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The Cosmic Origin of Our Water

If Earth was born dry, how did it get oceans? p. 22

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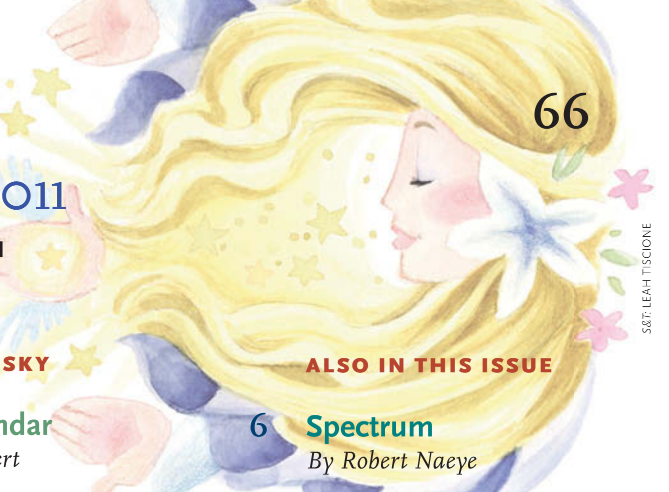
On the cover: Somehow, Earth acquired a large inventory of water. But exactly where our planet's water came from remains a mystery.

January 2011

VOL. 121, NO. 1



66

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FEATURES

THIS MONTH'S SKY

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ALSO IN THIS ISSUE

30

FROM LEFT TO RIGHT:
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BINOCULARS: VIXEN OPTICS

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MEADE INSTRUMENTS

Robert Naeye
Spectrum

Unsung Heroes and Our First App

ONE OF THE PERKS of my job is the opportunity to travel to different astronomy events. But even by the high standards set by previous trips, my two most recent forays were particularly enjoyable. Over Labor Day weekend I attended the Almost Heaven Star Party (AHSP) in West Virginia. Two weeks later, my colleague Sean Walker and I flew to L.A. to attend the Pacific Astronomy and Telescope Show (PATS) in Pasadena. The organizers of both events did a superb job, with dynamic speakers and other exciting activities.

This was the third time I attended the AHSP, which is run by the Northern Virginia Astronomy Club. We enjoyed crystal-clear weather, and I had the pleasure of looking through many different scopes under exceptionally dark skies — something I don't experience from the Boston metro area. I also had a lot of fun talking to nice folks about astronomy and space exploration.

This was the third year of PATS, and my second time attending. A core group of people in the Riverside Telescope Makers organizes PATS so that amateur astronomers living in the West have their own trade show, to complement the annual Northeast Astronomy Forum (NEAF) held in Suffern, New York. This year, several dozen vendors set up booths at PATS, including all the major telescope manufacturers. Attendance was up from last year, and just like NEAF, PATS has become a well-oiled machine. Sean and I had a great time talking to various attendees and hearing positive feedback about *S&T*.

From my time working at the Astronomical Society of the Pacific, which holds annual meetings, I know that a *huge* amount of work goes into putting together these events. The people who volunteer large chunks of their personal time to organize star parties, trade shows, and other astronomy gatherings are astronomy's unsung heroes. They deserve a thunderous round of applause from the rest of us. These events bring astronomers together from far-flung locations for face-to-face interactions, and this leads to meaningful community building. Without the dedication of these volunteers, amateur astronomy would be nowhere near what it is today.

Before closing, please note that 2011 is *S&T*'s 70th anniversary year (and the AAVSO's 100th). One way we're celebrating is with the introduction of our first application for the iPad, iPhone, and iPod Touch: S&T SkyWeek. Every week this app automatically delivers our website's most popular feature, "This Week's Sky at a Glance," to an Apple mobile device. There are plenty of good planetarium apps, so we created something unique for skygazers. SkyWeek goes beyond typical planetarium apps by providing a weekly report of special sky events each night, with links to interactive sky charts that tell you when and where to look. The app is customized by location, and it costs only 99 cents. Check it out!

Robert Naeye
Editor in Chief

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letters can receive personal responses.

Finding E.T.

Please count me among those who are in complete agreement with Robert Naeye ("E.T. and the Eiffel Tower," November issue, page 6).

As a former E.T. optimist, I was caught up in the Drake equation and the optimism of Carl Sagan. However, the more I studied the history of life on Earth, the more I realized the improbability of our emergence. As Stephen J. Gould said, if you rewind the tape of the history of life on Earth and play it again, nothing approaching our level of consciousness and intelligence would occur again. This is further evidenced by the extinction of the dinosaurs. Had the chance impact of that large asteroid not occurred, the dinosaurs would probably still be here and we would not.

The history of life on Earth, combined with the Fermi paradox, implies to me that we are probably not only alone in our galaxy, but alone in the Local Group as well.

Chester Hollaway
Sunnyvale, Texas

We should avoid trying to make contact with aliens. In view of the way many human cultures have treated other cultures of "less sophistication," and you may apply that term to any aspect of a culture you want, I think humanity is only looking for trouble in its search for E.T. We could end up as a footnote in some E.T.'s history book.

Ray Powell
Dundas, Ontario

I appreciated the comments on E.T. and SETI in the November issue (page 6); however, I think you are way too pessimistic about the chances for our contact with aliens. Recent discoveries of numerous planets on nearby stars show that planets are not a rare occurrence in our Galaxy. Life appears on even the most extreme regions of Earth. Therefore, it seems likely that other civilizations have developed and may be much further advanced technologically than ours, which, after all, has only been around for a few tens of thousands of years. Alien societies could have the advantage of being around for much longer and thus have more advanced technology. They may have access to advanced communication and space travel that is beyond our ken. Keep in mind that 200 years ago our own technology only allowed us to travel at the speed of a horse. Ninety years ago, we did not even know about other galaxies.

I think the classic sci-fi film of the 1950s, *The Day the Earth Stood Still*, may illustrate why we have not had overt contact. The alien(s) are waiting for us to become civilized and then blow ourselves up! Or perhaps they are trying to decide whether we are too dangerous to inhabit the Galaxy. In any case, we would still do well to investigate the many, many reports of E.T. sightings and even reported contacts in a systematic and scientific way. Currently there is such stigma associated with E.T. sightings that any real investigation by the scientific community is minimal. Galileo is no doubt turning in his grave at our failure to challenge conventional wisdom.

Dan Syroid
Park City, Utah

Something I have not heard scientists discuss is the inherent risk involved in our search for E.T. Our own species' "alien" discoveries have always involved the plunder of anything of value to us. Why would we expect other-world beings to be any different? Maybe we won't find extraterrestrials sending out signals to proclaim their location, because they know that would be stupidly dangerous. Perhaps that thought should be ours as well. If other highly advanced civilizations have ventured into deep space, can't we expect that they would bring their own needs to our world?

Life, if it exists on other worlds, would be just as demanding on the creatures there as it has been here on our world. Only the fittest survive in a demanding struggle. Can we therefore expect E.T.s to be benign, loving creatures interested in our own survival? This is a sobering thought to consider, today or 1,000 years from now.

Michael Ashton
Chico, California

In his November editorial, Robert Naeye appears to make a common and unwar-

ranted assumption: there is life elsewhere in the cosmos that is more advanced than humanity. While it may be so, there is no reason to assume it and to speak of these civilizations as if we already know they actually exist. The whole SETI effort is based on that assumption, and although we must pursue that possibility, we must also be aware of its hypothetical nature.

We should all be very careful when speaking and writing about E.T., making sure that others, and we ourselves, know that advanced civilizations are merely hypothetical, whether millions of years old or just a few thousand. This is especially so for magazines like *S&T*, which has a certain value as an authority. Writing of an advanced E.T. as a certainty, not a hypothesis, is misleading at best.

Has anyone ever considered that we, mere humans, may be the most advanced civilization in the cosmos? There's no reason why not, but that too is hypothetical.

K. A. Boriskin
Bellingham, Massachusetts

Editor's note: *To reiterate my stated position: we simply don't know if more advanced civilizations exist. — Robert Naeye*

Support for Landmark Restoration

I read Allan Cook's Letter to the Editor with great interest ("Big Bang Landmark in Trouble," October issue, page 8). The letter focuses on the sad condition of the neglected Holmdel Horn Antenna. I would like to see it restored to operating condition and protected by a "weather bubble" or something like that! (Perhaps that would also attract much-needed public attention?)

I have been an amateur scientist since I was a kid — I was born about a month after Sputnik went up — and the history of science is one of my greatest passions. Everybody needs a hobby, but I would ideally like to go back to college and get a degree in it.

I first read about the Holmdel Horn Antenna (and the discovery of cosmic microwave background radiation) when I read *The Red Limit* by Timothy Ferris back in the mid-1980s. There is a great photo of it in that book, and the antenna has fascinated me ever since.

Now it seems that, instead of its being a Big Bang monument, the legendary Horn Antenna has become a demonstration of the laws of entropy and fallen into decay.

My writing to you might not change anything, but I had to say something. Here's hoping that the Horn Antenna will be restored to its proper place as a landmark in the history of science!

Stephen C. Emmons
Fort Collins, Colorado

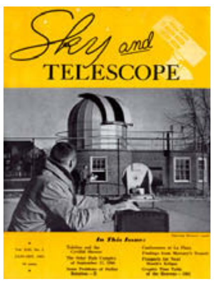
50 & 25 Years Ago

Leif J. Robinson

January 1961

North Star Ring "With my 7x50 binoculars and good seeing conditions, I have often observed what I call the 'engagement ring' of Polaris. It is a fairly round circlet about one degree in diameter. . . .

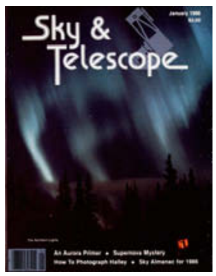
"When looked at through a telescope's finder, the circlet is too small to be noticed; it is also too faint unless viewed with a 2-inch objective."



This little-appreciated asterism was described by William L. Dutton of Noroton, Connecticut.

January 1986

Giant Stars "The case for supermassive and superluminous stars received a series of blows recently. For several years astronomers have suspected that stars much more massive than the Sun might be lurking in giant nebulae. However, new observations have shown that there is no supermassive star in one of the most likely locations for such an object, the mysterious heart of the 30 Doradus nebula in the Large Magellanic Cloud."



A firm upper mass limit for stars is still an open question.

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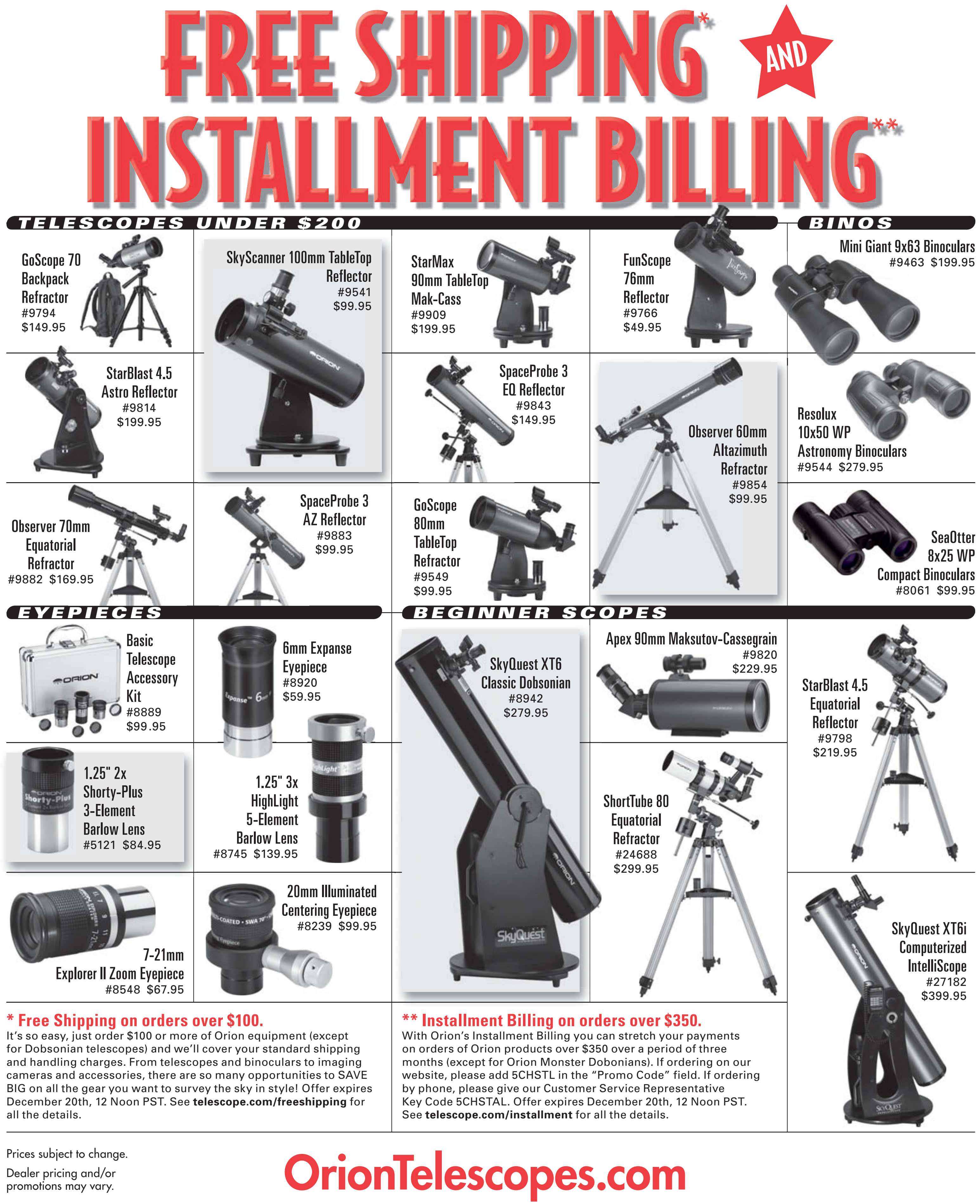
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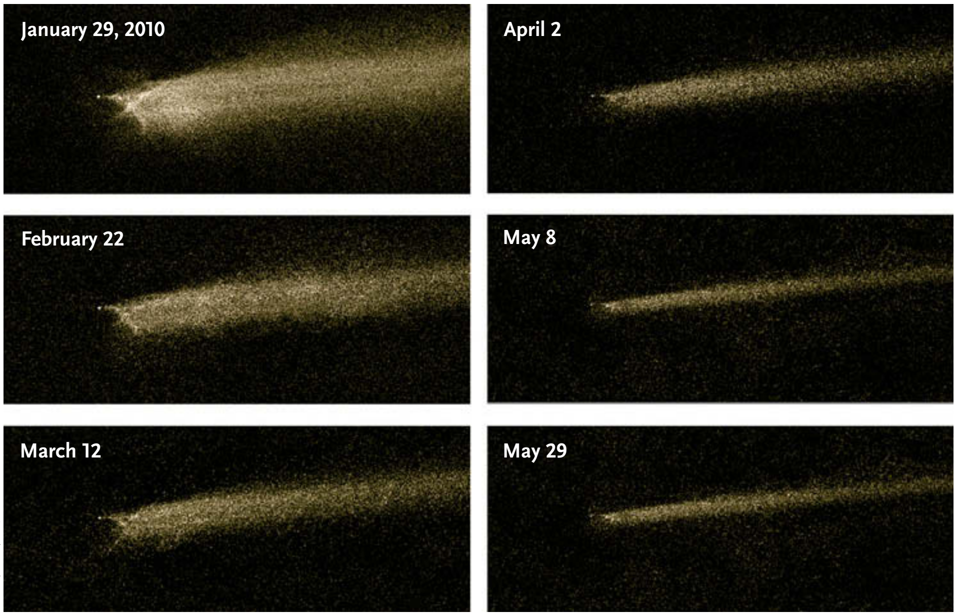
Asteroid Collision Update



NASA / ESA / D. JEWITT (UCLA)

Hubble Space Telescope images show that the odd, slowly-dispersing debris in "Comet" P/2010 A2 probably represents a collision between two small asteroids.

Remember the thing in the top frame above? Its discoverers suspected last January that they were seeing not a comet, as they first assumed, but debris from a collision between two unknown asteroids (*S&T:* May 2009, page 12). Now it looks like they were right.

Named "Comet" P/2010 A2, the weird object turned out to contain no gas at all, just dust and rubble. This series of Hubble images track the rubble's unexpectedly slow dispersal. According to David Jewitt (UCLA) and others, the tiny, 24th-magnitude dot on the left is a previously unknown asteroid about 400 feet (120 meters) across that was likely hit by another just 15 feet (5 meters) across. The collision kicked off the X-shaped debris cloud seen in the first images. Solar radiation pressure sorted fine particles from the X into the long streamer behind.

The whole thing proved to be dispersing much more slowly than first expected. On tracing everything back, astronomers have found that all the debris emerged from a single event within a few weeks of February 10, 2009. That was nearly a year before the object's discovery.

Team member Jessica Agarwal (European Space Agency) says the 100,000 tons of ejected material is mostly millimeters to centimeters in size, far coarser than the usual cometary fluff. No one has yet explained the X shape.

If an impact was indeed the cause, Jewitt says similar small smashups should occur in the asteroid belt about once a year. And because the debris of this recent collision remained visible longer than that, he concludes that on average, "One of these should be observable at all times. The door is open to disruption studies."

To see astronomy news as it breaks, visit SkyandTelescope.com/newsblog.

New Twist on Dark Energy

Astronomers have a new way to measure how fast the universe was expanding at various times in its long history — a tricky but crucial thing to know.

Until about 5 billion years ago the cosmic expansion was gradually slowing down, due to the gravity of everything pulling on everything else. Then the expansion started to speed up. Apparently, as the universe thinned out, a mysterious "dark energy" in space began overpowering gravity on the cosmic scale. Accurately tracking the dark energy's effect across time might tell something about what it is.

A group headed by Eric Jullo (Jet Propulsion Laboratory) and Priyamvada Natarajan (Yale) tackled the question a new way, using the gravitational-lensing power of the galaxy cluster Abell 1689 in Virgo. This massive cluster is 2.2 billion light-years distant. Around its fringes the astronomers identified 114 multiple images of 34 tiny, faint galaxies far in the background. The multiple images were created where different light paths from the same background galaxy were bent toward us by passing through the cluster's gravitational field. The team was also able to measure the redshifts of 24 of the background galaxies involved.

Combining these observations allowed the team to measure the actual bending of each light path — revealing not only the total mass of Abell 1689, but also the way in which dark energy altered the geometry of spacetime all along the route by affecting the cosmic expansion rate. "The precise effects of lensing depend on the mass of the lens, the structure of spacetime, and the relative distance between us, the lens, and the distant object behind it," Natarajan explains. Determine the exact light paths through 3-D space, and you can find all three things.

The result is a new check on dark energy's "equation of state" — how its strength changes in a given volume of space (one cubic meter, say) as space expands.

The answer: it doesn't change at all, to

NASA / ESA / E. JULLO / P. NATARAJAN / J.-P. KNEIB

Scores of faint background-galaxy images, broken up or distorted into thin arcs by gravitational lensing, surround the massive galaxy cluster Abell 1689 in Virgo 2.2 billion light-years away. Many of the faint arcs are multiple images of the same galaxies.

a newly refined uncertainty of just ± 7% when combined with other studies.

This is consistent with the idea that dark energy, whatever it is, is a property of spacetime *itself*, as Einstein proposed with his "cosmological constant" in 1917, rather than something that exists *in* space, such as particles or fields (or galaxies). Physical things in space spread out as space expands.

This new method is a crucial check on others. "We have to tackle the dark energy problem from all sides," says Jullo. "It's important to have several methods, and now we've got a new, very powerful one."

"Coreshine" in a Cloud's Black Heart

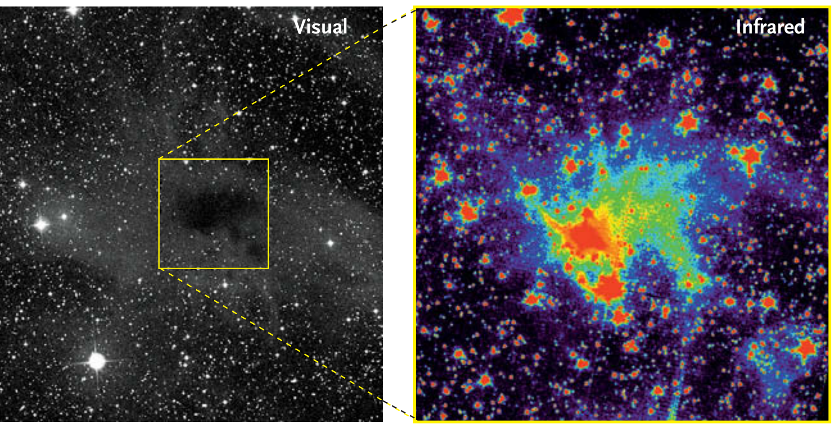
Star formation, with planet formation as its byproduct, looks like a more tangled and quirky process the more astronomers study it. The old picture of a dark cloud simply shrinking down to star size and lighting up is being replaced by complex models involving turbulence, narrow infalling streams, magnetically driven jets, and other spectacular nonlinear phenomena.

But a key to understanding star formation is simply being able to see it! The process is usually buried out of sight in dense, opaque interstellar clouds. Penetrating these clouds is one reason why astronomers have been keen on building infrared telescopes.

Now, using the infrared Spitzer Space Telescope, a team has identified a new aspect of these hidden scenes, which they've named "coreshine." The team, led by Laurent Pagani (Paris Observatory), found copious infrared starlight being reflected and scattered from large dust grains deep inside some of the dark cocoons that surround infant stars.

The size of the grains makes all the difference. Near some clouds' dense cores, grains have apparently grown to about 1 micron in diameter, large enough to scatter infrared light with a wavelength of 3 to 5 microns. One such cloud is CB 244, seen below. Its internal glow at these wavelengths made no sense if its dust grains are only 0.1 micron wide like most interstellar dust. Such small grains would be transparent to light waves 30 to 50 times larger. Apparently we're seeing early grain growth where new stars and solar systems are forming, or are about to form.

The team observed this reflected light inside about half of 110 dense clouds studied. "The core structure seems very smooth," says Pagani. "The coreshine reveals this very clearly, as it is the first time we have a sensitive tracer going deep into the cloud."

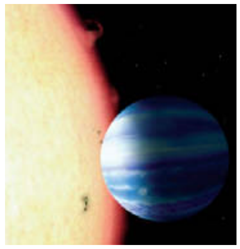


MPIA / NASA / JPL / A. STUTZ (2)

The dense molecular cloud CB 244, seen in visible light at left, is 650 light-years away in Cepheus. The false-color image at right shows mid-infrared starlight being scattered by relatively large dust grains inside — the newly discovered "coreshine."

A Planet's Death Spiral?

Some of the hottest "hot Jupiters" orbit their stars so closely that tidal forces ought to be dragging them slowly to their doom. Now astronomers say they've seen signs of it happening.



D. AGUILAR / CTR. FOR ASTROPHYSICS

How does this work? Consider how the Moon raises tides in Earth's oceans. Because the Moon takes a month to complete an orbit, while Earth spins in just 24 hours, the exchange of tidal energy is a net gain for the Moon, so it's gradually edging farther from Earth.

But a hot Jupiter completes its orbit in a few days — sometimes in less than 24 hours — while most stars turn more slowly. So in this case, tides that the planet raises in the body of the star should have the opposite effect: slowly dragging the planet inward.

That's apparently the destiny facing OGLE-TR-113b, a roaster with a little more mass than Jupiter crowding a Sun-like star 1,800 light-years away in Carina. Because the planet transits its star, astronomers can time its orbital period to high precision. Six transit timings over the past few years indicate that the planet's 1.42-day period is speeding up (barely) by about 60 milliseconds per year.

It's possible, notes observing team leader Elisabeth Adams (MIT), that we're seeing the effect of an undetected body tugging on the planet (see last month's issue, page 18), though the perturber couldn't have more than twice Earth's mass. But the likeliest explanation is that astronomers have indeed captured a hot Jupiter in its final death spiral. Within less than 2 million years at this rate, the orbit should

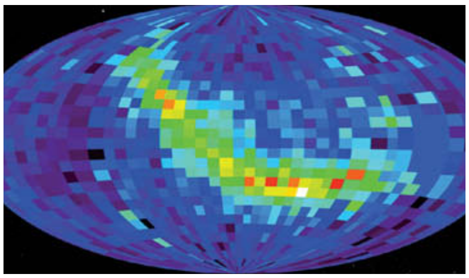
shrink and speed up to a period of 10.8 hours. At that point the tidal force acting on the *planet* will become great enough that it will literally be torn apart, spreading into a ring of matter around the star like the rings of Saturn. But the ring will last only briefly before the star's intense heat and wind blow it away.

Sun's Heliopause: A Moving Target

If a spacecraft doesn't even go as far as the Moon, how can it be called the Interstellar Boundary Explorer?

The IBEX craft, in Earth orbit, has been "imaging" the solar system's interstellar boundary thousands of times farther away, 85 to several hundred astronomical units out. This is where the Sun's solar-wind bubble, the *heliosphere,* meets the interstellar medium. IBEX sees what's going on there not by light or other electromagnetic radiation, but by incoming neutral hydrogen atoms.

When the outward-racing solar wind hits the heliosphere's edge, it mingles with atoms of the interstellar medium. Here the energetic solar-wind protons can steal electrons from the slower-moving hydrogen atoms drifting between the stars. The result is neutral high-speed



NASA / GSFC SCIENTIFIC VISUALIZATION STUDIO

IBEX's first all-sky map of the heliopause showed an irregular ribbon of activity strung far across the sky. The map is centered on the "upwind" point, where the interstellar medium hits the solar wind head-on.

hydrogen atoms flying off in all directions. Without electric charge, they're no longer constrained by the solar wind's magnetic field. So they spray everywhere, including back toward Earth. Two particle detectors on IBEX record them, building up a complete image of the heliopause enveloping the solar system.

The first such image showed that the interactions around the heliopause are more varied and dramatic than expected, punctuated by a long "ribbon" with origins still unknown.

Now IBEX has completed its second all-sky scan, and again the results are surprising. The interactions shape-shifted here and there during the intervening six months. Most notably, a hot spot in the ribbon smeared out. Says David McComas (Southwest Research Institute), IBEX's lead scientist, "These observations show that the interaction of the Sun with the interstellar medium is far more dynamic and variable than anyone envisioned."

Only two spacecraft, Voyagers 1 and 2, have ventured far enough to probe the heliopause directly, and only in two locations. Voyager 1 is now 115 astronomical units from Earth; Voyager 2 is 94 a.u. away.

