with the ghost of old King Hamlet (Leonard Digges) seeking revenge on his evil brother (Claudius Ptolemy). As the drama unfolds, some of Prince Hamlet's more enigmatic lines are seen in a new light. Consider his claim that he could be "bound in a nutshell" while still counting himself "a king of infinite space." To Usher, this one line serves to highlight the essential difference between the old and new models: A "shell" of fixed stars forms the universe's "bounds" not only in the outdated Ptolemaic model, but in those of Copernicus and Tycho as well; they were eliminated only when Digges put forward his vision of an unbounded cosmos—a world of "infinite space." In the end, although Hamlet dies, his ideas live on: When Rosencrantz and Guildenstern are killed, it represents the demise of the Tychonic system; and when Claudius is killed, it's the long-overdue downfall of Ptolemy and geocentrism. Finally we have the return of Fortinbras from Poland, and his salute to the English ambassadors—symbolizing the final triumph of Copernicus, the Polish astronomer.

Usher was also struck by the prominence given to the German city of Wittenberg, the university town where Hamlet and Horatio, as well as Rosencrantz and Guildenstern, are said to have studied, and to which Hamlet is apparently intent on returning. In Shakespeare's time, Wittenberg was renowned for scholarship. ... Wittenberg was also the seat of the Protestant Reformation: Luther studied there, and in 1517 he nailed his ninety-five theses to the door of the city's Castle Church. But as Usher points out, Wittenberg is also connected to Copernicanism: Rheticus, the only pupil of Copernicus, studied and later taught there, before supervising the publishing of *De revolutionibus*. The city is mentioned four times in *Hamlet*, and was the home of the heliocentric theory's first supporter; for Usher, it's not a coincidence. When Hamlet announces his intention to return to Wittenberg to resume his studies, Claudius declares that such a move is "most retrograde to our desire" (1.2.114). Usher sees this as both an allusion to the retrograde motion of the planets, which had originally motivated so much astronomical investigation in the first place, and to Claudius's (that is, Ptolemy's) opposition to the Copernican system, which was being taught at the famous German university. ...

Usher is fully aware that his ideas are unorthodox, and that they may strike many Shakespeare scholars (and perhaps many ordinary readers) as far-fetched. ... But acceptance, or lack thereof, doesn't seem to trouble him. "Change comes very, very slowly," he says. "But I'm not concerned about that. I'm a scholar, and I've written a scholarly book, and we'll see where it goes."



Copernicus' Sun-centered cosmology; the bard.



DIGGING FOR GERMS

The first Mars landers hunted for microbes in the planet's dirt

THE SETUP

The first successful Mars landers — the twin Vikings of the 1970s — were bristling with scientific instruments, including several designed to look for evidence of microscopic life in the planet's red dirt. Their findings touched off a controversy that continues today.

THE EXCERPT

The grip that Mars holds on the popular imagination is grounded in the question of whether Mars ever was, or is, alive. The Viking landers were explicitly designed to search for evidence of life in the Martian regolith or perhaps in the planet's geological past.

The short section of the mission science summary on life detection is worth quoting in full because of the surprising ambiguity of the wording: "Three experiments were conducted to test directly for life on Mars. The tests revealed a surprisingly chemically active surface—very likely oxidizing. All experiments yielded results, but these are subject to wide interpretation. No conclusions were reached concerning the existence of life on Mars."

The Viking landers packed a substantial scientific punch in their 200-pound payloads. ... The landers had cameras that could take 360-degree panoramic images. They had seismometers and instruments to test magnetic fields. They had meteorology booms that measured temperature, pressure, and wind speed and direction. Most importantly, they had robotic arms that could scoop up soil samples and deposit them into temperature-controlled and sealed containers on each spacecraft.

