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ABOUT THE UNIVERSE p. 30

APRIL 2013

Astronomy

The world's best-selling astronomy magazine

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of our supergalaxy p. 24

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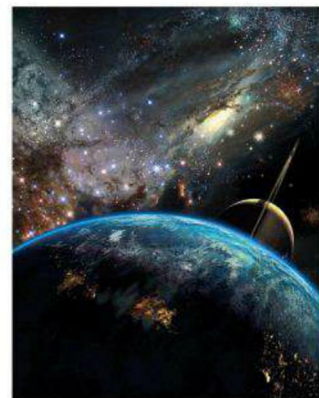
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DON DIXON FOR ASTRONOMY

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We partner with *Distant Suns* app

I'm delighted to announce that *Astronomy* magazine is now in partnership with a longtime leader in digital planetarium software, *Distant Suns*. Originally released for the Commodore Amiga in 1987, *Distant Suns* has grown to become a dominant player in the computer astronomy software world, having long been available as astronomy software and as an app on nearly every computer platform and operating system.

The brainchild of Silicon Valley astronomer and programming genius Mike Smithwick, *Distant Suns* is one of the longest lived, continuously operating computer software titles on the market, bested only by products like Windows, Microsoft Word, and Broderbund's *Print Shop*. *Distant Suns* will now regularly feature content from *Astronomy* magazine and Astronomy.com.

The current version of *Distant Suns*, as you'll see, is very exciting and an indispensable aid to viewing the night sky. The product also has partnered with the SETI Institute to offer a real-time display showing where astronomers are searching for extraterrestrial signals.

Distant Suns has also teamed up with NASA's Night Sky Network and the Astronomical Society of the Pacific



to include local U.S. listings of astronomical events and activities in the app version.

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For more information on the current product line and supported systems, see www.distantsuns.com/products.

We are proud to announce this partnership, and I know you will enjoy hours under the stars with *Distant Suns*.

Yours truly,

David J. Eicher
Editor

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HOT BYTES >>

TRENDING TO THE TOP



PLANET PLETHORA

NASA announced 461 new Kepler candidate planets, bringing the mission's total to 2,740 possible worlds orbiting stars other than the Sun.



GUIDE STAR

A recent paper in *The Astrophysical Journal Letters* claims Polaris (Alpha Ursae Minoris) is 323 light-years, instead of 434 light-years, away.



NEO STUDY

New infrared observations show asteroid 99942 Apophis is 1,070 feet (325m) wide — that's 20 percent bigger than thought.

SNAPSHOT

How the Sun will die

For years, astronomers have believed they understood how our star will expire. But not so fast.

Astronomers will tell you they have known how the Sun will die for a long time. It will become a planetary nebula — perhaps resembling the Dumbbell Nebula (M27) pictured here. And long after we're gone, the Sun will become one of them, with a remnant white dwarf star stuck in the center. Or so astronomers thought for many years. Now research by Noam Soker of the Israel Institute of Technology and his colleague Orsola DeMarco from Macquarie University in Australia casts a little doubt, suggesting that perhaps most planetaries (and all those with butterfly shapes) form not from solitary stars like the Sun but from double star systems. In some cases, even inner massive planets can shape the planetary nebula into an elliptical, not spherical, shape. So the thinking on planetaries, like that on so many citizens of the universe, may be more complicated than we believed. Stay tuned. That is one of the great attributes of the cosmos, its ability to surprise you.

— David J. Eicher



The Dumbbell Nebula (M27) in Vulpecula shows us what the Sun's future may hold.

R. JAY GABANY (DUMBBELL NEBULA); NASA/KEPLER MISSION (PLANET PLETHORA); DIGITIZED SKY SURVEY (GUIDE STAR); ESA/AOES MEDIALAB (NEO STUDY)

A royal bubble

A fierce stellar wind gusting from a massive star shapes the intricate Bubble Nebula (NGC 7635) in Cassiopeia the Queen. The star also emits lots of ultraviolet radiation that excites the nebula's atoms and causes them to glow. This photo comes from the One Degree Imager (ODI), a new camera being commissioned on the 3.5-meter WIYN Telescope on Kitt Peak in Arizona. The original image covers an area 25 arcminutes on a side (this version is cropped to show more detail). When fully operational, the ODI will record 1 square degree of sky — some five times the

Full Moon's area. • T. A. RECTOR
(UNIVERSITY OF ALASKA, ANCHORAGE)/WIYN
ODI TEAM/WIYN/NOAO/AURA/NSF





STRANGEUNIVERSE

BY BOB BERMAN

Astro April Fools

Some pranks were deliberate, some accidental.

Imagine a giant saucer hovering above Earth. Over every TV, aliens announce they'll destroy our planet in one hour. When the time is up, they say, "Just kidding!" And then they fly off to mess with everyone's head on some other world.

It does seem that one of nature's traits is playfulness. Look at kittens or dolphins or some of your friends. They just want to fool around.

Do people ever do celestial stuff for a goof? The late Howard Koch did when he wrote the *War of the Worlds* radio script. Orson Welles grimly read it over CBS radio in 1938, convincing more than a million listeners that martians were invading. The pair did the broadcast just for fun. Two years later, Koch co-wrote *Casa blanca*. (And much later, in his 80s, collaborated with me on a book, which is how I got to know that tall, classy gentleman.)

Apollo 14 created some strange goofing on the Moon when Alan Shepard pulled a famous prank on NASA. He removed a ball he had secreted in his space suit, grasped the handle of a geology instrument, and announced he'd play golf. His one-handed attempts kept missing, but when he made contact, he exclaimed, "There it goes, miles and miles and miles." Later analysis showed it went more like 400 yards. Still, not bad.

On that same mission, Edgar Mitchell, perhaps channeling the self-proclaimed psychic Edgar Cayce, took out a deck of cards and performed unauthorized ESP experiments to test for telepathy between Earth and the spacecraft. NASA looked on in disbelief.

During the Apollo 16 mission, John Young drove the lunar rover

like a dune buggy, with sharp turns and flying dust. Filming it, Charlie Duke said, "Indy's never seen a driver like this."

Apollo 17 witnessed astronaut Harrison Schmitt hopping around singing, "I was strolling on the Moon one day, in the merry, merry month of December ...," with NASA doctors later concluding that euphoria is indeed an odd recurring effect of being on the lunar surface. The Moon can apparently drive people a little loony.

But the greatest astronomical pranks were unintentional. The beloved NASA administrator Dan Goldin, surrounded by a team of experts, held a press conference in 1996 to announce the existence of life on Mars. Say what? They'd based it on apparent fossils in a martian meteorite found in Antarctica in 1984, like plot lines from *The Thing*. The

IT DOES SEEM THAT ONE OF NATURE'S TRAITS IS PLAYFULNESS.

"martian life" conclusion was soon discredited, however, especially after scientists saw similar "fossils" in lunar rocks. NASA didn't later say, "April Fool! We got you!" but that's what it amounted to.

A goof-up is not the same thing as a deliberate prank, of course, but it can create a similar effect. In July 1962, the first Mariner spacecraft to Venus exploded. A missing hyphen in the computer instructions had sent the rocket incorrect guidance signals, so NASA's range safety officer ordered it destroyed. The absence of a single hyphen cost tens of millions of taxpayer dollars. April Fool.

FROM OUR INBOX

The hunt for life in the cosmos

Thank you for your thought-provoking article "Civilizations in the universe" on p. 9 of the January 2013 issue. Given the astounding evidence for the possibility of life in the universe, I am extremely optimistic that we will discover conclusive evidence for basic or intelligent life in the cosmos — if not in our lifetime, then soon afterward. I don't think Earth is a cosmic accident.

The work that biologists have provided regarding life in some of the most hostile environments on our planet shows how life can exist in unexpected places given the right physical and chemical environments, and life doesn't even need solar energy because the geothermal energy of the planet itself sustains it.

On Earth, if we could take the oceans and atmosphere out of the equation, we would find that our world would be eerily similar to our neighbor Mars. Too much atmosphere, and it looks like Venus. We're right in the middle as a seemingly perfect cosmic cocktail.

Unfortunately, I don't believe it will ever make economic sense for our civilization to explore other potentially hospitable worlds, and given the current cutbacks on many areas of scientific exploration, we are only delaying our inevitable discovery of what life may exist beyond Earth. We are so close to, yet so far from, finding out what our galactic neighbors are up to. — **Gavin Sullivan**, Las Vegas

Perkin-Elmer of Danbury, Connecticut, the world's most prestigious optical company, won the commission to build the Hubble Space Telescope mirrors. It took them four years. After all that labor, they delivered the main 94-inch mirror polished to the wrong shape. A miscalibrated testing device and their

falling from the sky and banks registering everyone's balance as zero. A hundred billion dollars was spent on the "problem." But many businesses ignored the peril. When the new year dawned, nothing happened. The world's computers got it right after all. April Fool.

Also in 1999, the \$125 million Mars Climate Orbiter failed to enter orbit around the Red Planet. The problem? NASA engineers commanded it using metric units while the company that designed it intended its guidance to be in Imperial units. Later that same year, the \$185 million Mars Polar Lander went silent while landing. Mission Control never heard from it again. A missing line of computer code was likely the culprit.

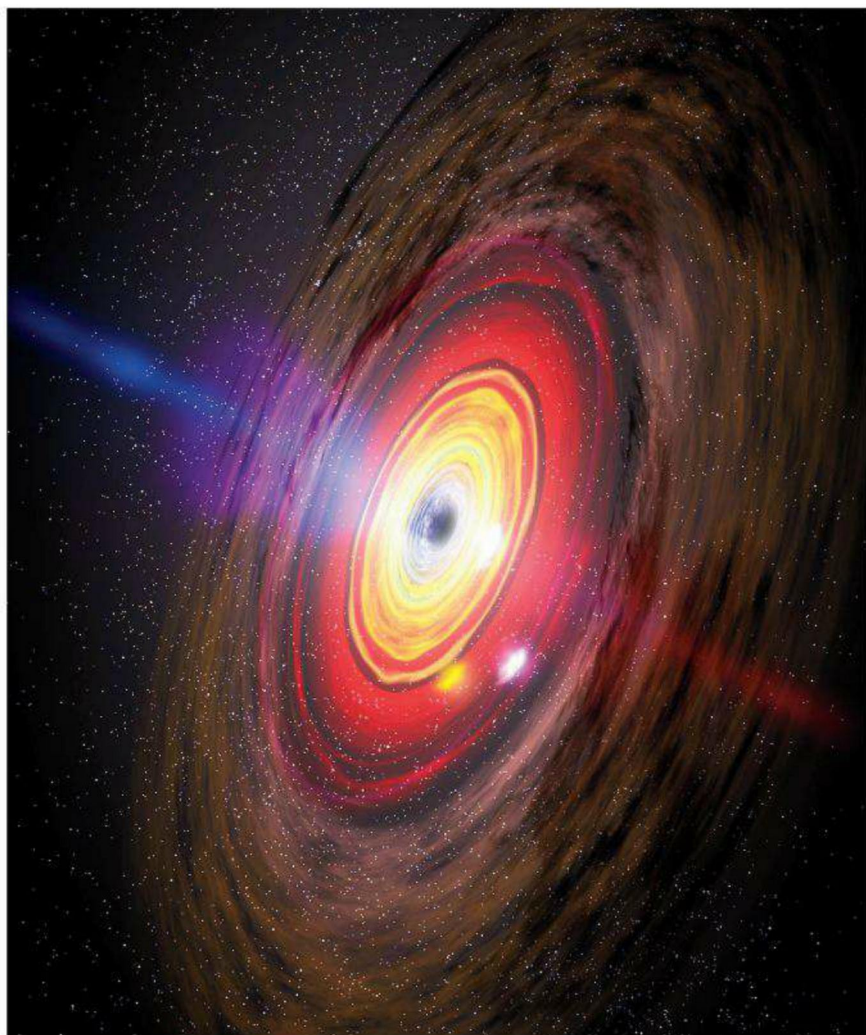
The 20th century thus ended with two April Fools from Mars. Howard Koch and Orson Welles had been one-upped.

Will a cosmic prank await us this month — our lives' only April Fools Day with a "13" year code? No way, right? ☹

Contact me about my strange universe by visiting <http://skymanbob.com>.



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BLACK HOLE BYLAWS. Astronomers have discovered that the jets streaming from stellar-mass black holes and supermassive black holes work according to the same rules, but further research is needed to determine what, exactly, those rules are. NASA/DANA BERRY (SKYWORX DIGITAL)

BLACK HOLES BIG AND SMALL HAVE SYMMETRICAL JETS

Jets emanating from black holes both supermassive and stellar-mass obey the same rules. While some black holes are remnants of stars, some are as massive as billions of stars. But when material falls onto either type, it forms a spiraling disk, and as the matter moves close to the black hole, some of it is accelerated into two polar, near-light-speed jets.

Supermassive black holes' jets emit gamma rays as long as they are gathering new material. Stellar-mass black holes, on the other hand, are a source of short-lived gamma-ray bursts (GRBs).

Scientists used NASA's Swift and Fermi gamma-ray telescopes to observe gamma

rays from 234 active galaxies — quasars and blazars — and 74 GRBs. When they compared the brightness of the gamma rays to the power of the accelerated particles, the ratio was the same whether the black hole was big or small, a result they report in the December 14 issue of *Science*.

The jets all use 3 to 15 percent of their kinetic energy to generate the bright radiation that scientists observe from Earth.

Says team member Markos Georganopoulos of the University of Maryland, Baltimore County, "It's a bit like a poor man and a billionaire spending the same percentage of their incomes on their heating bills." — **Sarah Scoles**

BRIEF CASE

THE MAGNETIC HIGHWAY

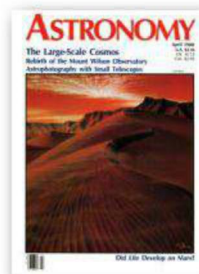
Voyager 1 is poised to leave our solar system, scientists from Johns Hopkins Applied Physics Laboratory say. It is now on the "magnetic highway," where the Sun's magnetic field connects to the interstellar field and particles flow both in and out of the solar system. Voyager's 35-year lifetime has so far resulted in unprecedented data about the solar system's outer reaches. — **S. S.**

THUNDEROUS GAMMA RAYS

NASA's Fermi telescope is 10 times more effective than it used to be at catching the terrestrial gamma-ray flashes (TGFs) that accompany lightning. Fermi is now alert constantly, rather than only on when a bright TGF triggers data collection, allowing scientists to find fainter flashes. The research team has seen 601 TGFs so far. Their results show that low-energy radio waves accompany the high-energy gamma rays, a paper forthcoming in the *Journal of Geophysical Research-Space Physics* will report. — **S. S.**

IRONING OUT IRON

X-ray observations of iron-16 in space are 30 percent dimmer than predicted, affecting the way scientists understand energetic phenomena like supernovae. Astronomers thought the discrepancy came from imperfections in computer models, but new experimental results from the Linac Coherent Light Source laser, published December 13 in *Nature*, show the problem, instead, is with the model of this atom itself. — **S. S.**



25 years ago in Astronomy

In April 1988, Stephen A. Gregory wrote about the universe's large-scale structure. Knowledge of groups of galaxy clusters (superclusters) and large spaces in between (voids) was only 10 years old, and Gregory described the technology and surveys making the discoveries possible.

"It seems that as we look to larger volumes of space we keep finding larger structures," Gregory said in "The Structure of the Visible Universe."

"Will we ever find an end to the tangle of superclusters and actually be able to say we are observing a 'fair sample' of the universe?"



10 years ago in Astronomy

In the April 2003 issue, Bob Berman took readers on a tour of Mauna Kea, Hawaii, a haven for telescopes since 1964. He showcased Keck Observatory, the Subaru Telescope, Gemini Observatory, and the Canada-France-Hawaii Telescope as well as the best images and discoveries from each.

The "staff, director, and volunteers" agreed that the best deep-sky object to see from the top of this volcano was globular cluster Omega Centauri. But Berman promised that "any time you make the pilgrimage, Mauna Kea will be waiting with something special." — **S. S.**



KAREN TERAMURA (ILLUSTRATION)/WEI-HAO WANG (PHOTOGRAPH)

TRIPLE THREAT. Two of the stars illustrated in this system are in a tight orbit, while the third is much farther away. Gravitational interactions likely kicked the third body to a distant part of the system, while the other two remain close together.

Wide binaries are, or were once, triplets

While some binary stars are so close that they touch, others have as much as a light-year between them. Astronomers have long wondered how binary stars could form as such widely separated pairs because the molecular clouds where stars are born are not big enough to support these initial separations. A December 13 *Nature* article solves the problem by showing that these apparent sibling stars are likely not twins but triplets.

Bo Reipurth of the Institute for Astronomy, University of Hawaii at

Manoa, and Seppo Mikkola of Tuorla Observatory, University of Turku, Finland, used computer simulations to track the evolution of star systems from formation to stable adulthood. Molecular cloud cores can collapse into one or multiple stars. The simulations showed that in the latter case, the gravitational interactions between the three stars fling the lightest one out of the core. The remaining star or stars are left to feast on the rest of the gas and continue to grow larger. The small star may return, only to be

thrown completely out or at least kicked very far away.

If the third member is distant but not gone and the two larger stars remain close, the system could look like a wide binary when it actually is a triple system. Astronomers have seen situations like this. However, sometimes there do seem to be only two stars. In these cases, the distant but connected stars must have formed in an unknown way, or the closely orbiting stars must have merged and become a single star. — **S. S.**

QUICK TAKES

NO SOIL SURPRISE

Scientists announced December 3 that the Curiosity rover had successfully analyzed its first soil sample and identified water, sulfur, and chlorine substances.

CITIZEN SCIENCE

The Andromeda Project, which began December 5, asks the public to search Hubble Space Telescope images for star clusters in M31's galactic disk.

LUNAR LIKENESS

Researchers from Washington State University announced November 28 that they had created small objects out of synthetic Moon rock material using a 3-D printer.

STILL CHUGGING

NASA's Mars Exploration Rover Opportunity has completed a counterclockwise route of the Matijevic Hill on the western edge of Endeavor Crater, scientists announced December 4.

SWIRLY SOLAR WIND

According to a November 9 paper in *Physical Review Letters*, the European Cluster satellites found turbulence in the solar wind with structure variations of just 12.4 miles (20 kilometers) — five times smaller than previously measured.

RADIOTELESKOP

The Square Kilometre Array (SKA) organization announced December 20 that Germany has joined the SKA radio telescope project. — **Liz Kruesi**

200,000,000

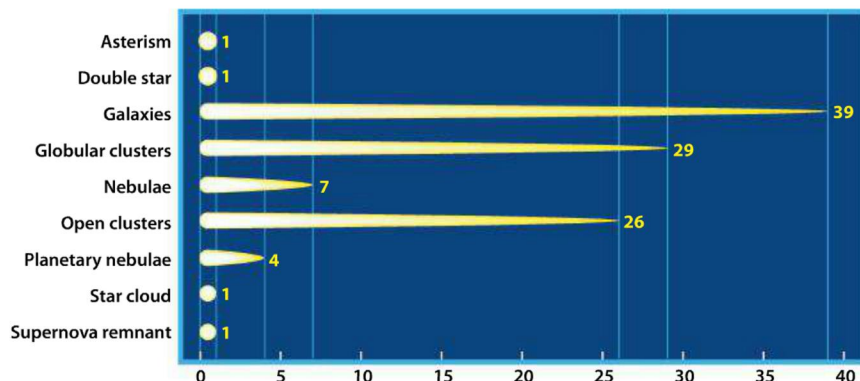
The number of years older that the star Vega might be than previously thought, according to a December 10 paper in *The Astrophysical Journal Letters*.

50

The number of years ago that NASA's Mariner 2 flew by Venus, marking the first successful planetary exploration mission by any country.

WHAT'S IN MESSIER'S CATALOG?

The constellation Sagittarius the Archer contains the most Messier objects — 15.



COMET CONFUSION. From 1758 to 1781, French comet hunter Charles Messier cataloged 109 deep-sky objects that were not comets. Today, his list is must-see observing for amateur astronomers. *ASTRONOMY*; MICHAEL E. BAKICH AND ROEN KELLY

FAST FACT



Do you know about Asterion?

This heavenly hound's stars may not be very bright, but the constellation has a shining history.

This month, I take you on a search for the most understated of all the official 88 constellations. Many of us have hunted popular deep-sky objects among its stars. I'm talking about Asterion, the northern animal of Canes Venatici the Hunting Dogs.

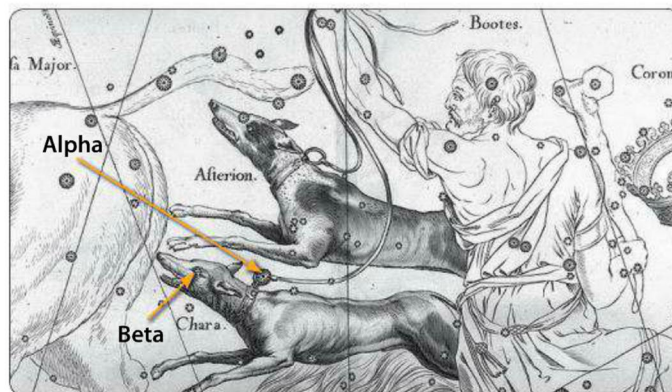
Polish astronomer Johannes Hevelius invented Canes Venatici in 1687 to honor the two hounds of Boötes the Herdsman, which he uses to drive Ursa Major the Great Bear away from his flock. To create the constellation, Hevelius used a scattering of stars "floating" between Boötes and Ursa Major. The southern hound he named Chara, the Greek word for "joy," and the northern one he called Asterion, meaning "little star."

Hevelius depicted the two dogs in his 1690 star atlas. Here, Chara alone contains the constellation's two brightest stars: 3rd-

magnitude Alpha (α) Canum Venaticorum, which marks the loop in Chara's collar, and 4th-magnitude Beta (β) Canum Venaticorum, which marks that dog's eye. Today, these are the two stars that most amateur astronomers recognize as Canes Venatici (CVn), but more on that later.

Stars of Asterion

Asterion's stars pale in comparison to Chara's, shining no brighter than 5th magnitude, making them a bear to see. The northern hound's brightest, 20 CVn, burns at lowly magnitude 4.7, yet it has a prominent rank within about a 1°-wide asterism of four 5th- to 6th-magnitude stars lying about 5° to the east-northeast of Alpha CVn (which is a gorgeous telescopic double). This asterism marks Asterion's right shoulder and is a guiding light to M63, a stunning Messier galaxy known as the Sunflower, just 1½° to the north-northwest.