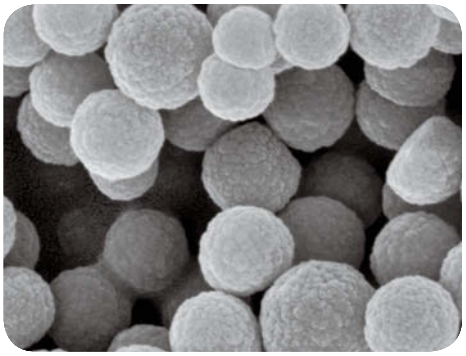
Titan's Hazes: A Rich Brew

Saturn's moon Titan has the most similar atmosphere in the solar system to Earth's. It's dominated by nitrogen (N_2) and contains a few percent methane (CH_4). Even way out at Saturn, ultraviolet sunlight is strong enough to break up these molecules so that they recombine into complex compounds forming layers of aerosol haze that hide Titan's surface. Now the stuff of the hazes turn out to be unexpectedly interesting — and familiar.

Cosmic chemists have long thought that Titan's haze is mostly ethane (C_2H_6), which should constantly drizzle out of the sky as the droplets grow large enough. There's only so much you can cook up with just nitrogen and methane. But now researchers realize the Titanian mix contains a little oxygen. It was discovered in 2004 when the Cassini spacecraft passed close enough to get a faint whiff of gases being stripped off Titan's upper atmosphere.

Oxygen is a game-changer, because it means more complex photochemistry. But while Cassini can tell that Titan's haze contains some very complex organic compounds, it can't tell what they are.

Now we have exciting clues. Sarah Hörst (University of Arizona) recently led an international team that re-created the conditions high above Titan, by pump-



EDITH HADAMCIK / UPMC / UNIV. OF PARIS

Tiny spheres of complex organic compounds, about 0.0003 millimeter wide, formed spontaneously in a laboratory simulation of Titan's uppermost atmosphere.

ing microwave energy into a low-pressure mix of nitrogen, methane, and oxygen. The result was a haze of tiny hydrocarbon particles no bigger than 0.1 micron across, a good match to the aerosol haze. In the particles, Hörst and her team discovered a trove of organics critical to Earthly life. Among them were adenine, cytosine, guanine, thymine, and uracil — the five key nucleotide compounds found in DNA and RNA — and a dozen amino acids.

"Finding all five nucleotide bases was terrifying," says Hörst. "It was as if someone had sneezed in the test tube."

News reports about finding familiar biological compounds in space often make it sound like cosmic chemistry is inexorably driving toward living things. But a less self-centered view might be that when life processes get started somewhere, they simply use whatever good stuff is lying around. ✦

NASA / JPL / SPACE SCIENCE INSTITUTE

Seen from NASA's Cassini orbiter on January 15, 2010, distant Tethys slipped behind haze-shrouded Titan in the foreground.

Cosmic Relief
David Grinspoon

Weathering New Worlds

A meeting of astronomers and climate modelers will lead to better predictions.

In September I attended ExoClimes 2010, at the University of Exeter, a workshop about the diversity of planetary atmospheres within our solar system and beyond. The cliché forecast for southwest England had me prepared for rain, but it stayed hot and sunny. Weather prediction will always be unreliable, but how well can we predict climate change? Increasingly, we're banking on accurate climate models for the future well being of civilization. If our models really are any good, shouldn't they also predict the climate on other worlds?

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The results are mixed for our neighboring planets. We still can't say why Mars started off warm and wet. Clearly, its atmosphere was thicker, but if we just pump up the carbon dioxide in our models, it never gets hot enough. We understand, in terms of basic climate principles, why Venus's thermostat became stuck at the hottest setting as the warming young Sun triggered a runaway greenhouse, but we don't know when this catastrophe occurred.

Planets are diverse and quirky, so three or four examples are insufficient to prove any pattern or improve our models. We need many more examples, and fortunately, we're about to get them as we slowly learn more details about exoplanets. The only ways we have right now of gaining any hints is through painstaking analysis of datasets at the hairy edge between noise and meaning. Scientists (many of them young) are displaying a fantastic amount of cleverness to bravely try new ways to use the available tools to glean information about these distant worlds.

Meanwhile, modelers are trying to understand possible exoplanet climates. At the workshop it was fascinating seeing astronomers trying to talk to terrestrial climate modelers. Our knowledge of exoplanet climates is so sparse. Each is at best a few numbers — mass, distance from a star, and in some cases, vague inferences about temperature or atmospheric composition. In contrast, Earth climate models are supplied with dense grids of data — millions of points of temperature, humidity, and wind velocity. The mismatch in perspectives made communication challenging.

Climate physics must be universal even if local conditions are infinitely variable. When we predict Earth's future climate, we change a few variables such as the abundance of greenhouse gases, and the model tells us what the new temperature pattern will be. A similar exercise should also work for another planet: take a garden variety Earth climate model, alter the gravity, the atmospheric composition, or the amount of sunlight, and you should get results that match observations. Unfortunately, it's not so easy in practice. Our best models are Rube Goldberg contraptions cobbled together from older models, modified and tweaked to add new physics, assumptions, and constraints. Nobody really knows how they work.

Efforts are underway to develop more universal climate models that will work for Earth as well as for Mars, Venus, Titan, and all the coming exo-Earths with arbitrary combinations of planetary variables. Exoplanets are a transformative watershed for planetary science. They will test our theories and deepen our insights in so many ways that have been impossible when we knew nothing about other planets.

Earth climate modelers might be slow to realize it, but they need exoplanets. During the workshop I felt like I was seeing a future era of climate understanding that will be made possible when we can study our planet's qualities in the context of thousands of its planetary peers. ✦

David Grinspoon (*www.funkyscience.net*) *is Curator of Astrobiology at the Denver Museum of Nature & Science.*

Where DID Earth's

Kristina Grifantini

The first evidence of ice on an asteroid suggests there may be much

NO WONDER WE CALL EARTH THE "BLUE PLANET." Our home world is the only known planetary object where substantial bodies of liquid water exist at the surface, creating the conditions for life as we know it. In total, oceans and lakes cover 71% of Earth's surface.

Forms of water are abundant throughout the universe, and H_2O from the original solar nebula accreted along with other elements and molecules as the planets were forming. But the young Earth formed from colliding planetesimals, heating the planet and its rocks to high temperatures. This, along with Earth's proximity to the blazing-hot young Sun, should have boiled off our world's original water supply, suggesting that something must have delivered water later as the planet was cooling. Because life is tied inextricably to the presence of water, unraveling the origins of Earth's oceans could give us tantalizing hints as to how and when life began.

Water, Water, Everywhere

As the solar system's dust and minerals accreted around 4.6 billion years ago, rocky and metallic agglomerations near the Sun condensed into small, dry objects such as the terrestrial planets and asteroids. In the frigid outer solar system, gas and water ice were abundant, and this material turned into large gaseous planets or icy clumps of rock, such as comets and moons. Researchers initially thought that the zone separating the hot and cold regions — the so-called *snow line* — lies somewhere near the current asteroid belt's outer edge.

Since Earth presumably formed hot and dry, researchers long suspected that impacting comets were the main objects that filled the seas. Comets are water rich and they originate beyond the snow line. But when astronomers spectroscopically analyzed the water sublimating (vaporizing) from several bright comets such as Halley, Hyakutake, and Hale-Bopp, they found that the hydrogen in the water had only about half the hydrogen-to-deuterium ratio (deuterium is a heavy isotope of hydrogen) as the water in Earth's oceans. This mismatch seemed to rule out comets as being the main source of Earth's water.

Recent discoveries in the asteroid belt have provided an alternative. Whereas comets are roughly defined as rocky ice balls in highly elliptical orbits that spend most of their time in the frigid outer solar system, asteroids are considered to be rocky protoplanets that revolve in roughly circular orbits in the warmer inner solar system. In the 1990s, astronomers started finding objects in the asteroid belt that look like comets, with tails and comae. Researchers initially explained the first sighting as a result of two asteroids colliding, but in 2006 Henry Hsieh and David Jewitt (University of Hawaii) argued that the tails were actually caused by sublimating ice, and defined the objects as "main-belt comets."

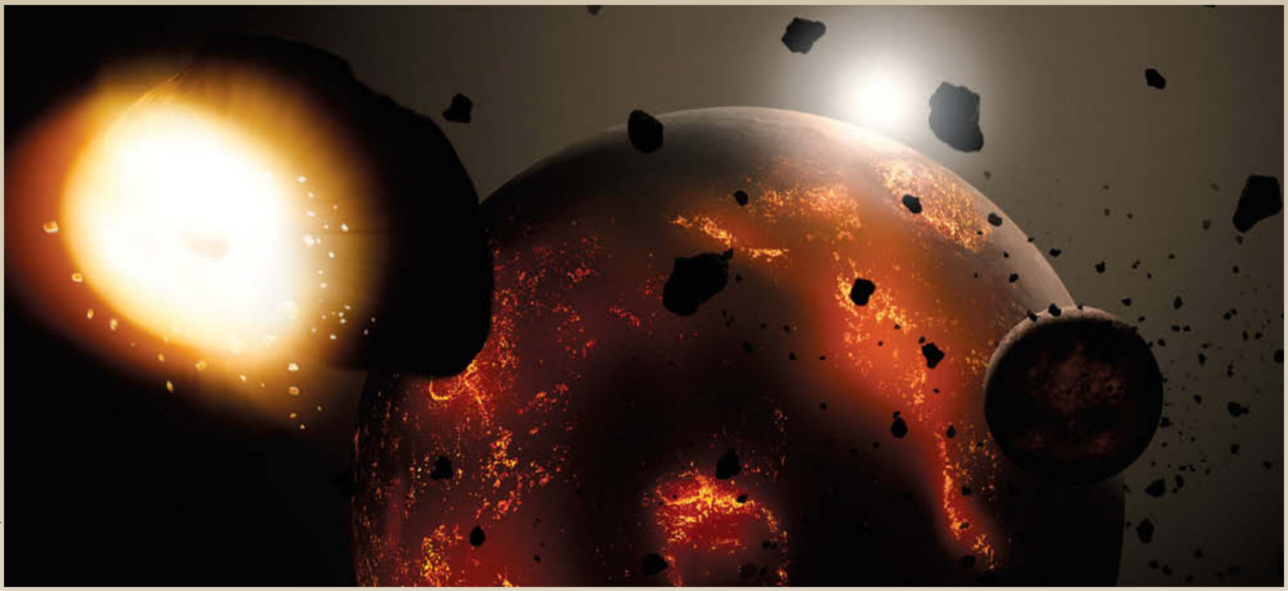
A year before, in 2005, Peter Thomas (Cornell University) and his colleagues reported Hubble Space Telescope observations showing that the largest main-belt asteroid, Ceres, is almost spherical, which means its interior has differentiated into layers. Based on Ceres's relatively low

Water Come From?

more water hidden in the solar system than we thought.

ROBERT NAEYE / IMAGE ABOVE: ©BIGSTOCK.COM / JAVARMAN

OCEAN WORLD **Despite comprising only about 0.03% of Earth's mass, water covers 71% of Earth's surface. This photo shows some of the large monoliths off the coast of Cannon Beach, Oregon.**



CHRISTIAN JOORE

BORN IN FIRE Earth formed from accreting planetesimals. Many scientists think that frequent large impacts melted the planet's exterior, boiling away the original water supply.

density, and spectral evidence for water-bearing minerals near its surface, Thomas suggested that Ceres has a thick water-ice mantle.

"The snow line was not a simple thing," says Jewitt (now at UCLA). "It didn't have a fixed radial location as we used to think. It moved around over a range of radial locations, probably sweeping over large swaths of the asteroid belt — it danced around in the early solar system."

With the snow line blurred, major comets a bad match for Earth's water, and the new main-belt comets and Ceres as potential candidates for hosting water, astronomers began to wonder if our planet's water might have come from comets' ancient cousins: the asteroids.

Unexpected Water

Even before the discovery of main-belt comets, impacting asteroids were considered potential sources of water. In bits of different asteroids that fall to Earth as meteorites, scientists find minerals with hydroxyl (OH) bound into their structure. They speculated that some asteroids began as a mixture of ice and rock, but that ice eventually melted and reacted to form those hydrated minerals. But Andrew Rivkin (Johns Hopkins University) notes, "We didn't think any of the original ice still existed in the asteroid belt. It had been thought that comets are objects that have ice and asteroids don't; they're too warm."

Despite these recent findings, few researchers suspected that rocky asteroids relatively close to the Sun would contain water. But that's exactly what two independent teams reported in early 2010 after studying the 120-mile-wide asteroid 24 Themis, which orbits at an average distance of 3.1 astronomical units (a.u.).

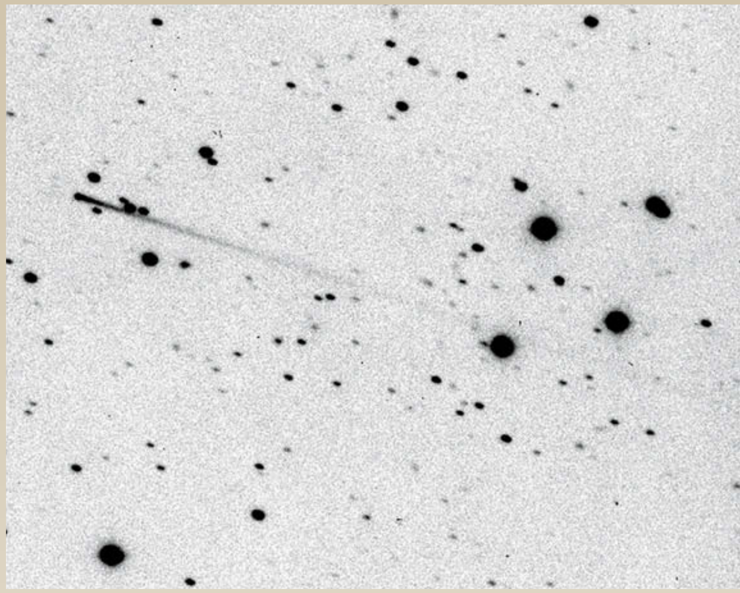
When Humberto Campins (University of Central Florida) began looking at 24 Themis with NASA's 3-meter Infrared Telescope Facility (IRTF) in Hawaii, he didn't expect to find ice. "It seemed improbable. We thought we might find hydrated minerals," says Campins. But when he looked at the data, "I was thinking, my God, that looks like ice."

He contacted Rivkin and Rivkin's research partner, Joshua Emery (University of Tennessee), who were also using the same telescope to collect data on Themis and other asteroids. Whereas Campins' group observed the asteroid over an entire rotation to derive a rough surface map, Rivkin and Emery observed several latitudes on Themis's surface at different times — 2003, 2005, and 2008 — in its orbit. "We had complementary data produced completely independently," says Campins.

Both teams picked up the feeble reflected sunlight from Themis. Spectroscopic analysis revealed a dip at 3.1 microns, a wavelength at which water ice absorbs infrared light. To make certain it was water ice, Rivkin and Emery compared the feature to absorption bands from other materials, such as clay minerals, whose water-bound structure absorbs infrared light at around 2.8 microns. "We went through a huge array of possibilities to whittle it down and convince ourselves that the position and width of the band could not be anything except for water ice," says Emery. Both teams confirmed that they had found water ice along with organic molecules, and they published their papers in the April 29, 2010 *Nature*.

"Spectral evidence for water ice is a bit counterintuitive, because Themis's surface temperature is high enough that water ice would sublimate away after thousands of years," says Emery. But because the ice shows up uniformly across the asteroid's surface, Emery and his colleagues don't think it was leftover frost from a collision with a comet, for example. The surface frost must be

S&T: DENNIS DI CICCO



ESO

WATER SOURCE Comets are rich in water ice and have been impacting Earth for billions of years. But the ratio of hydrogen isotopes in long-period comets is a poor match for Earth's oceans, meaning that comets are not the dominant source of our planet's water. Water ice vaporizing from the nucleus of Comet Hale-Bopp, pictured here, ended up in the coma and the bluish ion tail.

MAIN-BELT COMETS Astronomers were stunned in the mid-1990s when they started finding asteroids that sported extended tails, such as Comet Elst-Pizarro. At first, astronomers thought the tail might be the result of recent collisions, but it now appears that at least some come from vaporizing water ice. This discovery showed that some asteroids contain significant amounts of water, and could have been a major source of Earth's oceans.

replenished by a large reservoir inside the asteroid, from ice that has been there since the solar system's formation.

"The Themis result was not a huge shock, but it was a nice surprise," says Jewitt. "It fits in perfectly with the idea that many asteroids hold ice inside, protected from the Sun's heat by a covering of dirt in most cases. If we saw ice sublimate from Themis, it would likely be classified as a main-belt comet." Jewitt thinks that ice-containing asteroids are common, particularly in the outer main belt. "We just think they're rare because we've only recently been able to detect them and we've only seen a few so far," he adds.

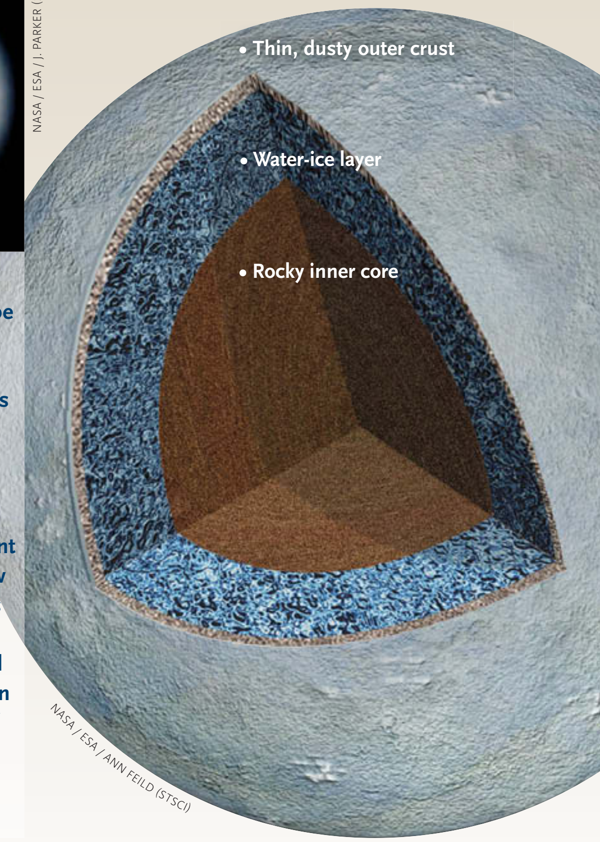
Looking for a Match

So, is asteroid water the same water as on Earth? "Unfortunately, we can't measure the isotope ratio on Themis," says Emery. Researchers can infer from ultraviolet observations the isotopes from sublimating ice in a comet's tail or coma, but Themis lacks these structures, and the known main-belt comets are too faint for this measurement. Meteorites provide information about asteroid composition, but scientists don't know which asteroids they come from. A few meteorites — carbonaceous chondrites — show a good match to Earth's hydrogen-to-deuterium ratio, but scientists don't know if those isotopes change when water forms hydrated minerals. Moreover, some of the other meteoritic materials (noble gas ratios such as neon and xenon) don't match those on Earth. The best way to find out more about water ice in the asteroid belt is to snatch a direct sample from Themis or a neighbor.

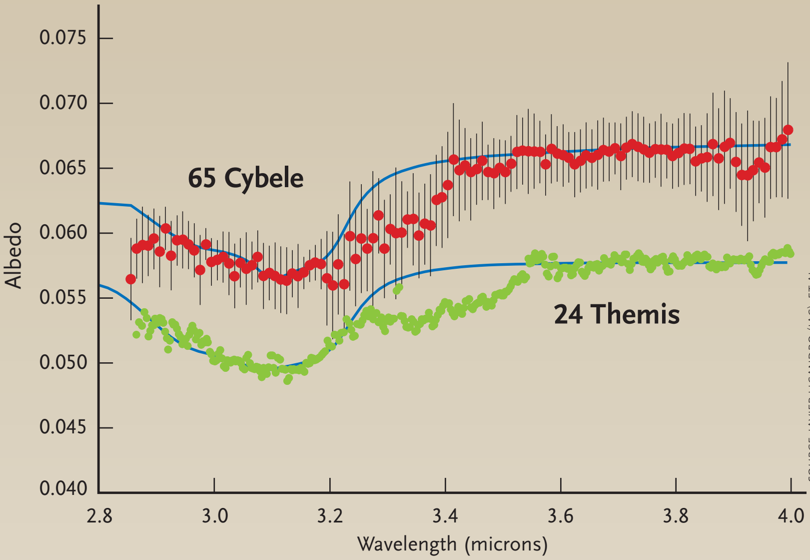
NASA / ESA / J. PARKER (SWRI), ET AL.

ICE STORAGE CHEST This Hubble Space Telescope image *(above)* proves that the largest asteroid in the main belt, 1 Ceres (605 miles across at the equator, 565 miles from pole to pole), is nearly spherical. A model of Ceres's interior structure *(right)* that takes into account the asteroid's shape and low density (2.08 g/cc) suggests that it contains a thick layer of frozen water. If the model is correct, Ceres may contain more fresh water than all of Earth's lakes, ponds, rivers, and streams combined.

Layers of Ceres

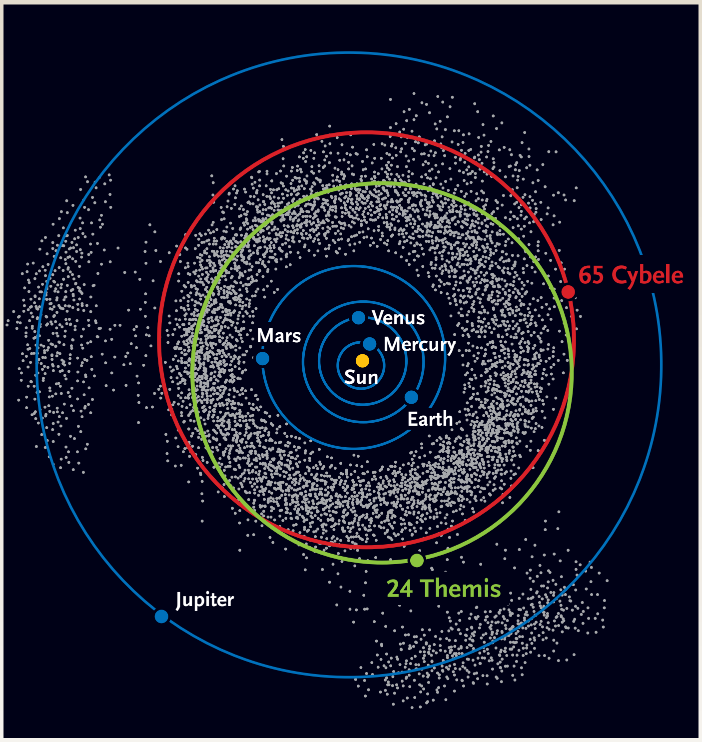


NASA / ESA / ANN FEILD (STSCI)



SOURCE: JAVIER LICANDRO (IAC), ET AL.

WATER SIGNATURE These recent spectra from NASA's Infrared Telescope Facility in Hawaii of the main-belt asteroids 24 Themis and 65 Cybele show a clear absorption feature at 3.1 microns, the wavelength where water ice absorbs light. These data offer powerful evidence that at least some main-belt asteroids contain a significant amount of water, which makes them prime candidates for delivering water to Earth.



S&T: LEAH TISCIONE / SOURCE: UNIVERSITY OF TENNESSEE

ASTEROID ORBITS The water-containing asteroids 24 Themis and 65 Cybele orbit in the outer part of the main asteroid belt. Themis orbits at an average distance of 3.1 astronomical units; Cybele orbits at an average distance of 3.4 a.u.

Various missions have been sent to asteroids to detect surface minerals. In 2007 NASA launched Dawn to the rocky asteroid Vesta, where it will arrive in July 2011. After spending a year orbiting Vesta, the spacecraft will head to Ceres to possibly reveal more about its suspected subsurface water ice. And just this past summer, the Japanese spacecraft Hayabusa returned to Earth after visiting the near-Earth asteroid Itokawa, where it attempted to obtain samples. (The research team is still working to determine if Hayabusa returned dust particles from Itokawa.) The proposed OSIRIS-REx mission would return a sample from a near-Earth asteroid.

Currently, there is no mission planned for Themis, but Rivkin, Emery, and Campins will continue to examine the asteroid and look for water ice on other asteroids. Using IRTF and NASA's Spitzer Space Telescope, a group led by Javier Licandro (Instituto de Astrofísica de Canarias, Spain) recently announced water ice on 65 Cybele, an asteroid slightly farther from the Sun than Themis. This work strengthens the probability that more asteroids containing water ice are waiting to be discovered.

Lingering Mysteries

Besides the question of where Earth's water comes from, researchers still debate when Earth's water was driven off. Some suggest that the huge, violent impacts at the beginning of Earth's formation (such as the one that produced the Moon) melted its entire surface, turning the planet's exterior into a sea of molten lava and boiling off any water. Other scientists speculate that Earth's original water boiled off during the Late Heavy Bombardment (LHB), when Earth was smashed by large objects around 3.9 billion years ago. Still others point to evidence that Earth's water dates closer to the time of formation.

Results announced shortly before this issue went to press suggest that planetary migration in the solar system's early history could have played a key role in disrupting the orbits of large numbers of asteroids. In particular, the migrations of Jupiter and Saturn might have scattered carbon- and water-rich asteroids that formed beyond the snow line into orbits in the outer asteroid belt. But some of these objects would have collided with Earth, delivering their precious inventory of water (see page 28).

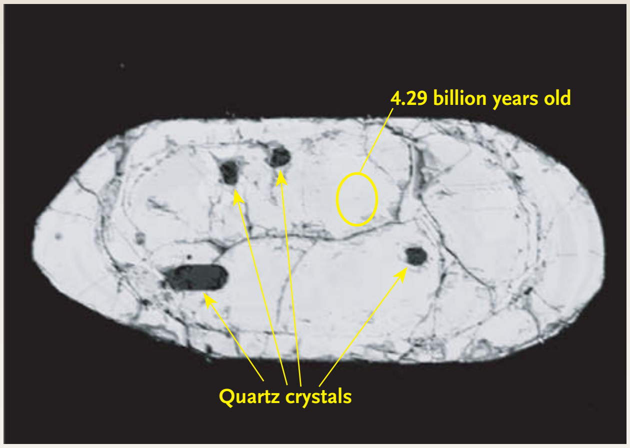
In addition to asteroid observations and solar system models, scientists also look to Earth itself to understand the origins of water. The shifting of continents and oceanic crust, as well as weathering, erased clues to Earth's formation; the earliest known rocks are only around 4 billion years old. But a clue to water's earliest history lies in tiny ancient mineral grains called *zircons,* some of which date to 4.38 billion years. Zircons preserve the isotopes 18-oxygen and 16-oxygen. When sedimentary minerals form in liquid water, they tend to favor the incorporation of ^{18}O over ^{16}O in their crystal lattice. This means they are strongly enriched in ^{18}O compared to seawater or normal crust. The oldest zircons show evidence of having had their parent magmas contaminated by sediments with this enrichment.