The biological package contained four instruments. A gas chromatograph and mass spectrometer heated soil samples and measured the molecular weight of each component of the vapor released, down to a concentration of a few parts per billion. The instrument found no significant levels of organic, or carbon-based, molecules. Mars soil had even less carbon than the lifeless soils tested on the Moon by the Apollo missions. This seemed to be prima facie evidence against life. The gas exchange instrument added nutrients, and then water, to a soil sample, and then looked for changes in the concentration of gases such as oxygen and methane in the sealed chamber. The hypothesis was that a living organism would process one of the gases. The result was negative.

The pyrolytic release experiment created an "atmosphere" in the chamber using radioactive carbon, in the hope that a photosynthetic organism would incorporate the carbon the way plants do on Earth. After several days of incubation under an artificial Sun (in this case, a xenon arc lamp), the sample was baked at a high temperature to see if any of the radioactive carbon had been converted into biomass. The results were also negative.

The only wild card was the labeled release experiment. A sample of soil had nutrients dissolved in water added to it, and the nutrients were "tagged" with radioactive carbon, which was once again used as a tracer. To the surprise of the instrument team, radioactive carbon dioxide was detected in the air above the samples, suggesting that microbes had metabolized one or more of the ingredients. The same result was seen in both Viking landers. However, when the experiment was repeated a week later, the air was free of radioactive carbon. The data were declared inconclusive.

Overall, the results were disheartening for those who hoped that Mars might be a living world. Terrestrial life is based on complex molecules with a carbon backbone—organic ingredients like carbohydrates, proteins, nucleic acids, and lipids. While organic does not mean biological, all life on Earth is carbon-based and so is made of organic ingredients. The Viking experiments detected virtually no organic compounds in the Martian regolith. This was somewhat surprising, since they are fairly common on small Solar System bodies like comets, asteroids, and meteorites. With no organic material, the biological experiments would have been doomed to failure, since their aim was to detect a metabolism that could incorporate carbon from the atmosphere, as microbes on Earth do. The lander could only gather samples from the top few centimeters of the regolith, and that layer is blasted with ultraviolet radiation and cosmic rays from space (Mars has no protective layer of ozone). The surface is strongly oxidizing, as the "rusty" red color of iron oxide indicates. So the conventional interpretation is that activity seen in the experiments was caused by chemical reactions involving oxidizing molecules in the soil, with no biological explanation required.

Could Viking Have Missed Life?

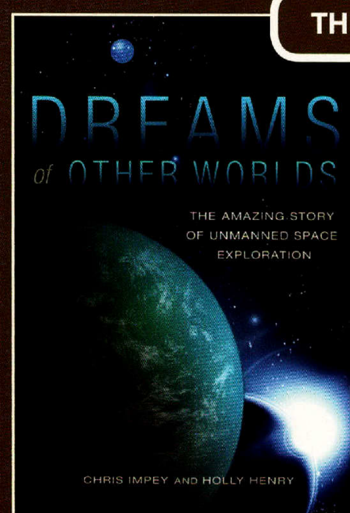
Gil Levin has never wavered. The principal investigator of Viking's labeled release experiment is now approaching ninety, but he's very active and stays current with research on Mars. Levin had an unusual career path, starting as a sanitation engineer before joining NASA. In addition to authoring 120 scientific papers, he owns fifty patents for items ranging from artificial sweeteners to therapeutic drugs. Levin insists that at two locations on Mars, and in seven out of nine tests, his experiment detected biological activity. No purely chemical reactions have been identified that would fully reproduce the labeled release results, which explains the cautious and equivocal wording of the science mission summary.

Levin is in the minority, but he's not alone in believing the Viking results bear revisiting. Rafael Navarro-Gonzalez and his team went to the highest and driest parts of the world, places like the Atacama Desert and Antarctic dry valleys, and duplicated the tests that Viking did more than thirty-five years ago. In northern Chile, they found arid soils with levels of organic material that would have been undetectable by the Viking instruments, yet there were bacteria in the soil. In other words, Viking was not sensitive enough to detect either organics or life in terrestrial locations that are the closest analogs to Mars. The team speculated that the organic material on Mars might have been too stable to turn into a gas, even at the blistering temperature of 500°C (932°F) reached inside the oven of the Viking experiment. They also noted that iron in the soil might oxidize the organic material and prevent its detection by the mass spectrometer. This would account for the carbon dioxide that was detected in the experiments.