In Johannes Hevelius' original 1690 drawing of Canes Venatici, Asterion contains only dim objects, while Chara contains the two brightest stars in the constellation. JOHANNES HEVELIUS

Asterion's next brightest star, 21 CVn, marks the back of the dog's snout. It shines at magnitude 5.1 and lies only about 3° north-northwest of another extragalactic dynamo: the famous Whirlpool Galaxy (M51), which tickles one of Asterion's ears.

Asterion's northern leg also contains the variable star Y CVn, one of the coolest, reddest stars visible without optical aid. Known as "La Superba," it varies from about magnitude 5.2 to 6.6 over 158 days.

While Asterion contains only these faint treasures, at one time during the hounds' history, astronomers considered bright Beta CVn to be part of Asterion.

Confusion sets in

In 1725, English astronomer Edmond Halley officially bestowed upon Alpha CVn the name "Cor Caroli," which honors King Charles I of England and means "Charles' heart." When King Charles II (yes, that King Charles II) returned to London at the Restoration of the Monarchy in 1660, Alpha CVn was said to have blazed with uncommon brilliancy. While this is an interesting story, there is no relation between the name of the star and the celestial dog in which it lies.

England's first Astronomer Royal, John Flamsteed, did not include that new moniker in his 1729 *Atlas Coelestis*. He did, however, reposition Asterion further to the north, so that its body no longer hugged its com-

panion, creating space for future renderings of Cor Caroli, like the one in Johann Bode's 1801 *Uranographia Sive Astrorum Descriptio*: an image of Charles' heart capped with a crown. In an attempt to link the politics to the dogs, Bode placed the heart at the top of Chara's collar, where it connected to the leash that Boötes held.

And this is how matters more or less stood until the 1950 *Skalnate Pleso Atlas of the Heavens* came on the scene. Its creator, Czech astronomer Antonín Becvar, assigned Alpha CVn to Chara and Beta CVn to Asterion and connected the two stars with a leash. Now, many beginning observers learn to identify the two hounds based on Becvar's image. While this notion erases a fascinating history, it at least makes sense: It associates the "little" star, Beta CVn, with Asterion, and the more "joyous" star, Alpha, with Chara, who wears the king's heart collar.

But that's just not how it is on many modern atlases, and not how it was when Hevelius first depicted the dogs. Alpha still remains Cor Caroli; Beta, however, is no longer Asterion, but Chara. Asterion has vanished from the scene — a faded memory of a dog that once guided backyard astronomers to deep-sky riches. Asterion's region has, once again, become a large and lonely void. Without your careful eye, Hevelius' original artistry may be forgotten.

As always, send thoughts to someara@interpac.net. ☾

FROM OUR INBOX

Stargazing au naturel

The other night, when I stepped out of the shower, I heard the weak whine of water still running in the pipes. I had forgotten to turn off the water sprinkler in the backyard, so I dashed out the back door into the dark to shut off the nearby spigot. Then, I looked up into the sky, and the display of stars was absolutely awesome — and I was au naturel.

It was a surprisingly beautiful, even spiritual, experience. I felt connected with man of thousands of years ago, just the stars and me. I reached my arms up to the stars and thought, "Yes, we are one."

(Please do not print my name. I don't want my stargazing buddies to trivialize my experience with their jokes.) — S. P., near Los Angeles



COMING UP IN OUR NEXT ISSUE

HOW LIFE SURVIVED A COOL EARLY SUN

The Sun was barely two-thirds as bright in its youth as it is today. So how did Earth's surface stay warm enough for liquid water to exist and life to emerge?

NASA/SDO/AIA

Why the universe has no center

Our cosmology experts clarify complex concepts

Astronomy: Reem Kelly

The science behind UFOs

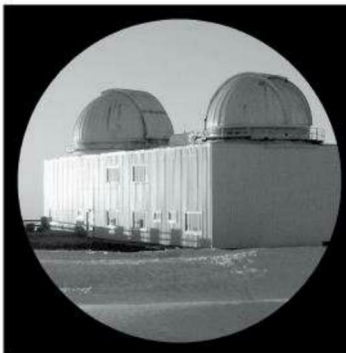
Even the strangest sightings have astronomical or technological explanations

PLUS

- ▶ Target Hubble's galaxy classes
- ▶ Dennis Mammana's cosmic portraits
- ▶ How to choose the right binoculars
- ▶ Explore 10 spring binocular gems
- ▶ Astronomy tests the Telescope Drive Master

Astronomy

magazine



FOCUS ON

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WHAT DEVELOPMENTS HAVE SCIENTISTS MADE IN EXOPLANET IMAGING?

In the past two decades, our knowledge of exoplanets has improved by leaps and bounds, with more than 850 confirmed detections to date. This has been an extraordinary advance, but the vast majority of these discoveries have been made by indirect methods, with only a tiny fraction of exoplanets having been directly imaged. The reason for the lack of direct observing successes is that a star is so much brighter than a planet, often by a factor of a billion. It is the equivalent of trying to distinguish a firefly looping around a light-house at night.

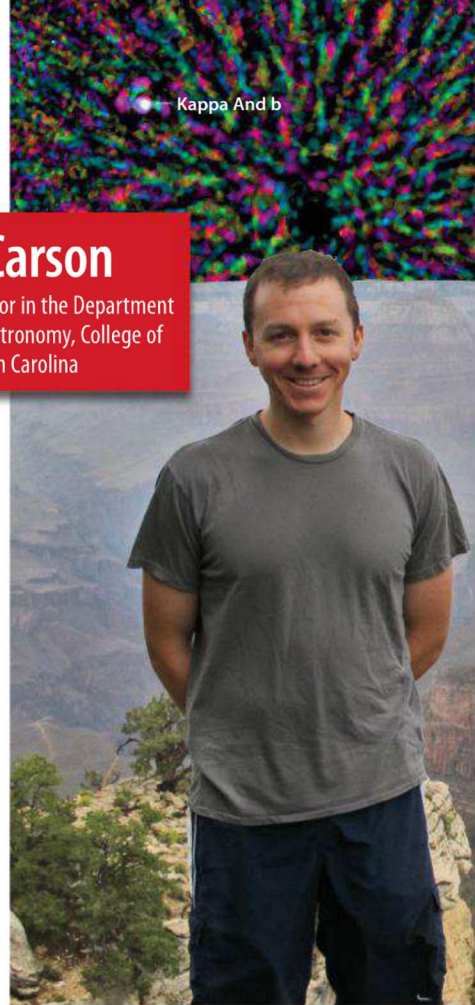
The majority of exoplanet imaging searches are carried out from ground-based scopes. As part of the Strategic Explorations of Exoplanets and Disks with Subaru survey (using the Subaru Telescope in Hawaii), for example, my colleagues and I announced this past year the direct-imaging discovery of a “super-Jupiter” around the massive star Kappa Andromedae (called Kappa And b). The newly imaged exoplanet’s orbit extends out to twice that of

Neptune. The host star is about 2.5 times as massive as the Sun, making it the most massive star ever known to harbor an exoplanet at a solar-system-like orbit. A system like this is so interesting because it is the first of its kind to show strong evidence that stars this massive seem to be fully capable of forming planet systems.

Direct imaging of exoplanets will continue to be important because this technique also offers more powerful opportunities for detailed follow-up measurements. For example, by analyzing the spectrum of light from a directly imaged exoplanet, scientists may uncover a treasure-trove of information on the exoplanet’s atmosphere. While scientists have so far only achieved this for a limited number of gas-giant exoplanets, they expect to eventually use this technique to probe for biosignatures on Earth-like planets. This would include measurements of atmospheric gases that might reveal the presence of life on the surface below.

Joseph Carson

Assistant professor in the Department of Physics and Astronomy, College of Charleston, South Carolina



COURTESY JOSEPH CARSON (PORTRAIT); NOAA/SUBARU; CARSON (COLLEGE OF CHARLESTON) (KAPPA AND B)

ASTRONOMERS

BAR STARS. Astronomers using the Sloan Digital Sky Survey announced December 19 that they have identified hundreds of stars that have long, looping orbits around the Milky Way’s center and are likely part of the galaxy’s bar.



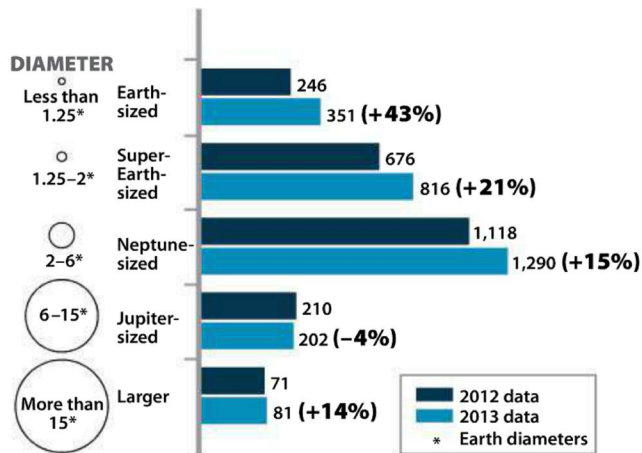
The glow of the Americas’ cities

NIGHT LIGHTS. The Suomi NPP satellite detects light on Earth with wavelengths that range from green to near-infrared. Scientists then removed radiation that results from aurorae, fires, and other stray light to emphasize our planet’s artificial city lights. This composite incorporates data from April and October 2012, and clearly shows where societies cluster in the Americas. NASA’s Earth Observatory released this image November 28. — **L. K.** NASA EARTH OBSERVATORY AND NOAA NATIONAL GEOPHYSICAL DATA CENTER

FAST FACT

The number of planetary systems also has increased in the latest Kepler results. Some 43 percent of all the candidates now appear to have at least one neighbor.

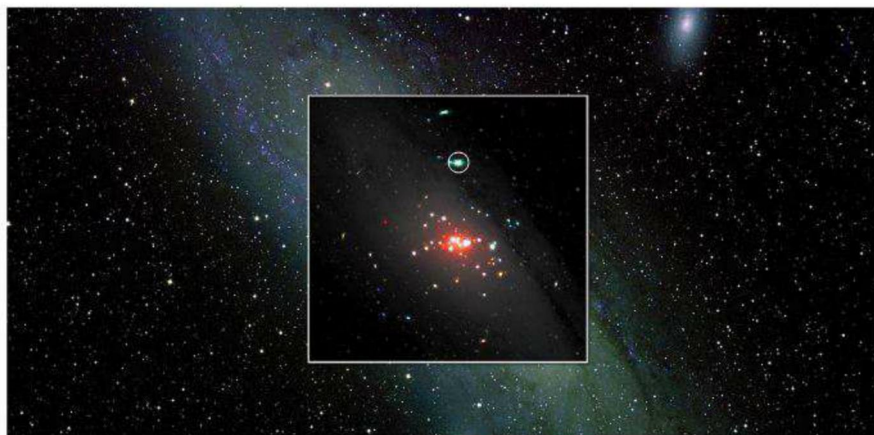
PLENTY MORE PLANET CANDIDATES



PLANETS GALORE. Scientists announced in early January the latest results from the Kepler mission searching for planets around other stars. The number of candidates now totals 2,740. (Astronomers require follow-up observations to confirm a planet.) That’s a 20 percent jump in the past 11 months, with the biggest rise coming from the smallest candidates. (The percentages don’t always add up because some earlier candidates were confirmed or rejected.) *ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY, AFTER NASA*

ASTRON^{NEWS}

AUSSIE ARRAY. The Murchison Widefield Array in Western Australia, completed November 30, will help monitor solar storms.



EXTRAGALACTIC X-RAYS. Astronomers have discovered the first microquasar outside the Milky Way, in the nearby Andromeda Galaxy. This bingeing black hole (circled) shows up in X-rays in this composite image.

B. SCHOENING, V. HARVEY/REU PROGRAM/NOAO/AURA/NSF (BACKGROUND); ESA/M. MIDDLETON, ET AL. (INSET)

Scientists discover bingeing stellar-mass black hole

In January 2012, astronomers witnessed a new ultraluminous X-ray source (ULX) flare and rapidly brighten in the nearby Andromeda Galaxy (M31) — only the second such object ever seen in M31. The event sent scientists off on an observation campaign using space- and ground-based telescopes to understand the cause of this outburst. Based on the data, astronomers report in the January 10 *Nature* that this ULX represents a stellar-mass black hole producing massive outflows of radio

waves, known as a microquasar — the first to be detected beyond our galaxy.

When a black hole begins feeding on gas, it compresses and heats the material to a point where the gas emits X-rays, causing astronomers to observe the black hole as a ULX. But researchers were unsure whether these sources indicated stellar-mass black holes bingeing on gas or more-massive singularities accreting material at a more sedate rate. "The discovery of the [radio] jets tells us that this particular ULX is a typical stellar remnant about 10 times the mass of the Sun, swallowing as much material as it possibly can," says lead author Matthew Middleton from the Anton Pannekoek Astronomical Institute in Amsterdam. "We may well find jets in ULXs with similar X-ray properties in other nearby galaxies, which will help us better understand the nature of these incredible outflows." — **Karri Ferron**

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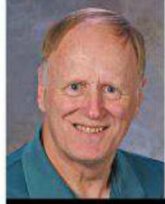
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OBSERVING BASICS

BY GLENN CHAPLE

Explore the Virgo cluster

The northern part of the Maiden's constellation is home to hundreds of galaxies.

Last month, we starhopped around the constellation Leo and explored some of the Lion's most prominent galaxies. This time, we test our galaxy-hunting skills with a plunge into the heart of the Virgo galaxy cluster, some 55 million light-years away. If you consult a star atlas, you'll see that this part of the sky contains an insane number of galaxies — hundreds of them! How can we possibly find our way through this galactic clutter?

If you're a small-scope user, you'll have an advantage over the folks who ply the skies with cannon-sized Dobbs. Small-aperture telescopes will capture only the brightest members of the Virgo cluster, greatly reducing the confusion. To further simplify things, we'll limit our galaxy cluster excursion to the northern part of Virgo the

Maiden and the eight Messier galaxies found here.

Our departure point is the magnitude 4.9 star Rho (ρ) Virginis. While some opt to launch from Vindemiatrix (Epsilon [ε] Virginis) and move westward, I prefer a northerly path from Rho. A trio of stars surrounding Rho forms a northwest-pointing arrowhead $\frac{3}{4}^\circ$ across that makes field orientation and size easy to determine. This is a big plus because I'll refer to directions and angular distances in degrees during our star-hop.

The chart on this page will serve as a guide. If you use a refractor or catadioptric scope with a star diagonal, make a reverse tracing of the chart to match the mirror image these instruments produce. As with any star-hop, start with an eyepiece that yields at least a 1° field, preferably 2° .

After centering Rho in the eyepiece field, move about $1\frac{1}{2}^\circ$ north. You should come across a pair of nebulous spots $\frac{1}{2}^\circ$ apart. These are the elliptical galaxies **M59** and **M60**. M59 is the more westerly of the pair — the one that exits first when you keep your scope still and allow them to drift out of the eyepiece field. Trace a line from M60 through M59 and extend it about twice that distance, and you'll come to the barred spiral **M58**.

Once you've identified the three 9th- to 10th-magnitude galaxies, carefully study each with higher magnification. Which seems brightest? Faintest? What is the shape of each? Can

you detect any concentration, or is the light uniformly distributed? When you've given M58, M59, and M60 a good look-over, it's time to move on to the next leg of our journey.

By following a trail of stars less than a degree northwest of M58, you'll arrive at the 10th-magnitude elliptical galaxy **M89**. An almost equal push north and slightly east of M89 brings you to the spiral **M90** — also around 10th magnitude. Return to M89 and move a little more than a degree westward. What looks like a defocused 9th-magnitude star is the giant elliptical galaxy **M87**.

While unimpressive to the eye, M87 is a true monster. The dominant member of the Virgo cluster, it contains the mass of 2 to 3 trillion Suns. In the heart of the beast is a 6- to 7-billion-solar-mass black hole that belches a plasma jet thousands of light-years into space. M87 is anything but unimpressive!

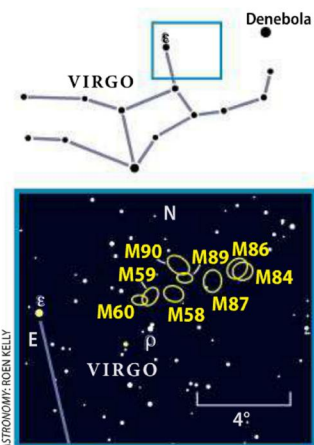
The final leg of our journey takes us on a $1\frac{1}{2}^\circ$ hop (more of a jump) to our last two Messier galaxies. From M87, move west and slightly north until you encounter two smudges separated by $\frac{1}{3}^\circ$. These are the 9th-

magnitude elliptical galaxies **M84** and **M86**. They are the brightest members of a remarkable $1\frac{1}{2}^\circ$ -long arc of galaxies known as Markarian's Chain, named after the Armenian astrophysicist Benjamin Markarian, who discovered their common motion in the early 1960s. Most of the remaining galaxies in the chain are too faint for small-aperture scopes under typical suburban skies. Ask your friend with the cannon-sized Dob to show you the others.

While alternating glances between eyepiece and chart, you may get lost. Don't despair. Just return to Rho and begin anew. Each successive journey will proceed more smoothly as you gain familiarity with the path.

The Virgo galaxy cluster is one of two sky regions I find most challenging to navigate — the other being the tangle of star clusters and nebulae in the Scutum/Sagittarius portion of the Milky Way. We'll tackle this maze of deep-sky treasures in September when it lies above the southern horizon after sunset.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: UFOs. Clear skies! ☾



The Virgo cluster provides eight Messier galaxies to target in the northern part of the Maiden's constellation.

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. by Sarah Scoles

Cold as space				Supernova hot
Vomit comet	Museum killing	Active learning	Cold case	
				
On March 15, Europe's zero-G Airbus goes commercial. For only \$7,700, you can have the privilege of experiencing both weightlessness and nausea in a padded room with 39 other people. And it will be awesome.	"Spidernaut" Nefertiti, who spent 100 days aboard the ISS, died less than a week after entering an insect zoo. Gone but not forgotten, Nefertiti answered the questions we've all been asking: Can spiders feed in space, and is it still creepy? (Yes.)	Students dubious of the truism, "In space no one can hear you scream," sent a voice recorder and a smartphone — loaded with 10 videos of shrieking people — into orbit. The results of the study will be published in <i>Alien V</i> .	Johannes Kepler was cleared as a suspect in the potential poisoning of his mentor, Tycho Brahe, after scientists found no mercury in samples of Brahe's 412-year-old beard and bones. With this crime cleared up, you'll finally be able to sleep at night.	

NASA (VOMIT COMET); SMITHSONIAN (MUSEUM KILLING); WEBMUSEUM (ACTIVE LEARNING); BRITANNICA (COLD CASE)

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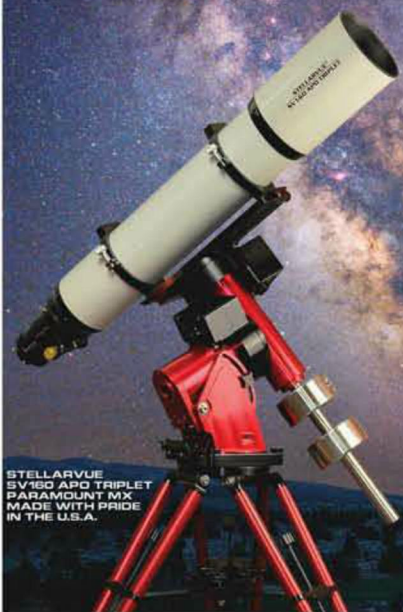
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MIDDLE-AGED GLOB. M53 is one of 20 globular clusters astronomers studied to find that they evolve at different rates and split into three age groups. ESA/HUBBLE & NASA

Globular clusters and their evolution

Although globular clusters — collections of hundreds of thousands of stars — are all similar ages, they evolve differently. To research this evolution, astronomers studied “blue straggler” stars in 20 globulars.

A blue straggler does not form with its cluster, but instead results from two older and smaller stars merging and regenerating stellar material. Because the

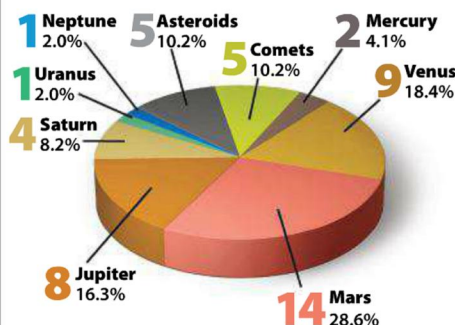
distribution of blue stragglers within a cluster depends on how condensed it is, astronomers can use these stars to learn about the globular's structure. Some globular clusters have condensed cores while others are diffuse.

In its December 20 letter to *Nature*, the team reports that these clusters group into three distinct evolutionary families. — L. K.

Within 3.5 years, the Juno probe will arrive at Jupiter and the New Horizons craft will reach Pluto.

FAST FACT

HOW MANY NASA CRAFT HAVE VISITED THESE WORLDS?



PLANETARY PROBES. NASA has launched many spacecraft to explore the planets — and also comets and asteroids — in the solar system. Some even studied objects in addition to their destinations during flybys. This chart shows how the exploration targets compare. ASTRONOMY: LIZ KRUESI AND ROEN KELLY

SPACE SCIENCE UPDATE

GRAIL MAPS MOON'S INTERIOR IN DETAIL

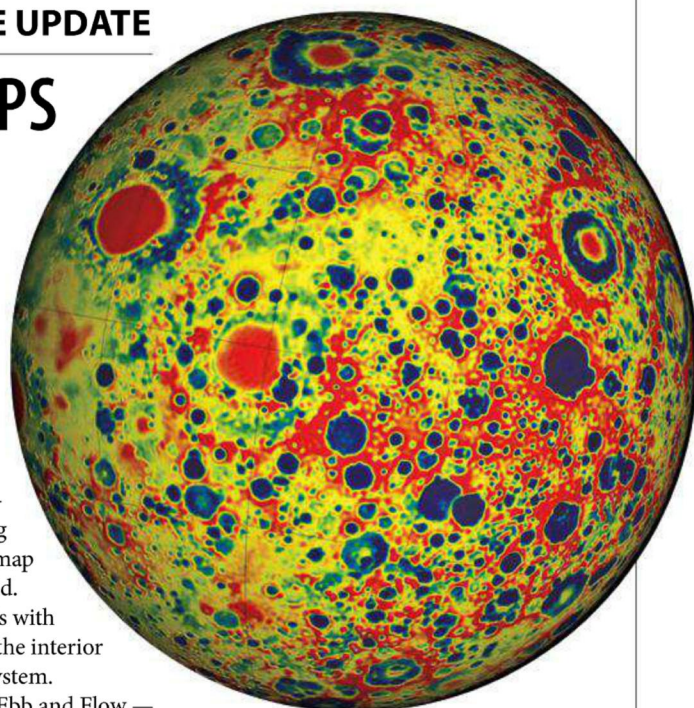
The twin spacecraft of NASA's Gravity Recovery and Interior Laboratory (GRAIL) slammed into the Moon on December 17 as planned, capping a four-month mission to map the lunar gravitational field. The data provide scientists with the most detailed map of the interior of any body in the solar system.