"When these little zircons crystallize, they incorporate information about their melt environment — including whether or not water is present. They're basically little time capsules," says Stephen Mojzsis (University of Colorado), who made some of the first measurements of the ancient zircons. "The chemistry of zircons and their mineral inclusions show that the sediments which contaminated the magmas that made the ancient zircons were formed in liquid water, not steam, not ice. Overall, they point to oceans on Earth before 4.4 billion years ago; it would mean water came to Earth very, very early." He adds that it's highly unlikely that the later LHB collisions would have boiled away all of Earth's water.

Aside from *when* Earth's oceans appeared, we still don't know *how much* water is in present-day Earth. Geologists have only a rough idea of the amount of water in Earth's mantle; estimates range from as much as 10 ocean masses to a bit more than 1 ocean mass. The actual amount affects ideas of water delivery profoundly.

Regardless of how much water was delivered, the discovery of ice in the asteroid belt strengthens the evidence that water may have come to us via asteroids, at least in part. "The oceans probably have multiple sources, from water in the asteroid belt, water in comets from the Kuiper Belt, and water carried by fine dust grains that went to make up the Earth," says Jewitt. "The name of the game is to figure out the relative contributions of these different sources."

As we figure out how water reached Earth, we'll likely have a better idea of how it reached other planets as well. "Whatever mechanism we find delivered water to Earth



STEPHEN MOJZSIS (UNIVERSITY OF COLORADO)

ANCIENT TIME CAPSULE This microscope image shows a 180-micron-wide grain of the mineral zircon, which has tiny embedded quartz crystals. The area within the oval is 4.29 billion years old. Inclusions of quartz within the zircon is consistent with molten magma rich in dissolved water and silica — evidence that early Earth already had substantial bodies of water.

NASA

GOLDILOCKS PLANET Earth has just the right amount of water for technologically capable life. There's enough water to cover much of the surface, but not enough to cover the entire surface.

Water and Technological Civilizations

From microbes to mammals, liquid water is essential for life. Even worlds completely covered by water could be teeming with diverse life, as are Earth's oceans, lakes, and rivers. But technological civilizations require dry land as well as water. Technical innovations such as metallurgy, electronics, and rocket engines require a dry setting. An underwater Einstein would struggle to invent fire.

So any planet hoping to host technological life should sport both land and sea. Are such dual-surface rocky planets common? *Star Trek* depicts "Class M" rocky planets as common as dirt. But recent research on the formation of terrestrial planets should dampen our optimism.

The final amount of water that a rocky planet accumulates depends on the shooting gallery of impacting asteroids and comets. Computer simulations of this random process done with different Jupiters, protoplanetary disk masses, and stellar companions, show that some rocky planets acquire less than 10% of an Earth's worth of water while others are literally drowned with more than 10 to 100 oceans of water. The water content of rocky planets varies by a factor of a thousand, and probably more.

If Earth had just twice as much water, our continents would be almost totally inundated, with Mount Everest barely poking above the waves. A rocky planet containing only half of Earth's water might absorb most of it into the mantle, leaving little on the surface.

Earth's precise water content seems a lucky sliver of all possibilities. Perhaps 1 in 100 rocky planets acquire just the right amount of water to avoid being a desert world or a water world. But our good fortune is no coincidence. If our Earth were not just so, we humans would not be here to think about it.

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*Kepler science team member and University of California, Berkeley astronomer **Geoff Marcy** has led or belonged to teams that have discovered more than 200 exoplanets.*

is a highly likely mechanism for delivering water to other planets," says Emery.

The origin of Earth's water is still unresolved, but the discoveries of the main-belt comets and ice on Themis and Cybele hint that there may be far more sources of water in the solar system than originally thought, pointing to a multitude of origins. As scientists continue to identify places with water and improve models of the solar system's evolution, they will refine targets for missions, and perhaps truly understand how Earth got its oceans. ✦

Kristina Grifantini is a science and technology journalist living in Cambridge, Massachusetts. She recently won the American Astronomical Society Solar Physics Division award for Popular Science Writing for her March 2009 S&T *cover story "Solar Impact."*

A New, Improved Solar System *by J. Kelly Beatty*

The long-term orbital stability of the Sun's planets has been taken as evidence that they formed right where they are now. But there have been problems with this view. Uranus and Neptune should have ended up much less massive, because billions of miles from the infant Sun the protoplanetary pickings were slim and the assembly process too slow. Conversely, Mars should have become 10 times more massive. And no one really understands why the inner asteroid belt is dominated by rocky bodies (called S types) and the outer belt by dark, carbon-rich chunks (C types).

Dynamicists solved the Uranus-Neptune dilemma a few years ago by positing that the four giant planets accumulated 5 to 12 astronomical units (a.u.) from the Sun. After a few million years Jupiter's gravity jostled Saturn into a wide-swinging orbit, triggering a chain reaction of close encounters that ultimately threw Neptune and Uranus out to their current orbits.

But the thorny problems of a too-small Mars and a stratified asteroid belt remained. As detailed at an October planetary science meeting, it *is* possible to assemble four correctly sized terrestrial planets and the right kind of asteroid belt. However, the solution requires dramatic new thinking about how Jupiter (and Saturn) migrated to their current locations.

The stage for this revolution was set in 2009, when Brad Hansen (UCLA) modeled the inner planets' formation in a new way. He took a cue from the close-in, Earth-size planets around the pulsar B1257+12, which must have assembled from a limited disk of hot material close to the pulsar.

When he tried this approach for our solar system, starting with a disk confined to just 0.7 to 1.0 a.u. from the Sun, his computer runs routinely coughed up sets of planets with relatively big ones (think "Earth" and "Venus") in the middle and smaller ones ("Mercury" and "Mars") near the inner and outer edges.

Meanwhile, others wondered how Jupiter avoided becoming a close-in captive of the Sun, like the hot Jupiters around other stars. As early as 1999, theorists showed that Jupiter should have indeed slid inward a bit, due to its tidal interactions with the Sun's protoplanetary disk. But it soon became gravitationally linked with Saturn in a 3:2 resonance, meaning that Jupiter completed three orbits for every two of Saturn's. At that point the paired planets would have reversed direction and headed outward.

Hansen's simulations, combined with the realization that the gas giants could have migrated inward *then* outward, gave modelers a "Eureka!" moment.

At the meeting, Kevin Walsh, who worked with Alessandro Morbidelli while at Côte d'Azur Observatory in France, described computer simulations that put Jupiter initially 3½ a.u. from the Sun but then allowed it to creep inward to 1½ a.u. (about where Mars orbits now). Jupiter's gravity would have created a perturbation-driven snowplow, piling all the rocky planetesimals into a mini-disk with an outer edge at 1 a.u. The computer runs confirmed that this truncated disk can yield four terrestrial planets — and a Mars that's not too big.

Meanwhile, Jupiter's inward trek would have completely swept clear the asteroidal region from 2 to 4 a.u., tossing roughly 15% of its occupants into a disk beyond Saturn. After reversing course, the outward-moving planets rescattered some of those same objects, this time *inward*, returning them to what's now the inner asteroid belt. Then Saturn and Jupiter would have disturbed a disk of carbon- and water-rich objects 6 to 9 a.u. from the Sun. These too would have been tossed inward by the planets' perturbations, largely settling into what's now the outer asteroid belt and even providing Earth with a key source of water.

In similar simulations done by David Minton and Hal Levison (Southwest Research Institute), Mars forms likewise within the mini-disk and migrates to its outer edge and beyond. A moving Mars would have kicked iron-rich planetesimals out of the disk and into the inner asteroid belt, where they're commonly found today.

Remarkably, Jupiter probably would have come in even closer to the Sun, perhaps sliding all the way into it, had not Saturn (already in tow via the 3:2 resonance) grown massive enough to hit the tidal brakes and reverse both planets' movement. The formation and survival of the terrestrial planets perhaps hinged not on Jupiter's existence but on Saturn's.

In one sweeping narrative, these theorists propose a way to form four inner planets (correct sizes, correct orbits); an asteroid belt with a rock-rich inner region and a carbonaceous, water-harboring outer belt; a source of water for Earth (C-type asteroids); and a near-Earth environment conducive to the presumed giant impact that formed the Moon. This radical scenario represents "a paradigm shift in our understanding of the evolution of the inner solar system," says Walsh.

Will "Jupiter's Grand Tack" (as Morbidelli dubs it) hold up to further scrutiny? "Many aspects of their model look good to me," observes SwRI's William Bottke, "but lots of first-order things have to be tested before they can declare victory on all fronts."

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Woodland Hills 888.427.8766	Astronomics 800.422.7876	Canada • Khan Scopes 800.580.7160	

MEADE INSTRUMENTS

Hot NEW Products for 2011

By the Editors of
SKY & TELESCOPE

Our 13th annual roundup of Hot Products highlights the most intriguing new astronomy gear in the worldwide market.

Like the sun, there are definite cycles of activity for new products entering the astronomical marketplace. Every other year seems to produce a bumper crop of gadgets for us to consider in our annual roundup of the most intriguing new products. So it isn't surprising that after last year's unprecedented burst of activity (see the January 2010 issue, page 36), this year would produce a more typical assortment of items for us to review. Indeed, our "short list" this year was half the size of last year's. But that didn't make the candidates any less exciting.

Following recent trends, the cost of imaging gear keeps dropping. In the following pages you'll find cameras, image-ready telescopes, quality equatorial mounts, and astrophotography accessories that offer some of the best-ever bangs for the buck. There are also products for visual observers, whether their interests involve the Sun, Moon, planets, or deep-sky objects (or all of the above).

As in the past, just because something is new doesn't mean we consider it "hot." For that we need to see an item offering a new technology, providing a simple solution to an old problem, or delivering a remarkable price-to-performance ratio. And that last qualification played a major role again this year. Whether or not you agree with our picks, we hope you'll enjoy reading about the products that intrigued us the most.

S&T: DENNIS DI CICCO (2)

◄ MEGAPIXEL IMAGING

For more than 20 years the folks at Santa Barbara Instrument Group have specialized in developing cutting-edge imaging products for the amateur community. That trend continues with the release of the ST-8300 CCD camera, based on the highly popular Kodak KAF-8300 chip, which has an impressive 8.3-megapixel array of 5.4-micron pixels, making it ideal for short-focus telescopes. With a $1,995 price tag, the ST-8300 set a new benchmark for low-cost megapixel imaging with a dedicated astronomical CCD camera. Our in-depth review of the ST-8300 appears in last October's issue, page 38.

ST-8300 CCD camera
U.S. price: $1,995
Santa Barbara Instrument Group
www.sbig.com

S&T: DENNIS DI CICCO

BIGGER *IS* BETTER

When it comes to eyeballing deep-sky objects, there's no substitute for telescope aperture. The trio of Monster Dobsonians from Orion Telescopes & Binoculars culminates with a 50-inch model that is the largest commercial reflector ever marketed for visual observing. That's not to say, however, that we think anyone will find the views offered by the 36-inch (pictured) and 40-inch versions ho hum.

Monster Dobsonians
U.S. price: from $55,600
Orion Telescopes & Binoculars
www.oriontelescopes.com

TELE VUE

◄ WIDEST VIEW YET

Long a leader in designing and manufacturing astronomical eyepieces with precedent-setting wide apparent fields of view, Tele Vue attained a new milestone with its 3.7-millimeter Ethos-SX. The one-of-a-kind eyepiece delivers a whopping 110° apparent field, which is so large that many people have to roll their eye around to see its entirety. The Ethos-SX also stands as a tribute to Al Nagler, Tele Vue's founder, for his work during the 1960s designing the 110° optics in the spacecraft simulator used to train Apollo astronauts for the Moon landings.

Ethos-SX eyepiece
U.S. price: $595
Tele Vue
www.televue.com

SKY SWEEPER ►

If there are people who don't like to observe the night sky with binoculars, we've never met them. Certainly the most popular binoculars for astronomical observing are 7× and 10× models with 50-mm objectives. Vixen's new Ascot 10×50 binocular is billed as "super wide," and with an 8.5° field of view, they drink in 2° more field diameter than typical 10×50 glasses. Their light 2-pound weight makes them easy to hold for extended periods.

VIXEN OPTICS

Ascot 10×50 binocular
U.S. price: $159
Vixen Optics
www.vixenoptics.com

LARGE-APERTURE Hα SCOPE

Solar activity is picking up, and so is amateur interest in observing the Sun at the deep-red hydrogen-alpha wavelength that highlights our star's dramatic activity. With its 152-mm objective, the LS 152 from Lunt Solar Systems is currently the largest dedicated hydrogen-alpha telescope on the market. Furthermore, the scope is a Hot Product twofer, since last year we honored Lunt Solar Systems for its pressure-tuning method that allows you to rapidly scan the scope's sub-angstrom passband over the hydrogen-alpha wavelength.

LUNT SOLAR SYSTEMS

LS 152 Solar Telescope
U.S. price: $7,495
Lunt Solar Systems
www.luntsolarsystems.com

TELE VUE

◄ DEALING WITH COMA

You don't have to look very far to find amateur astronomers singing the praises of fast-focal-ratio Newtonian telescopes. Observers love their compact size, while astrophotographers covet their bright images of deep-sky objects. But fast Newtonians are limited by coma, the optical aberration that transforms stars away from the center of the field into seagull shapes. Coma correctors have been around for years, but Tele Vue's new Paracorr Type 2 is designed for visual and photographic applications with amazingly fast Newtonians, giving an f/3 mirror the performance of an uncorrected f/12 system. Except for specialized photographic correctors, previous commercial coma correctors worked best with mirrors only as fast as f/4.5.

Paracorr Type 2
U.S. price: $460
Tele Vue
www.televue.com

DEALING WITH COMA, TAKE TWO ▼

Starlight Instruments, makers of the highly acclaimed Feather Touch focusers, has joined forces with Tele Vue and created a 2-inch focuser with a built-in Paracorr Type 2. Called SIPS for Starlight Integrated Paracorr System, the unit is designed to automatically place any eyepiece the correct distance from the corrector when it is brought to focus. SIPS is available as a complete unit or as a $650 retrofit for those who already own a Feather Touch focuser.

STARLIGHT INSTRUMENTS

Starlight Integrated Paracorr System
U.S. price: $935
Starlight Instruments
www.starlightinstruments.com

BETTER CONTRAST

Since its introduction in 2004, Coronado's P.S.T. (short for Personal Solar Telescope) has been recognized as the most cost-effective way to view the Sun in hydrogen-alpha light. But the view gets even better when you "stack" a second etalon filter in front of the P.S.T.'s objective, narrowing the passband to approximately 0.5 angstrom. The only H-alpha views we've seen that are better are with telescopes costing significantly more money. That puts the double-stack P.S.T. in a class by itself, and that, in our opinion, makes it a Hot Product.

Double-Stack P.S.T.
U.S. price: $999
Coronado
www.meade.com

S&T: DENNIS DI CICCO

S&T: DENNIS DI CICCO

◄ DIGITAL TREASURE CHEST

Okay, maybe the jury was biased, but did anyone really think we wouldn't select our DVD archive as a Hot Product? It has, after all, been the one item that readers have most requested for more than a dozen years. *The Complete Sky & Telescope: Seven Decade Collection* includes a detailed picture and computer-searchable text of all of the nearly 70,000 pages of the magazine published between November 1941 and December 2009. If it appeared in *Sky & Telescope*, you can now view it on your computer. Think of it as a way to replace an 11-foot stack of magazines weighing 384 pounds with a 2-pound boxed set of DVDs.

The Complete Sky & Telescope
U.S. price: $249
Sky & Telescope Media, LLC
www.SkyandTelescope.com

ANOTHER BIG BARGAIN ▶

During the last decade, Ritchey-Chrétien telescopes migrated from their lofty status at professional observatories to become the darlings of many elite amateur astrophotographers. For three years in a row, Astro-Tech has released Ritchey-Chrétien astrographs with such precedent-setting prices that we deemed them worthy of Hot Product status. In 2009 it was a 6-inch f/9 (that's now priced at $299), then last year it was bargain-priced 8- and 10-inch f/8 models, and for 2011 it's a 12-inch f/8 version equipped with a Feather Touch Focuser. Although not finalized at press time, we're told that if the estimated $4,495 price changes, it will be downward. We can't complain about that.

12-inch Ritchey-Chrétien astrograph
U.S. price: $4,495 (anticipated)
Astro-Tech
www.astronomics.com

S&T: DENNIS DI CICCO

TELESKOP-SERVICE

Refractor Flattener
Price: 249 Euros
(about $345)
Teleskop-Service
www.teleskop-express.de

◀ FLATTER FIELD

The increasing popularity of small refractors for astrophotography has spawned the development of several "universal" field flatteners suited for focal ratios from about f/5 to f/8. The TsFlat2 from Germany's Teleskop-Service stands out from its competition because of its larger 45-mm clear aperture and longer 100-mm back focus, making room for accessories such as off-axis guiders. The company also offers a full range of telescope adapters for the 2-inch TsFlat2.

ONE-STOP SHOPPING ▶

In the field of astronomical imaging, Orion Telescopes & Binoculars distinguishes itself as a single manufacturer of everything you need, from telescopes to equatorial mounts to filter wheels to CCD cameras and autoguiders. The company's new Parsec 8300 CCD camera, based on the Kodak KAF-8300 chip, is the crown jewel in its imaging lineup. And the camera's $1,999.95 price makes it one of the market's best values in high-performance astronomical imaging.

ORION TELESCOPES

Parsec 8300 CCD Camera
U.S. price: $1,999.95
Orion Telescopes & Binoculars
www.oriontelescopes.com

OBSERVATORIES TO GO

While we can't bring dark skies to our telescopes, we do have the option of taking our telescopes to dark skies. For that reason, some enterprising amateurs have built trailer-mounted observatories, but Pier-Tech is the first to offer a commercial unit. The Star Traveler is available in a range of sizes and with options to fit most observers' needs.

Star Traveler Mobile Observatory
U.S. price: from $14,000
Pier-Tech
www.pier-tech.com

PIER-TECH

LEAVE THE LAPTOP HOME ▸

Vixen's new heavy-duty AXD German equatorial mount (70-pound load capacity) comes with the Star Book Ten, the most sophisticated stand-alone hand controller yet made for a Go To telescope. The controller is quite simply a dedicated computer with a high-resolution color screen that makes navigating the sky a "see-to" experience before you push the Go To button. Detailed star charts and images of many deep-sky objects are just a few of the things you can display on the 5-inch screen.

AXD mount and Star Book Ten

U.S. price: $9,999

Vixen Optics

www.vixenoptics.com

S&T: DENNIS DI CICCO

VIXEN OPTICS

ASTRO-TECH

◂ MORE BIG BARGAINS

Few amateurs would argue that Newtonian reflectors aren't the hands-down winners when it comes to offering deep-sky astrophotographers the biggest bang for the buck. So we suspect there will be a lot of interest in the new 10- and 12-inch f/4 Imaging Newtonians from Astro-Tech. Both feature a 3.3-inch, dual-speed Crayford-style focuser, a primary-mirror cooling fan, a finder, and a pair of tube-mounting rings — very substantial packages at very attractive prices.

f/4 Imaging Newtonians

U.S. price: $599 (10-inch); $749 (12-inch)

Astro-Tech

www.astronomics.com

CUSTOM ADAPTERS

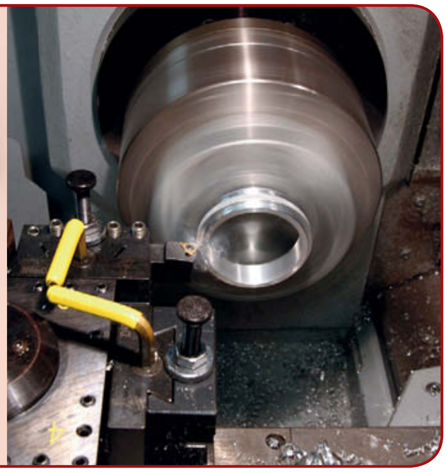
With almost no design standardization for astronomical CCD cameras, there's an ever-increasing need for custom adapters that will accurately connect cameras to telescopes and optical accessories. PreciseParts maintains an extensive database of telescope and camera specifications, which coupled with the company's new online program, lets you design unique adapters with just a few mouse clicks. Within days the custom-machined part will be in your hands.

Build Your Own Adapter

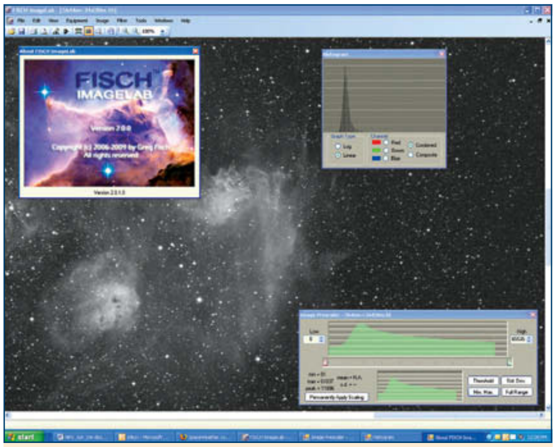
U.S. price: available via online estimator

PreciseParts

www.preciseparts.com



PRECISEPARTS (2)



MORE THAN CAMERA CONTROL

Today's astrophotographers who are also PC users will enjoy this software program for camera control and image processing that won't break the bank. *Fisch ImageLab* features simultaneous control of imaging and autoguiding cameras while you're out under the stars making exposures, as well as a host of sophisticated image-processing techniques specifically tailored to astronomy. Included are automatic routines for calibrating images and post-processing tools for creating dramatic color views from individual exposures made through color filters. The program runs under Windows XP, Vista, and Windows 7.

Fisch ImageLab
U.S. price: $249
Explore Scientific
www.explorescientific.com

TWICE THE VIEW ►

Most everyone agrees that their first view through a binocular telescope was an "Oh-Wow!" experience. But sharing that view generally required finicky adjustments to get the inter-eye spacing of the eyepieces and focus set just right for each individual's needs. That will be a lot easier with the RBX Reverse Binocular Telescopes from JMI, since the motorized adjustment for the inter-eye spacing is now accomplished without affecting the focus. A styling update adds a 21st-century appearance to the new 8- and 12-inch RBX models.


S&T: SEAN WALKER

RBX Reverse Binocular Telescopes
U.S. price: RBX8 $4,995; RBX12 $8,995
JMI Telescopes
www.jimsmobile.com

PORTABLE PARAMOUNT ►

For nearly a decade, Software Bisque's heavyweight Paramount ME has been a powerhouse among astrophotographers with permanent setups. The mount was also a leader in the field of robotic imaging, and it played a major roll in the growth of automated remote observatories. Now the company is introducing a smaller version called the Paramount MX. It offers the same level of performance for telescopes weighing up to 90 pounds (40 kg). But unlike its bigger brother, the Paramount MX is designed for observers who favor portable equipment that can be quickly set up and polar aligned in the field.

Paramount MX
U.S. price: $8,500 (introductory)
Software Bisque
www.bisque.com


SOFTWARE BISQUE

LIGHTWEIGHT GO TO MOUNT

Celestron now offers its full range of Go To telescope mounts as stand-alone products. The company's medium- and heavyweight CGEM and CGE Pro German equatorial models were Hot Product picks for 2010. But it's the lightweight LCM Computerized Mount that caught our eye for 2011. It offers a low-cost way to add altazimuth Go To pointing and tracking to small telescopes weighing 5 pounds (2.3 kg) or less.

LCM Computerized Mount
U.S. price: $199.95
Celestron
www.celestron.com

CELESTRON

ORION TELESCOPES & BINOCULARS

SkyQuest XTg Dobs
U.S. price: 8-inch $849.95;
10-inch $1,099.95
Orion Telescopes & Binoculars
www.oriontelescopes.com

DOBS ON THE GO ▲

Go To technology has infiltrated just about every corner of the telescope market except for low-cost Dobsonians — until now. The new SkyQuest XT8g and XT10g Go To Dobsonian Telescopes are the first to offer motorized Go To pointing and tracking on moderately priced Newtonian reflectors under 12-inch aperture. In our eyes, bringing together the observing potential of 8- and 10-inch reflectors with the push-button ease of computerized pointing is a winning combination.

TRACKING STARS

Celestron's NexGuide is a self-contained autoguider that requires no external computer and can run for days powered by a battery pack with four D cells. The built-in LCD screen aids in system setup, focusing, and monitoring the guiding accuracy during long exposures. Watch for our review of the NexGuide in the coming months, but we can tell you now that our initial tests are very encouraging.

S&T: DENNIS DI CICCO

NexGuide
U.S. price: $299.95
Celestron
www.celestron.com

iEQ45 mount
U.S. price: $1,599
iOptron
www.ioptron.com

S&T: DENNIS DI CICCO

PORTABLE GEM ▲

Given its relatively light 25-pound (11-kg) weight, the new iEQ45 German equatorial mount from iOptron is noteworthy for its 45-pound load capacity. Features such as storage of the counterweight shaft within the declination axis add to the portability of this Go To mount, which comes complete with a stainless-steel tripod and adapter plates for Losmandy- and Vixen-style dovetails.

S&T: DENNIS DI CICCO

A DARKER VIEW

There's no shortage of ways to blacken the inside of telescope tubes, but one of the easiest-to-use products we've seen is the new FlockBoard from ProtoStar. An ultra-light-absorbing textured material is bonded to a stiff 0.03-inch (0.75-mm) thick plastic backing. The material, which is made in 24-inch-wide rolls, is springy enough to expand and conform to the inside of telescope tubes, eliminating the need for messy adhesives.

FlockBoard
U.S. price: 24-inch-wide rolls cost $0.65 per linear inch
ProtoStar
www.fpi-protostar.com

FINGER LAKES INSTRUMENTATION

Atlas Large Payload Focuser
U.S. price: $2,295
Finger Lakes Instrumentation
www.flicamera.com

◀ FOCUSING HEAVYWEIGHT

Experienced astrophotographers know the challenges that go with achieving critical telescope focus, especially when their imaging setups involve heavy CCD cameras, filter wheels, and off-axis guiding equipment. One of the finest solutions we've seen is the Atlas Large Payload Focuser from Finger Lakes Instrumentation, which is rated for loads up to 25 pounds. It has a clear aperture of 3¾ inches and a maximum travel of 0.35 inch in remarkably small 100-nanometer increments. Its USB 2.0 computer interface is ASCOM compliant for use with most auto-focusing software.


FROM DREAM TO REALITY
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Oceanside Photo and Telescope (OPT)
www.optcorp.com
Stellarvue Telescopes
www.stellarvue.com
Skies Unlimited
www.skiesunlimited.net
NEW STELLARVUE Q DUAL FLUORO RIDING PROUDLY ON THE CELESTRON CGEM MOUNT
MILKY WAY OVER THE STELLARVUE DARK SKY STAR PARTY BY JON TALBOT
STELLARVUE®
WWW.STELLARVUE.COM
CELESTRON®
www.celestron.com

R Gem, a Pulsing S Star

Rare elements enrich this winter red variable.