Mars is an alien chemical and physical environment, so it makes sense to think "outside the box" when considering how biology might operate there. If we only look for life as we know it, that's all we'll be able to detect and we may miss life with a different biochemical basis. Dirk Schulze-Makuch and Joup Houtkooper have speculated that Mars might be home to microbes that use water and hydrogen peroxide as the basis for their metabolism. Hydrogen peroxide is a toxic household disinfectant and seems implausible as a basis for life, but the researchers note that it's more life-friendly under the extreme conditions typical of Mars. It attracts water and when mixed with water freezes at –57°C, yet it doesn't form cell-destroying ice crystals at even lower temperatures. Hydrogen peroxide is tolerated by many terrestrial microbes and is the basis of the metabolism for *Acetobacter peroxidans*. It's used as a defensive spray by the bombardier beetle and even performs useful functions in the cells of some mammals. As Schulze-Makuch pointed out in 2007, "We can be absolutely wrong, and there might not be organisms like that at all. But it's a consistent explanation that would explain the Viking results. ... If the hypothesis is true, it would mean we killed the Martian microbes during our first extraterrestrial contact, by drowning—due to ignorance."

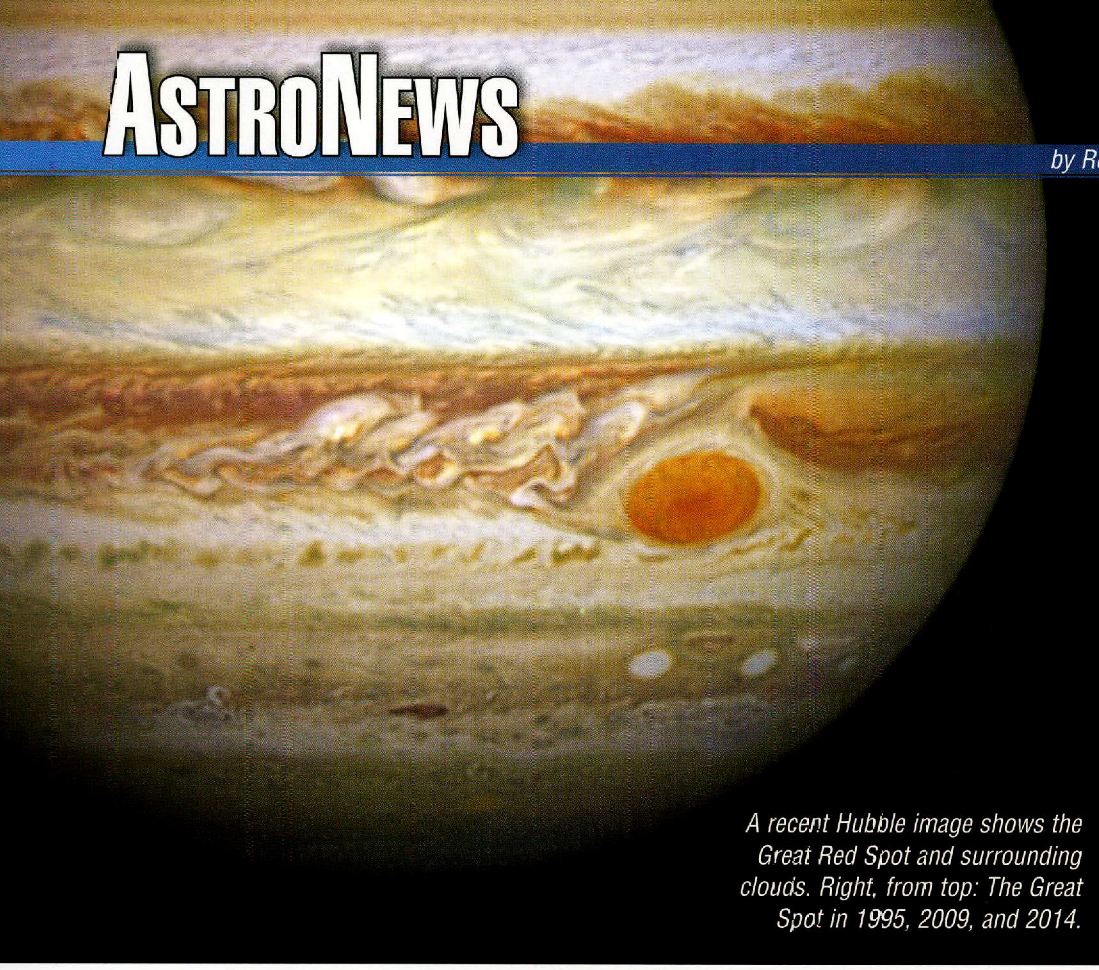
Another speculation was spurred by the discovery of perchlorate in a Martian polar region by the Phoenix lander in 2008. Phoenix carried out a wet chemical analysis of Martian soil, finding it to be alkaline and low in the type of salts found on Earth, but it had enough perchlorate to act as antifreeze and allow the soil to hold liquids for short periods during the summer. Perchlorate is strongly oxidizing and so generally considered to be toxic for life, but some microbes metabolize it. In 2010, the Viking results were reinterpreted in the light of the Phoenix discovery, giving support to Gil Levin's lonely position. When perchlorate was added to Atacama Desert soils and analyzed in the manner of the Viking samples, it released chlorine compounds. When these were seen in the Viking experiments back in the 1970s, they were presumed to be cleaning fluid contaminants from Earth. But if perchlorate is present in the mid-latitude Martian soil, it would explain the data. Since perchlorate becomes a strong oxidant when heated, it would have destroyed any organics and so explain why Viking didn't detect any. It's remarkable that the Viking legacy continues to provide so many surprises and unanswered questions.