The GRAIL probes — Ebb and Flow — launched from Cape Canaveral Air Force Station in Florida on September 10, 2011, and entered lunar orbit December 31, 2011, and January 1, 2012, respectively. After 27 maneuvers to make their orbits nearly circular, they began their primary science mission March 6.

As Flow followed Ebb around the Moon at an altitude ranging from 15 to 53 miles (24 to 86 kilometers), the spacecraft precisely monitored the distance between each other via microwave signals. When Ebb flew over a spot with extra mass — like the rim of a crater — it would be pulled slightly toward the lunar surface. Flow would detect this distance change to a precision of 20 to 50 nanometers, even though the crafts were traveling at about 3,600 mph (5,800 km/h).

Scientists then converted these distance differences into a map showing the Moon's gravitational pull, which tells them about the features on the lunar surface and masses hidden below. The GRAIL data show features as small as 8 miles (13km) across and many never before seen in detail, such as crater central peaks, tectonic structures, volcanic landforms, and basin rings. Scientists also discovered that impacts left the lunar surface with fractures that may reach the Moon's mantle.

This gravity map illustrates the history of lunar impacts. Such information can help planetary scientists learn more about the Moon's evolution — told by its interior — which also provides a better understanding



MASS MAP. The Gravity Recovery and Interior Laboratory (GRAIL) probes monitored gravity changes as they orbited the Moon. The mission produced this map of the lunar mass and the most detailed study of the interior density of any solar system body. Red corresponds to excess mass, blue to less. NASA/JPL-CALTECH/MIT/GSFC

of how the solar system's rocky planets developed into those observed today.

The lunar density allowed researchers to “find that the average thickness of the Moon's crust is between 21 and 27 miles [34 and 43km], which is about 6 to 12 miles [10 to 20km] thinner than previously thought,” says Mark Wieczorek of the Institut de Physique du Globe de Paris.

Scientists found another surprise in the GRAIL map. “This data revealed a population of long, linear gravity anomalies, with lengths of hundreds of kilometers, crisscrossing the surface,” says Jeff Andrews-Hanna of the Colorado School of Mines in Golden. These structures “indicate the presence of dikes, or thin, long, vertical bodies of solidified magma in the subsurface.” Such features confirm that the Moon expanded during its first billion years.

These results are from GRAIL's primary mission, which ended May 30. Team members then dropped the probes to an average altitude of just 14 miles (22km) above the lunar surface to begin an extended mission August 30. As the spacecraft fuel ran low, GRAIL undertook a controlled crash landing into the Moon.

The primary mission's results appeared online December 5 in *Science Express*. — L. K.

Hubble telescope takes census

Scientists used the Hubble Space Telescope to look more deeply into the universe than ever before, obtaining an image of part of the universe as it looked 300 to 600 million years after the Big Bang. The first results from the analysis are forthcoming in *The Astrophysical Journal Letters*. The project, called Hubble Ultra Deep Field 2012, aims to take a census of galaxies and determine how their number has changed over the universe's history.

Researchers found that as they look farther away and thus further back in time, the number of galaxies decreases smoothly, meaning that they likely formed continuously. Still, their ancient abundance and energy may have been sufficient to heat the earliest hydrogen. Formed after the Big Bang, the cool neutral hydrogen gas transformed into a hot ionized plasma during the "epoch of reionization," perhaps because of galaxies like these. The data show reionization was a gradual process, spanning hundreds of millions of years.

Hubble scientists uncovered seven previously unseen galaxies more than 13 billion light-years from Earth and may have found the oldest known galaxy, shining only 380 million years after the Big Bang. — S. S.



FAMILY PHOTO. The Hubble Ultra Deep Field 2012 image shows the oldest galaxies yet found. The new census is the most robust count at this early epoch and reveals seven previously undiscovered galaxies as they appeared when the universe was 4 percent of its current age. NASA/ESA/R. ELLIS (CALTECH)/UDF 2012

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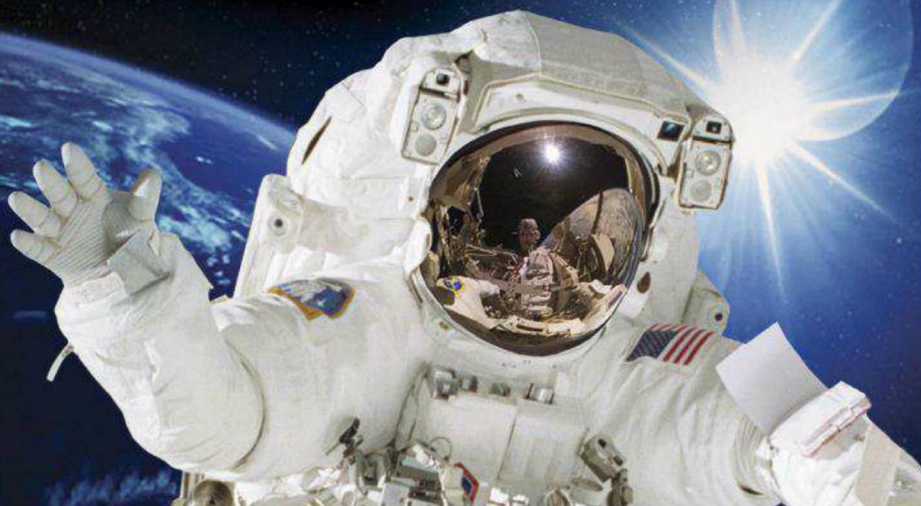
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Lack of heavy elements in quasar suggests star formation just beginning

The most distant quasar known, ULAS J1120+0641, contains no heavy elements, according to a paper published in *Nature* on December 6. The active galaxy is 13.3 billion light-years from Earth, and the light that reaches our planet shows a picture of the universe as it was some 700 million years after the Big Bang. According to the evidence, ULAS J1120 is made almost entirely of hydrogen that has not yet become stars.

Every element and molecule has its own light signature, or "spectrum," and when scientists see a particular chemical spectrum in space, they know that the element or molecule must be present.

Researchers analyzed ULAS J1120's light for the signatures of elements heavier than hydrogen, helium, and lithium. While the lightest elements formed soon after the Big Bang, heavier species



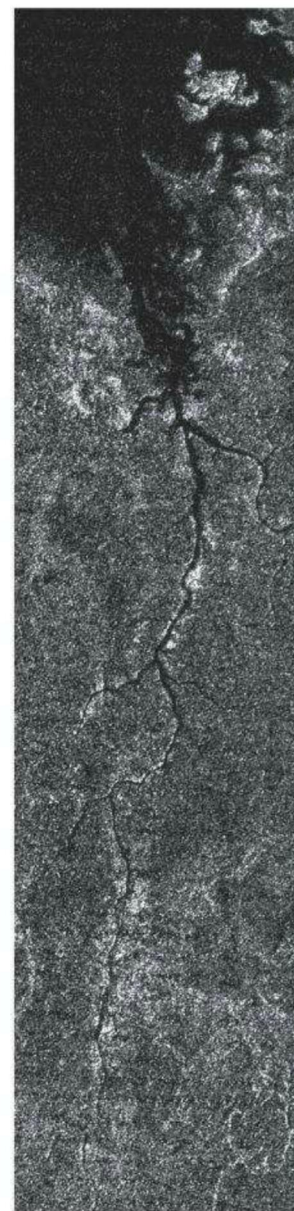
ANCIENT ACTIVITY. ULAS J1120, a quasar like the one illustrated here, contains only the lightest elements, proving that while gravity and dark matter have shaped its gas into a galaxy, that gas has not coalesced into stars. ESO/M. KORNMESSER

had to form via fusion in stars and supernovae. By looking for the spectral signatures of heavy elements in the earliest galaxies, scientists can determine whether stars were fusing elements at this point in the universe's evolution.

This particular quasar, discovered in August 2011, is so far away and dim that the researchers built a new instrument to study it. They attached their infrared spectrometer to the 6.5-meter Magellan Telescope in the Atacama region of Chile and looked for elemental evidence that there were stars in this galaxy. They found none.

"[The birth of the first stars] is one of these important moments in the history of the universe," says lead author Robert Simcoe of MIT. "It went from looking like the early universe, which was just gas and dark matter, to looking like it does today, where there are stars and galaxies. ... It's the point when the universe started to resemble what it looks like today. And it's sort of amazing how early that happens. It didn't take long."

This is the first time astronomers have seen a galaxy so young that its gas has not yet collapsed into stars. — S. S.



NASA/JPL-CALTECH/ASI

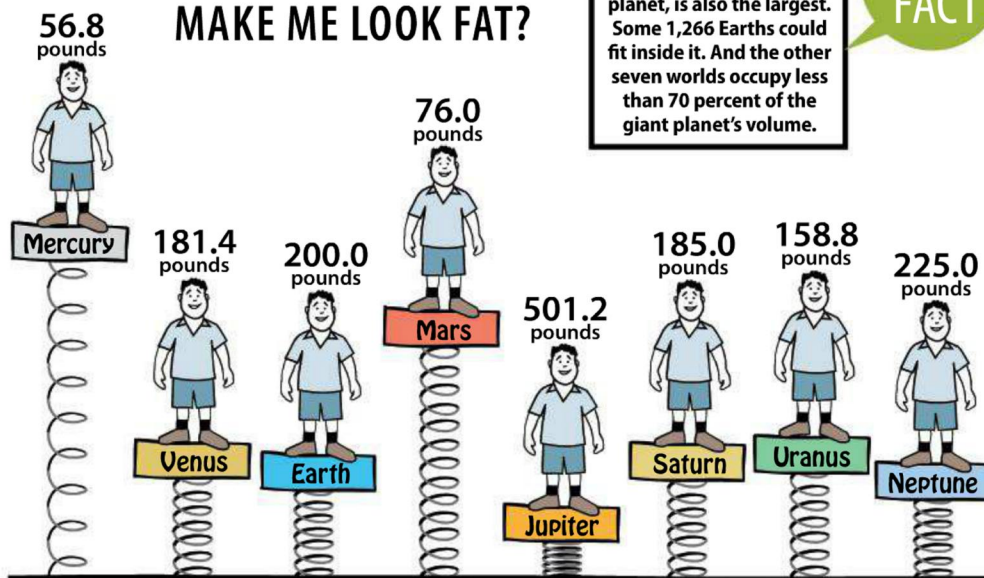
Cassini spies mini Nile

TITANIAN RIVER. NASA's Cassini spacecraft has captured the first high-resolution radar image of a vast river system on any world other than Earth. On September 26, the mission, which has been studying the Saturn system since 2004, spied a river valley on the moon Titan that spans more than 240 miles (400 kilometers) from its "headwaters" to a large sea known as Ligeia Mare. This area at the moon's north polar region looks like a smaller version of Earth's Nile River valley, except this river likely is filled with liquid hydrocarbons such as ethane and methane. Titan is the only world beyond ours where scientists have found moving liquid. — K. F.

DOES THIS PLANET MAKE ME LOOK FAT?

FAST FACT

Jupiter, the most massive planet, is also the largest. Some 1,266 Earths could fit inside it. And the other seven worlds occupy less than 70 percent of the giant planet's volume.

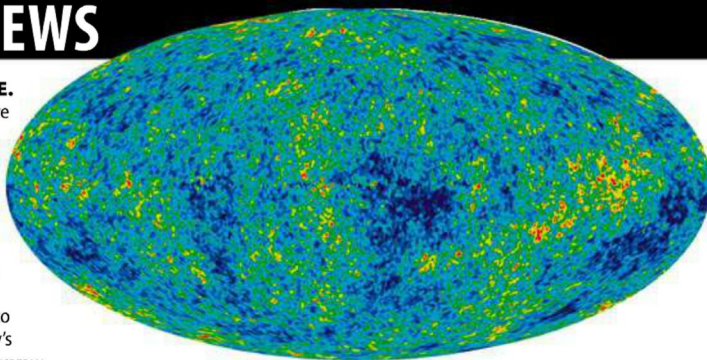


FEAST OR STARVE? The eight planets of our solar system do not all have the same masses. Because they differ, a 200-pound person would weigh different amounts on each of them (and might want to eat accordingly). ASTRONOMY: MICHAEL E. BAKICH AND ROEN KELLY

ASTRONNEWS

INFANT UNIVERSE.

The cosmic microwave background shows structure from just 375,000 years after the universe began. This map illustrates temperature differences of smaller than $1/10^{10000}$. Those slight variations evolved into the structure in today's universe. NASA/WMAP SCIENCE TEAM



WMAP TEAM RELEASES FINAL DATA

Scientists with NASA's Wilkinson Microwave Anisotropy Probe (WMAP) released the project's nine-year — and final — results December 20. WMAP studied the residual radiation from an era in cosmic history when electrons and atomic nuclei combined. Light photons could then stream free — those photons are now seen in the microwave portion of the electromagnetic spectrum and make up what scientists call the cosmic microwave background (CMB). This radiation glows at just an almost-constant 2.725° above absolute zero, with temperature differences of a few hundred-thousandths.

From the probe's study of the CMB, cosmologists have been able to refine many parameters of the universe. The nine-year results give the universe's age as 13.772 billion years old and

the time when photons streamed free from atoms at 375,000 years after the universe began. The WMAP team also pinned down the percentages of cosmic composition: 4.6 percent is normal (or "baryonic") matter, 24.0 percent is mysterious dark matter, and 71.4 percent is the even more mysterious "dark energy."

The team says the data also support the idea that just moments after the universe began, it experienced a period of hyperacceleration, known as inflation.

WMAP launched in 2001 to map the sky from a gravitationally stable region behind Earth from the Sun's viewpoint — called L2. The craft needed to remain in shadow to study the cold microwave radiation. The observatory stopped collecting data in 2010. — L. K.

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SKYFI

The impending birth of our supergalaxy

The Andromeda Galaxy is on a collision course with the Milky Way. What effects will this cosmic crash have on future astronomers? **by Ray Villard**

The proverb that claims “nothing is certain but death and taxes” can now be recast for the cosmos.

The approaching collision between the Andromeda Galaxy (M31) and the Milky Way is the only major astronomical event affecting our entire galaxy that scientists can predict with absolute certainty. These two heavy-weight “island universes,” each having more than 1 trillion times the Sun’s

mass, are destined to slam into each other like a pair of sumo wrestlers.

The Milky Way’s smashup with Andromeda won’t happen for 4 billion years and will drag out over another billion years, culminating in a mature elliptical galaxy 7 billion years from now. Long before this scenario plays out, Earth will have become uninhabitable. The Sun’s increasing luminosity will make our planet unlivable within the next billion years or so. Our distant descendants will have to migrate elsewhere in the solar system or colonize another star system to watch these galaxy-collision fireworks unfold.

Although it’s possible that the Sun will collide with another star during this encounter, the chances are almost infinitesimal. The typical gaps between stars are far greater than stellar diameters, so the probability of a collision is akin to two bullets hitting each other during a duel between gunslingers a mile or more apart.

As glacial as the galaxy collision will be, it will change radically what far-future astronomers — human and alien alike — will see in the sky. At Andromeda’s closest approach, emission nebulae and brilliant star clusters will scatter across the celestial sphere

Ray Villard is news director for the Space Telescope Science Institute in Baltimore.

RE

Two great island universes — the Andromeda and Milky Way galaxies — begin to merge a few billion years from now. Earth in the far future shows no signs of the life that once spread across its surface.

DON DIXON FOR ASTRONOMY

from horizon to horizon. Burgeoning astronomers might develop a quick understanding of stellar evolution, but this would come at the cost of difficulty making cosmological observations in the cluttered sky.

Incoming!

For much of human history, the Andromeda Galaxy has enticed stargazers. To naked eyes, it appears as a curious cigar-shaped object larger than the Full Moon. This elongated glow lies in the constellation Andromeda the Princess, to the northeast of the neighboring Great

Square of Pegasus. Persian astronomer Abd al-Rahman al-Sufi first recorded the galaxy in A.D. 964, calling it a “small cloud” in his *Book of Fixed Stars*. In 1764, French astronomer Charles Messier designated it the 31st entry in his catalog of objects that looked like comets but were not.

When 19th-century photographs revealed M31’s spiral structure, most astronomers assumed it to be a nearby whirlpool of dust and gas surrounding a newborn star. Little did they realize that the so-called Andromeda Nebula was actually an immense island universe of stars even

larger than the Milky Way, which most scientists at that time thought encompassed the entire cosmos.

In 1912, Vesto Slipher of Lowell Observatory in Flagstaff, Arizona, first measured M31’s velocity with respect to our solar system. Although Slipher had no clue about its true galactic identity, he concluded that it is moving toward the Sun at approximately 670,000 mph (1,080,000 km/h). That’s fast enough to travel from Earth to the Moon in 20 minutes. Slipher determined this radial velocity using the Doppler effect, which is the change in the wavelength

The Milky Way and Andromeda merger (early years)



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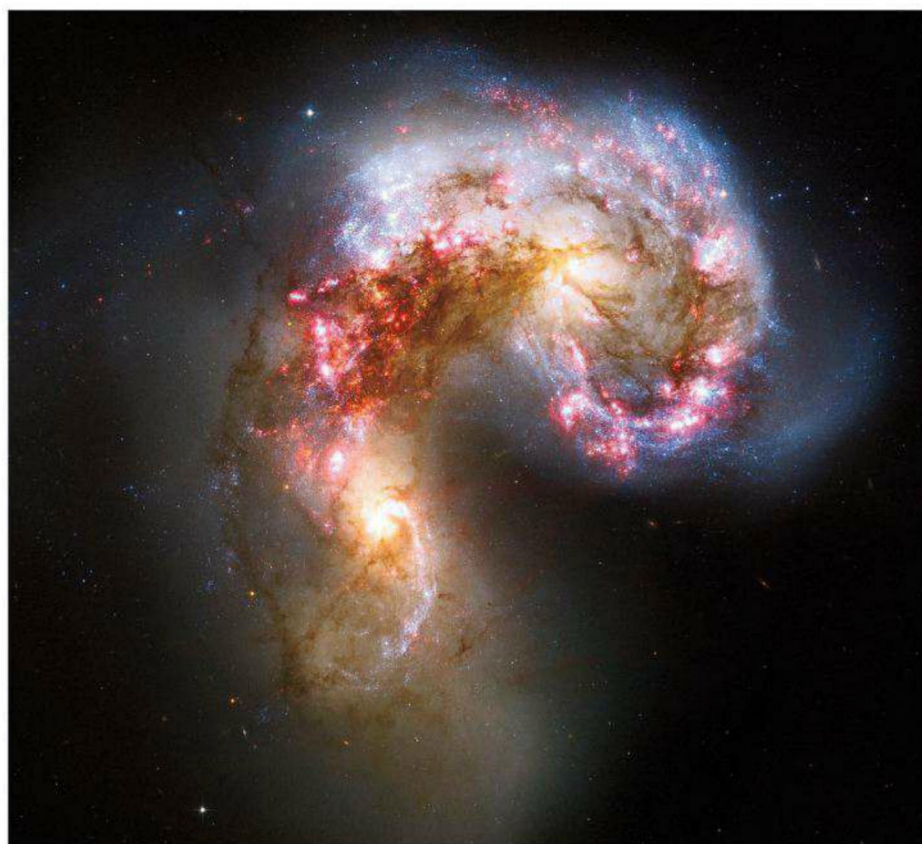
The bright band of the Milky Way dominates the current nighttime sky. The Andromeda Galaxy appears as a faint spindle a few times the Full Moon's diameter from 2.5 million light-years away.

ALL ILLUSTRATIONS ALONG THE TOP OF THE NEXT FOUR PAGES BY NASA/ESA/Z. LEVAY AND R. VAN DER MAREL (STScI)/T. HALLAS/A. MELLINGER



2 BILLION YEARS

After heading straight at us for a couple of billion years, the Andromeda Galaxy looms much larger in our sky. The two galaxies, however, have yet to exert a noticeable influence on each other.



The Antennae Galaxies (NGC 4038-9) in Corvus hint at what lies in store for the Milky Way and Andromeda galaxies. The two large spirals of the Antennae started to interact a few hundred million years ago, sparking a firestorm of star formation. NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

of light produced by a source moving toward or away from an observer.

In 1923, American astronomer Edwin Hubble uncovered a bright pulsating star in M31 that served as a milepost marker. The intrinsic brightness of this type of star, called a Cepheid variable, is linked directly to its period of pulsation. By comparing the star's apparent brightness to its intrinsic brightness derived from the period, Hubble

calculated M31's distance. He found that it lies far beyond the Milky Way's most distant stars, proving that the Andromeda Nebula is actually an island of billions of stars entirely separate from our home galaxy.

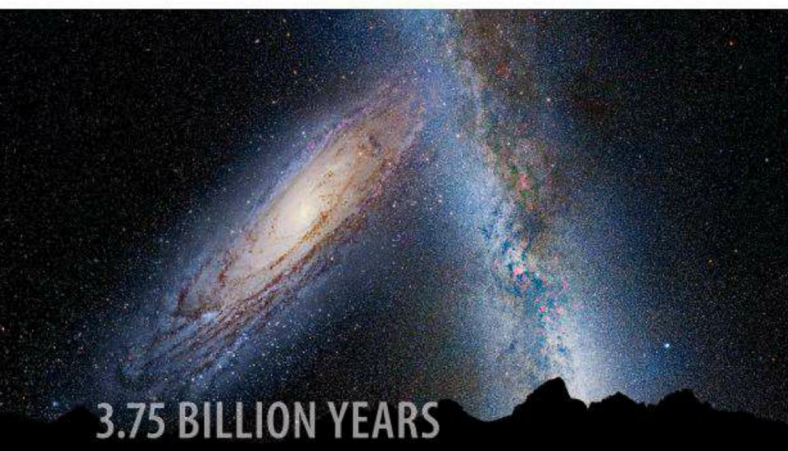
Although astronomers have known for a century that M31 is getting closer to us, no one knew if it was heading straight for us or whether it would deliver a glancing blow or make a distant encounter. Think of it this

way: A baseball batter knows that a pitched ball is coming toward him, but he has to decide whether it will be over the middle of the plate, a bit inside, or at his head.