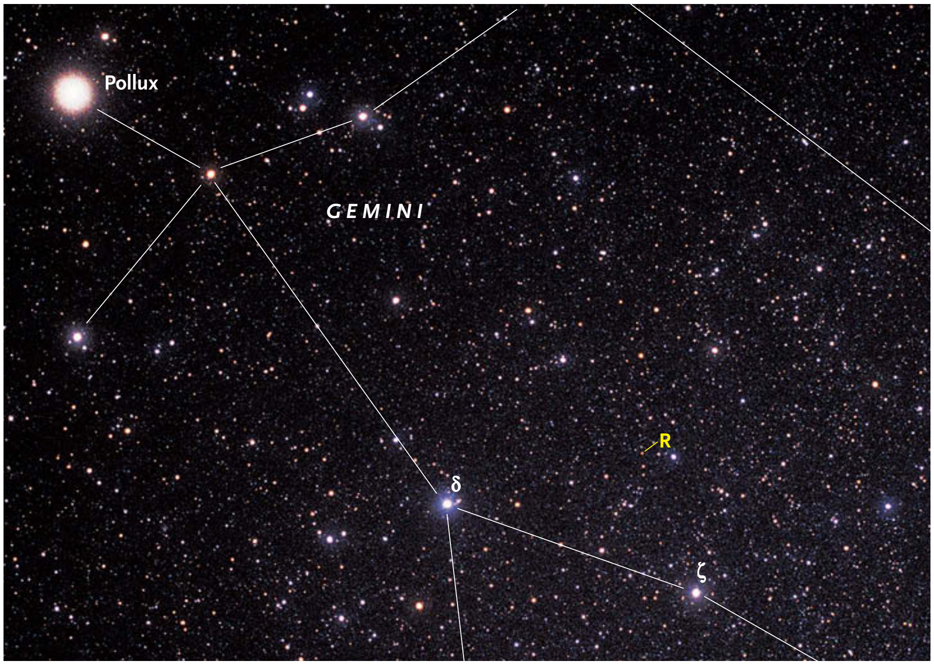
LEFT OF ORION in the eastern sky on December and January evenings lie the Gemini twins, currently in their horizontal pose. Between the Gemini stick figures (see the map on page 44) is R Geminorum, a long-period red variable star that's now brightening rapidly.

Just last August R Gem was around its minimum light of magnitude 13.5. By December 1st it should be 8th magnitude: just visible in binoculars. It should peak at about 7.1 on December 31st, according to the American Association of Variable Star Observers, though it's never entirely predictable. It should spend January beginning to fade slowly. Use the comparison-star chart at right to estimate its brightness.

R Gem has been a December show-off for several years now; it's pulsation period is a year and five days.

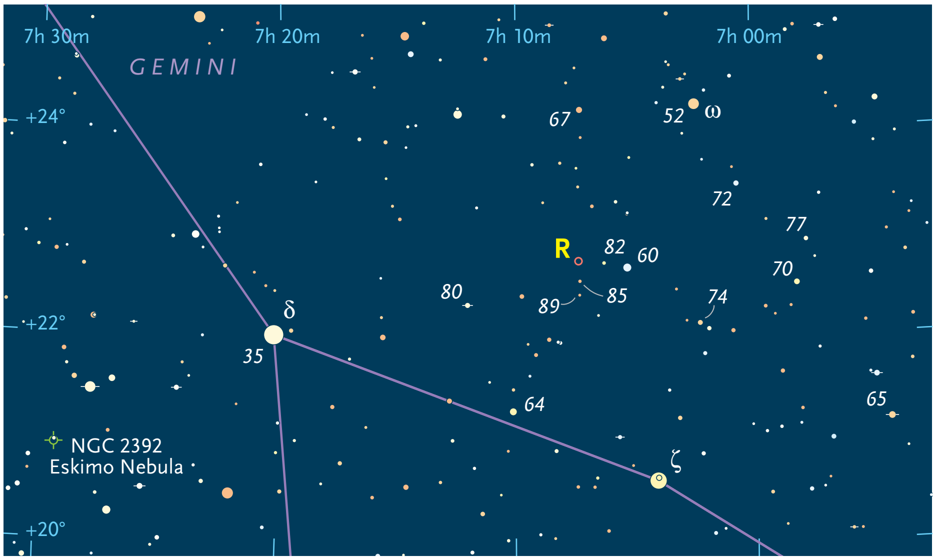
Like all Mira-type variables, R Gem is a red giant in its unstable late stages of life. Violent events have begun at its increasingly hot, dense core, and its surface is streaming off as a thick stellar wind. Even among Miras, though, R Gem is special. It's one of the brightest stars of spectral type *S*, a type paralleling *M* giants but with spectra showing zirconium oxide, yttrium oxide, and technetium. These rare heavy elements are formed by other heavy elements slowly capturing neutrons in or near the star's increasingly extreme core.

Astronomers were especially surprised to identify technetium in these stars' spectra in 1952. Technetium (atomic number 43) is an "artificial" element, as its name implies, made in nuclear reactors; its longest-lived isotope has a half-life of just 4.2 million years. So it must have been dredged up from the stars' active cores relatively recently. R Geminorum shows an unusual amount of it even for an *S* star.



AKIRA FUJII

R Geminorum, located between the Gemini stick figures, may be the only place where you'll ever look at the element technetium.



Comparison stars around R Geminorum are labeled with their visual magnitudes to the nearest tenth with the decimal point omitted. Magnitudes courtesy AAVSO (www.aavso.org).

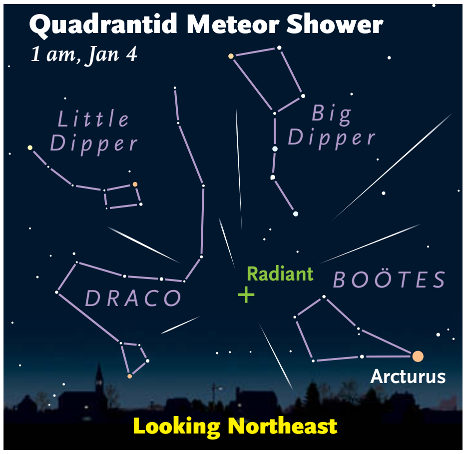
The Bitter-Cold Quadrantids

Early to mid-January is the coldest time of year (in northern latitudes). The hours before dawn are the coldest time of night. A clear sky means radiational cooling, and a wide-open sky exposes you to the most radiational cooling possible (and wind). And lying still for an hour or more to count meteors means you generate your minimum body heat. Welcome to the Quadrantids.

But observers with the right attitude see the challenges of winter meteor watching as an adventure. The fact is, you *never* get cold outdoors if you prepare properly . . . by definition.

The Moon is new on the night of January 3–4 when the Quadrantid meteor shower is due to peak. The shower is rich but brief, with 60 to 120 or more meteors visible per hour under ideal conditions for just 2 to 4 hours. The peak this year is predicted to come around 1^h UT on the 4th, good for Europe and Central Asia but early for North America (8 p.m. Eastern Standard Time, 5 p.m. Pacific, the previous evening). However, outbursts of Quads have been seen several hours early or late.

Moreover, the shower's radiant point (between the Big Dipper's handle end and the head of Draco) is circumpolar if you live above latitude 41° north (New York). The radiant is above the horizon at nightfall (and heading lower) if you live north of 37°: southern Virginia. Very few meteors



Not until early morning does the radiant of the Quadrantid meteor shower start to rise high. (And don't expect to see several at once!)

Phenomena of Jupiter's Moons, January 2011

Jan. 1	2:03	I.Oc.D
	5:35	I.Ec.R
	6:42	II.Oc.D
	12:08	II.Ec.R
	17:06	IV.Oc.D
	18:50	IV.Oc.R
	23:23	I.Tr.I
Jan. 2	0:41	I.Sh.I
	1:37	I.Tr.E
	2:54	I.Sh.E
	20:32	I.Oc.D
Jan. 3	0:04	I.Ec.R
	1:07	II.Tr.I
	3:43	II.Sh.I
	3:51	II.Tr.E
	6:22	II.Sh.E
	11:12	III.Tr.I
	14:18	III.Tr.E
	16:37	III.Sh.I
	17:52	I.Tr.I
	19:10	I.Sh.I
	19:23	III.Sh.E
	20:06	I.Tr.E
	21:23	I.Sh.E
Jan. 4	15:02	I.Oc.D
	18:33	I.Ec.R
	20:05	II.Oc.D
Jan. 5	1:27	II.Ec.R
	12:22	I.Tr.I
	13:39	I.Sh.I
	14:36	I.Tr.E
	15:52	I.Sh.E
Jan. 6	9:31	I.Oc.D
	13:02	I.Ec.R
	14:28	II.Tr.I
	17:01	II.Sh.I
	17:12	II.Tr.E
	19:41	II.Sh.E
Jan. 7	1:04	III.Oc.D
	4:12	III.Oc.R
	6:24	III.Ec.D
	6:52	I.Tr.I
	8:08	I.Sh.I
	9:06	I.Tr.E
	9:11	III.Ec.R
	10:21	I.Sh.E
Jan. 8	4:01	I.Oc.D
	7:30	I.Ec.R
	9:26	II.Oc.D
	14:46	II.Ec.R
Jan. 9	1:22	I.Tr.I
	2:37	I.Sh.I
	3:36	I.Tr.E
	4:50	I.Sh.E
	22:30	I.Oc.D
Jan. 10	1:59	I.Ec.R
	2:48	IV.Tr.I
	3:49	II.Tr.I
	4:13	IV.Tr.E
	6:19	II.Sh.I
	6:33	II.Tr.E
	8:59	II.Sh.E
	15:26	III.Tr.I
	18:31	III.Tr.E
	19:51	I.Tr.I
	20:40	III.Sh.I
	21:06	I.Sh.I
	22:05	I.Tr.E
	23:19	I.Sh.E
	23:24	III.Sh.E
Jan. 11	17:00	I.Oc.D
	20:28	I.Ec.R
	22:49	II.Oc.D
Jan. 12	4:05	II.Ec.R
	14:21	I.Tr.I
	15:35	I.Sh.I
	16:35	I.Tr.E
	17:48	I.Sh.E
Jan. 13	11:30	I.Oc.D
	14:57	I.Ec.R
	17:10	II.Tr.I
	19:38	II.Sh.I
	19:55	II.Tr.E
	22:17	II.Sh.E
Jan. 14	5:20	III.Oc.D
	8:27	III.Oc.R
	8:51	I.Tr.I
	10:04	I.Sh.I
	10:27	III.Ec.D
	11:05	I.Tr.E
	12:17	I.Sh.E
	13:13	III.Ec.R
Jan. 15	6:00	I.Oc.D
	9:26	I.Ec.R
	12:12	II.Oc.D
	17:24	II.Ec.R
Jan. 16	3:21	I.Tr.I
	4:33	I.Sh.I
	5:35	I.Tr.E
	6:46	I.Sh.E
Jan. 17	0:29	I.Oc.D
	3:55	I.Ec.R
	6:32	II.Tr.I
	8:56	II.Sh.I
	9:17	II.Tr.E
	11:36	II.Sh.E
	19:43	III.Tr.I
	21:51	I.Tr.I

Partial Solar Eclipse

It'll be nighttime in the Americas, but on January 4th the Sun undergoes a partial eclipse as seen from Europe and North Africa through the Middle East to Central Asia, Pakistan, and parts of India. The eclipse will be deepest in northern Europe and western Russia around sunrise. See SkyandTelescope.com/jan-4-2011 for maps and full details.

Minima of Algol

Dec.	UT	Jan.	UT
3	7:35	3	20:36
6	4:24	6	17:26
9	1:13	9	14:15
11	22:02	12	11:04
14	18:52	15	7:53
17	15:41	18	4:43
20	12:30	21	1:32
23	9:19	23	22:22
26	6:08	26	19:11
29	2:58	29	16:00
31	23:47		

These geocentric predictions are from the heliocentric elements Min. = JD 2452253.559 + 2.867362E, where E is any integer. Derived by Gerry Samolyk (AAVSO), they reflect a slight lengthening in the star's period that seems to have occurred in early 2000. For more about this star, visit SkyandTelescope.com/algol.

appear in the sky when a shower's radiant is low. But those that do are spectacular "earthgrazers" that skim along the upper atmosphere far across the sky. Just one of these can make your night. So keep an eye out on the evening of January 3rd. Any Quadrantid earthgrazers will be flying from the north-northwest after dusk, from north around 8 or 9 p.m., and north-northeast later in the evening.

Not until 1 a.m. does the radiant start climbing high in the northeast so you can start to do a proper meteor count (see Skyand Telescope.com/meteors). The radiant is highest before dawn.

The meteors late in this shower tend to be brighter than the early ones. Minor activity has been reported as much as a week before and after the peak date. ✦

*Senior editor **Alan MacRobert** sometimes dresses properly for winter observing.*

	22:48	III.Tr.E
	23:02	I.Sh.I
Jan. 18	0:05	I.Tr.E
	0:42	III.Sh.I
	1:15	I.Sh.E
	3:26	III.Sh.E
	12:37	IV.Oc.D
	14:11	IV.Oc.R
	18:59	I.Oc.D
	22:24	I.Ec.R
Jan. 19	1:36	II.Oc.D
	6:43	II.Ec.R
	16:21	I.Tr.I
	17:31	I.Sh.I
	18:35	I.Tr.E
	19:44	I.Sh.E
Jan. 20	13:29	I.Oc.D
	16:52	I.Ec.R
	19:55	II.Tr.I
	22:15	II.Sh.I
	22:39	II.Tr.E
Jan. 21	0:54	II.Sh.E
	9:39	III.Oc.D
	10:51	I.Tr.I
	12:00	I.Sh.I
	12:46	III.Oc.R
	13:05	I.Tr.E
	14:12	I.Sh.E
	14:30	III.Ec.D
	17:15	III.Ec.R
Jan. 22	7:59	I.Oc.D
	11:21	I.Ec.R
	14:59	II.Oc.D
	20:02	II.Ec.R
Jan. 23	5:21	I.Tr.I
	6:29	I.Sh.I
	7:35	I.Tr.E
	8:41	I.Sh.E
Jan. 24	2:29	I.Oc.D
	5:50	I.Ec.R
	9:17	II.Tr.I
	11:33	II.Sh.I
	12:02	II.Tr.E
	14:13	II.Sh.E
	23:51	I.Tr.I
Jan. 25	0:04	III.Tr.I
	0:58	I.Sh.I
	2:05	I.Tr.E
	3:07	III.Tr.E
	3:10	I.Sh.E
	4:45	III.Sh.I
	7:27	III.Sh.E
	20:59	I.Oc.D
Jan. 26	0:19	I.Ec.R
	4:23	II.Oc.D
	9:21	II.Ec.R
	18:21	I.Tr.I
	19:27	I.Sh.I
	20:35	I.Tr.E
	21:39	I.Sh.E
	22:51	IV.Tr.I
	23:53	IV.Tr.E
Jan. 27	15:29	I.Oc.D
	18:48	I.Ec.R
	22:40	II.Tr.I
Jan. 28	0:52	II.Sh.I
	1:25	II.Tr.E
	3:31	II.Sh.E
	12:51	I.Tr.I
	13:56	I.Sh.I
	14:02	III.Oc.D
	15:05	I.Tr.E
	16:08	I.Sh.E
	17:07	III.Oc.R
	18:33	III.Ec.D
	21:16	III.Ec.R
Jan. 29	9:59	I.Oc.D
	13:17	I.Ec.R
	17:47	II.Oc.D
	22:40	II.Ec.R
Jan. 30	7:21	I.Tr.I
	8:25	I.Sh.I
	9:35	I.Tr.E
	10:37	I.Sh.E
Jan. 31	4:30	I.Oc.D
	7:46	I.Ec.R
	12:04	II.Tr.I
	14:10	II.Sh.I
	14:48	II.Tr.E
	16:49	II.Sh.E

Every day, interesting events happen among Jupiter's satellites. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time). Next is the satellite: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it re-appears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**.

JUPITER'S RED SPOT: For the times when Jupiter's Great Red Spot crosses the planet's central meridian, see SkyandTelescope.com/redspot.

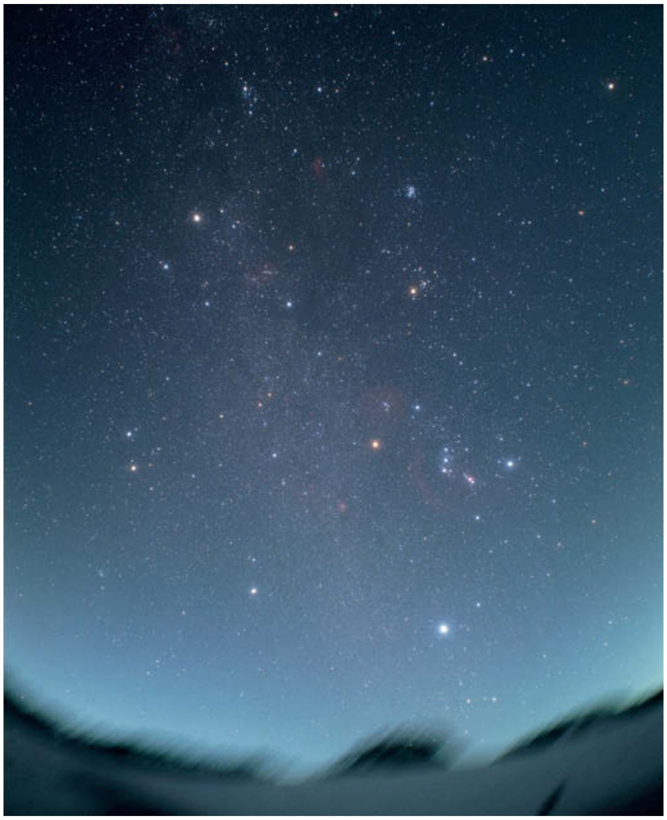
A Time for Beginnings

The original zodiac's first constellation is highest on January evenings.

As we pass from one year into the next, it's always a good time to take a look back — and then forward.

In last month's column I cited the astronomical applicability of a line from a Bob Dylan song. I didn't stop to think that January 2011 is the 50th anniversary of Dylan's arrival in New York City to begin his remarkable musical career. By strange coincidence, this is also the 50th anniversary of when I began my astronomical career — or, rather, my passionate, permanent love affair with astronomy.

I had just turned six that month 50 years ago. Using information from a book, I first sighted and identified Rigel and then, wonder of wonders, Sirius through my bedroom window. Some come to this hobby, avocation, or obsession called astronomy early in life, others late — but, whatever our age and background, we all share the marvelous fellowship of the stars.



AKIRA FUJII

Start at the Taurus Hour. The constellation that's nearing the central meridian on our all-sky map (page 44) is linked with many important beginnings. I'm talking about Taurus the Bull, whose high position at this sidereal time can lead us to call this the Taurus Hour.

The Sun lay in Taurus on the first day of spring when our Western zodiac was invented, about 4,000 to 5,000 years ago. So Taurus was presumably the first constellation of the original zodiac. (Today we start with Aries, the constellation where the Sun lay in spring when the zodiac was formalized and frozen, roughly 2,000 years ago.) *Astronomical Calendar* creator Guy Ottewell has speculated that early, upside-down versions of our letter A found in ancient documents may represent the pattern of Taurus. If this idea is correct, then A may be first in our alphabet because Taurus was first in the zodiac.

Stars at the Taurus Hour. At the Taurus Hour, Vega has finally reached the horizon, but Deneb lingers above it. The Great Square of Pegasus is sinking but still hangs halfway up the west sky. And upward from it extends Andromeda, containing the great galaxy Messier 31. Cassiopeia the Queen is very high in the northwest.

But it's the constellations in the southeastern sky (shown in the photo at left) that really draw our attention. Perseus hovers overhead. Taurus himself glitters high in the southeast, seizing our vision with two mighty star clusters: the Pleiades and Hyades. Directly below Taurus blazes Orion, brightest of all constellations, and below Orion is Sirius, brightest star of the night sky. Just to the left of the Sirius-Orion-Taurus tower in the southeast is an even taller one in the east: working upward, the star Procyon, the constellation Gemini (with bright stars Pollux and Castor), and Auriga (with the bright star Capella).

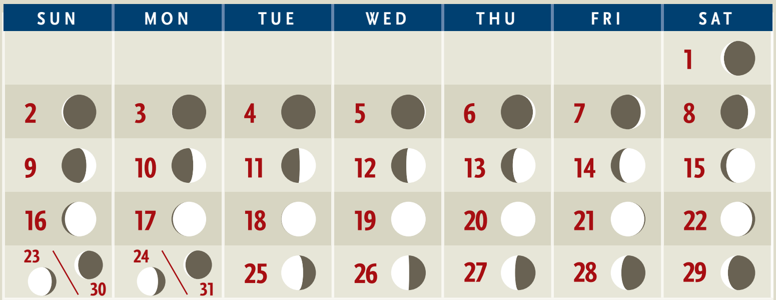
Start the Decade of the Sky. Last year I proposed the idea of having an International Decade of the Sky. Decades officially begin with the "1" year, so technically the new decade arrives on January 1, 2011. I can't imagine anything better to do to combat light pollution and bring the sky and astronomy to millions more people. So please send your ideas for the International Decade of the Sky to me at the e-mail address below. ✦

Fred Schaaf *welcomes your comments at fschaaf@aol.com.*

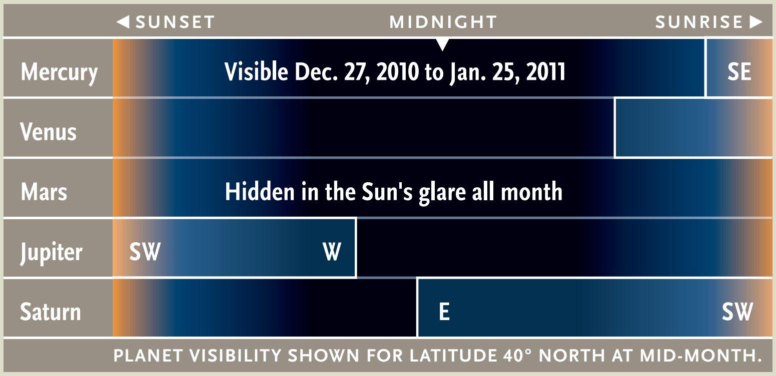
SKY & TELESCOPE

January 2011

MOON PHASES



PLANET VISIBILITY



THE NORTHERN LIGHTS made a rare appearance over the Anza-Borrego Desert in Southern California on July 27, 2004.

DENNISMAMMANA.COM

1 **DAWN:** Look for the waning crescent Moon far below Venus on New Year's morning. Antares and Mercury are also in the scene, as shown on page 48.

1–11 **DAWN:** Mercury has an excellent apparition, shining more than 10° above the southeastern horizon a half hour before sunrise for observers at latitude 40° north.

2 **DAWN:** A very thin crescent Moon shines lower right of Mercury very low in the southeast.

2–5 **EVENING:** Binoculars and telescopes show 5.9-magnitude Uranus within ½° of Jupiter. This is a rare opportunity to identify Uranus without a star chart, since it's the brightest "star" just above or upper right of Jupiter (as seen through binoculars from mid-northern latitudes). Don't confuse it with the 5.5-magnitude star 20 Piscium to Jupiter's lower right.

3 **DAYTIME:** Earth passes through *perihelion*, its closest point to the Sun for the year, around 2 p.m. EST.

4 **PREDAWN:** The Quadrantid meteor shower peaks, depending on your location; see page 40.

NEW MOON (4:03 a.m. EST). The Moon creates a partial solar eclipse for most of Europe and parts of Africa and Asia; see SkyandTelescope.com/jan-4-2011 for details.

9 **EVENING:** The waxing crescent Moon is right or lower right of Jupiter. Callisto and Europa are both in front of Jupiter from 7:49 to 8:13 p.m. PST (9:49 to 10:13 p.m. CST). See page 40 for other Jupiter satellite events.

10 **EVENING:** The Moon is upper right of Jupiter.

12 **FIRST-QUARTER MOON** (6:31 a.m. EST).

17 **NIGHT:** Algol is at minimum brightness for about 2 hours centered on 11:43 p.m. EST (8:43 p.m. PDT). See page 41.

19 **FULL MOON** (4:21 p.m. EST).

20 **EVENING:** Algol is at minimum brightness for 2 hours centered on 8:32 p.m. EST.

25 **PREDAWN:** The waning Moon is right of Saturn and Spica, forming a triangle with them.

26 **LAST-QUARTER MOON** (7:57 a.m. EST).

29, 30 **DAWN:** The waning crescent Moon is right of bright Venus on the 29th and lower left of Venus on the 30th, as shown on page 49.

See SkyandTelescope.com/ataglance for details on each week's celestial events.

Facing North
Facing NE
Facing East
Facing SE
Facing South
15h
12h
18h
9h
6h
3h
0h
+60°
+80°
+40°
+20°
0°
−20°
−40°
Alcor
Mizar
Big Dipper
URSA MAJOR
DRACO
Thuban
URSA MINOR
Little Dipper
M81
M82
Polaris
Vega
Deneb
CYGNUS
Northern Cross
M29
M39
LACERTA
CEPHEUS
M52
CASSIOPEIA
Double Cluster
CAMELOPARDALIS
LYNX
LEO MINOR
LEO
CANCER
M44
Moon Jan 19
Pollux
Castor
GEMINI
Capella
AURIGA
M35
M36
M37
M38
PERSEUS
Algol
M34
Zenith
M31
M33
TRIANGULUM
ANDROMEDA
Great Square
PEGASUS
HYDRA
M67
CANIS MINOR
Procyon
Moon Jan 15
Pleiades
Hyades
Aldebaran
TAURUS
ARIES
PISCES
Moon Jan 11
Circlet
Jupiter
ECLIPTIC
EQUATOR
M48
MONOCEROS
M50
Betelgeuse
Bellatrix
ORION
M42
Rigel
Mira
CETUS
ERIDANUS
M47
M46
Sirius
M41
CANIS MAJOR
Adhara
LEPUS
FORNAX
COLUMBA
CAELUM
SCULPTOR
–1
0
1
2
3
4
Star magnitudes

Using the Map

WHEN

Late November	11 p.m.
Early December	10 p.m.
Late December	9 p.m.
Early January	8 p.m.
Late January	7 p.m.

These are standard times.

HOW

Go outside within an hour or so of a time listed above. Hold the map out in front of you and turn it around so the yellow label for the direction you're facing (such as west or southeast) is at the bottom, right-side up. The curved edge is the horizon, and the stars above it on the map now match the stars in front of you in the sky. The map's center is the zenith, the point overhead.