THE BOOK



Dreams of Other Worlds
The Amazing Story of Unmanned Space Exploration
By Chris Impey and Holly Henry

by Rebecca Johnson and Damond Benningfield



A recent Hubble image shows the Great Red Spot and surrounding clouds. Right, from top: The Great Spot in 1995, 2009, and 2014.

NASA/ESA (4)

Starvation Diet?

Jupiter's Great Red Spot is trimming down in a hurry

Jupiter's Great Red Spot appears to be on a starvation diet. The solar system's most prominent feature has slimmed down by several thousand miles in recent decades, with most of that loss in the last few years. Planetary scientists say there's no way to know whether it will dissipate or rebound to its former dimensions.

When the twin Voyager spacecraft flew past Jupiter more than three decades ago, the oval-shaped storm was about 14,500 miles (23,200 km) long, or roughly twice the diameter of Earth. By two decades ago, it had lost about a thousand miles of that size, and earlier this year Hubble Space Telescope measured its length at 10,250 miles (16,400 km). Observations by amateur astronomers suggest the spot currently is shrinking by almost 600 miles (1,000 km) per year. It's also become more circular.

"We really think the way it has lived all these years is the same life cycle as in the oceans: big fishes eat little fishes," says Reta Beebe, an astronomer at New Mexico State University and an expert on the atmospheres of the giant outer planets. "Big eddies eat little eddies on Jupiter, and the little eddies are not coming in so he can grab them right now."

The Great Red Spot is sandwiched between strong jet streams to its north and south. Interactions between the spot and the jet streams spin off eddies that travel around the planet and eventually merge with the Great Red Spot, adding energy to the system, Beebe says. "But the past couple of years, there have been very few of these big eddies coming in and meeting the red spot," she says. "And if the red spot shrinks down, so that the clouds are flowing past it and creating a new weather pattern, then there'll be trouble getting those eddies in to be ingested in the red spot. So we think the red spot has gone on a diet."