Roeland van der Marel, Jay Anderson, and Tony Sohn of the Space Telescope Science Institute in Baltimore conducted extraordinarily precise observations with the Hubble Space Telescope that removed any doubt that M31 is heading straight toward us. They accomplished this by repeatedly observing selected regions of the galaxy over a five- to seven-year period. The researchers measured the angular motions of thousands of M31's stars with respect to the fixed background of far-more-distant galaxies to gauge their sideways motion, or tangential velocity. The team found that M31 has essentially *no* tangential motion relative to the Milky Way — the galaxies are on a collision course.

Although the technique sounds straightforward, the task proved arduous. The stars' angular motions over this short period is just $\frac{1}{200}$ of Hubble's angular resolution. The astronomers used sophisticated data analysis techniques to tease out the slight offset between the positions of Andromeda's stars and the background galaxies. The team then used a computer model to eliminate the stars' individual motions within the galaxy from M31's motion as a whole.

Gurtina Besla of Columbia University in New York City ran computer simulations that show various encounter scenarios based on how directly M31 hits the target. In one simulation, Andromeda passes extremely close to our galaxy. It then slows down and makes an abrupt U-turn relative to the Milky Way's motion. This leads to a direct impact that jostles the stellar populations of both galaxies. The galaxies' cores



The Andromeda Galaxy nearly rivals the Milky Way some 3.75 billion years from now. Tidal forces between the two galaxies have started to warp the outer spiral arms of both objects.



Interstellar clouds collide during the two galaxies' first close approach, triggering a burst of star formation. The most active stellar nurseries appear as reddish emission nebulae and dot the entire sky.

merge, and their stars settle into randomized orbits to create an elliptical galaxy.

Into the future

In H. G. Wells' 1895 novel *The Time Machine*, the story's time traveler journeys far enough into the future to see the final days of Earth as the Sun swells into a bloated red giant. Like Wells' story, we'll now ride a time machine into the distant future and speculate how astronomers then might piece together an understanding of the cosmos from their chaotic sky.

We'll imagine that Earth formed at a much later date and intelligent life appears at different epochs during the collision. How will the smashup influence the discovery of the universe, assuming science develops in a similar way in these alternative future worlds?

Three billion years from now

To start with, the Andromeda Galaxy appears as a huge slash of light and nebulousity that bisects our Milky Way. Gas concentrated in the disks of both galaxies gets compressed, triggering a firestorm of star birth. The center of the X pattern might take on mystical significance to skywatchers.

Not until the invention of the telescope, and its use by someone with Galileo Galilei's curiosity, does anyone discover that the hazy glow consists of innumerable stars. But attempts to construct a three-dimensional model of the galaxy by counting stars don't get far because of the odd and intermingled structures in the sky. Edwin Hubble's future counterpart can't

calibrate distances between galaxies because no nearby galaxies equivalent to Andromeda exist for him to determine that "spiral nebulae" are extragalactic.

Scientists eventually stumble across the cosmic microwave background (CMB) radiation — the fading echo of the Big Bang — just as Arno Penzias and Robert Wilson did in the 1960s as they attempted to debug a satellite communications antenna. Without the concept of an expanding universe derived from distances to faraway galaxies, however, astronomers can't explain the CMB's uniform glow in a cosmos structured so chaotically.

Four billion years

As Andromeda makes its initial close approach, its stars completely intermingle with the Milky Way's. The entire celestial sphere appears as a crazy quilt of brilliant bluish open star clusters and innumerable reddish emission nebulae. Imagine taking the rich region we currently see in Scorpius and Sagittarius and using a cookie cutter to plaster it across the entire sky.

Twice as many stars now appear in the night sky than we see today. Half of these luminaries (from Andromeda) stream in a different direction than the other half (from the Milky Way). Although observers don't see the more-distant stars move much, nearby stars travel the angular width of the Full Moon in little more than a decade. The constellation patterns change noticeably during a human lifetime.

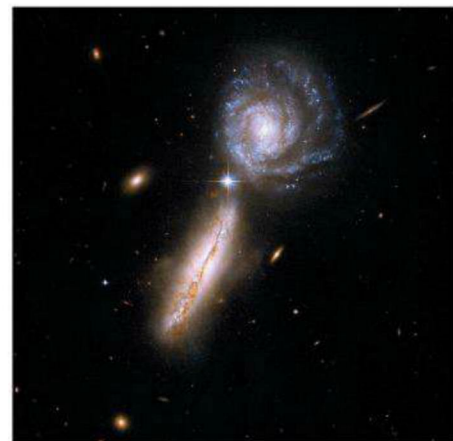
Most of the background galaxies are lost in the glare of the bright star-forming

regions that dominate the local neighborhood. And the spiral nebulae that manage to shine through do not look as exotic as nearby nebulae, so astronomers don't pay much attention to them for a long time.

Astronomy 101 textbooks cover planetary science and stellar evolution, but not much else. Conventional wisdom holds that we live at the center of a mottled ball of stars, star clusters, nebulae, and dust filaments. Stellar astronomy advances rapidly because of the plethora of open star clusters, emission nebulae, supernovae, and supernova remnants. But few clues exist to the nature of the extragalactic universe.

Five billion years

Following our first close pass by M31, the bright cores of the Milky Way and Andromeda form twin stellar bulges in the sky. This confounds astronomers and fuels debate over where the true center of our



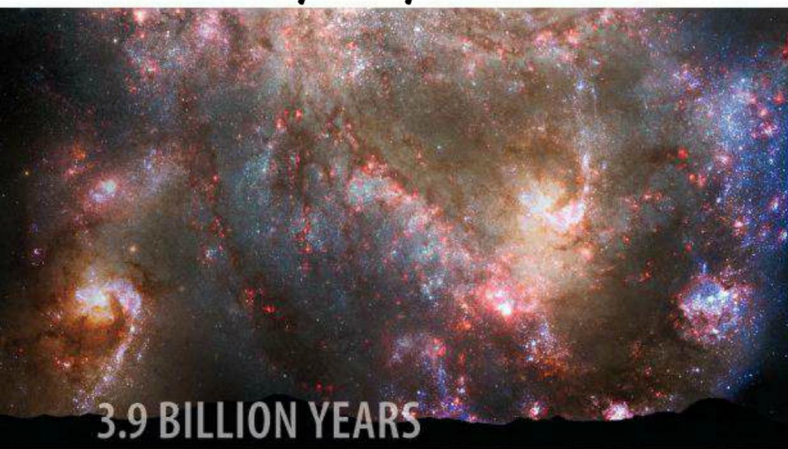
These two gas-rich spiral galaxies, jointly cataloged as UGC 9618 or Arp 302, are just starting to interact. Although the two don't yet appear distorted in visible-light images like this one, infrared observations reveal lots of new star formation.

NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

LEARN MORE

Galaxy collisions — both near and far — have excited astronomers for half a century. To purchase a PDF package of *Astronomy* articles on this topic, visit www.Astronomy.com/extraccontent.

The Milky Way and Andromeda merger (later years)



Rampant star formation continues for tens of millions of years. The first wave of star birth gave rise to innumerable open star clusters filled with hot massive stars that glow strongly in blue light.



The first close pass plays out quickly, ending some 100 to 200 million years after it began. At its conclusion, both galaxies have been tidally stretched almost beyond recognition.

island universe lies, or even if it has a center. Early in the 20th century, Harlow Shapley studied the distribution of globular clusters and deduced that the Milky Way's center lies in Sagittarius. But his technique proves impossible now because the ongoing collision disperses the globulars widely.

Emission nebulae appear much less prominent now because the earlier bursts of star formation significantly depleted the gas and dust needed to form new stars. This thinning out of the interstellar medium lets distant galaxies shine through clearly and allows observers to establish them as separate entities. Ultimately, astronomers tie images of distant colliding galaxies to the conditions they see in the local night sky, but piecing this jigsaw puzzle together is a painstaking task.

Seven billion years

The Sun has now burned out and collapsed to become a white dwarf. It's not inconceivable that some technologically advanced civilization could survive into the Sun's final years. And certainly any sentient beings still around would be curious about the galaxy's fate.

By now, the Milky Way and Andromeda have merged into a single giant elliptical galaxy that some call "Milkomeda" and I've dubbed the "Milky Splay." Emission nebulae, open star clusters, and interstellar dust are gone. Astronomers have little understanding of stellar evolution in the absence of any evidence for star birth or supernovae.

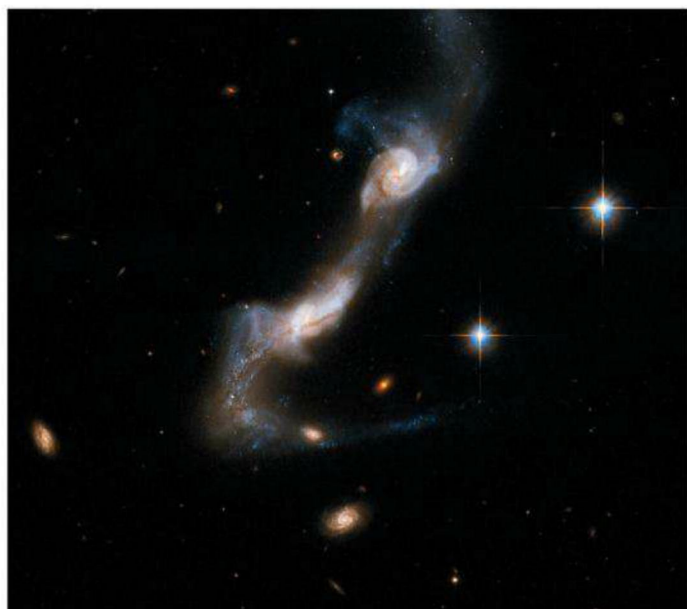
Former satellite galaxies of the Milky Way, such as the Large and Small Magellanic Clouds, are still around. They are

harder to discern, however, because the collision greatly increased the number of stars in the sky and flung the satellites much farther away than they are today.

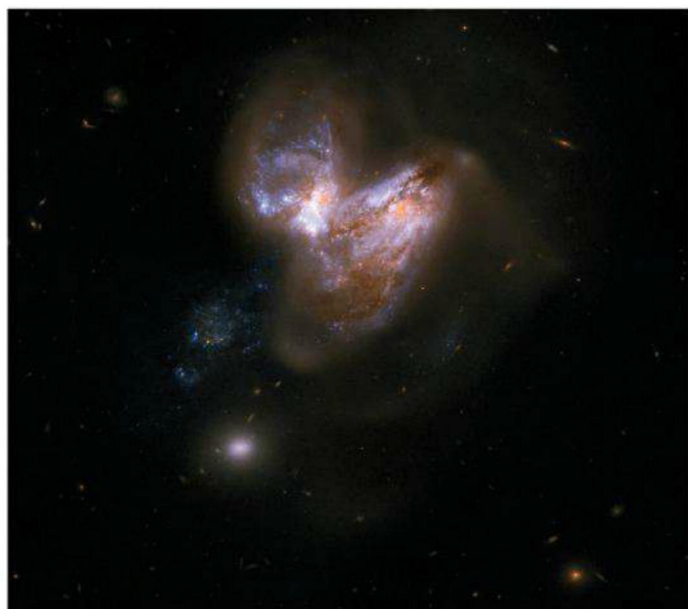
These wayward companions eventually return to our vicinity. They provide observational evidence that our galaxy accretes smaller bodies, bolstering the idea that galactic cannibalism plays a major role in how galaxies form and evolve. Astronomers also use the satellites' orbits to estimate the mass of the Milky Splay and find that it ranks among the largest galaxies in the nearby universe.

Eight billion years

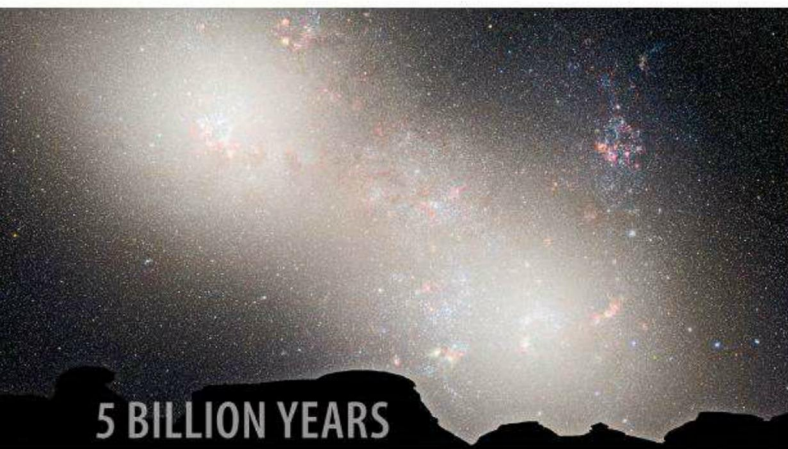
The view of the sky now depends on the Sun's trajectory in the new galaxy. Momentum from the Milky Way-Andromeda



The galaxies of UGC 8335 (Arp 238) show signs of an impending merger. A bridge of gas and dust seems to join the objects while long tidal tails of stars and gas curve away from their outer edges. NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)



These two galaxies, cataloged as NGC 3690 or Arp 299, made a close pass to each other some 700 million years ago. They have lost their individual identities as a result of their ongoing merger. NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)



5 BILLION YEARS
After the galaxies make a U-turn, they approach each other for a second and final time. Little new star formation takes place because the first encounter nearly exhausted the available interstellar gas.



7 BILLION YEARS
The Milky Way and Andromeda galaxies merge into a single giant elliptical galaxy some 7 billion years in the future. An invisible supermassive black hole in its core weighs more than 10 million Suns.

encounter has to go somewhere, and the chief beneficiaries are stars. The collision speeds up their motions and launches them onto randomly inclined orbits, helping build a spherical shell of stars.

Today, the solar system orbits the Milky Way's center at a speed of roughly 500,000 mph (800,000 km/h). But the collision's energy significantly increases the Sun's velocity, so our star passes others more frequently. These close encounters disrupt the Oort Cloud, a vast reservoir of comets located in a shell around the Sun that spans 2 light-years. The solar system's surviving planets undergo frequent comet showers.

A small chance exists that the Sun will migrate over to the relatively small Pinwheel Galaxy (M33), which Andromeda dragged along during the encounter like a dog on a leash. This spiral companion now orbits the Milky Splay, but it can capture stars scattered by the collision. Some objects might even get thrown into an orbit that shuttles between the two galaxies.

Nine billion years

By this late date, many stars travel along highly eccentric and inclined orbits. This is a boon for any far-future astronomers. At the orbit's peak, scientists obtain exquisite views of the universe. Soon after these distant descendants turn their telescopes to the sky, they deduce that they live on the periphery of a giant elliptical galaxy. And a quick look toward the Virgo cluster of galaxies shows them close analogs of their home galaxy.

The Milky Splay's core contains two co-orbiting supermassive black holes. They eventually must merge, which launches

gravitational waves that ripple across the galaxy at light-speed. They momentarily distort the physical dimensions of Earth (if it has survived) — and every other object in the galaxy — by one-millionth of an inch.

Thankfully, the black-hole merger does not shoot out a jet of subatomic particles traveling at near the speed of light. Nor does it sterilize the galaxy with a flood of radiation from a newly born quasar. Quasars exist only where black holes have plenty of gas to fuel them, and the collision between the Milky Way and M31 has converted most of the gas into stars.

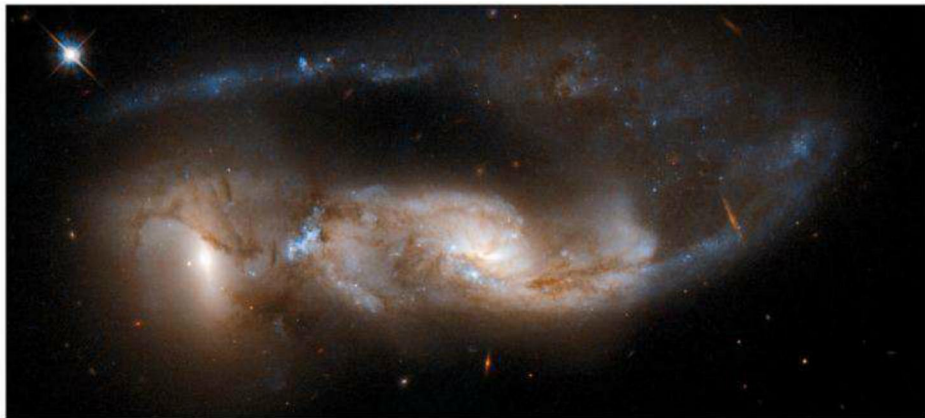
Astronomers living in a few unlucky planetary systems reach a sobering conclusion, however. The highly elongated orbit of their host star causes it to plunge through the Milky Splay's crowded center. They realize that their star system just might pass dangerously close to the central black hole, which weighs more than 10 million times as much as our Sun. This

certainly would herald the downfall for any civilization. The astronomers likely would predict when the black hole's tidal forces will rip their star apart. And unlike the 2012 doomsday debacle linked to the Mayan calendar, the black hole encounter really would be the end of times.

Back to the present

The 21st century certainly is a special time. Astronomers can observe the Milky Way's orderly construction and view through a wide window into the deep universe. It's what has allowed them to pull together a coherent view of both stellar and cosmic evolution. But for amateur astronomers, the best sky views are yet to come — a few billion years from now.

Regardless of how the Milky Way Galaxy changes, inquisitive minds always will find it full of mystery and wonder. Yes, we live in a special time, but given our restless universe, all cosmic epochs are special. 🌌



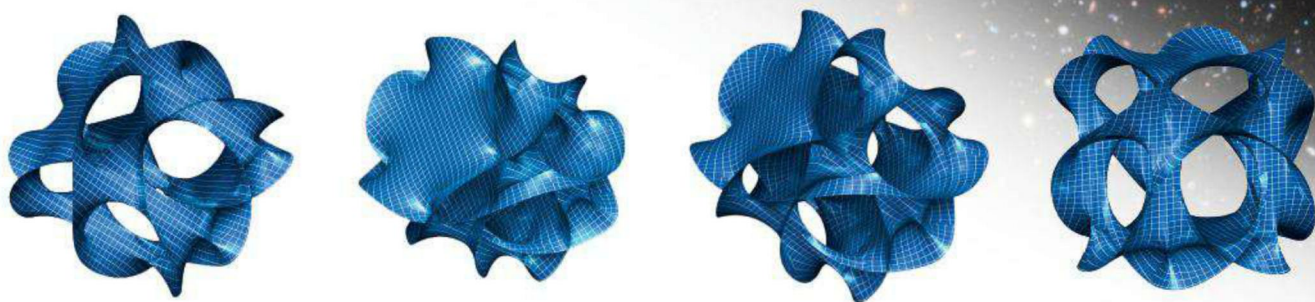
The colliding galaxies NGC 6621-2 (Arp 81) made their first close pass about 100 million years ago and soon will head back for a second and, presumably, final time. Note the long tidal tail that stretches behind the pair. NASA/ESA/THE HUBBLE HERITAGE TEAM (STSC/AURA)



WATCH COMPUTER SIMULATIONS OF GALAXY COLLISIONS AT www.Astronomy.com/toc.

What string theory tells us about the universe

A universe with 10 dimensions forms the backbone of a grand theory that describes astronomers' observations. The race is on to prove it. **by Sten Odenwald**



Scientists have known for nearly a century that matter is composed of atoms, which are various combinations of electrons, protons, and neutrons. In the 1960s, physicists uncovered a deeper level to matter when they found that protons and neutrons in turn are composed of particles whimsically called quarks. We now know of six kinds of quarks, and combinations of them (in pairs or triplets) explain all of the heavier particles in the universe — protons, neutrons, and many other exotic particles (like gluons and bosons) that turn up in experiments.

That's the basic understanding of the matter in the universe, but how do particles interact? Beginning in the 1930s, physicists

developed a detailed set of mathematical models of four fundamental forces in the universe: gravitation, electromagnetism, and the strong and weak nuclear forces. We can think of each of them in terms of fields acting in space. More amazingly, these four basic “force fields” are themselves constructed from the exchanges between new families of particles and the elementary electrons and quarks. The photon transmits electromagnetic forces; eight different gluons transmit the strong nuclear force that holds quarks together inside protons; three intermediate vector bosons transmit the weak nuclear force, which is responsible for radioactivity; and some physicists believe that gravitons transmit gravitational forces, but these particles remain undiscovered.

In the “standard model,” scientists group the description of matter and forces by these various detailed mathematical theories. It forms the backbone of every calculation that physicists perform when they

Sten Odenwald is an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

For superstring theory to make sense, scientists must add six dimensions of space to the three we already know of. Theories suggest that these dimensions are closed in on themselves and crammed into tiny shapes, called Calabi-Yau manifolds, which span just 10^{-33} centimeter.

ESO/MARIO NONINO/PIERO ROSATI/THE ESO GOODS TEAM (BACKGROUND); ASTRONOMY: ROEN KELLY, AFTER JEFF BRYANT/A. J. HANSON (CALABI-YAU MANIFOLD)

try to predict what will happen in one of their expensive “atom smashers.” Whenever they design new technologies, perform new experiments, or even study the nature of black holes, they begin with the heavily tested mathematical equations of the standard model.

The standard model is beautiful and simple, but it also seems to be incomplete. Scientists can “unify” two of the forces — electromagnetism and weak nuclear — into a single mathematical theory. And they can combine this with the strong nuclear force in the

“grand unification theory.” But the mathematics of gravity remains stubbornly different, and thus physicists need two separate descriptions of how the four forces work in nature. Wouldn’t it be wonderful if they had only one description instead? This is what some have called the search for a “theory of everything,” and the most promising approach is “superstring theory.” So why did physicists have to reach for strings to fix the standard model, and what does it tell us about the universe?