Example: Rotate the map a little so that "Facing SE" is right-side up. Nearly halfway from there to the map's center is the constellation Orion. Go outside, face southeast, and look halfway up the sky. There's Orion!

Note: The map is plotted for 40° north latitude (for example, Denver, New York, Madrid). If you're far south of there, stars in the southern part of the sky will be higher and stars in the north lower. Far north of 40° the reverse is true. Jupiter is positioned for mid-January.

You can make a sky chart customized for your location at any time at SkyandTelescope.com/skychart.

Binocular Highlight:
Gemini's Lone Messier

Despite Gemini's Prime Location in the winter Milky Way and the constellation's generous size, the Twins have only a single Messier object to call their own. Fortunately, it's a good one: **M35**. For binocular users, this is one of the season's finest.

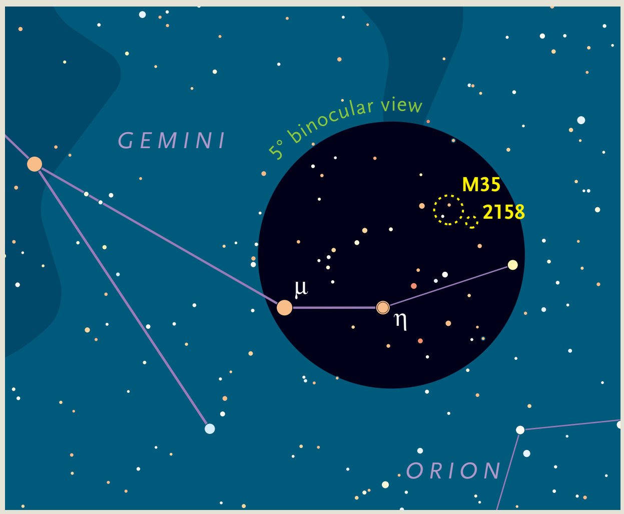
The 5.1-magnitude open cluster is situated just above the westernmost foot of the Twins. You should have no trouble finding it once you place 2.9-magnitude Mu (μ) Geminorum at the eastern edge of your binoculars' field of view.

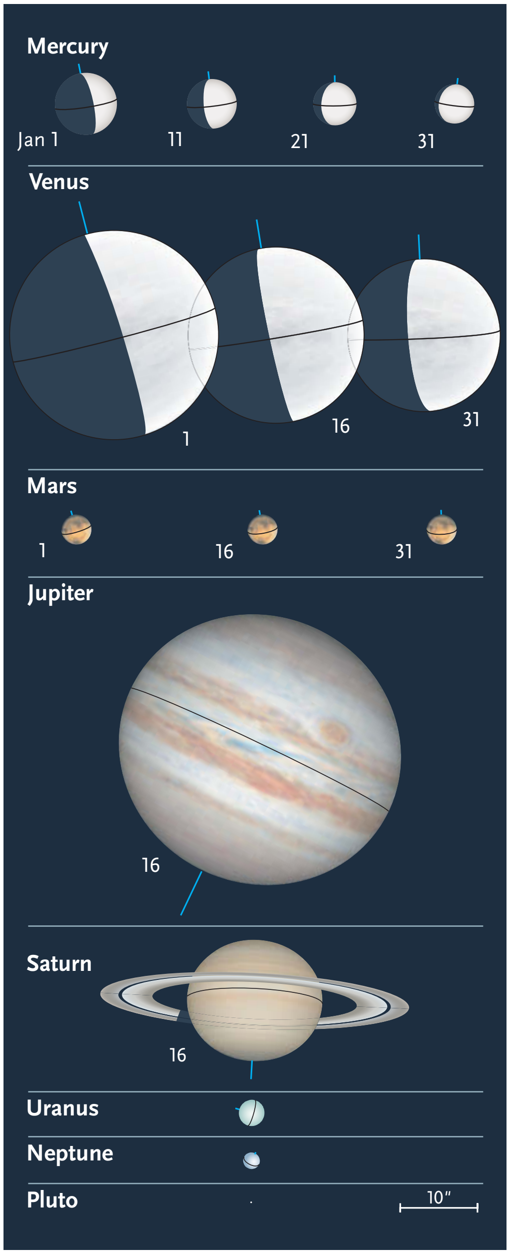
My 10×30 image-stabilized binos reveal a half-dozen individual stars in M35, attractively sprinkled across a mist of fainter cluster members. Switching to 10×50s, M35 takes on a roughly triangular shape owing to the arrangement of its brightest stars. The triangle is anchored by a 7.4-magnitude sun at its apex, while 7.6- and 8.6-magnitude stars nail down the other corners. As good as the view is in 10×50s, the cluster really comes alive in 15×70s. The boost in aperture and magnification are enough to resolve much of the background haze into individual flecks of starlight. It's a lovely sight.

Are you up for a challenge? If so, try for **NGC 2158**, a neighboring 8.6-magnitude open cluster. A ragged string of 10th-magnitude stars leads southwest from M35 to NGC 2158. Under a dark sky, I can see NGC 2158 in 10×50s, though it's tricky to sort out the faint cluster from nearby field stars. Averted vision helps, but sighting NGC 2158 does take some effort. The 15×70s make the task much easier.

The differences between M35 and NGC 2158 are partly the result of their relative distances: M35 lies comparatively nearby at 2,700 light-years, while little NGC 2158 is some five times more distant. Can you make it out? ✦

— *Gary Seronik*



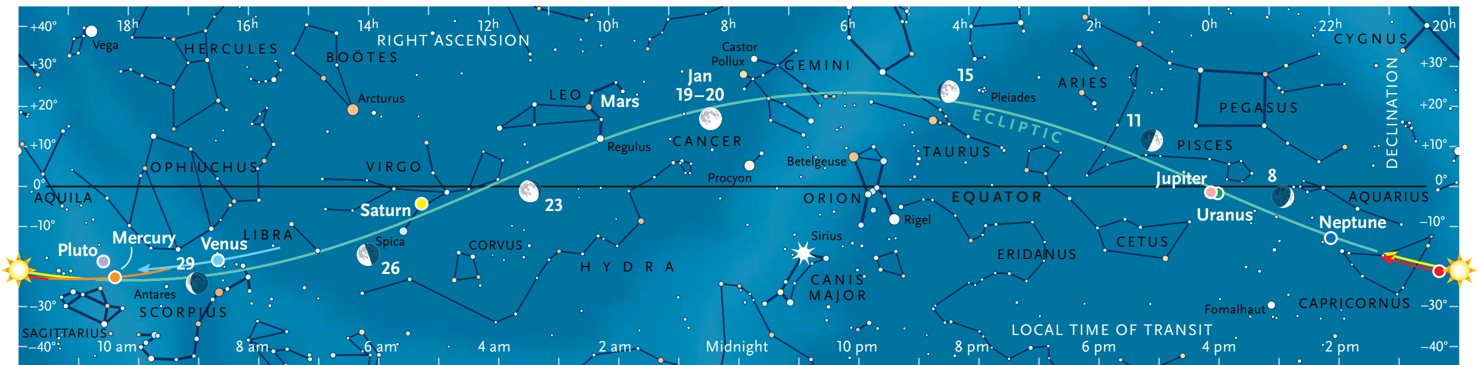


Sun and Planets, January 2011

	January	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$18^h\ 43.7^m$	–23° 03′	—	–26.8	32′ 32″	—	0.983
	31	$20^h\ 52.2^m$	–17° 35′	—	–26.8	32′ 28″	—	0.985
Mercury	1	$17^h\ 16.1^m$	–20° 12′	21° Mo	+0.1	8.0″	38%	0.836
	11	$17^h\ 47.3^m$	–21° 56′	23° Mo	–0.3	6.5″	67%	1.041
	21	$18^h\ 41.2^m$	–23° 06′	21° Mo	–0.2	5.6″	81%	1.202
	31	$19^h\ 43.7^m$	–22° 29′	17° Mo	–0.3	5.1″	90%	1.313
Venus	1	$15^h\ 27.7^m$	–15° 14′	47° Mo	–4.6	27.1″	46%	0.616
	11	$16^h\ 08.3^m$	–17° 27′	47° Mo	–4.5	24.1″	51%	0.692
	21	$16^h\ 52.2^m$	–19° 20′	47° Mo	–4.4	21.7″	56%	0.768
	31	$17^h\ 38.9^m$	–20° 38′	46° Mo	–4.3	19.8″	61%	0.843
Mars	1	$19^h\ 19.5^m$	–23° 11′	8° Ev	+1.2	3.9″	100%	2.379
	16	$20^h\ 09.2^m$	–21° 12′	5° Ev	+1.1	3.9″	100%	2.379
	31	$20^h\ 57.7^m$	–18° 19′	2° Ev	+1.1	3.9″	100%	2.376
Jupiter	1	$23^h\ 48.8^m$	–2° 36′	76° Ev	–2.3	38.7″	99%	5.089
	31	$0^h\ 07.0^m$	–0° 31′	51° Ev	–2.2	35.8″	99%	5.512
Saturn	1	$13^h\ 04.5^m$	–4° 16′	84° Mo	+0.8	17.2″	100%	9.646
	31	$13^h\ 06.8^m$	–4° 20′	114° Mo	+0.7	18.1″	100%	9.158
Uranus	16	$23^h\ 50.9^m$	–1° 46′	62° Ev	+5.9	3.4″	100%	20.534
Neptune	16	$21^h\ 57.7^m$	–12° 57′	32° Ev	+8.0	2.2″	100%	30.846
Pluto	16	$18^h\ 24.1^m$	–18° 50′	20° Mo	+14.1	0.1″	100%	32.885

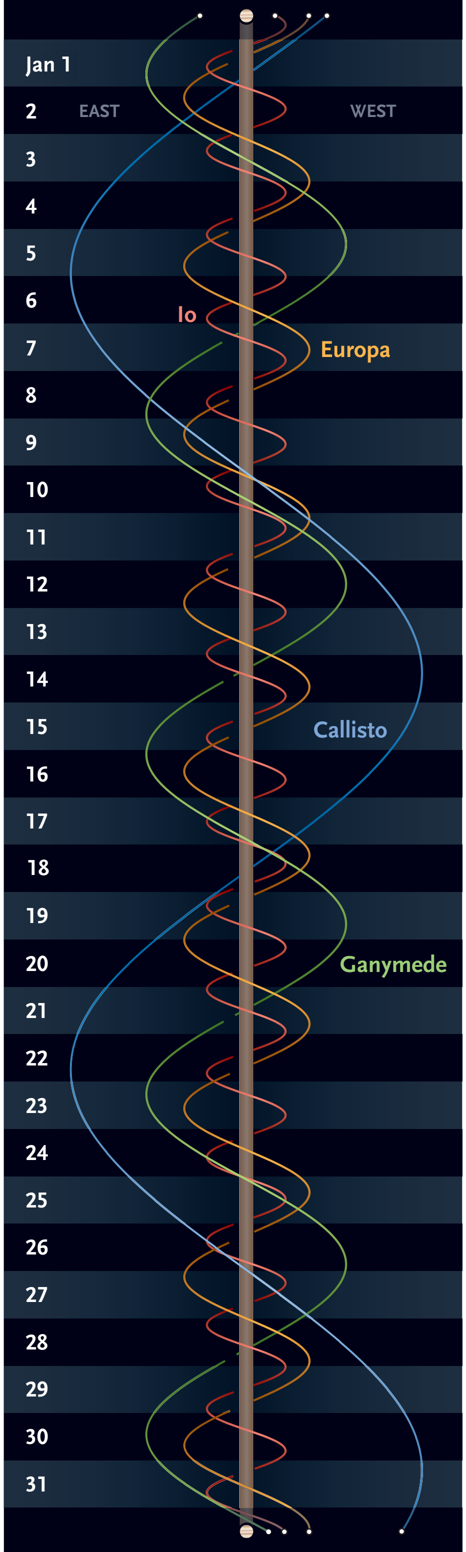
The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial diameter.) Last are the percentage of a planet's disk illuminated by the Sun and the distance from Earth in astronomical units. (Based on the mean Earth–Sun distance, 1 a.u. is 149,597,871 kilometers, or 92,955,807 international miles.) For other dates, see SkyandTelescope.com/almanac.

Planet disks at left have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.



The Sun and planets are positioned for mid-January; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side). All Moon dates are in January. "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.

Jupiter's Moons



The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites' positions east or west of Jupiter.

Fred Schaaf
Sun, Moon, and Planets

Planets in the Morning

Venus, Mercury, and Saturn put on a fine show at dawn.

As 2011 begins, Jupiter shines as the only bright planet at dusk, with dim Uranus nearby in the background. Saturn starts rising before midnight this month and is highest in the south at dawn. But the brightest planet at dawn in January is Venus, burning brilliantly well up in the southeast sky. Far to the lower left of Venus, modestly bright Mercury puts in a good showing fairly high in the dawn sky during the first half of the month.

DUSK AND EVENING

Jupiter starts the year shining at magnitude –2.3 about halfway up the sky in the south-southwest at nightfall (for viewers at mid-northern latitudes). The planet remains above the horizon until around 11 p.m. local time as the year begins, but it sets before 9:30 by the end of January. Jupiter glows under the Great Square of Pegasus, near the faint Circlet of Pisces.

On the evenings of January 2–5, binoculars and telescopes show **Uranus**, magnitude 5.9 and 3.4″ wide, just ½° north or northwest of Jupiter's 38″-wide disk. This is the last in the series of three Jupiter-Uranus conjunctions in 2010–2011. Not until 2038 will these planets again approach within 1° of each other.

Neptune is still observable at dusk in westernmost Aquarius during the first half of January, but it's near or below the horizon by the time the sky is fully dark. See the September issue, or SkyandTelescope.com/uranusneptune, for finder charts for the outermost major planets.

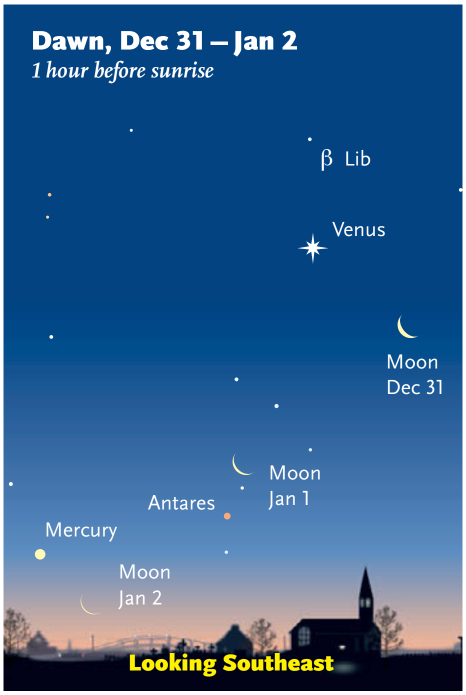
Mars sets too soon after the Sun to be visible. It will pass behind the Sun on February 4th.

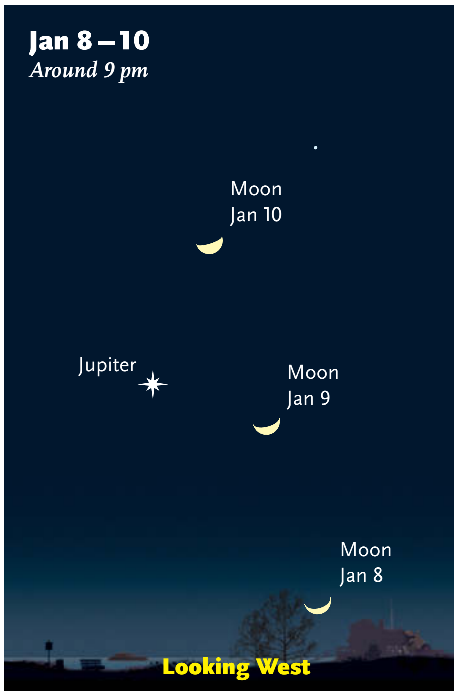
MIDNIGHT TO DAWN

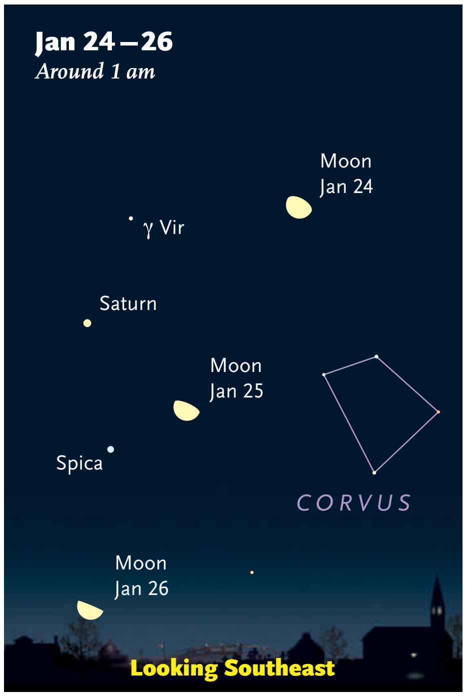
Saturn rises around 12:30 a.m. on New Year's Day, and it rises two hours earlier in the night by January's end. The ringed world glows at magnitude +0.7. That makes it marginally brighter than Spica, which comes up not far below it. Saturn pulls to within 8° of Spica before beginning retrograde motion (westward relative to the stars) on January 27th.

Saturn is at its highest (halfway up the south sky) at dawn, so that's the best time to observe it in a telescope. The planet reaches quadrature — 90° west of the Sun — on January 7th. So this month the shadows of Saturn and its rings fall farthest to the side, enhancing their three-dimensional appearance.

The rings begin 2011 tilted 10° from edge-on, the widest they've been since 2007.

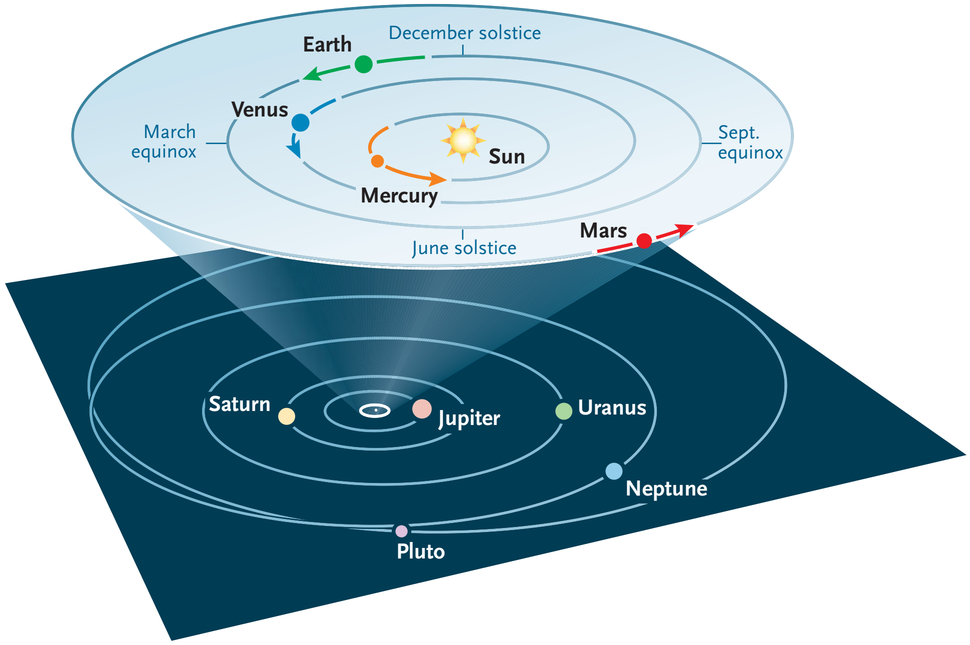






ORBITS OF THE PLANETS

The curved arrows show each planet's movement during January. The outer planets don't change position enough in a month to notice at this scale.



Venus is a magnificent sight before and during dawn. On New Year's morning, observers around 40° north latitude can watch Venus rise a rare 3¾ hours before the Sun, and climb to 20° above the southeastern horizon while the sky is still fully dark. Venus reaches greatest elongation, 47° west of the Sun, on January 8th.

Mercury comes to its own greatest elongation from the Sun (23°) the next morning. For the first two weeks of January — when the Sun is conveniently rising at its latest times for the year — Mercury shines far to Venus's lower left. It's well above the horizon an hour before sunrise, as shown on the facing page. Venus flames around magnitude –4.5 and Mercury around magnitude 0.

The 25″-wide globe of Venus is 50% illuminated on January 8th, but it may *look* that way on a different date. Try to see for yourself in the telescope on which date this appearance (called "dichotomy") occurs. The 6.6″-wide disk of Mercury is 64% illuminated at its own greatest elongation on January 9th.

Also at this greatest elongation, Mercury rises nearly 1¾ hours before the Sun for viewers at mid-northern latitudes — almost the maximum possible. By January 31st, however, the speedy planet rises only ¾ hour before the Sun, though it still shines brightly at magnitude –0.3.

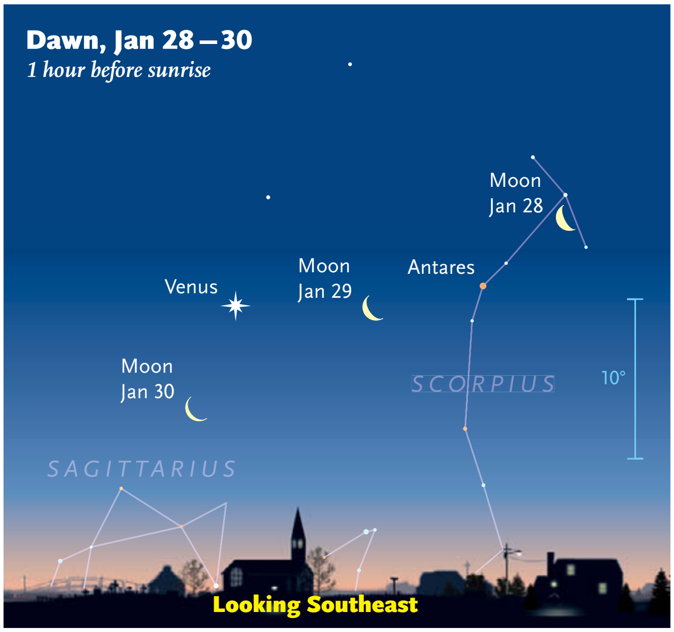
Meanwhile, Venus appears a little lower each morning as the month progresses, sliding down and to the left of ascending, vertical Scorpius, the Scorpion. Venus passes 8° upper left of 1st-magnitude Antares on January 17th.

SUN, MOON, & EARTH

A partial eclipse of the **Sun** takes place over parts of Europe, Africa, and Asia on January 4th. See SkyandTelescope.com/jan-4-2011 for details.

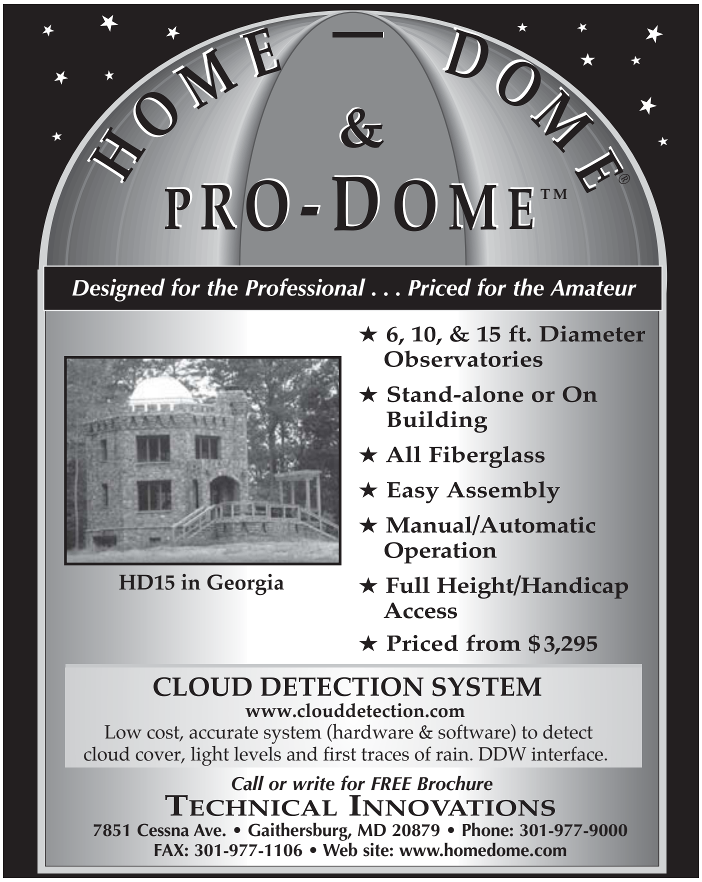
The **Moon** is a dawn crescent to the lower right of Venus on December 31st, above Antares on January 1st, and lower right of Mercury on January 2nd. The Moon's thick waxing crescent is to the right of Jupiter on the evening of January 9th. On the morning of January 25th a waning gibbous Moon forms a triangle with Saturn and Spica. At dawn on January 29th, the waning lunar crescent is almost directly between Venus and Antares. On the 30th it's lower left of Venus, as shown at left.

Earth reaches perihelion, its closest point to the Sun in its annual orbit, around 19^h UT on January 3rd. It is then 91,407,000 miles from the Sun, 1.7% less than average. ✦



These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist at arm's length. For clarity, the Moon is shown three times its actual apparent size.

SkyandTelescope.com/skychart can show you what the sky looks like at any given time and place.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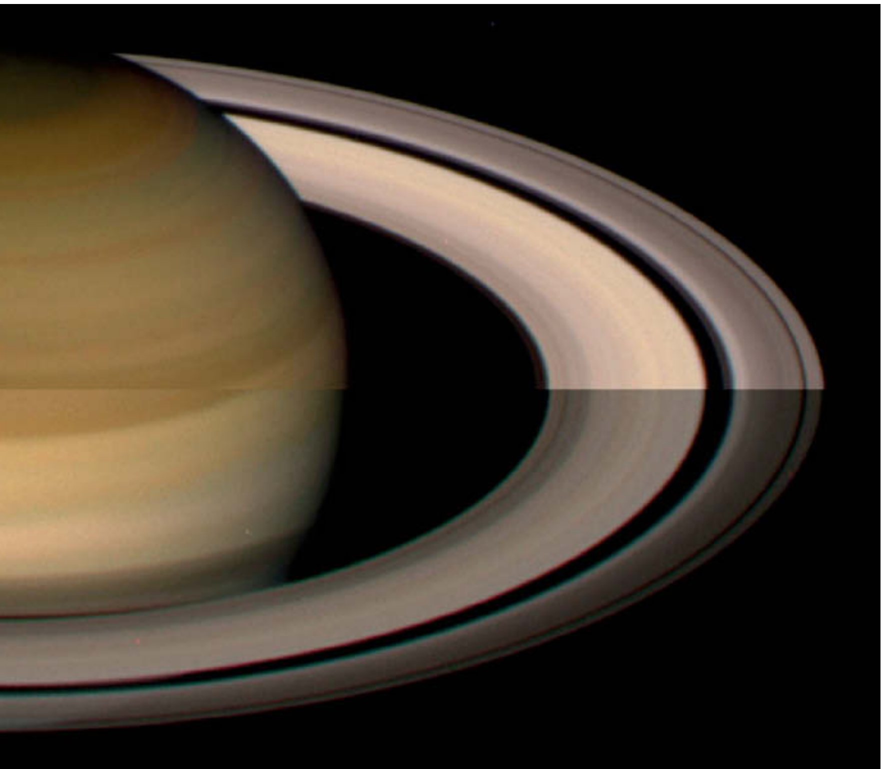
Anthony Mallama

Planetary Magnitudes

A planet's light curve gives important clues to its composition.