Much about the system remains enigmatic. Scientists aren't even sure what gives the Great Red Spot its color. It probably pulls up compounds from deep below Jupiter's visible cloudtops that turn red when they're exposed to ultraviolet radiation from the Sun, but these compounds have not yet been identified.

Despite the spot's great surface area, it's probably only a few miles thick, so it's shaped like a giant pancake. Winds at its rim blow at hundreds of miles per hour, but are almost still at its center. Some observations suggest the perimeter winds have accelerated as the spot has shrunk.

Observations in the 1800s revealed an earlier cycle of shrinkage and expansion, so the Great Red Spot could rebound from its current contraction phase or, like many smaller oval storms on Jupiter, it could eventually fizzle out. "Things may have slowed down to the point that it may damage the red spot," Beebe says, "or we may get more convective outbursts and it may start to feed again" — allowing Jupiter to retain its most famous feature. **DB**

Mercury's Explosive History Revised

Views of Mercury's surface sent back by the MESSENGER orbiter are changing planetary scientists' take on the tiny planet's volcanic past and altering ideas of its formation.

Brown University graduate student Tim Goudge led a team that studied surface deposits of pyroclastic volcanic ash, an indicator of explosive volcanic eruptions.

The find was surprising, as Mercury would need to contain "volatiles" — compounds with low boiling points such as water and carbon dioxide — for volcanoes to violently explode. When lava pushes toward the planet's surface, volatiles dissolved in it turn from liquid to gas, expanding and potentially causing the crust overhead to explode.

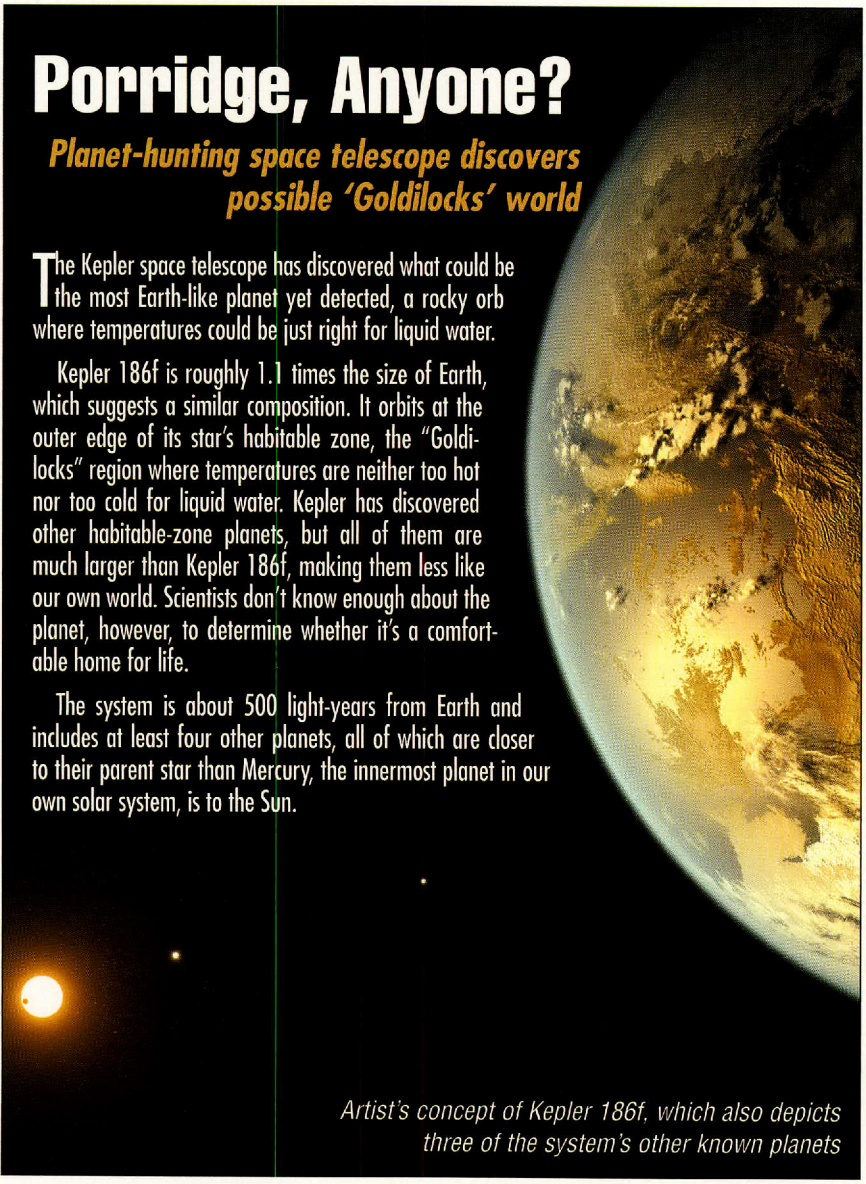
Goudge's team wanted to know when in Mercury's history the explosive eruptions occurred. Their studies of 51 ash deposits show that some of their sources (volcanic vents) are more eroded than others.