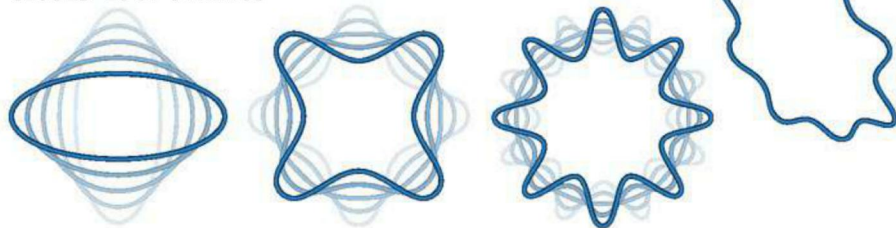
The fundamentals of strings

1 In string theory, particles are not points but vibrating strings; their identities depend on the vibration's frequency.

OPEN-ENDED STRINGS



CLOSED-LOOP STRINGS



2 A string is a one-dimensional object; it is also called a "world-line" in 1-D space. A string's size is much smaller than current technology can detect.

3 After you add the additional dimension of time, strings sweep out a two-dimensional "worldsheet."

Into the depths

Over the past 70 years, scientists have proposed many technical approaches for achieving grand unification, but most of these theories suffered from severe mathematical flaws. For example, sometimes a calculation would result in probabilities that were negative or exceeded 100 percent. According to one model, calculations spewed out legions of faster-than-light particles called tachyons. But one interesting approach has gained a huge following among physicists since the early 1980s — strings.

According to the standard model, particles are pointlike; no matter how deeply scientists try to probe one's interior, all they would find was a still-smaller "point" of energy that represents all of the particle's properties, such as its mass, charge, and spin. This turns out to be a huge mathematical problem. Imagine trying to crowd the mass and energy of, say, an electron into a smaller and smaller sphere. Eventually, it would become a vanishingly small point in space, and the particle's density and energy would reach infinity. This infinity would then cause any calculation that incorporates density and energy to "blow up" into nonsense. So about 30 years ago, physicists came up with a solution to replace the internal shape of a particle with some other kind of shape that didn't have a vanishing point: a mysterious, closed loop of energy called a string.

The basic idea is that every particle of matter (an electron, quark, ghostlike neutrino, etc.) and every particle that transmits a force (photon, gluon, intermediate vector boson, and graviton) is actually a small one-dimensional loop of *something*. It can be either open with two ends or closed in a loop. As this 1-D loop of string moves forward in time, it sweeps out a two-dimensional surface. It also can split to form two separate loops of string that in turn shape two other closed surfaces. These surfaces are called "worldsheets," and the splitting of one string into two is a model for the decay of one particle into two. (To visualize this, imagine that the string is a belt on a pair of pants. As the belt slides down to the ground, it sweeps out the surface of the pants, and splits into the two pant legs to form two other closed belts that continue down to the ground to form the surface of the legs.) Going the other direction, two strings change into one as two particles collide and combine.

These loops also can vibrate like closed guitar strings, and the precise way that one vibrates determines the exact properties of the fundamental particles it represents or transmutes into. The vibration's frequency is higher for more-massive particles and lower for less-massive ones.

So, out of what are these strings fashioned? Well, when was the last time you encountered something that was 1-D? I've never experienced a 1-D object, and thus I have no expectation of what

characteristics to assign to its appearance, like color, mass, size, etc. Every property we would want to describe a string by is rooted in our 3-D experience, so the very question of what such a physical object *should* represent is beyond our experiences. Fortunately in mathematics, this is not a problem at all. That's why physicists can work with 1-D strings in such a precise, and logical, way.

Plus, scientists know that particles like the electron are not just tiny spheres with a surface. In fact, these objects have nothing like a surface at all. They are just infinitesimal knots of energy that have specific properties. It is a major challenge to the human

THE PARTICLES OF THE STANDARD MODEL

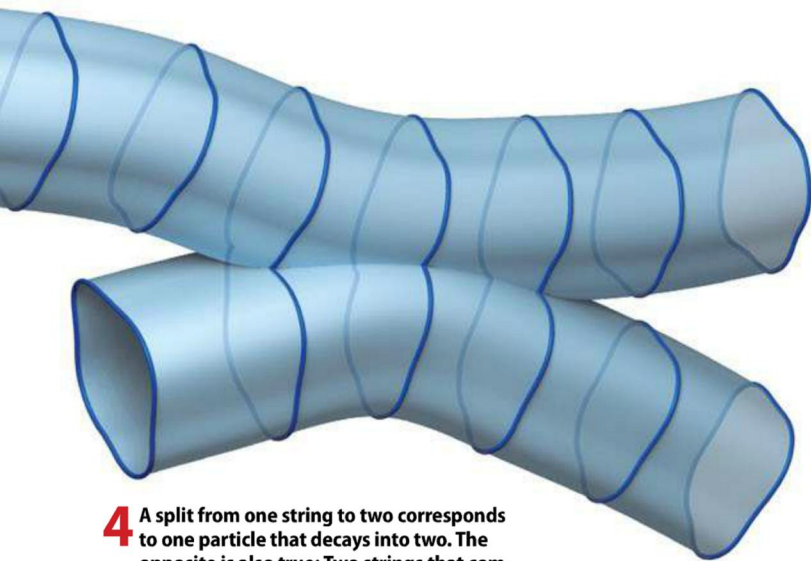
LEPTONS

Name	Mass	Discovery
Electron	0.511 MeV	1897
Muon	105.7 MeV	1936
Tau	1.778 GeV	1974
Electron neutrino	<2.2 eV	1956
Muon neutrino	<0.17 MeV	1962
Tau neutrino	<15.5 MeV	2000

QUARKS

Name	Mass	Discovery
Up	1.7–3.1 MeV	1968
Down	4.1–5.7 MeV	1968
Strange	104 MeV	1968
Charm	1.29 GeV	1974
Bottom	4.2 GeV	1977
Top	172.9 GeV	1995

Masses are shown in traditional electron volt (eV) energy units ($E=mc^2$) where $c^2=1$.



4 A split from one string to two corresponds to one particle that decays into two. The opposite is also true: Two strings that combine into one represent two particles that collide into one. ASTRONOMY: ROEN KELLY

STRING SPEAK

Boson: Type of subatomic particle of which a multiple number can occupy the same energy state; examples are force-carrier particles, like the photon and gluon.

Fermion: Type of subatomic particle of which only one can occupy an energy state; examples are electrons and neutrinos.

Hadron: Type of subatomic particle that takes part in the strong nuclear force and is made up of quarks.

Quark: Type of elementary particle that combines in sets of two or three to form hadrons; comes in six “flavors.”

Standard model: A mathematical description of the elementary particles and how they interact.

Supersymmetry: Theory that incorporates the known particles into the more complicated universe, which suggests that every kind of elementary particle has a corresponding heavy particle.

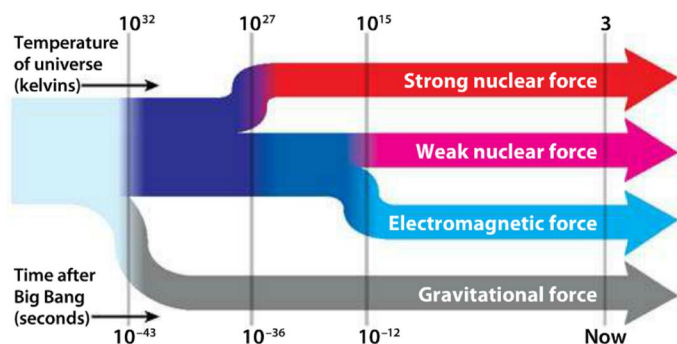
mind to think about the true essence of a fundamental particle — whether a point of energy or a string.

Exploring different dimensions

The story gets even weirder because the mathematics that relates these strings to normal particles and their properties cannot exist unless these 1-D strings are moving in a 10-dimensional universe of space and time. Our normal universe has three dimensions of space and one of time, so string mathematics requires that there be an additional six that are completely closed upon themselves and that have finite sizes close to 10^{-33} centimeter.

Take a 2-D piece of paper and crumple it up tightly. Now, stuff that paper into a pingpong ball and crush this ball down to a size of only 10^{-33} centimeter across — some scientists say six dimensions could be hiding in that object. Now, repeat this exercise again and again with different crumpled sheets of paper and pingpong balls at every possible point in 3-D space; string theory says that every time you compact the six dimensions like this, you can end up with a different kind of universe. The exact geometry of these compact dimensions determines exactly what kinds of particles the universe has and their detailed properties.

When forces were unified



According to the standard model of particle physics, three of the four fundamental forces were unified in the early universe. Gravity, however, doesn't seem to fit. Superstring theory offers a way for these four forces to fall under one overarching force. ASTRONOMY: ROEN KELLY

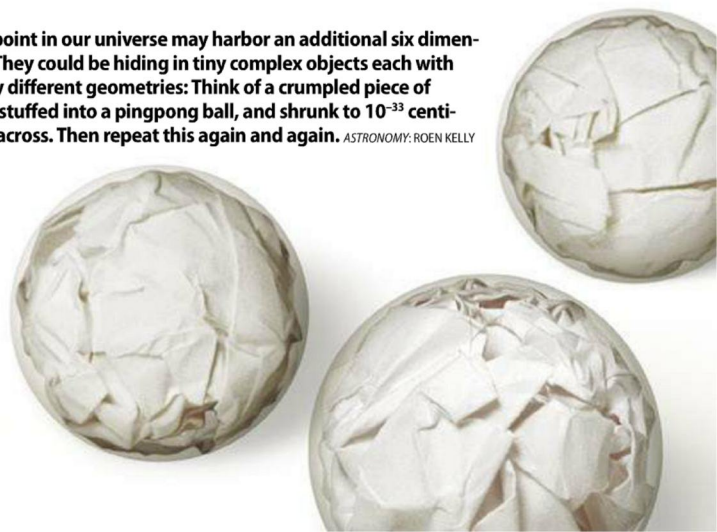
A 3-D sphere has a certain geometry that allows particles on its surface to move in certain ways; similarly, the string tension and geometry formed by the spaces of these compact dimensions control the vibrations of a string (and what particle it corresponds to). Every kind of particle has a specific six-number address in this compact space, just as Paris has a unique latitude and longitude on the 2-D curved surface of spherical Earth.

It is, of course, difficult to draw a 6-D object, which physicists call Calabi-Yau manifolds. Even if we could, we would be busy trying to draw all of the possible ways they could look: In string theory, there are an estimated 10^{500} of these spaces, and each one describes a separate mathematical universe of particles and fields. In some of these spaces, electrons do not exist, while perhaps in others we could have a dozen different kinds of quarks, but no photons. These spaces, for example, would not allow rainbows to form.

But wait, there's more

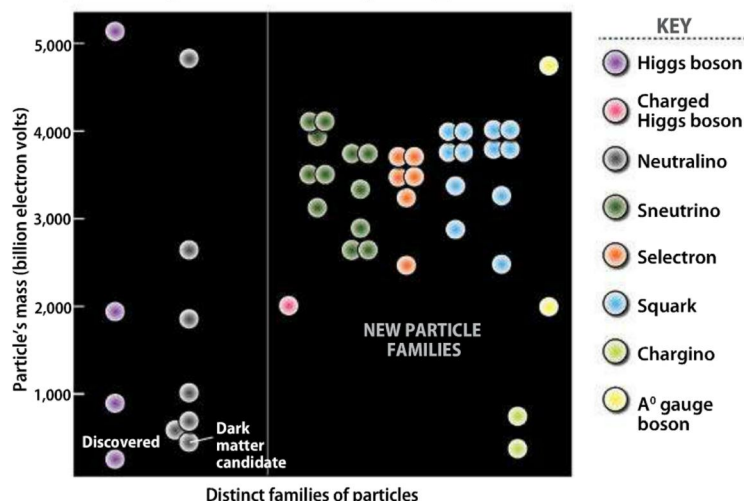
If all we had were a new model for what particles look like — vibrating loops in space rather than points — we would not have simplified or unified our standard model. We only would have gained more complex mathematics to account for things we already know. But string theory also has a second ingredient, called “supersymmetry.” As any geometry student has learned, symmetry often makes solving problems easier.

Every point in our universe may harbor an additional six dimensions. They could be hiding in tiny complex objects each with slightly different geometries: Think of a crumpled piece of paper, stuffed into a pingpong ball, and shrunk to 10^{-33} centimeter across. Then repeat this again and again. ASTRONOMY: ROEN KELLY



Supersymmetry's particles

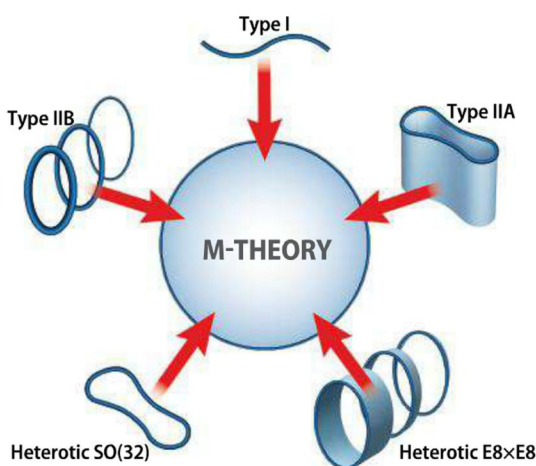
Five theories, projected



The simplest supersymmetry theories predict many new particles, shown in this diagram. Physicists calculate multiple particles of every family and each with a different mass. This diagram is based on predictions from Ben O'Leary of the University of Würzburg and colleagues. *ASTRONOMY: ROEN KELLY, AFTER STEN ODENWALD*

Because of a cube's symmetry, one can rotate it in the three dimensions of space by 90° and see a new face, but the shape of the cube remains exactly the same. Scientists call this "rotation symmetry." In the early 1970s, physicists discovered that the particles in the standard model also could be "transformed" into each other by using supersymmetry. (This operation involves quantum mechanics and one of the particle's intrinsic properties, called spin.) What makes this theory so *super* is that it automatically includes gravity as a consequence of supersymmetry among the known kinds of particles — finally, all four forces fit naturally in a theory.

But in nature, you never get something for nothing, so scientists had to add a new ingredient to make the math work. In this case, every particle in the standard model has a new superpartner particle to make the transformations work out mathematically. By extending the standard model in this way, scientists now have what is called the Minimal Supersymmetric Standard Model (MSSM). Not only does MSSM correct a number of problems with the standard model, but it also introduces a new candidate particle for the mysterious material that makes up about 85 percent of the universe's mass — dark matter. The standard model has no way to explain this invisible mass, but the least massive "neutralino" of MSSM has exactly the right properties to account for dark matter.



In the 1980s, physicists had five separate superstring theories that each involved 10 dimensions: type I, type IIA, type IIB, heterotic type SO(32), and heterotic type E8xE8. By 1995, they realized that these five were all the same one, called M-theory, but from different projections. *ASTRONOMY: ROEN KELLY*

Tying it together

In the early 1980s, physicists applied supersymmetry to string theory — to form superstring theory — and came up with five different kinds of superstring theory, each explaining the physical world from A to Z but in various ways. Then in 1995, they realized that these five theories were themselves one, which scientists called "M-theory."

The way these theories are connected is by precise mathematical operations that involve changing length scales — called "duality transformations." An example of a more familiar kind of transformation that instead involves rotations is a cube with six faces, each a 2-D projection of the 3-D cube. The true shape of a cube in 3-D can be pieced together from its various 2-D projections, which we see as separate faces of the cube. Each 2-D face can be transformed into one of the other faces by rotating the cube in 3-D space. You can think of each face of the 11-D M-theory "cube" as a separate 10-D superstring theory. The detailed mathematics of 11-D M-theory tells scientists how to transform the 10-D superstring theory into one of the other 10-D superstring theories.

The evidence, so far

Some physicists look at MSSM as the easiest way to move beyond the standard model without adding a drastic amount of assumptions.

The theory also provides new predictions they can test at the world's most powerful particle accelerator, the Large Hadron Collider (LHC) at the European Organization for Nuclear Research. For instance, scientists are scouring the data for evidence of the known particles' superpartners, and the lightest should have masses of a few teraelectron volts (TeV), which the LHC can access. (An electron volt, eV, is a unit of energy; visible light photons range from 1.5 to 3.5 eV; a TeV is a million million eV.) If researchers don't find any, then they will need to replace MSSM with more-complicated models that push the masses

GAUGE BOSONS — THE FORCE-CARRIER PARTICLES

Name	Force	Mass	Discovery	Function
Photon	Electromagnetic	0 eV	1909–1916	Force between charged particles
W ⁺	Weak	80.38 GeV	1983	Particle decay
W ⁻	Weak	80.38 GeV	1983	Particle decay
Z ⁰	Weak	91.19 GeV	1983	Particle decay
Gluons (eight)	Strong	0 eV	About 1980	Binds quarks into protons, neutrons, etc.

Masses are shown in traditional electron volt (eV) energy units ($E=mc^2$) where $c^2=1$.

AN EARLY STRING THEORY

Superstring theory isn't the first model in which physicists came up with a stringy solution to a problem. Scientists originally invented string theory in the 1960s to explain how subatomic quarks are confined inside protons. In this theory, quarks were the ends of a string, and when you pulled too hard on the string to overcome its tension, it would snap into two pieces — each with a quark at its free end. This mechanism provided an intuitive, but mathematically difficult, answer to why you could never pull a single quark out of a proton. But in the early 1970s, physicists abandoned this version of string theory. That's when they discovered the real reason quarks are contained: They exchange *gluons* in such a way to hold protons and neutrons together via the strong interaction. — S. O.

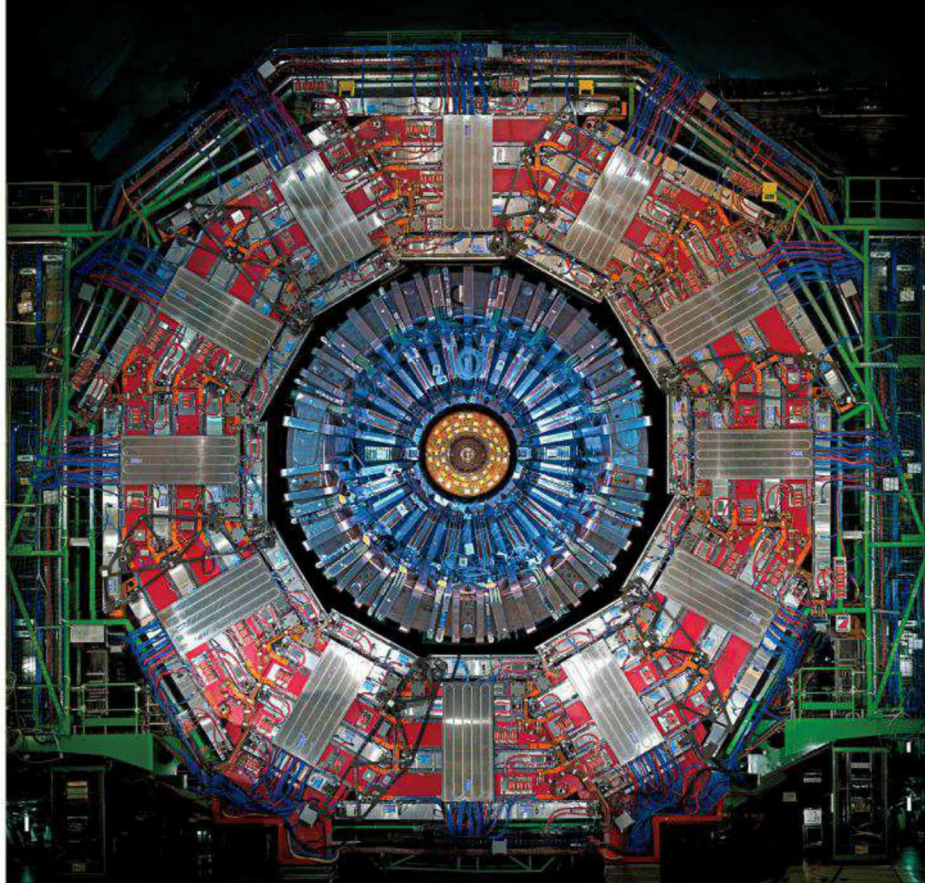
of the superpartner particles to still higher energies. So where does this search stand today, now that the LHC has been taking data for more than two years?

The good news is that the standard model is pretty well confirmed. In July 2012, physicists announced that they had discovered a particle that looks just like the last standard-model holdout, the Higgs boson, with a mass of 126 billion eV/(speed of light)², following a search lasting more than four decades.

The bad news is that, in August 2011 and again in November 2012, a team of physicists at the LHC reported that its study of the decay of exotic particles called B-mesons turned up no sign of supersymmetry. These particles should have decayed far more quickly with the help of supersymmetry, but scientists have found no indication of this effect among the trillions of decays studied.

More bad news: Scientists haven't found any evidence for the supersymmetric particles below 7 TeV, which is interpreted as a major failing for the simplest supersymmetry models (and specifically MSSM). Supersymmetry is the simplest mathematical model that scientists have to unify the four fundamental forces, and nature seems to favor the most basic theories that explain our world. If MSSM fails, it will be the biggest bait-and-switch job that nature has ever foisted on scientists.

By early 2013, the LHC shut down; in 2015, it will power back up and will begin operating at its full designed collision energy of 13 TeV. Physicists have only begun to study what the various theories predict for the lightest supersymmetry particles. They've calculated the existence of dozens of new particles spread across the full operating energy range of the LHC, so some optimism is warranted.



Scientists hope that the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) in Europe will discover the least massive particles hypothesized by supersymmetry theory. If the LHC detectors come up empty after the particle accelerator is running at its full energy in 2015, then the superstring model is wrong and physicists will need to rewrite their theories. CMS COLLABORATION/MICHAEL HOCH/MAXIMILIEN BRICE

The stakes are extremely high: If supersymmetry is found, the discovery road will be opened for superstring theory as the next step beyond MSSM. If they continue to find no evidence of supersymmetry at the LHC, then the simplest versions of MSSM must fall, and superstring theory will seem a far less elegant explanation of a theory of everything. And that would be a shame.

The string theory description of loopy particles offers a rich landscape of new particles and phenomenology, and can extend

human understanding of space and time's creation. The down side, however, is that most of these particles have masses that are well beyond the searchable LHC energy scale. And that's the biggest problem.