"How bright is that planet?" Thousands of amateur skywatchers ask this question every year, and many look to *Sky & Telescope*'s Planetary Almanac for the answer. But how can *S&T* predict the planets' magnitudes ahead of time? And what can we learn about planets by measuring how bright they are?

A planet's brightness varies with the inverse squares of its distances to the Sun and Earth. If you could double either distance, the planet would appear one-fourth as bright. If you doubled both, the planet would appear just one-sixteenth as bright. But the most interesting effects emerge once you compensate for the variations in distance, and measure planets' inherent luminosities.



This composite of two Hubble Space Telescope images shows that Saturn's rings are much brighter when Saturn is directly opposite the Sun (top half) than when the phase angle is 6° (bottom half, see diagram at right). The icy particles in the rings reflect a large fraction of the incoming light directly back toward its source.

DATA: NASA / ESA / STSCI, PROCESSING: ANTHONY MALLAMA

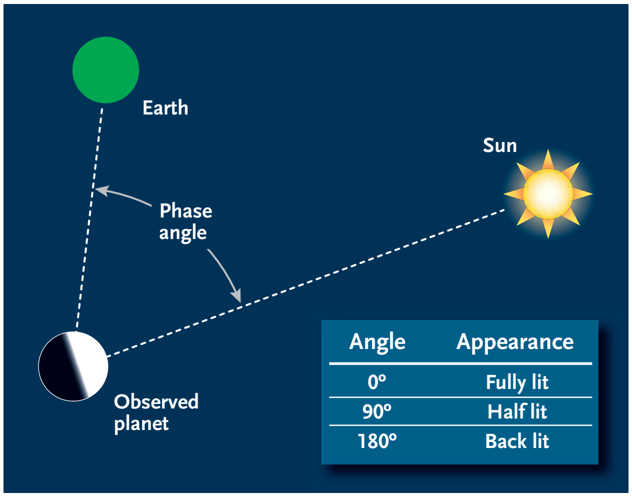
The other factors that affect a planet's brightness are its size, its composition, and the *phase angle* — the angle between the Sun and Earth from the perspective of an imaginary observer on the planet (see the diagram below). The phase angle alters both how much of the planet's lit surface is visible from Earth and also how bright that surface appears. When the phase angle is 0°, all of a planet's sunlit surface is visible from Earth, and the brightest part — the place on the planet where the Sun is overhead — is in the center of the view. As the phase angle approaches 180°, the planet appears as an increasingly thin and dim crescent.

The shape and slope of a planet's *phase curve* (magnitude corrected for distance and plotted as a function of phase angle) tells us a great deal about its composition. Let's see what has been learned from the phase curves of Mercury and Venus.

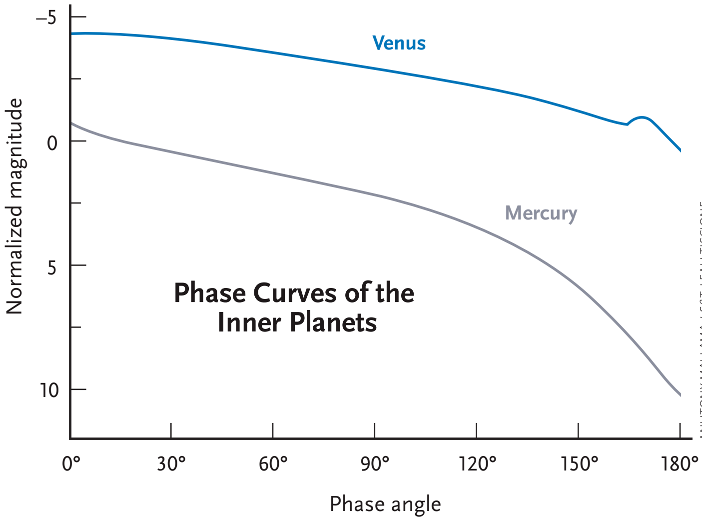
The Inner Planets

When I began studying the brightness of the terrestrial planets (Mercury, Venus, Earth, and Mars) about 12 years ago, many of the magnitudes in use dated back to the 1800s and were not very precise. Thanks to a novel space-

The *phase angle* is the separation between Earth and the Sun as seen from another planet. It determines how much of the planet's lit surface we can see and how the sunlight reflects back to us.



ANTHONY MALLAMA / *S&T*: LEAH TISCIONE



ANHTONY MALLAMA / S&T: LEAH TISCIONE

Mercury and Venus are characteristic of rocky and cloudy planets, respectively. Their magnitudes shown here are normalized for a distance of 1 a.u. from each planet to the Sun and Earth.

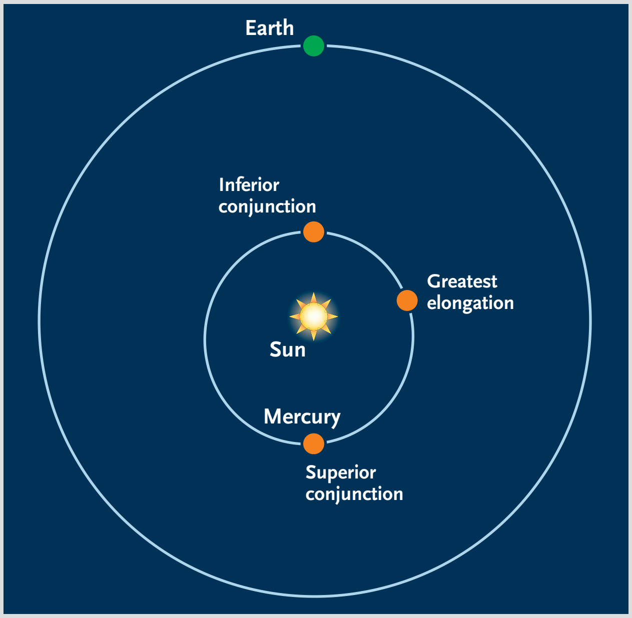
craft instrument and the availability of CCDs for Earth-based observation, it was prime time for an update. The Large Angle and Spectrometric Coronagraph (LASCO) aboard the ESA/NASA Solar and Heliospheric Observatory (SOHO) was designed to photograph the solar corona. But it's also ideal for observing Mercury, because the planet's small elongation from the Sun often places it in the same field of view. LASCO principal investigator Russell Howard (Naval Research Laboratory) approved a program to observe Mercury from 1999 to 2000, and LASCO scientist Dennis Wang obtained images when Mercury was in the field but outside of the solar occulting disk.

Photometric analysis of LASCO imagery provided luminosity data near inferior conjunction, when the planet is between the Sun and Earth, and superior conjunction, when it's behind the Sun. These are the times when solar glare makes it hardest to measure a planet's brightness through Earth's atmosphere. Ground-based CCD observations by the author during the same years covered phase angles closer to 90° degrees, when Mercury was near greatest elongation from the Sun and outside of the LASCO field of view.

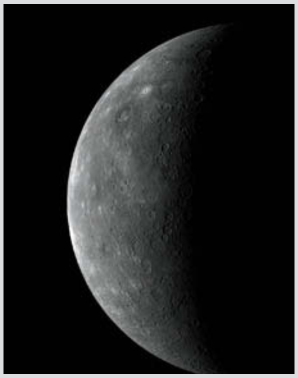
Generally, the steeper a planet's phase curve — the more it varies in brightness from new to full phase — the rougher the surface. Our analysis indicates that the average slope on the surface of Mercury is 16°, somewhat smoother than the Moon. The phase curve also indicates that Mercury's regolith (soil) is compacted about as much as the Moon's, and the distribution of particle sizes is similar too. These findings will be compared to results that NASA's Messenger spacecraft obtains when it starts to orbit Mercury in March 2011.

A similar LASCO program for Venus in 2003 and 2004 shows a phase curve distinctly different from Mercury's. At small phase angles the brightness maximum is rounded for Venus and steeper for Mercury. That's because Venus's clouds scatter the incoming light over a wide angle, whereas solid surfaces tend to reflect light in the direction from which it came.

There's a surprising reversal in the phase curve of Venus near 170°, where the planet actually gets more luminous as its crescent becomes thinner! Based on the phase angle where the reversal occurs and on the planet's atmospheric composition, we attribute the excess bright-



S&T DIAGRAM: LEAH TISCIONE



VENUS: S&T: SEAN WALKER; MERCURY: NASA / JHUAPL / CIW

Left: **Mercury and Venus exhibit a full range of phase angles, from 0° at superior conjunction to 90° near greatest elongation to 180° at inferior conjunction. But solar glare makes the inner planets hard to observe when the phase angle is very small or very large.** ***Center:*** **Venus's clouds scatter light over a wide range of angles. Even so, its terminator, which is lit by the setting Sun, appears much fainter than the center of the sunlit area.** ***Right:*** **This image from the Messenger spacecraft shows that the brightness of Mercury's surface varies greatly depending on the angle from which it's viewed and illuminated.**

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DSLR image of M31 above by Jason Blaschka using an Astro-Tech AT65EDQ and a Celestron CGEM mount.

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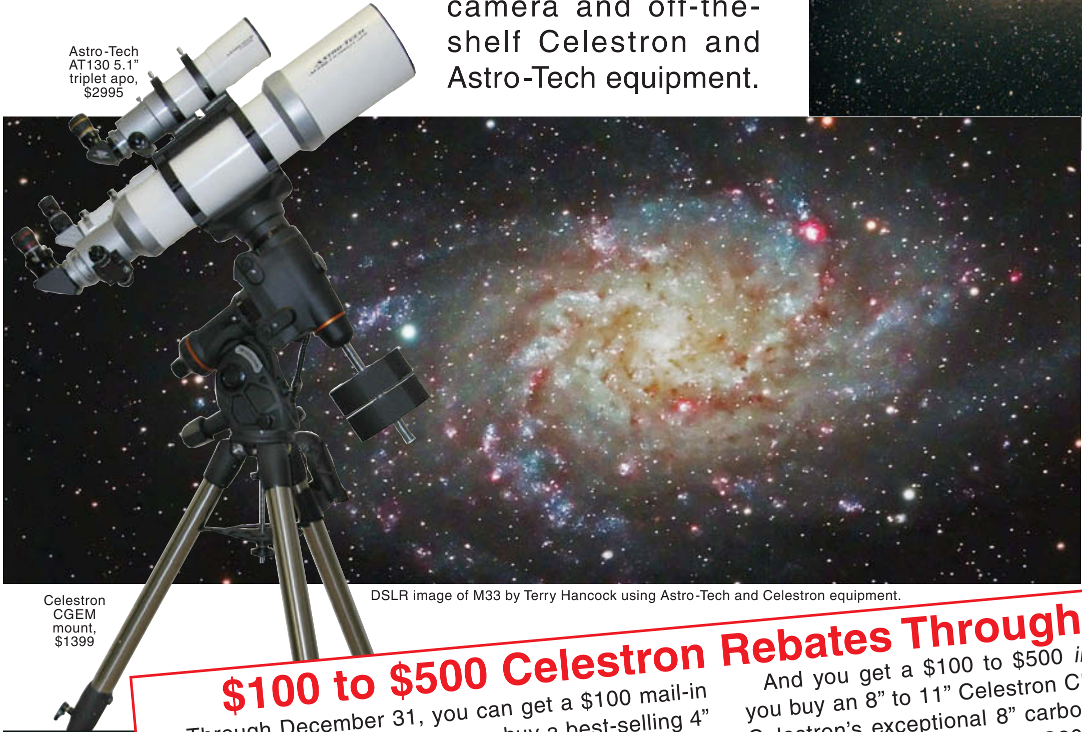

DSLR image of M33 by Terry Hancock using Astro-Tech and Celestron equipment.

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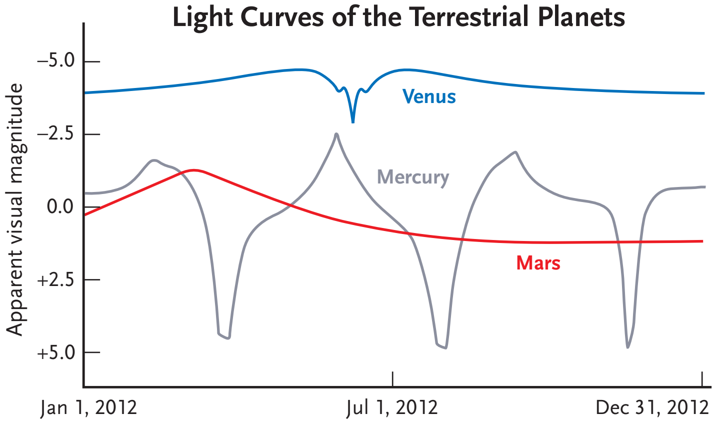
ness to droplets of sulfuric acid. The acid droplets appear to be suspended high in Venus's atmosphere, above its opaque cloud tops. We have been able to estimate the droplets' abundance from the amount of excess brightness. Halos sometimes seen around the Sun and Moon are an analogous phenomenon caused by water droplets in Earth's atmosphere.

When we consider Mercury and Venus's apparent magnitudes (not corrected for distance), they vary less than the phase curves. The inner planets are between the Sun and Earth (near *inferior conjunction*) in their thin crescent phases, and on the far side of the Sun (at *superior conjunction*) when they're full. So the effects due to distance and phase tend to cancel each other.

This is particularly true for Venus, which shines between magnitude –3.8 and –4.9 except for a few weeks around inferior conjunction, when it can fade to –3.0. (Venus is brightest around phase angle 125°, when it's a 21%-lit crescent.) Mercury, by contrast, routinely varies from magnitude +2 to –1 even at phase angles between 70° and 140°, when it's easy to observe from Earth's surface. And LASCO data shows that Mercury can fade to magnitude +5 near inferior conjunction and brighten to magnitude –2.6 at superior conjunction — a thousand-fold variation in brightness!

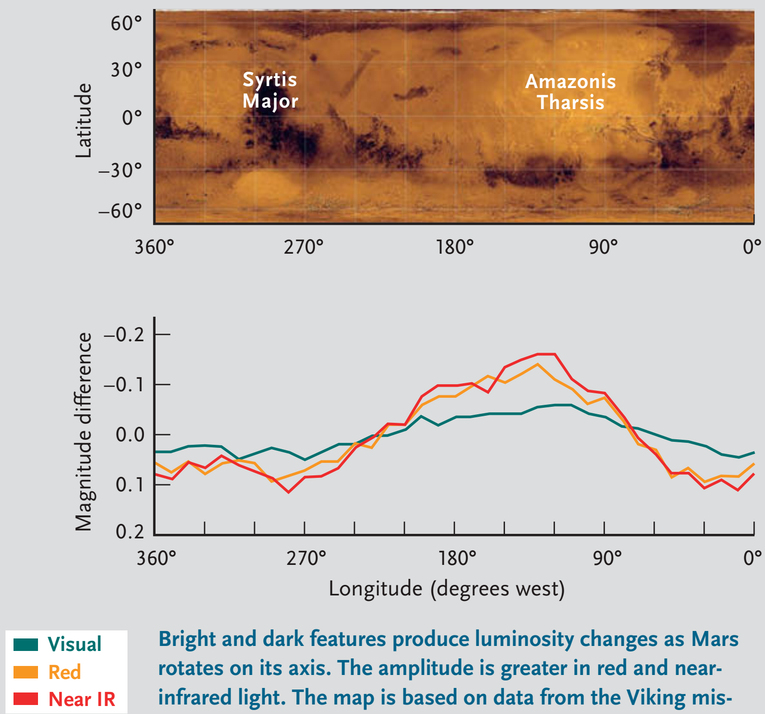
The new LASCO and ground-based photometry for Mercury and Venus were also analyzed by James Hilton (U.S. Naval Observatory). The formulas he derived for predicting magnitudes in the *Astronomical Almanac* depend exclusively on the new observations for Mercury and rely heavily on them for Venus.

Light Curves of the Terrestrial Planets



ANTHONY MALLAMA / S&T: LEAH TISCIONE

The predicted magnitudes of Mercury, Venus, and Mars are shown for the year 2012. Mercury's asymmetric light curve is due to its eccentric orbit.



ANTHONY MALLAMA / S&T: LEAH TISCIONE / MAP DATA: NASA

Bright and dark features produce luminosity changes as Mars rotates on its axis. The amplitude is greater in red and near-infrared light. The map is based on data from the Viking mission processed by Paul Geissler and Alfred McEwen.

Mars

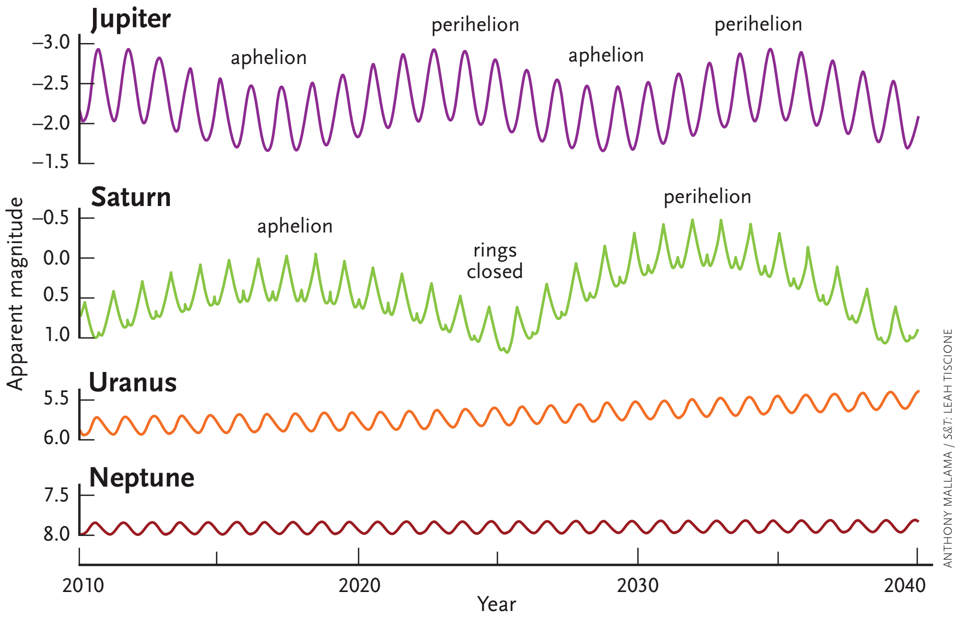
Mars has an eccentric orbit, so its magnitude varies significantly even from one opposition to another. At the very close approach that occurred in August 2003, Mars shone at magnitude –3.0. At a distant opposition, like the one in March 2012, it will be much fainter at –1.4. When Mars is on the far side of the Sun, it can be as dim as magnitude +1.6.

The prominent surface marking on Mars and its dynamic atmosphere add complexity to the study of its luminosity. Fortunately, abundant magnitudes are available to distinguish between these effects, including a 15-year run of measurements obtained by Richard Schmude (Association of Lunar and Planetary Observers), SOHO data, and new ground-based observations by the author. The ensemble of magnitudes indicate that Mars averages 10% to 15% brighter than previously thought.

The magnitude of Mars changes every few hours as bright and dark albedo features cross its central meridian. The visual luminosity is elevated by about 10% at west longitude 100°, when the bright Amazonis-Tharsis region is in view, compared with longitudes near 300°, where dark Syrtis Major is visible. The effect is even more pronounced at red and near-infrared wavelengths.

Dust storms can affect the luminosity of Mars even more strongly than its albedo markings. During the global dust storms of 2001 and 2003 the brightness surged by about ¼ magnitude. Photometric data suggest that the first of those storms came on suddenly and lasted at least several months, while the second storm began more gradually and ended more quickly.

Mercury, Venus, Earth, and Mars span the full range



The magnitudes of the outer planets vary on a yearly basis and on the much longer timescale from one perihelion to the next. Saturn also varies due to the angle of its rings and the surge near phase angle 0°, as modeled by ALPO's Richard Schmude.

of terrestrial planet characteristics. From a photometric perspective, Venus is a bright cloud orbiting the Sun, while Mercury is a dimmer sphere of regolith. Earth and Mars are intermediate between those extremes.

The Outermost Planets

The giant planets (Jupiter, Saturn, Uranus, and Neptune) orbit at much greater distances from the inner solar system. So their phase angles are restricted, and their disks are always almost fully illuminated. The magnitudes of these planets oscillate over the course of a year as they cycle between oppositions. Jupiter typically attains magnitude –2.7 at opposition and then fades by a magnitude at superior conjunction. However, Jupiter can be as bright as –2.9 when opposition occurs near perihelion, the closest point to the Sun in its orbit.

Saturn's disk is magnitude +0.7 at an average opposition and does not change as much as Jupiter's. But the ring system adds a full magnitude of luminosity at its maximum inclination of 27°. Moreover, images from the Hubble Space Telescope and the Cassini spacecraft demonstrate that the rings produce an extra brightness surge near opposition, giving scientists insight into the size of the ring particles. Saturn will be unusually brilliant (magnitude –0.5) during the opposition of December 2032, when perihelion coincides with a wide ring opening and a phase angle of just 0.01°.

Uranus is twice as distant as Saturn and less than half Saturn's diameter. Ranging between magnitudes 5 and 6, the planet is just bright enough to be seen with the unaided eye. Uranus is becoming a little easier to see each year as it approaches its next perihelion, in 2050.

Neptune is so remote that the intensity of sunlight is barely a thousandth of that received on Earth, and its clouds reflect less incoming light than any other giant planet. Glowing weakly at magnitude 8, Neptune is the faintest major planet.

The planets are constantly changing in brightness as they course along their orbits. Each planet reveals something of its itself by the variations that repeat as it cycles through its phases. Add a planet's reflectivity and size to the mix, and factor in any weather and surface markings. Then you can answer the question "How bright is that planet?" ✦

Anthony Mallama is a member of the American Astronomical Society, American Geophysical Union, and American Association for the Advancement of Science.

Going Squirrely

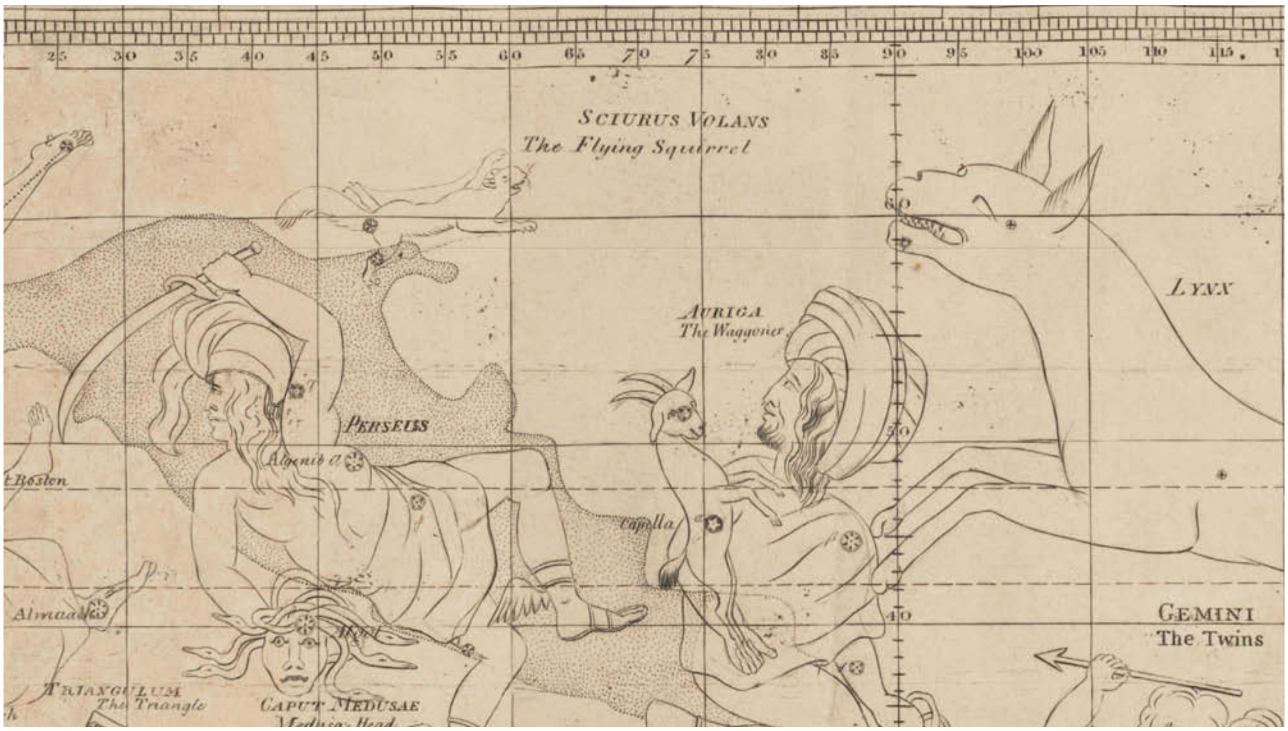
Southwestern Camelopardalis by any other name still looks as sweet.

In 1810 Bostonian William Croswell produced the earliest known American star chart, *A Mercator Map of the Starry Heavens*. Croswell engaged in several pursuits, including private teaching and cataloging the Harvard Library's collection, but he maintained a lifelong interest in astronomy. Only 600 copies of Croswell's celestial map were printed, and he credits the constellation outlines to Samuel Harris. These include two constellations that have never been found on any other chart. Marmor Sculptile, the Bust of Columbus, replaces the southern constellation Reticulum; and little Sciurus Volans, the Flying Squirrel, is positioned where Camelopardalis should be, as shown in the reproduction below.