"If [the explosions] happened over a brief period and then stopped, you'd expect all the vents to be degraded by approximately the same amount," Goudge said. "We don't see that; we see different degradation states. So the eruptions appear to have been taking place over an appreciable period of Mercury's history."

The team used established methods for dating craters on Mercury's surface to work out the ages of the various ash deposits, some of which overlie fairly young craters. They found that some of the ash deposits are young, geologically speaking: between 3.5 million and 1 billion years old.

This means that volatiles have been around beneath the planet's surface over a large part of its evolution, disproving two leading theories of the planet's early history. Because the planet has a relatively large iron core, scientists thought it might have once been much larger. They supposed either the solar wind or a major impact removed its outer layers. But either event would have boiled away the planet's volatiles much earlier in its history.

"These results define specific targets for future exploration of Mercury by orbiting and landed spacecraft," said Brown professor Jim Head, a MESSENGER co-investigator. **RJ**



Porridge, Anyone?

Planet-hunting space telescope discovers possible 'Goldilocks' world

The Kepler space telescope has discovered what could be the most Earth-like planet yet detected, a rocky orb where temperatures could be just right for liquid water.

Kepler 186f is roughly 1.1 times the size of Earth, which suggests a similar composition. It orbits at the outer edge of its star's habitable zone, the "Goldilocks" region where temperatures are neither too hot nor too cold for liquid water. Kepler has discovered other habitable-zone planets, but all of them are much larger than Kepler 186f, making them less like our own world. Scientists don't know enough about the planet, however, to determine whether it's a comfortable home for life.

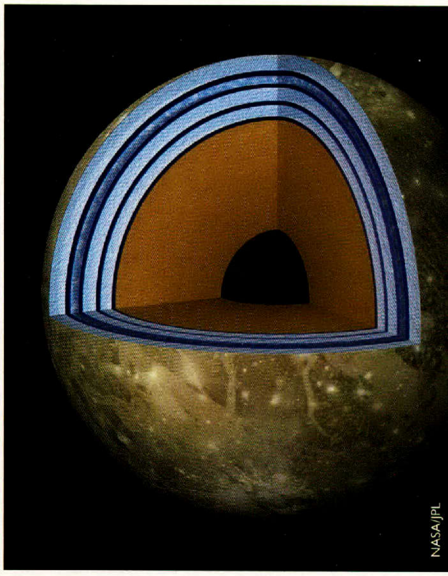
The system is about 500 light-years from Earth and includes at least four other planets, all of which are closer to their parent star than Mercury, the innermost planet in our own solar system, is to the Sun.

Artist's concept of Kepler 186f, which also depicts three of the system's other known planets

NASA/ARC/SETI INSTITUTE/JPL

A Parfait Moon

Ganymede, the solar system's largest moon, may be built like a self-frosting layer cake, with alternating layers of liquid and frozen water extending hundreds of miles below its icy crust.