No scientist seriously thinks that after a community of world governments has spent billions of dollars to build the LHC to find "new physics" and hasn't discovered any, it will garner additional funding to create an even larger collider to probe beyond 13 TeV. If there is no sign of new physics or new particles at the LHC, the negative results will force extremely dif-

ficult decisions on physicists: Either innovate a completely new (and inexpensive) technology for accelerating particles to high energies, or languish for decades to come with no new data upon which to test an increasing number of "elegant" theories. So, the next few years of accelerator physics may just give us the verdict on the success of superstring theory. ☛

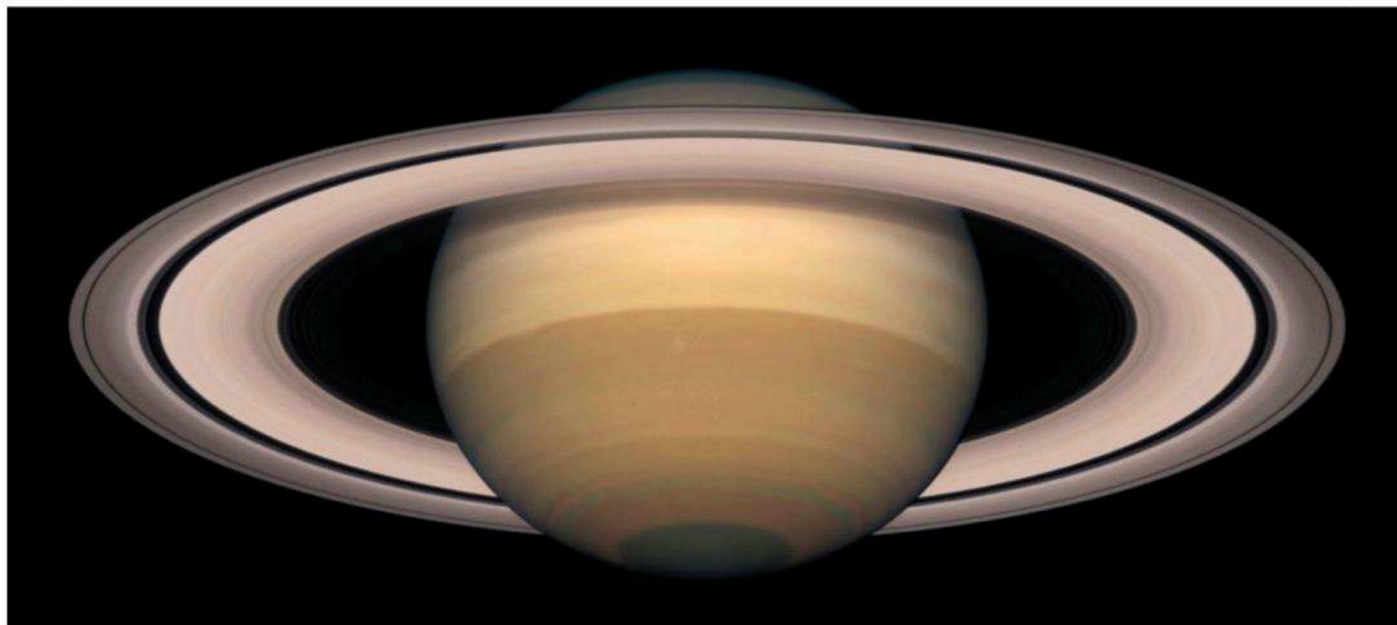
WHAT'S IN A NAME?

Some physicists, like Nobel Prize winner Steven Weinberg of the University of Texas at Austin, imagine strings as one-dimensional rips in the smooth fabric of space. Other physicists, such as Lee Smolin of the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, imagine them as 1-D but not made of anything at all.



LEARN MORE ABOUT THE SHAPE OF SPACE AND THOSE SIX HIDDEN DIMENSIONS AT www.Astronomy.com/toc.

April 2013: Saturn struts its ringed glory



Saturn's rings open wider this year than they've been since 2006, giving observers great views through telescopes of any size. NASA/ESA/THE HUBBLE HERITAGE TEAM (STSC/AURA)

Of the solar system's eight major planets, only two show up nicely during April. But what a pair they are. Jupiter blazes in the western sky after darkness falls, a beacon on these balmy

spring evenings. And glorious Saturn hangs low in the east at nightfall before climbing high in the south around midnight. It reaches opposition and peak visibility in late April.

The appearance of Comet C/2011 L4 (PANSTARRS)

could be a nice addition to the April sky. It should be a fine binocular object when it passes 2° from the Andromeda Galaxy (M31) during the month's first week. The comet climbs highest shortly after sunset and again before sunrise.

The brightest point of light in the April sky belongs to **Jupiter**. The giant planet spends the month in Taurus the Bull, to the northeast of the V-shaped Hyades star cluster. By late April, it forms an equilateral triangle with the Bull's horns — 2nd-magnitude Beta (β) Tauri and 3rd-magnitude Zeta (ζ) Tau. At magnitude -2.0, however, Jupiter blazes far brighter than either star.

A three-day-old crescent Moon stands between the

Hyades and Pleiades star clusters April 13 with Jupiter about 10° above. The following evening, Jupiter and the Moon lie a little more than 2° apart.

The viewing window for Jupiter shrinks noticeably during April. The planet sets after midnight local daylight time early in the month, but it's gone before 11 p.m. by month's end. For the best views of the giant world through a telescope, catch it early in the evening when it lies higher in the sky. The planet spans a healthy 35" in mid-April and will show a wealth of detail in its turbulent atmosphere. Look for an alternating series of parallel dark belts and bright zones — the most obvious features in the jovian cloud tops.

Observing Jupiter's four bright moons is no less fascinating. As Io, Europa, Ganymede, and Callisto circle the planet, they change positions noticeably from night to night and sometimes hour to hour.



Saturn reaches opposition the night of April 27/28, when it shines brightly in the southeastern sky after darkness falls. ASTRONOMY: JAY SMITH

Martin Ratcliffe provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist **Alister Ling** works for Environment Canada in Edmonton, Alberta.

RISINGMOON

One glorious sight after another

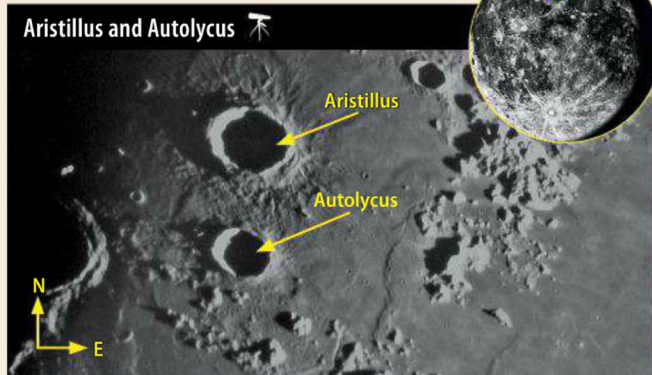
The waxing crescent Moon offers exceptional views in mid-April. A magnificent array of lunar wonders hugs the terminator — the dividing line between night and day where the rising Sun throws features into sharp relief — and changes noticeably from night to night.

On the 17th, just a day before First Quarter phase, the rugged lunar Apennines thrust diagonally into the sunlit domain slightly north of the Moon's equator. Just north of this mountain range and along the terminator stand two prominent craters — Aristillus and Autolycus — protruding from the flat

floor of Mare Imbrium. They formed a couple of billion years ago, near the end of the last major lunar bombardment. Their high walls catch the sunlight on the 17th while their central peaks and floors remain in shadow.

On the next night, the higher Sun angle illuminates the rugged debris apron that splattered out of each of these craters. As you might guess, the larger impact that created Aristillus excavated a lot more material.

Compare the characteristics of these relatively youthful impact scars to the pair of larger round craters Hipparchus and Albategnius just south of the



A pair of large craters stands out just after the Sun rises over the lunar landscape the evening of April 17. CONSOLIDATED LUNAR ATLAS/UA/LPL; INSET: LICK OBSERVATORY

equator. Evidence of their greater age comes from the rounded walls pockmarked with dozens of craterlets.

Observers in the eastern half of North America have a rare

opportunity April 17. Great timing allows them to see the Lunar X and Lunar V that Glenn Chaple discussed in "Observing Basics" in the September 2012 *Astronomy*.

If you don't see all four at first glance, it means one or more is passing in front of Jupiter's disk (a transit) or behind it (an occultation). For North American observers, the best satellite action takes place April 2. The planet occults Io starting at 10:40 P.M. EDT and then moves in front of Ganymede commencing at 12:02 A.M. And in the middle of this period (at 11:04 P.M.), Europa begins to transit Jupiter. For much of the night, Callisto will be the only moon visible against a dark sky.

Saturn lies opposite the Sun in our sky the night of April 27/28. Opposition marks an outer planet's peak because it remains visible all night and also lies closest to Earth, so it shines brightest and appears biggest through a telescope.

In early April, the ringed planet hangs low in the east-southeast around 10 P.M. local daylight time. Use Spica, Virgo's 1st-magnitude luminary and already some 15° high, as a guide. Saturn lies 15° east (to the lower left) of Spica among the much fainter background

— *Continued on page 42*

METEORWATCH

The Lyre plays a sad song

The year's longest drought for meteor viewing comes between the Quadrantid shower in early January and the April Lyrids. Unfortunately, a bright gibbous Moon interferes at the Lyrids' peak the morning of April 22. The Moon sets just after 4 A.M. local daylight time, less than a half-hour before twilight begins. Your best observing should come during that brief window.

Plan to head away from the lights of the city and find a location where a building, trees, or a low hill blocks your view toward the western horizon, where the Moon will be. Such a site should give you a decent sky for an hour or so before our dazzling satellite sets.

The Lyrid shower typically produces up to 20 meteors per hour at its peak, but the Moon's presence likely will cut that

number in half. The meteors — streaks of light produced when tiny bits of dust burn up high in Earth's atmosphere — appear to radiate from a point in Lyra the Lyre. This compact constellation

Lyrid meteors

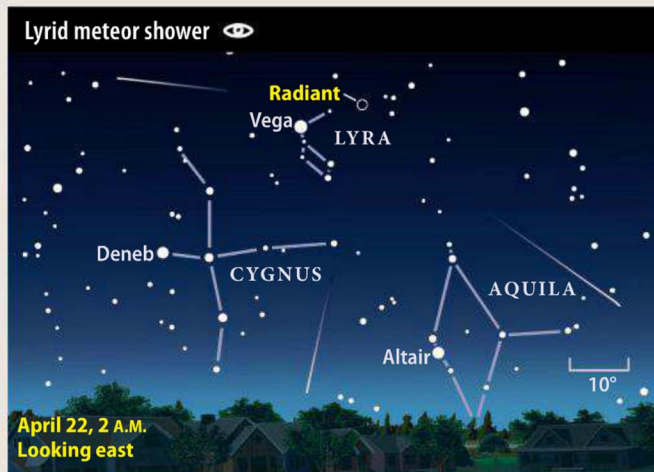
Active Dates: April 16–25

Peak: April 22

Moon at peak: Waxing gibbous

Average rate at peak:
20 meteors/hour

rises as darkness falls and passes through the zenith as dawn starts to break.



Lyrid meteors must battle a bright gibbous Moon at their peak, but viewers should still see a number of shooting stars. ASTRONOMY: JAY SMITH

OBSERVING HIGHLIGHT

The 27-minute-long partial lunar eclipse April 25 is the shortest such eclipse since May 3, 1958.



STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight April 1
11 P.M. April 15
10 P.M. April 30

Planets are shown at midmonth

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless magnified





APRIL 2013

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	 1	 2	 3	 4	 5	 6
 7	 8	 9	 10	 11	 12	 13
 14	 15	 16	 17	 18	 19	 20
 21	 22	 23	 24	 25	 26	 27
 28	 29	 30				

Calendar of events

- 3**  Last Quarter Moon occurs at 12:37 A.M. EDT
- 6** The Moon passes 6° north of Neptune, 9 P.M. EDT
- 8** The Moon passes 7° north of Mercury, 6 A.M. EDT
- 10**  New Moon occurs at 5:35 A.M. EDT
- 12** Pluto is stationary, 3 P.M. EDT
- 14** The Moon passes 2° south of Jupiter, 2 P.M. EDT
- 15** The Moon is at apogee (251,570 miles from Earth), 6:21 P.M. EDT
- 17** Mars is in conjunction with the Sun, 8 P.M. EDT
- 18**  First Quarter Moon occurs at 8:31 A.M. EDT
- 19** Mercury passes 2° south of Uranus, 5 P.M. EDT
- 22** Lyrid meteor shower peaks
- 24** The Moon passes 0.004° north of Spica, 8 P.M. EDT
- 25**  Full Moon occurs at 3:57 P.M. EDT; partial lunar eclipse
- The Moon passes 4° south of Saturn, 10 P.M. EDT
- 27** The Moon is at perigee (225,103 miles from Earth), 3:52 P.M. EDT
- 28** Saturn is at opposition, 4 A.M. EDT

SPECIAL OBSERVING DATE

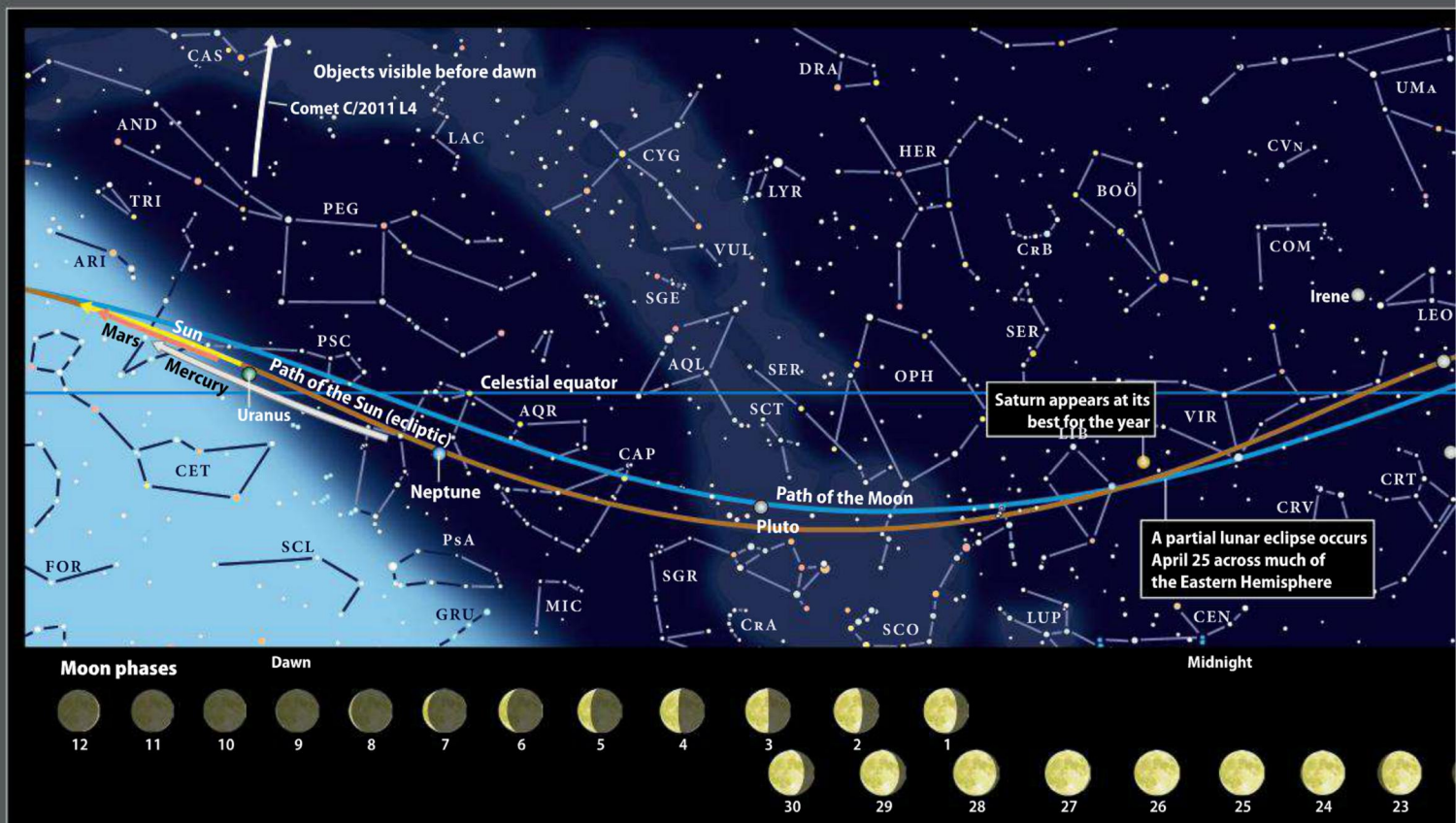
28 Saturn reaches its 2013 peak, shining at magnitude 0.1 and appearing 18.9" across through a telescope (the rings span 42.8" and tilt 18° to our line of sight).

See tonight's sky in Astronomy.com's

STARDOME

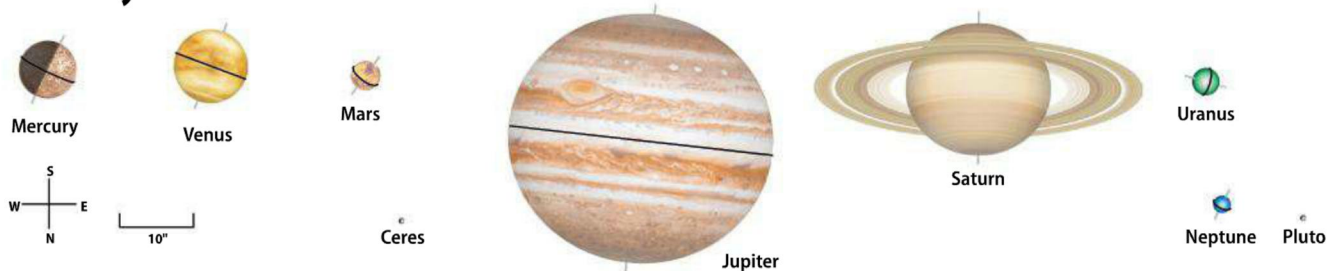


BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT www.Astronomy.com/starchart.



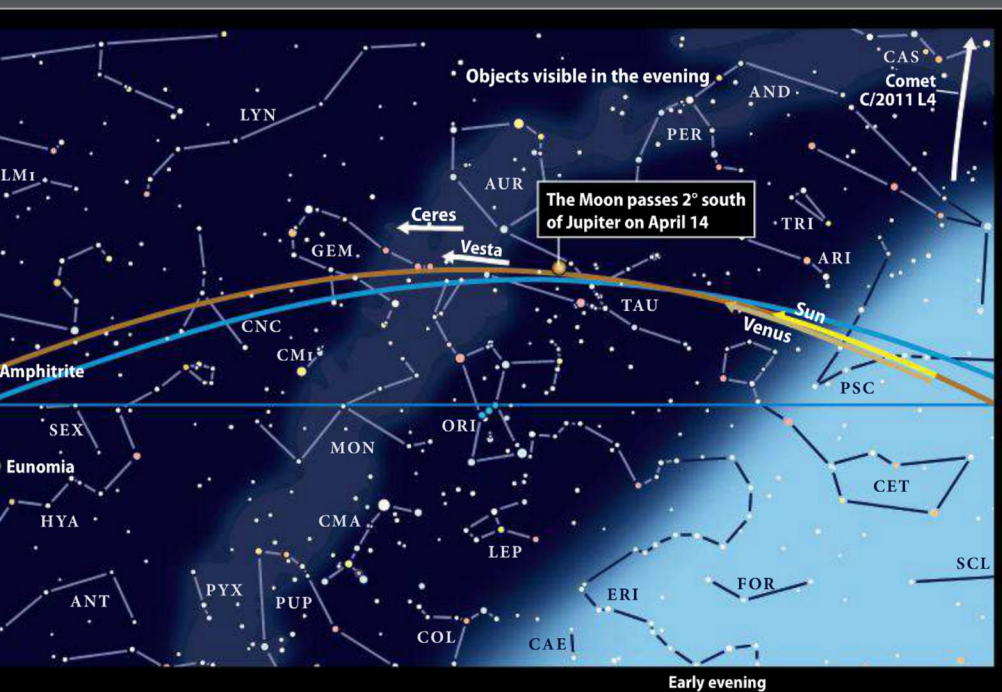
The planets in the sky

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.