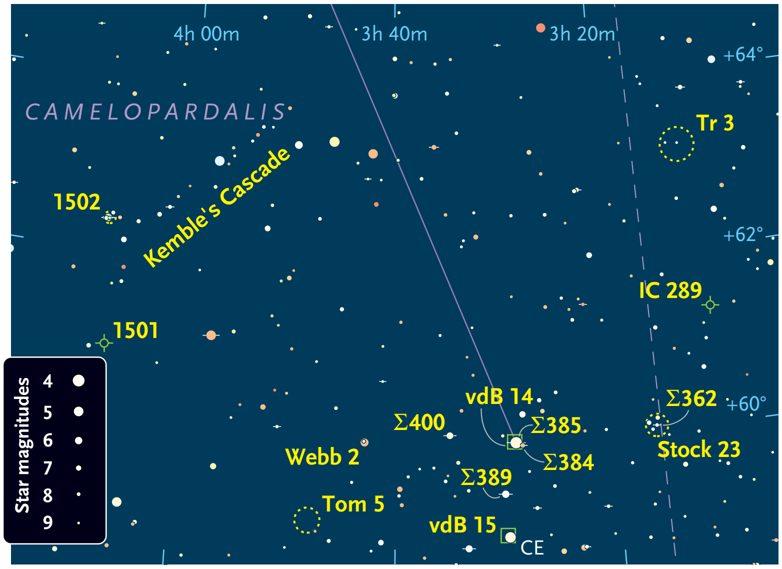
Only two stars were plotted in the Flying Squirrel. The double star Σ385 marks the base of his tail, while the low-amplitude variable star CE Camelopardalis decorates an outstretched hind leg. Our Squirrel's body soars east-northeast from there, while his tail glides across the modern constellation boundary of Cassiopeia. Sciurus Volans has squirreled away many deep-sky acorns, some easy and some difficult to observe.

Σ385 consists of a 4.2-magnitude primary with a 7.8-magnitude companion 2.3″ away. Cursed with a spell of mediocre seeing, I needed my 10-inch reflector cranked up to 220× to pull the faint star out of the brighter one's dancing glare. I saw the little speck south-southeast of its primary, both stars appearing white.

Σ385 forms a slightly curved, east-west line with three additional double stars, all viewed with my 130-mm (5.1-inch) scope. **Σ384** sits 4.8′ west-southwest of Σ385. At 102× I see a deep yellow primary with a close, pale yellow companion to the west. This pair is a bit tighter than Σ385, but it's easier to split because the stars are more evenly matched. This is also true of **Σ400**, 45′ east and a bit north of Σ385, which shows a hairline split at 117× and remains quite close at 164×. The primary is a very pale



COURTESY HARVARD MAP COLLECTION



Star charts: **Camelopardalis is sometimes cited as the most obscure of all constellations. But it's as rich in deep-sky objects as it is poor in bright stars and striking star patterns.**
Image below: **The faint nebulae vdB 14 and 15 appear colorless to the eye, but photographs show that they shine blue from reflected starlight.**

shade of yellow-white, with its attendant nuzzling it from the west. Nearly 1° farther east, colorful **Webb 2** is a wide, yellow-orange and blue-white duo that's well split at 23×.

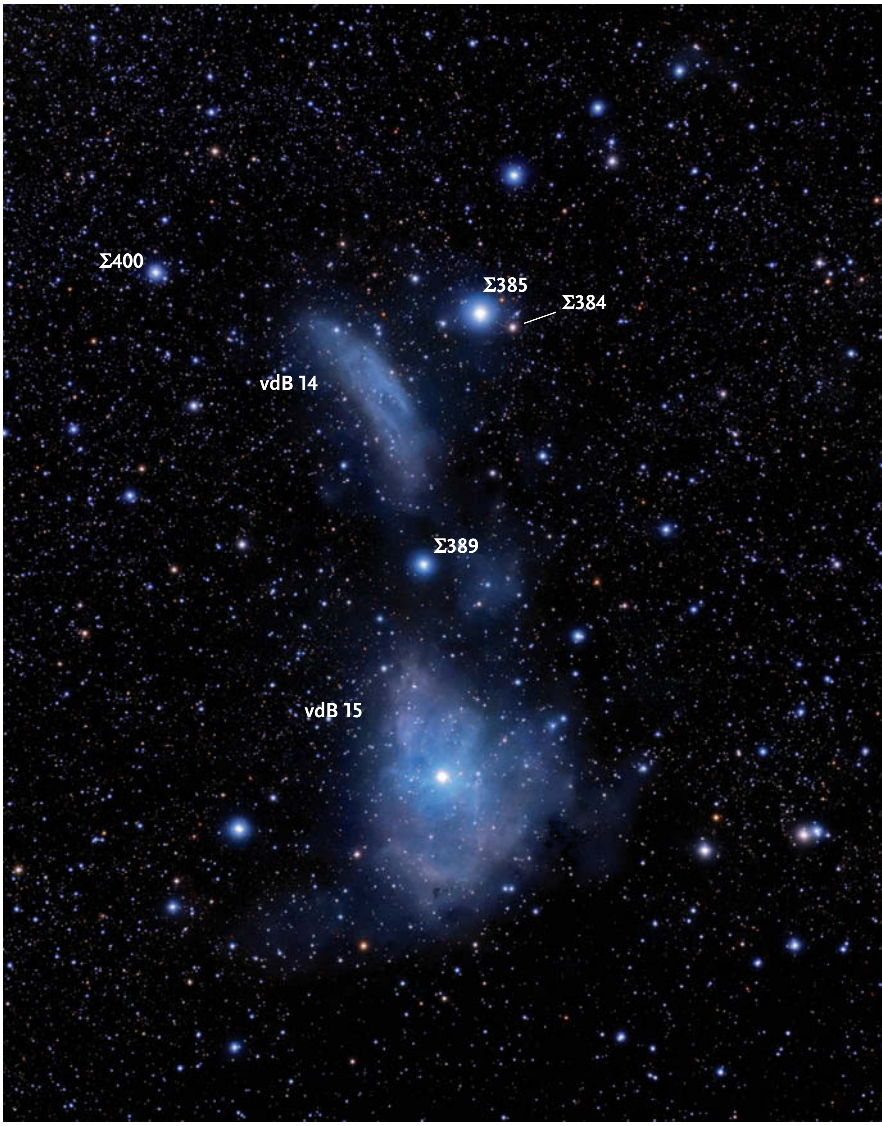
CE Camelopardalis is the source of illumination for **van den Bergh 15**. This nebula is visible mainly by scattered light from the cocooned star, so it does not respond well to most nebula filters. Depending on observing conditions, a broadband filter can kill enough skyglow to improve the contrast a skosh.

Through my 10-inch reflector at 68×, vdB 15 is extremely faint and shaped like a westward-pointing triangle with rounded corners. The triangle's base (east) spans about ½°, and its height is about ⅓°. CE Cam is offset east of the nebula's center.

The double star **Σ389** hovers north of vdB 15. Through my 130mm refractor at 102×, it shows a white primary with a close, yellow-orange companion east-northeast. The pair sits off the southern end of another very challenging reflection nebula, **van den Bergh 14**. The least difficult patch in my 10-inch scope is an ashen bar trending north-northeast for about ⅓°. Its source of illumination is the primary star of Σ385.

A much easier target dwells 1½° west of Σ385 in our Squirrel's airfoil tail. The showy cluster **Stock 23** covers about ½° and boasts several stars in 10×50 binoculars. My 130-mm refractor at 37× reveals a very cute group with 50 stars of mixed brightness, many arranged in chains. Most of the bright stars are packed into a 10′ clump that looks as though it has a grin and two eyes. The northwestern eye is the nicely matched double **Σ362**. The westernmost smile star shines golden, and there's a touch of color in some of the lesser jewels.

Inventive folks have pictured some curious shapes in the star patterns of Stock 23. In the *Binocular Certificate Handbook* of the Irish Federation of Astronomical



STEVE CANNISTRA

Societies, John Flannery writes, "One of the more imaginative descriptions of the cluster is that it resembles a man, arms flailing, fleeing a swarm of bees!" And in the Prescott Astronomy Club's newsletter, Arizona amateur Ken Reeves pens, "The shape is unusual, kind of robot shaped with the left arm being poor and the head to the northwest. The head is the bright star and the right shoulder is a nice double." What do you see?

Climbing 1½° north-northwest takes us to the nice little planetary nebula **IC 289**. In my 130-mm scope 117×, it's visible as a little round ball making a right triangle with a 10th-magnitude star 1¾′ south and a faint star 1¼′ east. At 164× with a narrowband nebula filter, IC 289 looks as if it might have a small, slightly darker center. This is confirmed through my 10-inch reflector with an O III filter at 192×. The wide annulus is a 40″-long oval, tipped northwest, that's rounded out by fainter nebulosity spreading out from its long sides.

The cluster **Trumpler 3** floats 2° farther north and shows in my 9×50 finder as a patch of fog harboring five stars. My 130-mm refractor at 37× displays 30 fairly bright to faint stars loosely flung across 18′ plus some stragglers northeast. An orange gem adorns the southeastern quadrant.

With a leap eastward into the Squirrel's body, we find **Tombaugh 5** lounging 1° southeast of Webb 2. It's a misty glow in my 9×50 finder and a lovely diamond-dust cluster in the 130-mm scope. At 37× Tombaugh 5 is elongated east-west and bedecked with 25 glittering flecks over a fleecy haze of unresolved suns. A magnification of 102× doubles the number of stars, with only scattered bits of fuzz remaining.

Tombaugh 5's stars appear relatively faint because the cluster is 5,700 light-years distant, compared to 1,200 light-years for Stock 23 and 1,500 light-years for Trumpler 3.

We find another enticing planetary nebula 3° northeast of Tombaugh 5. **NGC 1501** is easily visible as a little gray disk through my 130-mm refractor at 23×. At 102× it appears about 50″ across and somewhat darker in the middle. The annulus shows much better with a narrowband filter. NGC 1501 looks blotchy at 220× in my 10-inch scope, which also reveals the central star. In photos the central star resembles a pearl at the heart of a textured oval shell, a combination giving this planetary its nickname of the Oyster Nebula. Visually, an O III filter improves the view of the shell's structure, but its pearl disappears.

VOLKER WENDEL / BERND FLACH-WILKEN

NGC 1501 is nicknamed the Oyster Nebula because of its textured shell and the bright star at its heart.

The open cluster **NGC 1502** perches 1½° north of the Oyster Nebula. My 130-mm scope at 23× displays four single stars and a line of four star pairs. At 102× I see 31 stars, with several nice pairs and trios, occupying 7′. The group's dominant pattern reminds me of a crossbow.

NGC 1502 guards the southern end of **Kemble's Cascade**, a charming asterism formed by a line of stars rippling northwest for 2½°. With 12×36 binoculars, I count 19 stars. Most are 7th to 9th magnitude, but a lone 5th-magnitude star ornaments the chain.

Father Lucian J. Kemble of Canada chanced upon this group while scanning the sky with 7x35 binoculars. He called it a "beautiful cascade of faint stars tumbling from the northwest down to the open cluster NGC 1502." Kemble mailed his description and a drawing to Walter Scott Houston, who published them three decades ago in this magazine (*S&T*: December 1980, page 547). Thereafter, Houston called this striking alignment Kemble's Cascade.

Small and forgotten, Sciurus Volans holds many celestial wonders. So the next time you take your telescope out on a clear night, look up at the sky's Flying Squirrel and say, "Hey Rocky!" ✦

Jewels from the Squirrel's Hoard

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Σ385	Double star	4.2, 7.8	2.3″	$3^h\ 29.1^m$	+59° 56′
Σ384	Double star	8.1, 8.9	1.9″	$3^h\ 28.5^m$	+59° 54′
Σ400	Double star	6.8, 8.0	1.5″	$3^h\ 35.0^m$	+60° 02′
Webb 2	Double star	5.7, 8.5	55″	$3^h\ 42.7^m$	+59° 58′
vdB 15	Reflection nebula	—	30′ × 20′	$3^h\ 29.4^m$	+58° 54′
Σ389	Double star	6.4, 7.9	2.6″	$3^h\ 30.2^m$	+59° 22′
vdB 14	Reflection nebula	—	20′ × 8′	$3^h\ 30.9^m$	+59° 45′
Stock 23	Open cluster	5.6	29′	$3^h\ 16.2^m$	+60° 07′
Σ362	Double star	8.3, 8.6	7.2″	$3^h\ 16.3^m$	+60° 02′
IC 289	Planetary nebula	13.2	48″	$3^h\ 10.3^m$	+61° 19′
Trumpler 3	Open cluster	7.0	23′	$3^h\ 12.0^m$	+63° 11′
Tombaugh 5	Open cluster	8.4	17′	$3^h\ 47.7^m$	+59° 05′
NGC 1501	Planetary nebula	11.5	52″	$4^h\ 07.0^m$	+60° 55′
NGC 1502	Open cluster	5.7	7.0′	$4^h\ 07.8^m$	+62° 20′
Kemble's Cascade	Asterism	4	2.4°	$3^h\ 58.6^m$	+62° 55′

Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

***Sue French**, a fan of the erstwhile* Rocky and Bullwinkle Show, *welcomes your comments at scfrench@nycap.rr.com.*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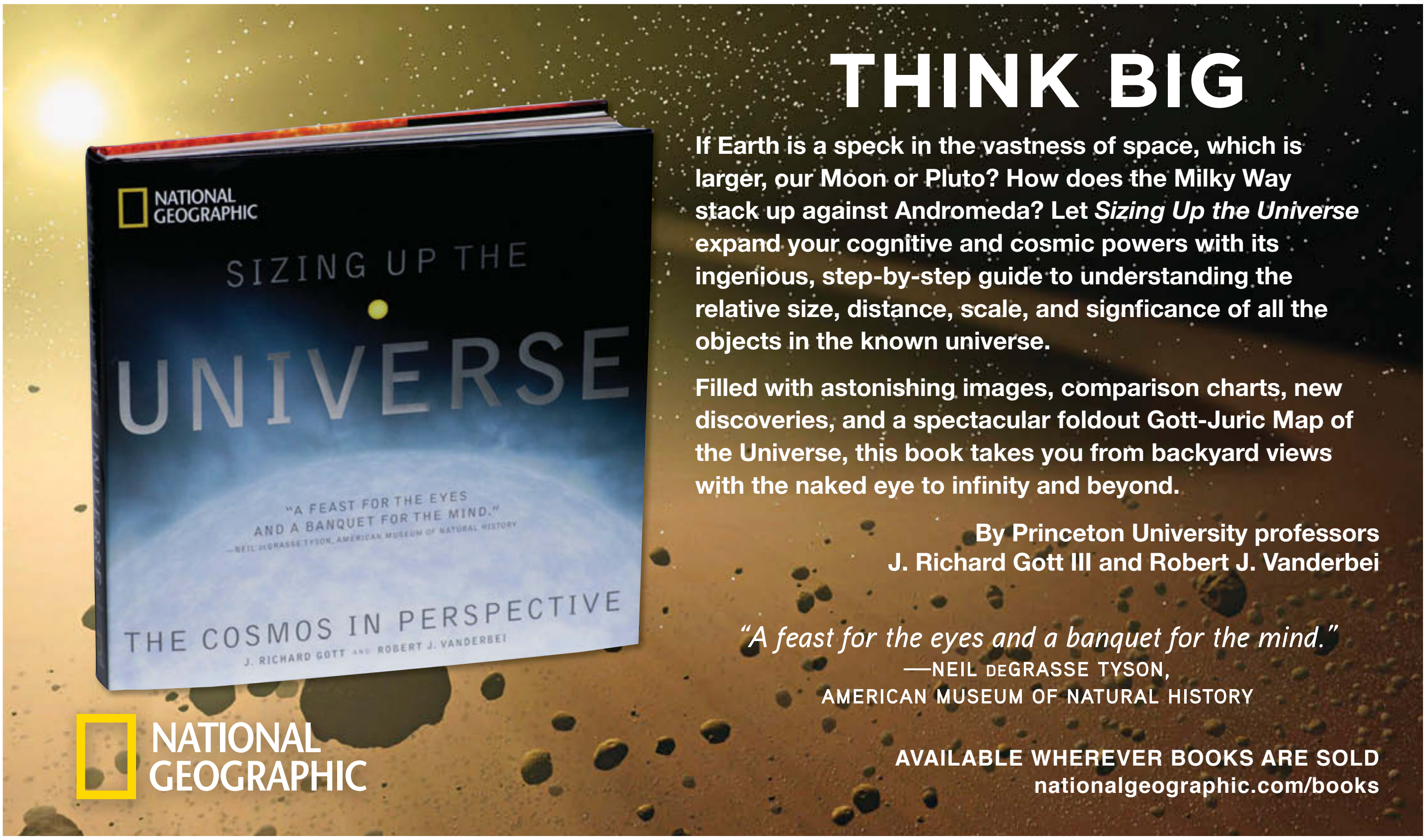
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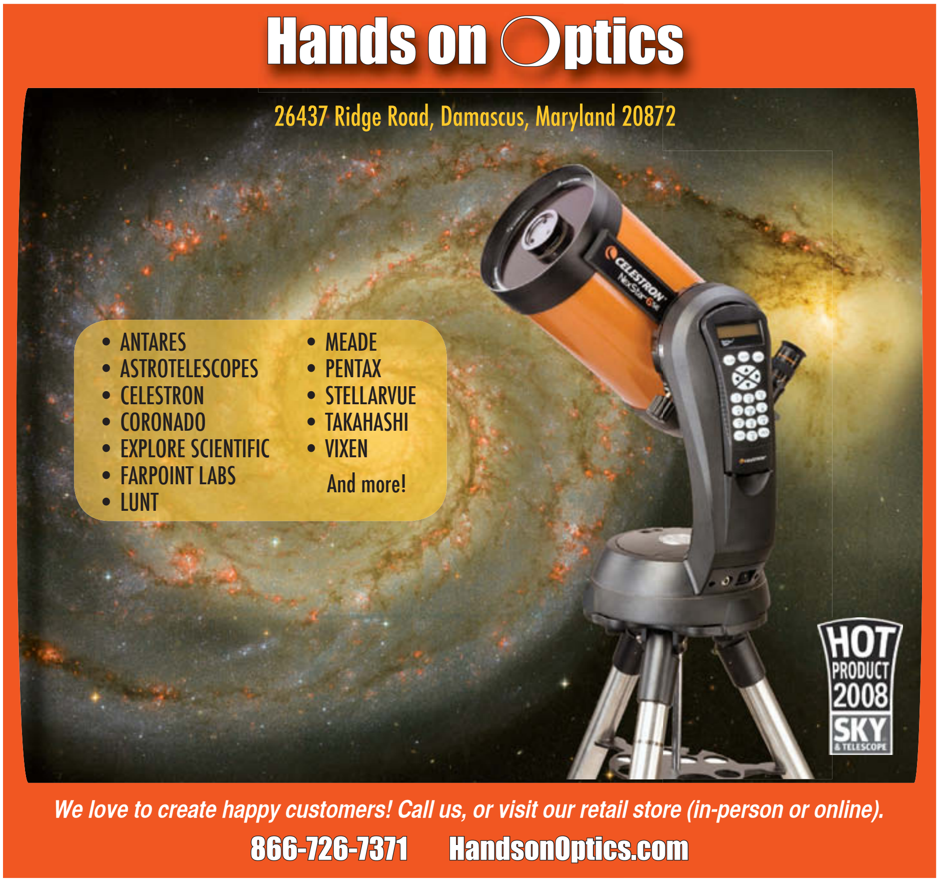
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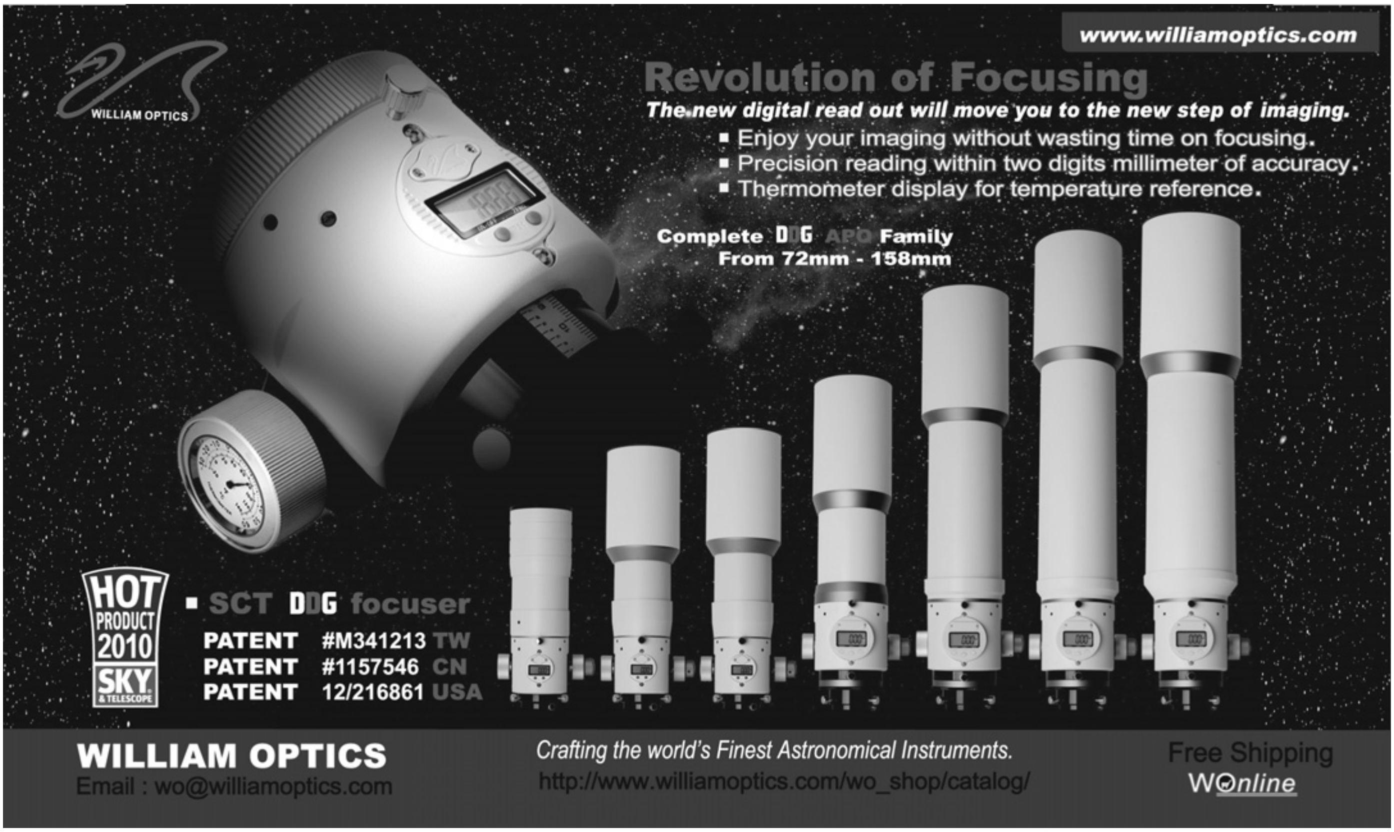
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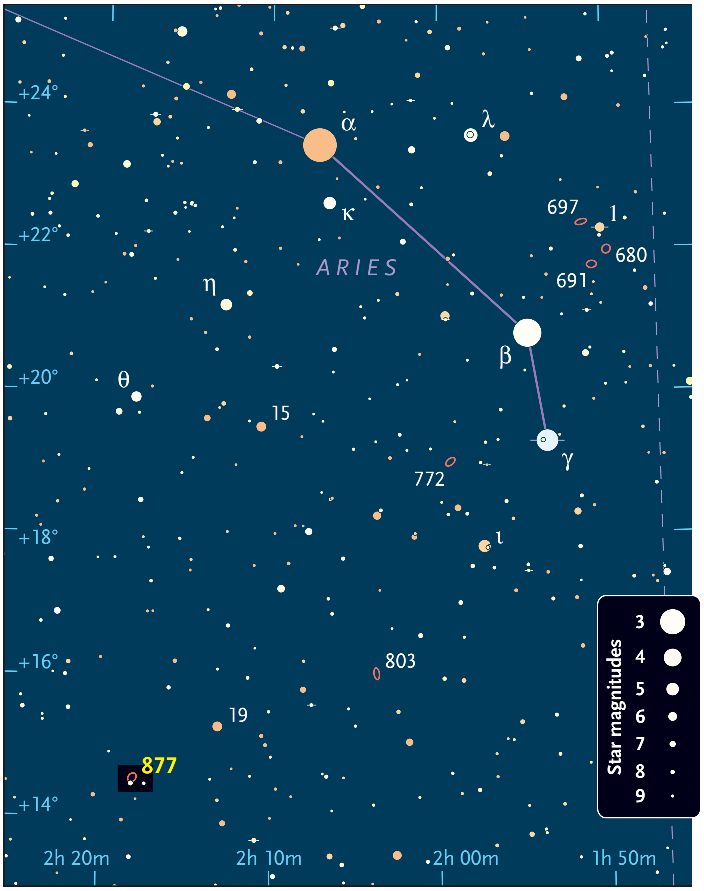
A "Double-Double" of Galaxies

These challenging galaxy pairs in Aries will test your observing mettle.

Off the beaten track in southwestern Aries is a group of four small NGC galaxies arranged in two close pairs, each "guarded" by a relatively bright star. The diminutive duos are located less than 1½° southeast of 5.7-magnitude 19 Arietis. The field is a quick find, but it comes with a challenge.

I first observed this modest collection in September 2009, then returned to it late last summer with my colleague Lee Johnson of Vancouver, British Columbia. Each of us owns a 17.5-inch f/4.5 Dobsonian, and we enjoy comparing views. The observations described below were conducted at two dark-sky sites at elevations of approximately 4,000 and 6,000 feet (1,200 and 1,800 meters), with the target area never less than 45° above the horizon.



The brighter guardian star, 7.7-magnitude HD 14192, is a mere 5′ south-southeast of the best galaxy pair. Just over 11′ westward, 8.6-magnitude HD 14108 shines a similar distance south-southeast of the more difficult galaxy pair. This simple "asterism" of stars and galaxies forms a parallelogram whose long dimension stretches east-west. The bright stars mark the southeast and southwest corners of the parallelogram, while the dim smudges mark the northeast and northwest corners, as shown on the following page. The pattern is a nice fit at 166×, though each pair of galaxies benefits from individual scrutiny at significantly higher power. The trick is to exclude those glaring guardians from the field of view.

Let's start near the brighter star (HD 14192) with NGC 877, the biggest and brightest galaxy here. This loosely-wound barred spiral glows at magnitude 11.8 and is 2.4′ × 1.8′ in extent, its major axis oriented northwest-southeast. A 13th-magnitude star lies off its southeast end. The first time I observed NGC 877 was at our lower-elevation site on a night of average seeing. At 166× the galaxy appeared narrow because I saw only the bar-like core. The surrounding halo materialized at magnifications above 200×. As the seeing improved, the bar appeared mottled, and the halo displayed hints of structure. One year later Lee Johnson and I tackled NGC 877 at our higher-elevation site in perfect seeing conditions. Lee needed only 222× on his telescope to detect portions of the two main spiral arms winding counterclockwise around the bar.