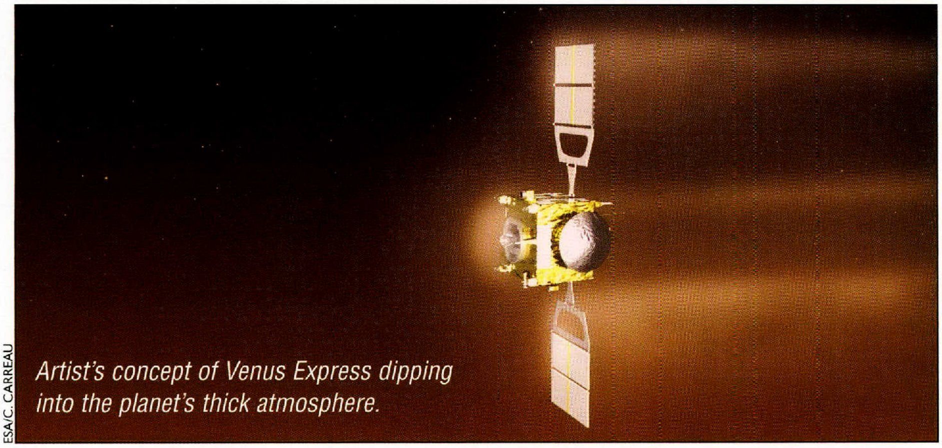


NASA/JPL

Ganymede, which orbits Jupiter, is almost 3,300 miles (5,300 km) in diameter, which is larger than the planet Mercury. Observations by the Galileo spacecraft, which studied the Jovian system more than a decade ago, indicated that a deep ocean of salty water lurked beneath a thick crust of ice.

A recent study led by Steve Vance of the Jet Propulsion Laboratory, however, suggested a more complex structure. The team used computer models that account for the water's mineral content, the extreme pressures at great depths, and other factors. The models indicate that a layer of dense liquid water could surround Ganymede's rocky core, with alternating layers of ice and liquid water above it — up to six layers in all (illustration).

Liquid water at the bottom of this layer-cake structure, which has not been confirmed, would make Ganymede more hospitable because heat from the moon's interior could provide an energy source to sustain microbes or other forms of life, the researchers say.



ESA/C. CARREAU

Artist's concept of Venus Express dipping into the planet's thick atmosphere.

Venus Express Takes the Plunge

The European Space Agency (ESA) is preparing to send its Venus Express orbiter down through the planet's dense, toxic atmosphere. After eight years, the craft has finished its planned science operations studying the planet's atmosphere, ionosphere and surface, and is running low on fuel. This is the perfect time for Venus Express to take on riskier experiments, mission managers said. The craft will plunge through the atmosphere to depths not before studied — perhaps as low as 80 miles (130 km) from the ground.

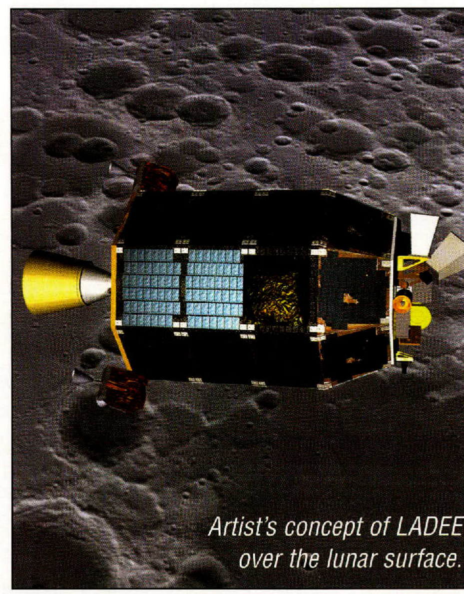
"It is only by carrying out daring operations like these that we can gain new insights, not only about usually inaccessible regions of the planet's atmosphere, but also about how the spacecraft and its components respond to such a hostile environment," ESA's Patrick Martin said.