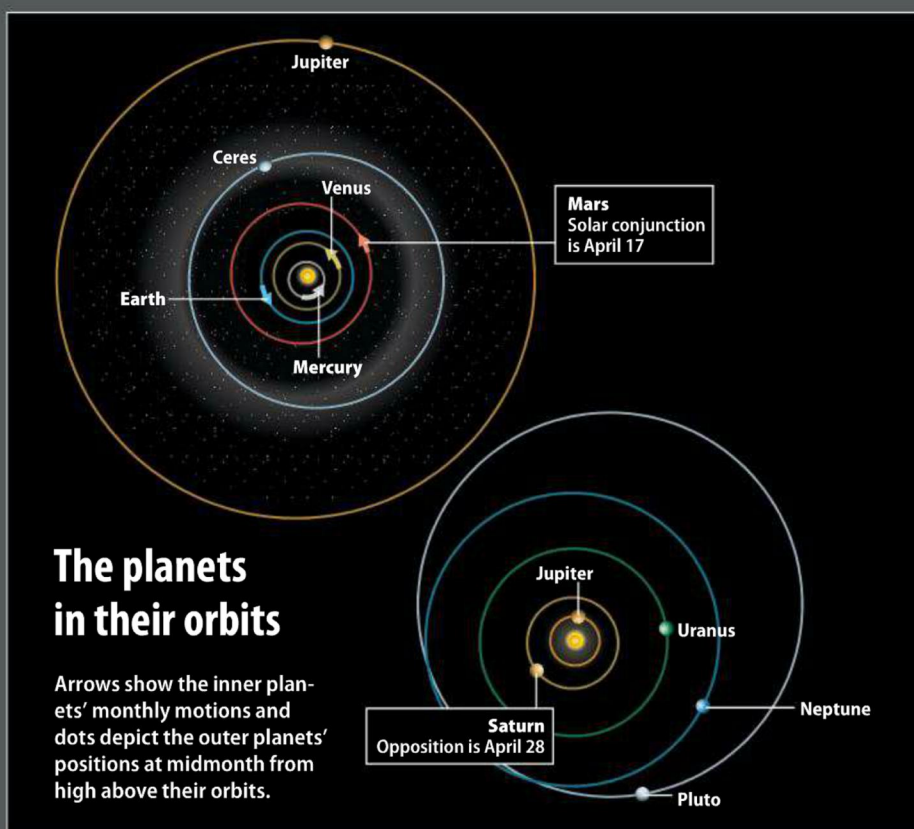


Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	April 1	April 15	April 15	April 15	April 15	April 15	April 15	April 15	April 15
Magnitude	0.2	-3.9	1.2	8.7	-2.0	0.2	5.9	7.9	14.1
Angular size	7.5"	9.7"	3.9"	0.5"	34.6"	18.8"	3.4"	2.2"	0.1"
Illumination	51%	100%	100%	97%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.891	1.720	2.428	2.797	5.698	8.843	21.015	30.615	32.169
Distance (AU) from Sun	0.467	0.724	1.425	2.596	5.098	9.819	20.051	29.987	32.420
Right ascension (2000.0)	23h01.5m	1h50.8m	1h35.9m	6h13.7m	4h51.4m	14h30.0m	0h35.1m	22h26.2m	18h48.4m
Declination (2000.0)	-8°00'	10°24'	9°32'	28°55'	22°09'	-11°58'	3°03'	-10°28'	-19°41'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

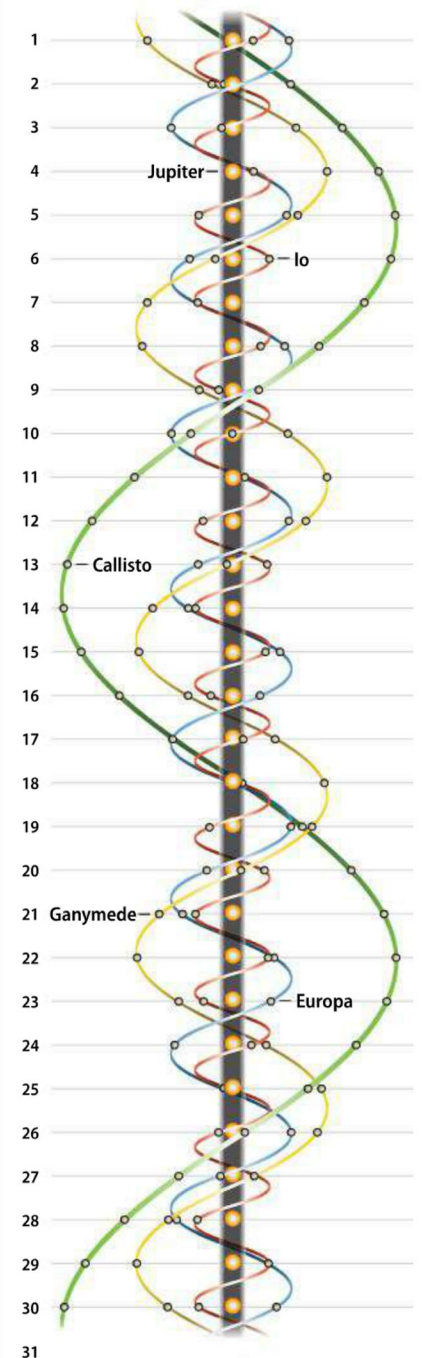


To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.



Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.



WHEN TO VIEW THE PLANETS

EVENING SKY

Jupiter (west)
Saturn (east)

MIDNIGHT

Saturn (southeast)

MORNING SKY

Mercury (east)
Saturn (southwest)
Uranus (east)
Neptune (southeast)

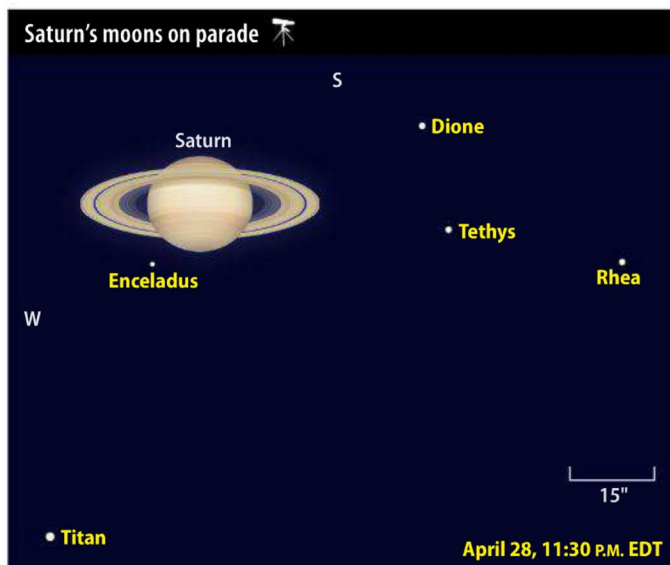
stars of Libra. The magnitude 0.2 planet appears noticeably brighter than Spica. Saturn climbs highest in the south around 3 A.M., when it shows up best through a telescope.

As this world approaches opposition, it rises earlier and delivers great views by midnight. The planet brightens slightly as well, reaching magnitude 0.1 in late April. The Full Moon passes 4° south of Saturn on April 25.

Saturn looks stunning through any telescope. Its disk

measures 19" across the equator at opposition and 17" from pole to pole. This 10 percent difference shows up quite easily in the eyepiece. Still, there's no question that the rings dominate any view. They span 43" and tilt 18° to our line of sight at opposition.

Astronomers label the brightest section of the ring system the B ring. The slightly dimmer one just outside of it is the A ring. The nearly black Cassini Division separates these two broad features.



Titan passes north of the ringed planet the evening of April 28, making this a good night to spot several saturnian moons nearby. ASTRONOMY: JAY SMITH

Saturn's moons offer observers more variety than the four almost equally bright satellites of Jupiter. The ringed world's brightest is magnitude

8.4 Titan, which shows up easily through any instrument. It orbits Saturn once every 16 days, so it completes nearly two circuits each month. Titan

COMETSEARCH

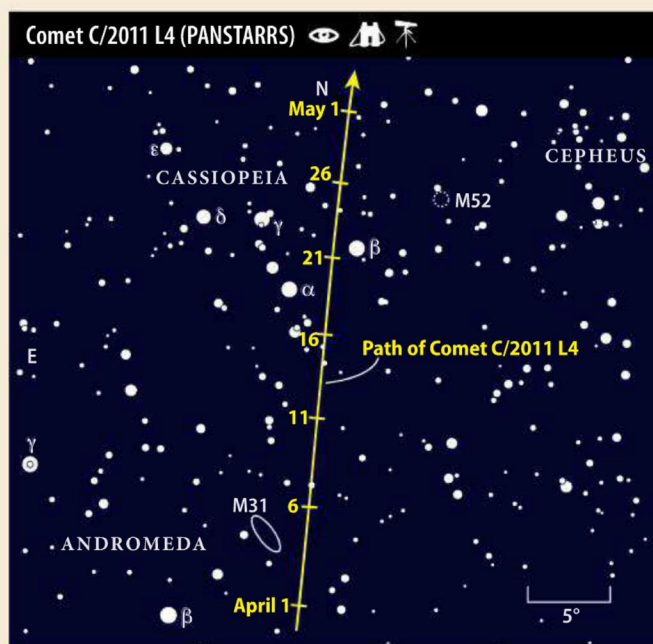
A celestial sword sails past a spiral

Many memorable observing sessions have a bright comet floating next to a terrific deep-sky object. And it looks like April may provide another. Comet C/2011 L4 (PANSTARRS) may reach 5th magnitude when it passes a few degrees from the Andromeda Galaxy (M31) during the month's first week. And we have the added fortune of the Moon being out of the way, which brings the great spiral galaxy into view of naked eyes from dark sites.

You can find the pair in the northwest as darkness descends and again in the northeast before dawn. (The finder chart shows the comet's morning positions because it appears a bit higher then.) PANSTARRS passes 2° west of M31 on April 4 and 5, the best nights for taking wide-angle images. Binoculars will provide superb views for comparing the objects' sizes, shapes, and characters.

The Andromeda Galaxy appears as an elongated oval that brightens toward the center. Contrast that with the comet's bright head, or coma, and the tail that spreads out from there. One characteristic shared by the two is a sharply defined edge. The galaxy's northwest flank, the one closest to the comet, has a prominent dark lane that abruptly ends the glow of M31's distant suns. For PANSTARRS, the side opposite the spiral galaxy shows a sharp boundary where the Sun's radiation sweeps up the dust on the comet's leading edge.

You also should take some closer views through a telescope. Look at the comet's head for a tiny bright speck, called the false nucleus. The dirty snowball's real surface lies shrouded within this cocoon of dust. M31's true core similarly is buried behind a cloud of surrounding stars.

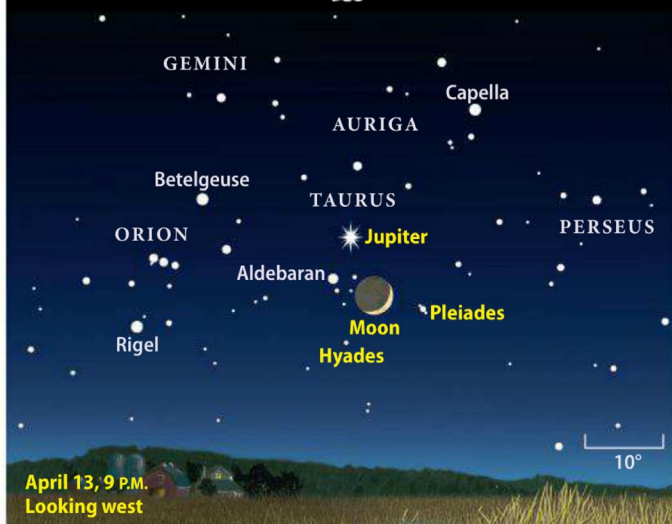


Spring's brightest comet passes near the northern sky's brightest island universe — the Andromeda Galaxy (M31) — April 4 and 5. ASTRONOMY: JAY SMITH

The Moon begins spilling its light into the evening sky after April 15, reducing the contrast between sky and comet. But keep observing on the following nights or make a morning

vigil to monitor changes in the tail. By the 26th, the comet likely has faded to 7th magnitude. It then lies in Cassiopeia, about one binocular field east of the bright open star cluster M52.

The Moon embraces the Bull



The Moon passes through Taurus on April 13, forming a pretty composition with the Pleiades and Hyades with Jupiter above. ASTRONOMY: JAY SMITH

appears closest to Saturn when it swings north or south of the planet. It passes north April 12/13 and 28/29 and south April 4/5 and 20/21.

Perhaps the most intriguing saturnian satellite is Iapetus. This moon's brightness varies by a factor of five, from magnitude 10.1 to 11.9, as it orbits the planet every 79 days. Iapetus always appears brightest when it lies far west of Saturn and dimmest when it's far east.

The biggest challenge to finding this moon is that its huge orbit carries it well away from Saturn. Iapetus' last western elongation occurred March 13, when it stood 10' from the planet. It passes 2.5' due north of Saturn the night of April 1/2, when it glows at 11th magnitude. The moon continues to fade as it swings east, reaching greatest elongation April 21/22.

Several other moons orbit much closer to Saturn. These satellites don't appear as obvious at first glance because the rings' brilliance diminishes their visibility. Still, a 4-inch or larger telescope should reveal at least three of them.

The brightest is magnitude 9.7 Rhea, which orbits Saturn in 4.5 days. It never strays more than 1.4' from Saturn. Next up is magnitude 10.3 Tethys. With an orbital period of 1.9 days, it always remains within 0.8' of

the planet. Magnitude 10.4 Dione orbits between these two moons. Enceladus is the most challenging moon for most backyard observers. Glowing at magnitude 11.8 and in a 1.4-day orbit that keeps it forever close to the rings, you'll need a 10-inch scope and good viewing conditions to spot it.

The morning sky brings a fleeting view of **Mercury** in early April. The innermost planet reached greatest western elongation on the final day of March. For observers at mid-northern latitudes April 1, the magnitude 0.2 object stands 4° high in the east 30 minutes before sunrise. You'll likely need binoculars to pick it out of the brightening twilight. A waning crescent Moon passes 7° north (to the upper left) of the planet on the 8th.

Neither **Venus** nor **Mars** appears in April — both lie too near the Sun. Venus will return to the evening sky in May while Mars waits until June to make a predawn appearance.

Uranus and **Neptune** are barely visible before dawn in late April. Sixth-magnitude Uranus hangs low in morning twilight; 8th-magnitude Neptune appears about 10° above the southeastern horizon as twilight begins. Both will make

LOCATING ASTEROIDS

An object fit for the Bull

The sky's brightest asteroid puts on a good show in April. The best time to track down 4 Vesta comes during the month's initial week. It then lies in front of some dark, dusty clouds in Taurus that blot out more distant stars in this part of the Milky Way. Glowing at magnitude 8.2, Vesta likely will be out of binocular range if you view from the suburbs, but a 3- or 4-inch telescope will pick it up quite easily.

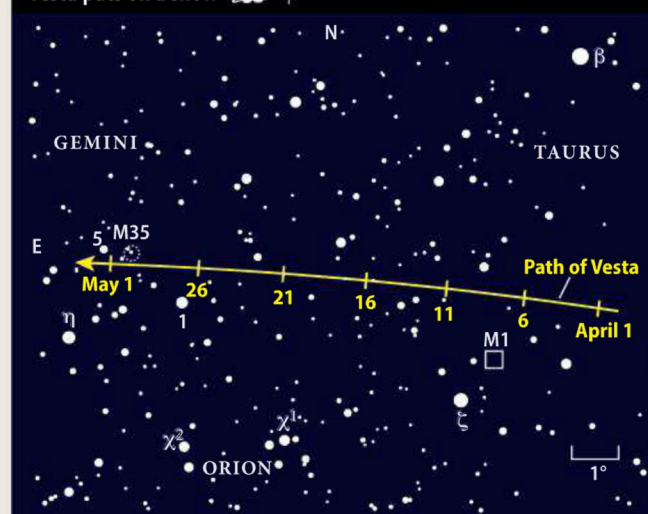
Start at 3rd-magnitude Zeta (ζ) Tauri, the star marking the tip of the Bull's southern horn, and then hop to the Crab Nebula (M1), the remnant of a supernova seen on Earth in 1054. Then use the finder chart below to move a little north and west to Vesta's position.

The next best time to visit Vesta comes in the waning days of April. A great place to start

any spring observing session is with the open star cluster M35 in western Gemini. Its bright stars readily punch through the veil of light pollution and make it an attractive sight. Use the nearby 6th-magnitude star 5 Geminorum to help you figure out which way is up in the eyepiece and then carefully make your way over to Vesta. The space rock will be one of the brightest dots visible through the eyepiece.

On the evening of April 29, the magnitude 8.4 asteroid passes directly in front of NGC 2158. This rich open star cluster lies less than ½° southwest of M35, but because it lies farther from Earth than its neighbor, it appears smaller and fainter. Vesta takes about two hours to cross NGC 2158, just enough time to watch before they set for the night.

Vesta puts on a show



The brightest asteroid continues to traverse the star-studded backdrop of Taurus the Bull, not far from Zeta (ζ) Tauri. ASTRONOMY: JAY SMITH

more tempting targets in the months ahead.

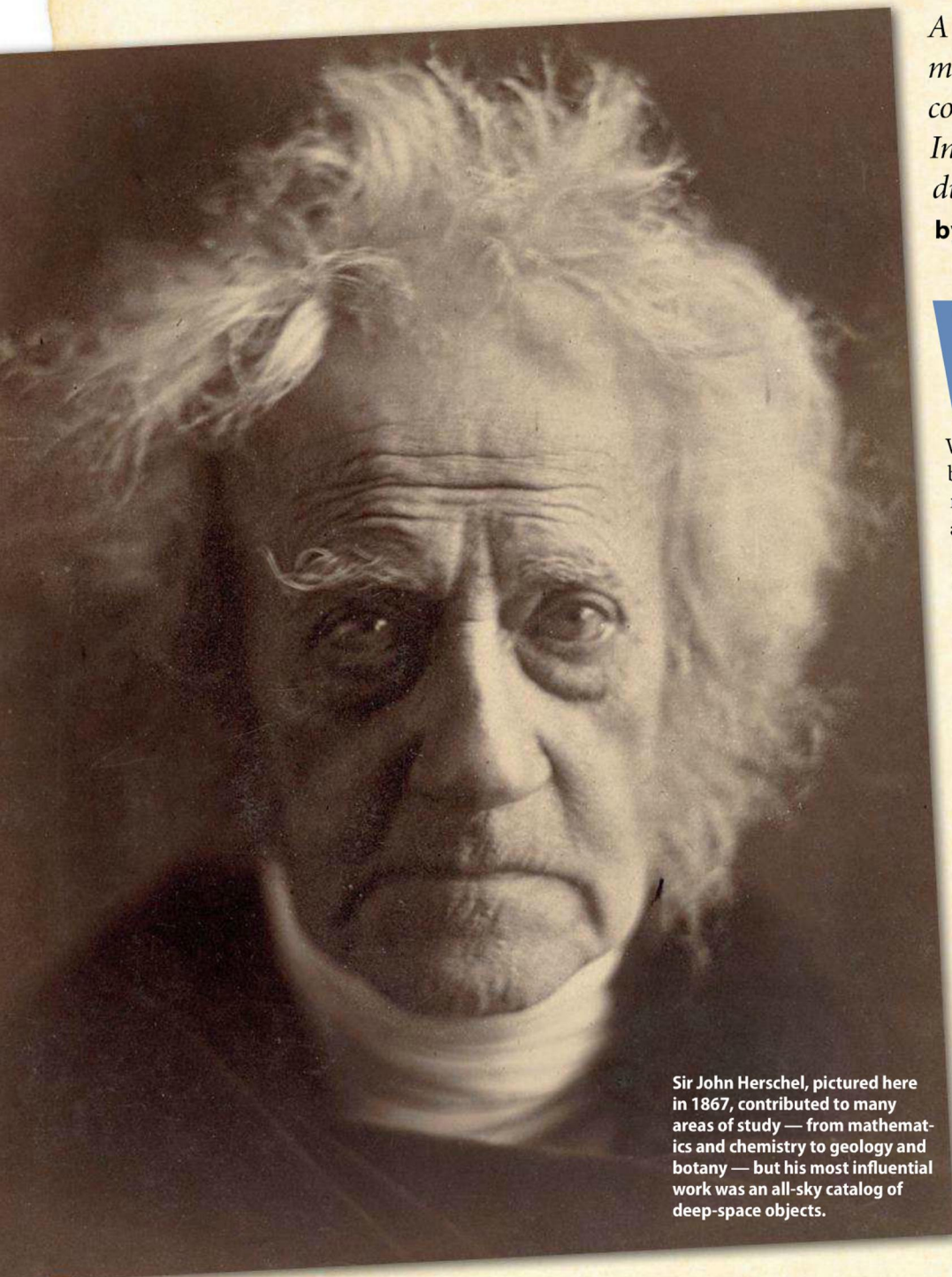
If you live in Europe, Asia, Africa, or Australia, watch the April 25 Full Moon. Our satellite then passes through the

southern edge of Earth's dark umbral shadow, bringing a minor **partial lunar eclipse**. When maximum arrives at 20h08m UT, just 1.5 percent of the Moon lies in the shadow. ☾



GET DAILY UPDATES ON YOUR NIGHT SKY AT www.Astronomy.com/skythisweek.

The reluctant astronomer



Sir John Herschel, pictured here in 1867, contributed to many areas of study — from mathematics and chemistry to geology and botany — but his most influential work was an all-sky catalog of deep-space objects.

A brilliant chemist and mathematician, John Herschel could have chosen many careers. Instead, he took up the “sacred duty” started by his father.

by Andy Burns and Nick Howes

When you think of the name Herschel, the first person who probably springs to mind is Friedrich Wilhelm — more commonly known as William Herschel, the famous German-born musician and self-taught astronomer who arrived in the United Kingdom as a penniless refugee in 1757. His discovery of the first planet since antiquity, Uranus, from a modest rented house in the English town of Bath in 1781 transformed our knowledge of the size and contents of the solar system.

Or perhaps the name Herschel might make you think of William’s illustrious sister, Lucretia Caroline Herschel, one of the first female professional astronomers, who supported and logged data for William’s nightly observations. She also discovered eight comets and undertook a remarkable reworking of the famous Flamsteed star catalog.

But that name should also make you think of William’s son, John, a brilliant mathematician, chemist, and astronomer who dabbled in many fields of study and produced an unprecedented all-sky catalog.

A young scholar

After his appointment as astronomer to the court of King George III in 1782, William moved to the English town of Slough, where he rented

what was to become “Observatory House.” He married the daughter of his landlady, the widow Mary Baldwin Pitt, who already had one child.

John, the couple’s only son, was born March 7, 1792, when William was 54 and still working with his “Great Forty-Foot Telescope” (named after the instrument’s focal length, the largest in the world at the time). Mary’s first son passed away young, which made her very protective of John. At age 8, he was enrolled in boarding school only to have Mary remove him months later after a boxing match in which she saw her son knocked down by an older boy.

The young Herschel then received private education and tutoring in mathematics at Observatory House, which probably contributed to his passing the entrance exam for the University of Cambridge St. John’s College at age 16. Studying mathematics and physics, Herschel subsequently went on to become Senior Wrangler (the leading academic) for the entire university, with competition in his year from the likes of Charles Babbage, eventual inventor of an automatic, mechanical calculator known as the difference engine (though Babbage also claimed that Herschel himself had the idea for this instrument). During his time as a student, Herschel also helped form the Analytical Society of Cambridge, changing the notation of mathematical algebra to that used throughout the rest of Europe — a daring feat, as it challenged the authority of Sir Isaac Newton, a revered name in English mathematics.

Herschel was a brilliant linguist, chemist, artist, and poet, though he never had enough time for all of his interests. He once wrote Babbage: “God knows how ardently I wish I had ten lives, or that capacity ... of husbanding every atom of time, which some possess, and which enables them to do ten times as much in one life.” Still, upon graduation, Herschel decided on the practical career of law, moving to London in 1814 to begin studying for the bar. This path didn’t last long, though, because he probably spent more time invested in science than law during those 18 months in the city.

So Herschel took a position as a mathematics tutor at St. John’s in Cambridge.

Andy Burns is a Herschel historian, chair of the Wiltshire Astronomical Society, and co-director of the Griffon Educational Observatory. **Nick Howes** is a freelance science writer for the European Space Agency and the pro-am program manager for the Faulkes Telescope.

► While in his 20s, John Herschel searched for a vocation that would allow him to work on a variety of scientific interests. He thought of being a lawyer but ultimately moved to his father’s home to be William’s astronomy assistant.