Less than 2′ southwest of NGC 877, and 1.5′ north of two 14th-magnitude stars, is NGC 876. This edge-on spiral measures 2.1′ × 0.4′ and glows at magnitude 13.8 — two magnitudes dimmer than its neighbor. NGC 876's modest surface brightness of magnitude 13.4 per square arcminute doesn't improve its visibility. My averted vision picked up the object as a stubby feather while I scrutinized the nearby spiral at 286×. Most of the edge-on's pallid light is concentrated in its hub, which images show to be cut by a thick dust lane. This specter of a spindle is aligned northeast-southwest, at roughly 90° to NGC 877. The contrasting orientation of these side-by-side objects is what makes them a pleasing, if unequal, double target.

The western galaxies barely qualify as a visible pair. The 13.2-magnitude spiral NGC 871 is a faint oval blob,

ADAM BLOCK

The two stars from the *Henry Draper Catalogue* and the four galaxies from the *New General Catalogue* form an almost perfectly symmetrical shape. Observers with really huge telescopes might enjoy looking also for the labeled galaxies from the *Upsalla General Catalogue of Galaxies* and *Flat Galaxy Catalogue*.

1.2′ × 0.5′ in extent, elongated north-south. However, it registered fairly easily at 166× as one of the "corners" of the parallelogram described on the previous page. In the NGC/IC Project Database, veteran California observer Steve Gottlieb comments that in his 18-inch reflector NGC 871 displays an "irregular surface brightness and a slightly asymmetric shape with the impression of a very faint star or knot at the south tip." Lee and I didn't notice any of these subtle features, but they're something to look for the next night out.

The final galaxy, 15.5-magnitude NGC 870, is barely 0.3′ × 0.3′ and appears almost stellar. Fortunately, this little fellow lies close to NGC 871 and sports a reasonably high surface brightness of magnitude 12.7 per square arcminute. The first night I investigated this region I glimpsed NGC 870 in the correct spot, immediately south of NGC 871 and just northeast of two 14th-magnitude stars. Lee identified the galaxy independently without reference to charts or images.

The appeal of these dim galaxies lies mainly in their arrangement. Each pair is offset from its guardian stars by virtually identical distances and position angles. Your mission, should you choose to accept it, is to try to detect all four galaxies in the same field of view as the two stars. It's not easy! ✦

***Ken Hewitt-White** hunts galaxies, galaxy pairs, and galaxy fields from dark sites in British Columbia.*

AN ASTRONOMER'S GUIDE TO HOLST'S

The Planets

JAMES REID

A music expert describes the influences on and legacy of Gustav Holst's most famous composition.

Mars, the Bringer of War

Venus, the Bringer of Peace

S&T ILLUSTRATIONS BY LEAH TISCIONE

Those who love both astronomy and music can point to few classical music compositions with direct references to astronomy. Some have quasi-astronomical titles, such as Haydn's "Mercury" symphony and Mozart's "Jupiter" symphony, but these names are fanciful additions by others, unrelated to their composers' musical conceptions. The most familiar music conceived on an arguably astronomical subject is *The Planets*, an orchestral set of seven pieces by British

HOLST BIRTHPLACE MUSEUM / CHELTENHAM ART GALLERY & MUSEUM

THE COMPOSER ***Left:*** **Gustav Holst (1874–1934) was a British composer with Latvian ancestry. Besides *The Planets,* he composed choral works, operas, ballets, orchestral pieces, song cycles, hymns, and chamber music. He was also highly regarded as a music teacher. Herbert Lambert took this photo of Holst in 1923, six years after Holst completed *The Planets***

PORTRAIT OF HOLST ***Right:*** **William Rothenstein sketched this portrait of Holst in 1921, shortly after *The Planets* started to gain widespread popularity.**

HOLST BIRTHPLACE MUSEUM

composer Gustav Holst (1874–1934). Written between 1914 and 1917, on holidays and weekends sandwiched between Holst's daily grind as a music teacher, *The Planets* is by far his best-known work.

It would be gratifying to report that Holst was an avid amateur astronomer who derived his musical inspiration from the night sky. Alas, he initially stated that the impetus for *The Planets* came from their astrological character. Moreover, Holst's eyesight was so poor that it's unlikely he ever could have become a keen observer.

Yet some years after composing *The Planets,* Holst read James Jeans's then-popular introduction to astronomy, *The Mysterious Universe,* and according to biographer Michael Short, "Holst realized with excitement that the ideas which were put forward in scientific terms were exactly the same as those which he had been trying to express in music many years before." Further, ". . . the enormity of the universe revealed by science cannot readily be grasped by the human brain, but the music of *The Planets* enables the mind to acquire some comprehension of the vastness of space where rational understanding fails."

Inception and Background

The immediate impetus for *The Planets* occurred during a vacation to Mallorca in March–April 1913 with three friends, two of them fellow composers. The non-musician friend, a writer, mentioned his interest in astrology, and the group reportedly held daily discussions on various subjects ranging from music to astrology to fears of impending war in Europe. Perhaps Holst's companions, or even Holst himself, knew enough basic astronomy to see some real planets. Tantalizingly, Holst's daughter Imogen recalled, "Majorca [sic] exceeded all Holst's expectations . . . the air was caressing, and at night the stars seemed nearer than in England." Early evenings around April 1, 1913, brilliant Venus was moderately high in Mallorca's western sky, more than 30° above the Sun, with Saturn some 20° to Venus's upper left. The other naked-eye planets did not rise until after midnight, and Mercury was too close to the Sun to be glimpsed. The Pleiades and Taurus (with 1st-magnitude Aldebaran) shone nearby. Perhaps Holst's eyesight, aided by glasses, was good enough to recognize the two bright planets against their starry backdrop.

Recent writers have focused attention on Holst's self-avowed interest in astrology, but I think that astrology amounted to little beyond a springboard for *The Planets.* Some have tried to link Holst's music to characterizations of the planets in astrology books he owned, but these books' descriptions of each planet's astrological character generally have little or nothing in common with the character of Holst's music. Once he decided on a basic plan, Holst let his own imagination and conception take their course. Reference to astrology also gave Holst a convenient justification for some aspects of his music not in accord with contemporary public and critical expectations.

Holst's generation was influenced by Richard Wagner (1813–1883), whose operas had a Teutonic mythological, philosophical, and literary apparatus that many took very seriously. Like many contemporaries, Holst rebelled against Wagnerianism as he matured as a composer. He would have been particularly on guard against a comparison with Wagner's romantic-erotic Venus, familiar to Holst's generation as she is portrayed in Wagner's *Tannhäuser.* Wagner's Venus has nothing in common with

MERCURY, THE WINGED MESSENGER

Jupiter, the Bringer of Jollity

Holst's "Bringer of Peace." Likewise, Holst would have been wary of comparisons of his joyous dance-like Jupiter with the arrogantly heroic Wotan, king of the Norse gods, as portrayed in Wagner's epic four-opera cycle *The Ring of the Nibelung*. Holst composed *The Planets* almost entirely during World War I. Anti-German sentiment in Britain was never higher. A patriotic Englishman of British and Latvian ancestry, Holst was determined not to let any hint of Wagner's brand of German ideology into his music.

Although Holst was at pains to deny it, the musical style of several planets suggests associations with classical mythology: Mars = God of War, Mercury = Messenger God, and even Neptune = God of the Sea, since Neptune's musical character supports a "watery" scene. The placid "beauty" of Holst's Venus, the Goddess of Beauty as well as Love, conforms to classic mythology and to her depiction in sculpture and painting. Jupiter's king of the mythological gods seems reflected in its grand central melody, which I'll call the "Big Tune."

Astronomy and Holst's "Planets"

The arrangement of Holst's seven planets will seem odd to astronomers, since it doesn't correspond to the ordering from the Sun outward. Holst conceived *The Planets* from the viewpoint of mankind looking up and the resonances that the planets can have in the human mind. Thus Earth is not included. "Mars" is more effective musically as the first planet, with "Venus" giving immediate and welcome contrast. Holst also recognizes astronomical fact and omits the Sun and the Moon, very important "planets" in astrology. He gives us only the proper seven non-terrestrial planets then known to astronomy.

Clyde Tombaugh discovered Pluto in 1930, years after Holst composed *The Planets,* so the suite ends with "Neptune." Holst was still active in 1930 with a few years to live, but he probably never considered adding an eighth planet. *The Planets* lay long behind him, and his total body of work demonstrates an intent not to repeat himself. The IAU has since officially demoted Pluto into "dwarf planet" status, so we're back to the original seven non-terrestrial planets known to Holst when he composed *The Planets*. Barring discovery of a giant trans-Neptunian object, the planets will remain as Holst knew them.

Recorded Performances

We have two 1920s recordings conducted by Holst himself. Though antique in sound quality, these priceless docu-

HOLST'S OTHER COMPOSITIONS

By far, *The Planets* is Holst's most famous and critically acclaimed composition. But Holst was a highly skilled and versatile composer. Other noteworthy Holst compositions include *The Hymn of Jesus, Egdon Heath*, two Suites for concert band, and his Christmas carol *In the Bleak Midwinter.*

ments directly convey the composer's own conception of *The Planets*. Holst's two recordings are consistent — and fast — in tempo. Conductors have since varied widely and differ most often in their slower tempos — often drastically in "Mars," "Saturn," and "Neptune." Since I believe Holst's second (1926) recording is "right" (and who can argue with the composer himself?), I have listed his timings for each movement in the table below, so that the reader can compare his tempos with later recordings.

Holst's friend Adrian Boult (1889–1983) conducted the first performance of *The Planets* in 1918, and recorded it at least five times between 1945 and 1978. Boult's recordings are inconsistent and often at odds with the composer's. A 1996 recording conducted by Roy Goodman emulates the composer's 1926 recording, including the tempos, and his orchestra uses museum instruments or replicas of instruments played in the 1920s. For anyone interested in this music, Goodman's is a must-hear recording.

Looking beyond Boult and Goodman, a rough average of timings of about 25 modern recordings is included in the table. Compare these to Holst's 1926 timings, and it becomes obvious that most later conductors are not playing *The Planets* as Holst conceived it. Ideally, all who love *The Planets* should have Holst's 1926 recording, to know how he wanted the work to go, and the Goodman recording, to hear it played "right" in modern sound. Goodman's CD is difficult to find but is readily available for download on-line, as are Holst's 1926 recording, Boult's 1978 recording, and many others.

Saturn, the Bringer of Old Age

A Brief Tour of The Planets

Holst once said, "There is nothing in any of the planets (my planets I mean) that can be expressed in words." Extramusical associations tend to be both personal and variable. But when a composer associates his music with specific objects in the physical world, I think we're justified in allowing our imaginations to find personal analogs or associations between the music and the objects — in this case, the seven planets.

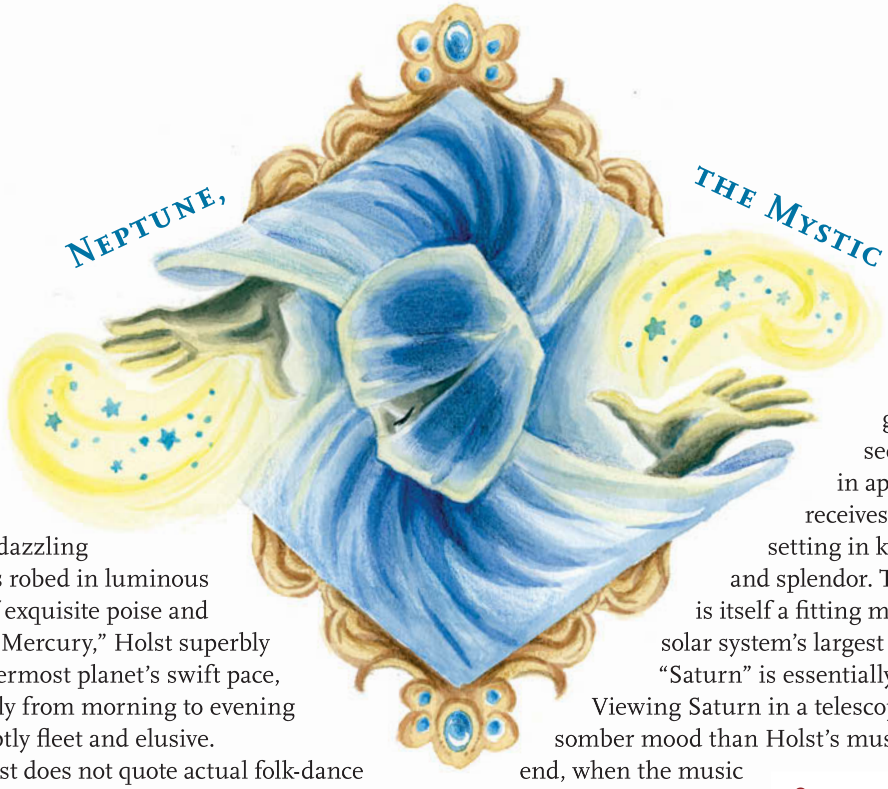
"Mars" was composed right before the August 1914 outbreak of World War I, and offers a stark premonition of mechanized warfare. Impending war was in the air and was discussed by Holst and his friends during their 1913 Mallorca vacation. "Mars's" relentless five-beat pattern, the ominous thump of the drums and strings, the wailing brass — all contribute to a powerful sonic image of war. In my view, most conductors play "Mars" too slowly — at least seven minutes, often pushing eight like Boult in 1978 — almost turning "Mars" into a different piece. Goodman is close to "right" here and in all the planets. The Red Planet receives a fitting musical analog in this menacing music. Baleful Mars, with his companion moons Phobos (Fear) and Deimos (Terror), could hardly be better imagined in music. Recalling Mars's 2003 spectacular apparition, with its dire red glow, and its apparition in the winter of 2009–10, many may sense a correspondence to Holst's music.

"Venus" enters with quiet beauty in the solo horn, answered by a lovely descent in the flutes. Throughout, this is music of calm and sensuous

Timings of *The Planets* from Recordings

Conductor, year	Mars	Venus	Mercury	Jupiter	Saturn	Uranus	Neptune
Holst, 1926	6:07	7:13	3:29	6:55	6:51	5:51	5:29
Boult, 1978	7:58	7:21	3:43	7:54	8:18	6:22	6:21
Goodman, 1996	6:18	7:33	3:33	7:28	7:19	5:50	6:14
Modern Average	7:15+	8:15	4:00	8:00+	9:15+	6:00	8:00

The timings in this table are taken from the documentation accompanying the CDs described in the article, plus a selection of about 25 others to give a rough modern average.



Neptune, the Mystic

grace. Along the way, a number of fine wind and string solos join to sing Venus's song of peace. Here our dazzling "Evening Star" is robed in luminous "white" music of exquisite poise and clarity. Then in "Mercury," Holst superbly captures the innermost planet's swift pace, zipping so quickly from morning to evening sky, in sounds aptly fleet and elusive.

Although Holst does not quote actual folk-dance tunes in "Jupiter," he composes in that spirit. The central dance is the "Big Tune." Holst's 1926 recording is a revelation. "Jupiter" is brisk and bracing, and above all, it dances. In the 1920s, Holst was commissioned to set to music a patriotic poem, "I vow to thee my country," as an elegy for the war dead. He realized that "Jupiter's" Big Tune can be made to fit these words, although the poem's sentiment is foreign to his original concept. The giant planet, usually second only to Venus in apparent brightness, receives a Jovian musical setting in keeping with its size and splendor. The grand Big Tune is itself a fitting musical analog of the solar system's largest planet.

"Saturn" is essentially a funeral march. Viewing Saturn in a telescope casts a less-somber mood than Holst's music, but toward the end, when the music opens up and the brass and strings soar with a broad and consoling variant of the opening bass motif, it often brings to my mind Saturn's shimmering rings, recently revealed anew by NASA's Cassini spacecraft. For me, Holst's elegy for the dead of World War I is "Saturn," not the patriotic poem later grafted onto "Jupiter."

To learn more about Gustav Holst and *The Planets*, and to watch YouTube videos of live concert performances recommended by the author, visit SkyandTelescope.com/holst.

"Uranus" bears perhaps the least relevance of any actual planet. To a parody of English military music, Holst adds the grotesque comedy of the bassoons, and sudden, humorous contrasts.

But "Neptune" again is music that, in my mind, can be an analog of the remote blue-green planet. Whatever he may have thought about "mysticism," Holst's "Neptune" also implies the mythological God of the Sea in providing a watery wash of sound and color. At the end, his score instructs a wordless female chorus to continue repeating its phrase ever softer until the music becomes inaudible. According to Michael Short, "In Neptune, Holst's aim was to depict in music the mystery and wonder of outer space." For the astronomer, Holst provides a sense of Neptune that leads to the edge of the solar system and echoes onward and outward into the vastness of space beyond. ✦

Uranus, the Magician

Long-time S&T *subscriber **James Reid** (Ph.D. in Music, UCLA, 1977) is a management consultant assisting high-tech companies with business development in Japan. He has taught Asian music as an adjunct at several universities in the San Diego area. E-mail: komagaku@earthlink.net.*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Treasures from the Archives

Thar's gold in them thar back issues.

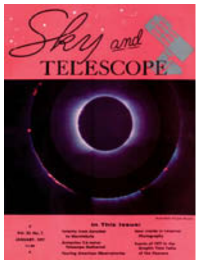
AMONG THIS magazine's readers, it was often telescope makers who most persistently pleaded for a "best-of" collection drawn from the pages of past issues. And for good reason: there's a ton of useful equipment-building information in those back issues. None of my colleagues and I can recall a single issue of the magazine that didn't have at least a page or two devoted to telescope making. Now that the complete *S&T* DVD collection has arrived, all those telescope-making articles, which amount to several thousand pages spread across the archive's 818 monthly issues, are readily available. In fact, there's so much material on those DVDs that you might be wondering where to start!

S&T: PATRICIA GILLIS-COPPOLA / ©BIGSTOCK / KMITU

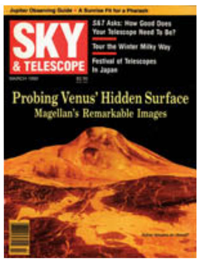
Listed here are a few of my picks of the best of the best. Of course, this is only a tiny sample of what's available, but it's at least a start.

A Graphical Approach to the Foucault Test (February 1976, page 127). This article describes the graphical tool that finally liberated weary glass pushers from the tedious calculations and rough-guess methods of mirror evaluation that had long been the norm. French amateur astronomer Adrien Millies-Lacroix's brilliant and intuitive technique makes it easy to plot readings from a knife-edge test to see if your mirror is good enough, or if it still needs work. Even today, the "M-L graph" is featured in many popular Foucault-analysis computer programs.

An Equatorial Table for Astronomical Equipment (January 1977, page 64). In this Gleanings for ATM's feature, Adrien Poncet, another French amateur, introduced his elegant tracking mount to readers — and the rest is history. As Dobsonian telescopes grew in popularity in the 1980s, so did the Poncet platform. Little wonder — it gives observers the best of both worlds: the option to have big aperture and alt-azimuth simplicity, with the tracking abilities of a true equatorial mount.



Optical Quality in Telescopes (March 1992, page 253). While this article is a feature rather than a story in the telescope-making department, it really got people talking. Ace Canadian optician Peter Ceravolo built four identical 6-inch f/8 Newtonian reflectors — identical, that is, except for the quality of the primary mirrors. The optics were the key ingredient in a bold, yet simple experiment: could observers tell the difference between bad (1-wave), fair (½-wave),



good (¼-wave), and excellent (1/10-wave) mirrors in actual use? The surprising results are as illuminating today as they were when the article first appeared nearly 20 years ago.

Rules of Thumb for Planetary Scopes (Part I: July 1993, page 91; Part II: September 1993, page 83). Most telescope makers and users know that central obstructions affect image quality, but by how much? What about spider diffraction? Spherical aberration? William Zmek's two-part article was groundbreaking for both the depth and the clarity with which it dealt with these (and other) topics. It's also the source of Zmek's rule of thumb, which predicts how an obstructed telescope will perform compared to an unobstructed one. If you really want to know why an apochromatic refractor often outperforms a same-sized reflector or, more to the point, if you really want to make your reflector perform like a refractor, this is the article you need to read.

Understanding Thermal Behavior in Newtonian Reflectors (September 2000, page 125). I think this is perhaps the most important article I've helped bring to the pages of *S&T* during my tenure as the magazine's fourth telescope-making editor. Until Bryan Greer's insightful and careful exploration of the subject, few observers gave the topic of mirror cool-down the serious attention it deserved. This in-depth article put the problem front and center, and added the phrase "boundary layer" to the ATM's lexicon. Greer's two-part follow-up (May and June 2004, pages 128 and 122, respectively) is equally groundbreaking. To the best of my knowledge, no better treatment of the subject exists in the amateur-astronomy literature.

Flexing Spheres into High-Quality Telescope Mirrors (November 2000, page 131). Alan Adler is one of the most fascinating people I know, and his method for parabolizing telescope mirrors highlights his inventiveness. Building on a concept pioneered by Bill Kelly (June 1992 issue, page 684), Adler showed how a quality spherical mirror can be flexed into a first-rate paraboloid with a mechanical cell. The method hasn't taken off like I imagined it would, but in the often geological timescale that ATMs operate within, it's still early.

A Drive Control in an Ammo Box (December 1978, page 566). I've included this article not because it's a classic, but rather because one of my colleagues says that it's the single most-requested Gleanings column year after year. With the internet providing a ready market of older, used telescopes, there's a corresponding small but steady demand for drive correctors that can control the 110-volt AC motors that dominated telescope drives a generation ago. Commercial drive correctors have all but disappeared from the market.

In addition to being simple, the electronic circuit Richard Koolish describes in the December 1978 issue uses components that are still readily available. Also, Marvin Harner described a slightly more complex variant of Koolish's design, which includes a frequency monitor, in the September 1983 issue, page 257.

If readers have their own favorite articles from the past, drop me a note and perhaps I can mention some in a future column. ✦

*Contributing editor **Gary Seronik** has built numerous telescopes, several of which are featured on his website, www.garyseronik.com.*

▼ **PICTURESQUE ENCOUNTER IN PERSEUS**
Rogelio Bernal Andreo
Short-period Comet 103P/Hartley 2 put on a fine show during the mid-fall of 2010, passing the Double Cluster, NGC 884 and NGC 869, on the evening of October 8th.

This wonderful portrait of the event includes NGC 1795, aptly known to astrophotographers as the Heart Nebula, at right. **Details:** *Takahashi FSQ-106EDX refractor with SBIG STL-11000M CCD camera. Three-panel mosaic with exposures totaling 131 minutes through Astrodon clear, red, green, blue, and Hα filters.*

Visit SkyandTelescope.com/gallery for more astrophotos online.

▲ **SHARPLESS CLOUDS**
Christopher Cook
Cepheus is a constellation riddled with nebulosity, such as this fine example known as Sharpless 2-171, a beautiful combination of emission and dark nebulosity.
Details: *Astro-Physics 130EDFGT refractor with an SBIG ST-8300M CCD camera. Total exposure was 8 hours through an Astrodon 5-nanometer Hα filter.*

► **PIERCING THE HYADES**
Sebastian Voltmer
The Perseid meteor shower produced many bright fireballs last year. This bright meteor was captured over the skies of Sainte-Jalle, France, during the early morning hours of August 13, 2010.
Details: *Canon EOS 500D DSLR with 30-mm lens at f/2.8. Total exposure was one minute at ISO 800.* ✦

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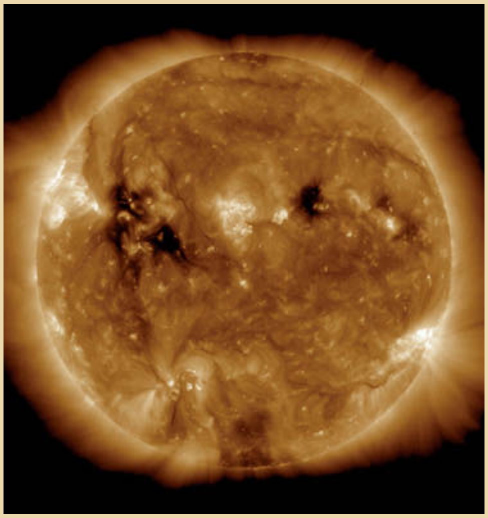

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The Library Telescope Program

An astronomy club's outreach program gets telescopes into peoples' hands.

"The strongest thing that's given us to see with's a telescope. Someone in every town seems to me owes it to the town to keep one." The words of Robert Frost in *The Star Splitter* inspired the New Hampshire Astronomical Society (NHAS) to develop a novel public outreach effort. Frost's "someone" could be the local librarian, and thus the Library Telescope Program was born.

Society members decided to place telescopes in town libraries, where patrons can check them out just like books. Libraries were chosen instead of schools, because libraries are geared for lending material and they are open year round.

After a successful trial run, word spread among New Hampshire librarians. In short order, the requests started pouring in. The NHAS Education/Outreach Committee began placing the telescopes and educational materials in December 2008. The goal was to help foster scientific literacy, stimulate an interest in astronomy, and provide people who have never looked through a telescope the chance to experience the excitement that comes from discovery.

NHAS has been holding regular public observing events (called Skywatches) for years; but members felt there were other ways they could expand their outreach activities. The Library Telescope Program (LTP) proved to be the perfect vehicle — a "grand-slam home run," according to Rich Schueller, co-chair of the NHAS Education/Outreach Committee. As of September 2010, NHAS has placed 16 telescopes in libraries across the state.

JENNIFER STOWBRIDGE

LIBRARY TELESCOPE Left to right: Nia Shea Ashby, Zeth Ashby, and their mother Karson Ashby learn how to focus one of the NHAS's loaner Orion StarBlast telescopes.

Our scope of choice is the Orion StarBlast 4.5. According to Marc Stowbridge, program originator and coordinator, "It's a very nice telescope with good optics, a large-enough aperture, and it's easy to carry and adjust. In my opinion, it rates 3 out of 4 stars as a loaner scope to nonastronomically skilled people."

But it's the "easy to adjust" part that can get people in trouble. So we make modifications to the StarBlast that help protect the scope. We also re-wrote the instruction manual.

A local NHAS member acts as a foster parent to each telescope. That person periodically cleans and adjusts the telescope, and acts as an astronomical resource to the library and its patrons. When a club member is unavailable, NHAS trains an interested member of the library's community to do the job.

Funding has come from a variety of sources, including the NHAS general budget, specific donations from members, business sponsors, members of the public who make donations at Skywatches, and library patrons interested in giving something back to their communities. Local funding is encouraged, since it gives the patrons "ownership" of the telescope and community participation in the libraries.

The LTP continues to be very well received. Most libraries have a list of patrons waiting to check out the telescope. Hundreds of people have participated, and the reports have been quite enthusiastic. "We're very pleased, and a little surprised, with the success of the program and we're delighted to provide an opportunity to share our love of the night sky in this unique way," says Stowbridge. "We encourage other clubs and organizations to start a Library Telescope Program of their own."

For detailed information on the program, including downloadable copies of manuals, instructions, and scope modifications, visit www.nhastro.com/ltp. ✦

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