The maneuver began on June 18 and could last through July 11. Venus Express will study the planet's magnetic field and chemical content during the plunge, and monitor the temperature and pressure on the spacecraft at those depths.

It's unknown if Venus Express will survive; it may run out of fuel or fall victim to the harsh atmosphere. If it does survive, the mission team will raise its orbit again and continue science operations for several months. Even in that best-case scenario, the spacecraft probably will run out of fuel by year's end. **RJ**

Farewell, LADEE

NASA directed its LADEE spacecraft, the Lunar Atmosphere and Dust Environment Explorer, to crash onto the Moon's surface on April 17. During the 3,600 mile-per-hour impact, the vending-machine-sized craft probably gouged a new crater. Impact occurred on the far side of the Moon. In the coming months, the LADEE team will determine the precise location of the impact site so that it can be photographed by Lunar Reconnaissance Orbiter.



Artist's concept of LADEE over the lunar surface.

NASA/DANA BERRY

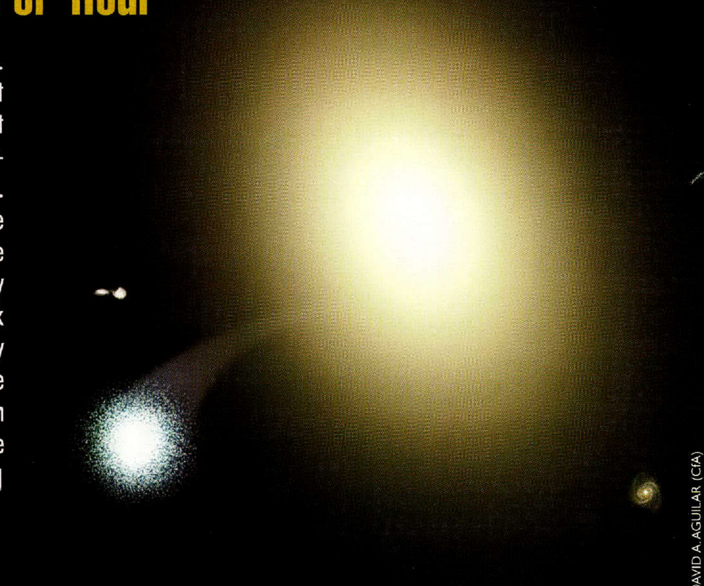
M87's Fastball Clocked at 2 Million Miles Per Hour

A cluster of ancient stars is hurtling toward us at more than 2 million miles per hour, but don't worry: Its trajectory shows it's doomed to wander between galaxies forever. Called HVGC-1, the cluster has been slung out on the giant galaxy M87.

HVGC-1 is a globular star cluster, a tight ball of thousands of stars formed early in the galaxy's evolution. About 150 inhabit the Milky Way, but M87 is home to thousands.

A team of astronomers led by Nelson Caldwell of the Harvard-Smithsonian Center for Astrophysics discovered HVGC-1 while studying the space around M87. At first, they thought the measurement showing the cluster's great speed must have been a computer mistake, but further examination proved the speed is real.

The team says the cluster may have been ejected after it wandered too close to the center of M87. The giant galaxy is known to harbor a supermassive black hole at its heart. If the galaxy actually holds not one, but a pair of supermassive black holes, their gravitational interaction may have acted like a slingshot on the cluster. **RJ**



The speeding globular cluster is shown escaping from the giant elliptical galaxy M87 in this artist's concept.

DAVID A. AGUILAR (CfA)

Mars' winds sculpt the surface of the Red Planet. They cause the sands, like those in the Nili Patera dune field seen here, to shift often. Mars Reconnaissance Orbiter constantly monitors this region. Tracking changes in the sand dunes allows scientists to see how Mars' winds vary seasonally and year to year.

NASA/JPL/UNIVERSITY OF ARIZONA