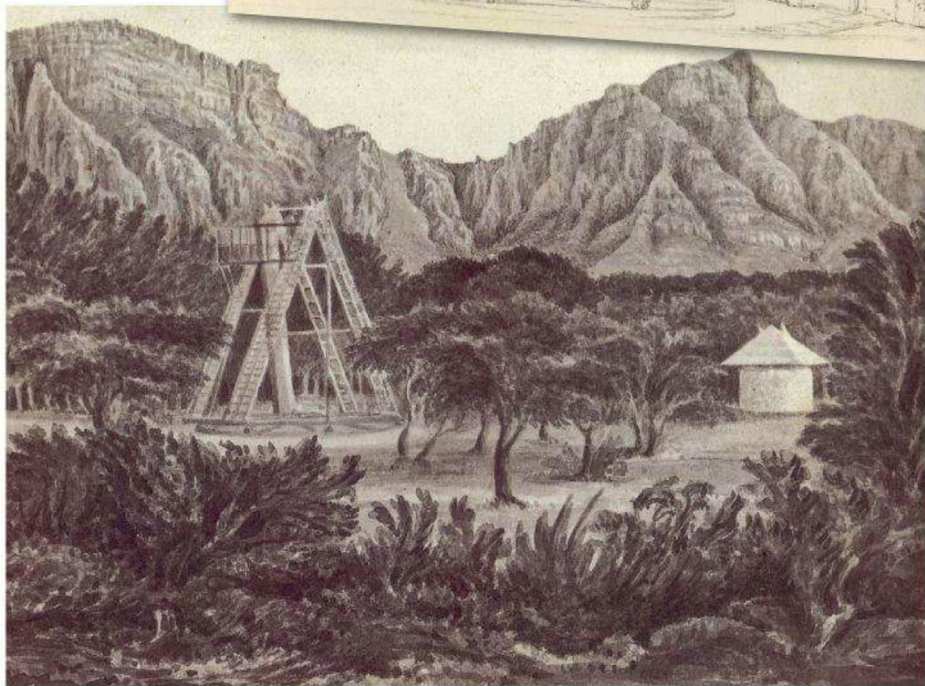
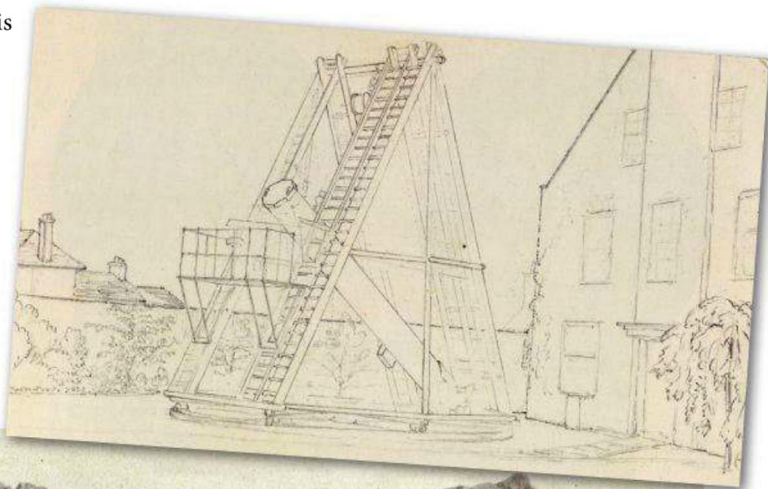


His brilliant mind, however, led to a growing restlessness with his students. Meanwhile, his aging father now needed an assistant to complete his work, and a note from William in 1816 encouraged the younger Herschel to return to the field of astronomy, which his aunt Caroline had taught him as a boy.

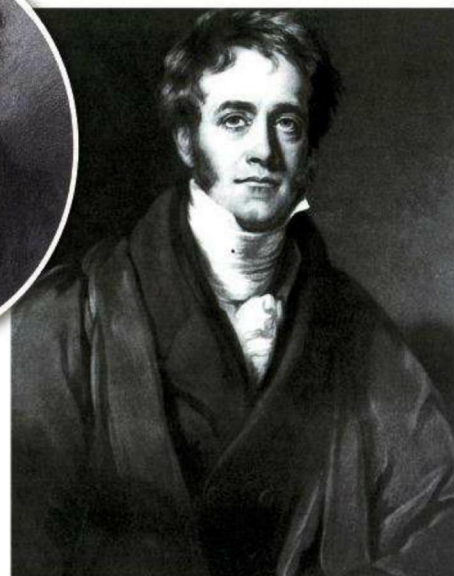
Continuing a legacy

Herschel’s astronomical career started when he measured 380 binary pairs in his father’s double-star catalog. Meanwhile, he and William helped found the Royal Astronomical

► Sir William Herschel’s 20-foot reflector next to Observatory House played an important role in John Herschel’s all-sky catalog.

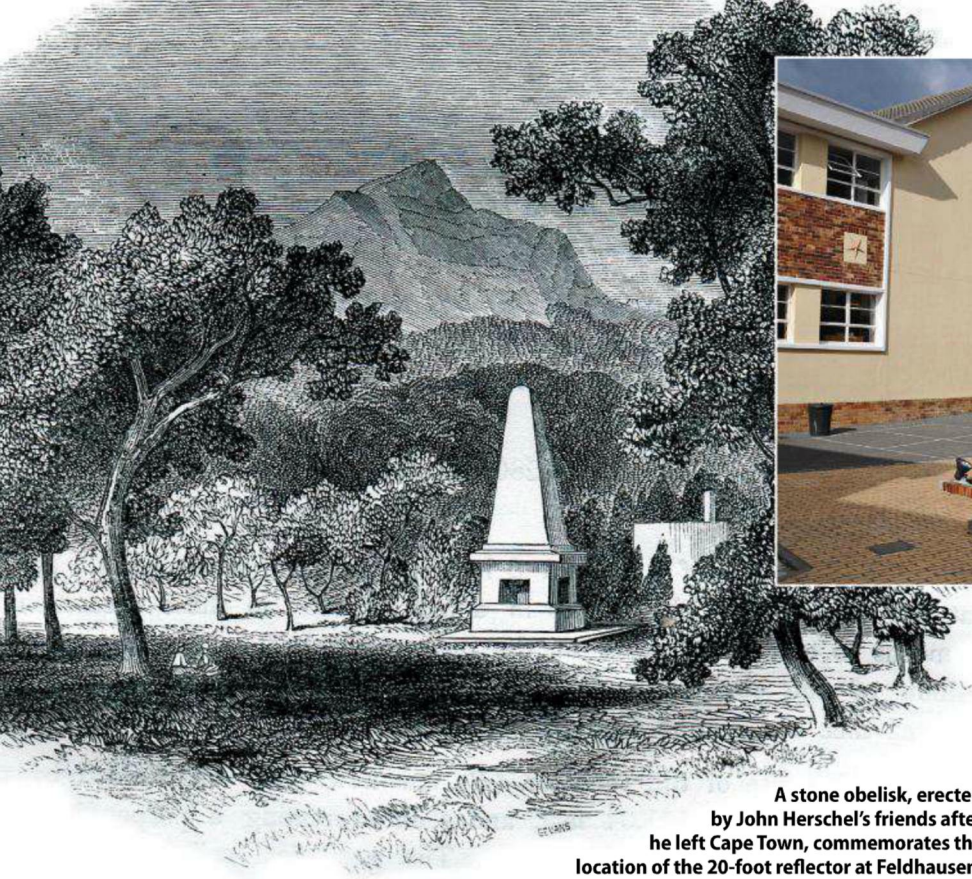


John Herschel built a replica of his father’s 20-foot focal length reflector at his Cape Town home, called Feldhausen, to use for his southern sky observations.

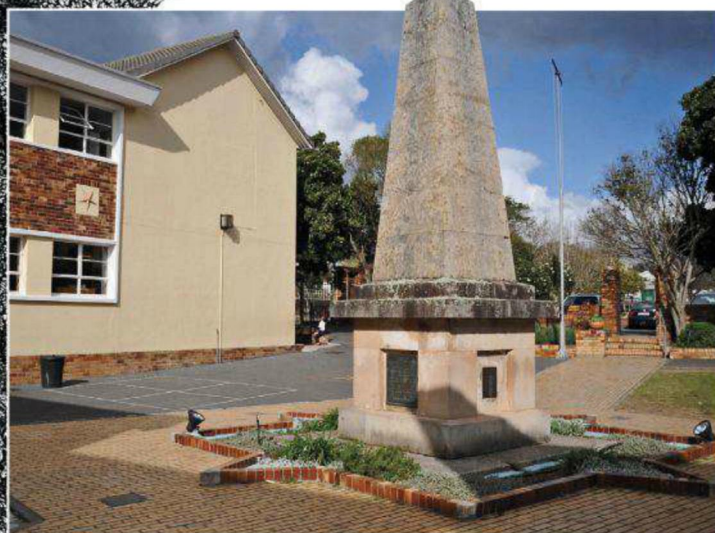


By age 38, John Herschel was nearing the completion of his Northern Hemisphere catalog of deep-sky objects and began to consider a move to Cape Town to study the southern sky.

ALL PHOTOS ON THIS PAGE: ANDY BURNS/HERSCHEL MUSEUM OF ASTRONOMY



A stone obelisk, erected by John Herschel's friends after he left Cape Town, commemorates the location of the 20-foot reflector at Feldhausen. It still stands today next to a primary school.



ANDY BURNS/HERSHEL MUSEUM OF ASTRONOMY; INSET: ANDY BURNS

Society in 1820, with the elder Herschel becoming the organization's first president (his son would serve as president three times between 1827 and 1848).

The younger Herschel's studies took him from England to many far-flung locations, and it was on one such trip in 1822

that he learned of his father's passing. While he continued to tour Europe multiple times afterward and completed studies in areas such as light (his "first love"), Herschel felt the need to focus on adding to his father's efforts: "I do the completion of this work not as a matter of choice or taste,

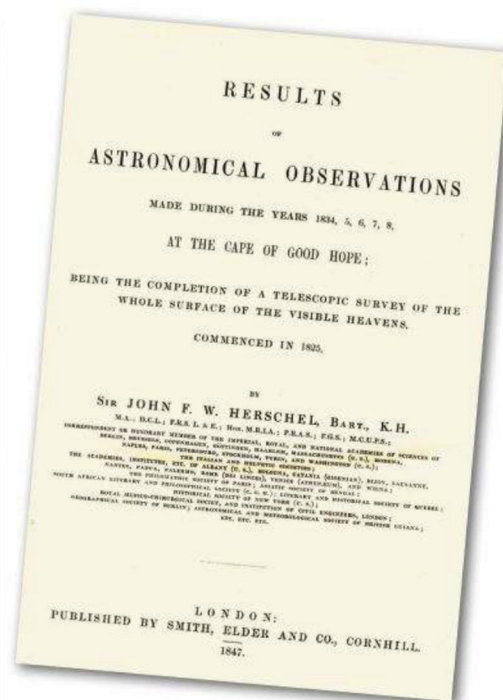
but a sacred duty which I cannot postpone to any consideration."

Between 1825 and 1833, the younger Herschel completed two great catalogs. The first was a six-part work on double stars that contained 5,075 objects (3,347 of his own and the rest from the work of his father, German astronomer Friedrich Georg Wilhelm von Struve, Sir James South, and others).

This work didn't always leave him fulfilled, though, and such an exhaustive task did take its toll on some nights. "Two stars last night, and sat up till two waiting for them," Herschel once wrote. "Ditto the night before. Sick of star-gazing — mean to break the telescope and melt the mirrors."



Detailed sketches of Comet Halley, like this one John Herschel drew October 29, 1835, played an important part in astronomers' understanding of the great comet. ANDY BURNS/HERSHEL MUSEUM OF ASTRONOMY



John Herschel's observations from Cape Town laid the foundations for the *General Catalogue* of the skies. ANDY BURNS/HERSHEL MUSEUM OF ASTRONOMY

His second catalog during that time was a detailed list of more than 2,300 nebulae and star clusters in the Northern Hemisphere that Herschel cataloged using his father's 20-foot telescope; it revised and extended William's list, which Caroline had compiled in 1929. Her work helped Herschel immensely, as he wrote to his aunt: "But I always find [your] catalogue most useful. I always draw out from it a regular *working list* for the night's sweep, and by that means have often been able to take as many as thirty or forty nebulae in a sweep."

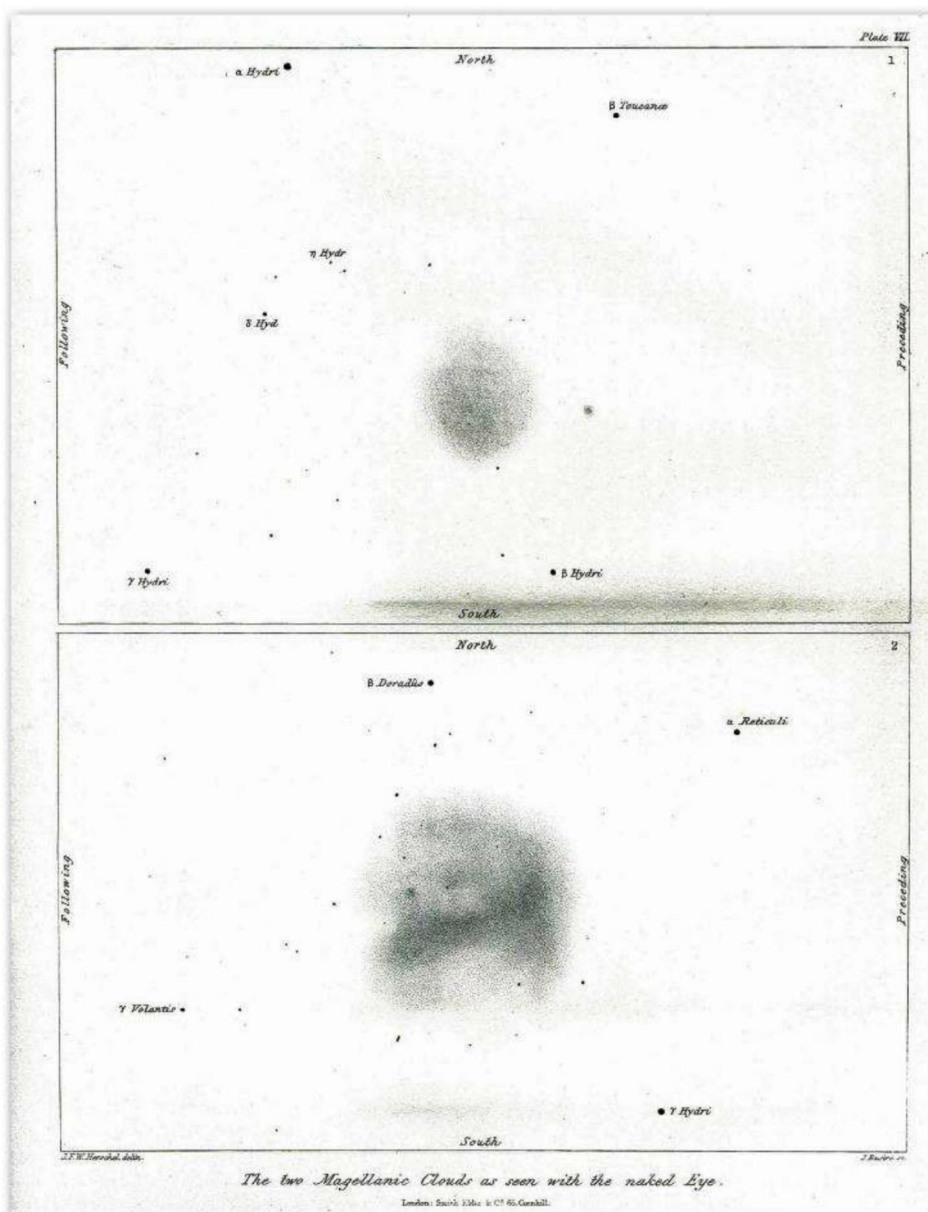
Meanwhile, Herschel's personal life went through significant change during this period. After William died, Caroline moved back to her home of Hanover, Germany, leaving a quiet house in Slough for John and his mother. He had been engaged twice (which led to two grand tours of Europe to escape the embarrassment), but only married in 1829 upon meeting Margaret Brodie Stewart, a young girl nearly 20 years his junior.

While Herschel was in Slough working on this Northern Hemisphere catalog, he narrowly missed being appointed president of the famed British scientific institution the Royal Society (his peers had elected him secretary in 1824). This is possibly one reason he decided to move to Cape Town in what is now South Africa. The final push to set out to view the southern skies came with his mother's passing in 1832.

Southern catalogs

The next year, Herschel left Portsmouth in the United Kingdom with 12 coach-loads of instruments, along with his wife, three young children, and their nanny. To allow himself the freedom to do whatever kind of research he chose and not be limited to one assignment, he paid for the trip himself, refusing offers of financial support from the British Admiralty and the Royal Society. The Herschel family reached the Cape Colony in January 1834, settling in a house called Feldhausen at the edge of Table Mountain.

Herschel arrived with a 20-foot telescope identical to the one he used for his Northern Hemisphere catalog, as well as a 5-inch refractor. During his southern sky surveys, Herschel managed to expand his double-star catalog to more than 10,000 examples. For this immense work, Herschel became one of only two people in history to receive the Copley Medal twice from the Royal Society (the first time being for his work in mathematics). He ultimately spent the last seven years of his life creating a complete catalog of all double stars in the sky, which was published after his death.



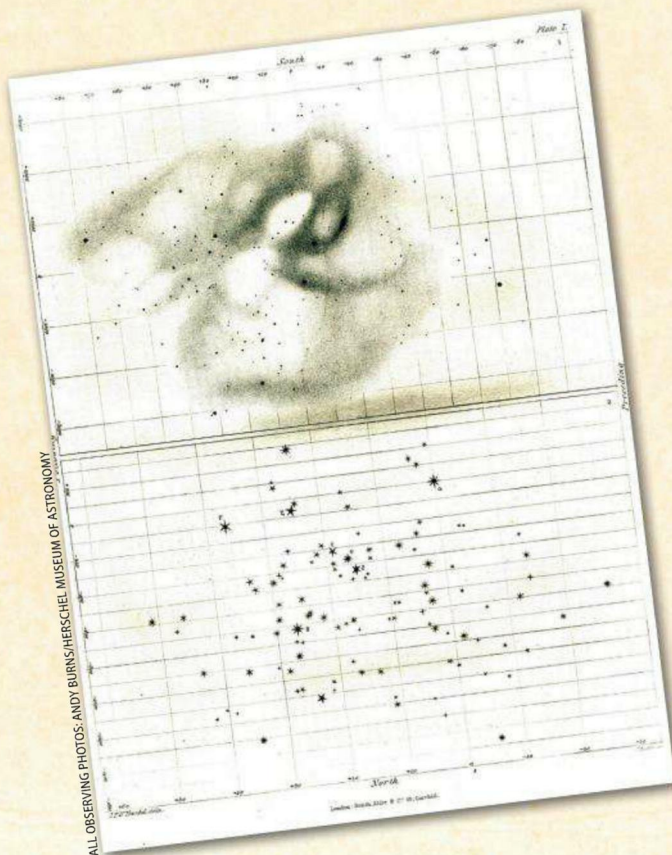
The Magellanic Clouds, sketched here as John Herschel saw them with his naked eyes, were a primary target for the astronomer during his southern sky studies from Cape Town.

While also at Feldhausen, Herschel compiled a catalog of 1,707 southern deep-sky objects, only 439 of which astronomers had previously observed. He would spend years putting together his observations from the Cape upon his return to England and ultimately compile them with his data from Slough to create the *General Catalogue of Nebulae and Clusters of Stars*, published in 1864 — the first all-sky catalog. It was unique because one person compiled it using the same telescope in both hemispheres, and it became commonly known as the *General Catalogue* (only updated by the *New General Catalogue* [NGC] in 1888 by John Louis Emil Dreyer).

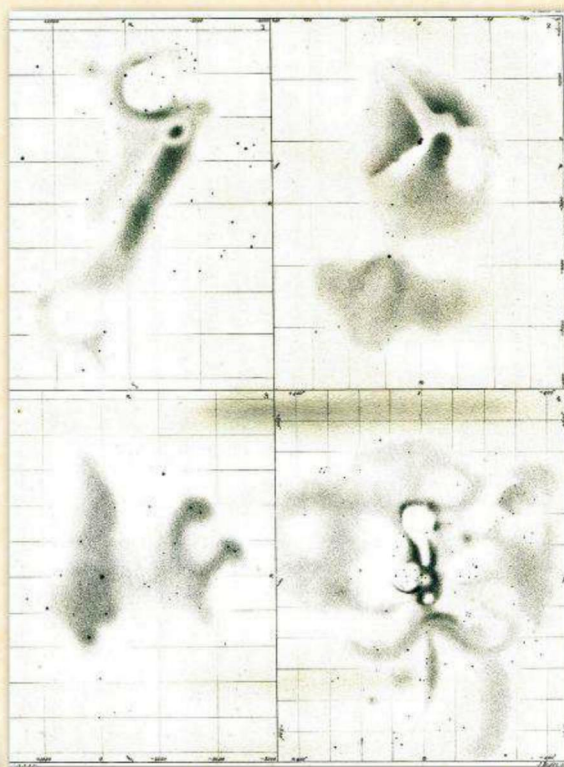
Herschel's work in Cape Town didn't end with cataloging double stars and deep-

sky objects, though. He made star counts that provided information on the structure of the Milky Way, even writing to a colleague in 1836: "It is impossible to resist the conviction that the Milky Way is not a stratum but a ring." He also produced maps of the Large Magellanic Cloud and the Orion Nebula, made important observations of Halley's Comet, formalized the names of seven moons of Saturn (and later four of Uranus), and measured the energy being received on Earth from the Sun.

Herschel even influenced the formation of a state-run educational system in South Africa to include free schooling for all. And he did this all while taking up a side interest as a geologist, collecting thousands of rock samples, and becoming an acclaimed



John Herschel sketched the Lagoon Nebula (M8, top) and the Jewel Box (NGC 4755) to compare with views from American astronomer Charles Mason.



John Herschel made detailed observations of the sky's famous nebulae, including (clockwise from top left) the Swan Nebula (M17), the Trifid Nebula (M20), the Tarantula Nebula (which he split into many individual objects), and the Eagle Nebula (M16).



botanist by producing a large volume of plant drawings, which Margaret colored.

All in all, Herschel was pleased with his time at Feldhausen, as he wrote later, "The days of our sojourn in that sunny land will stand marked with many a white stone as the happy part of my earthly pilgrimage."

Lasting influence

On his return to England in 1838 (now with six children in tow), Herschel went to work finishing his "Cape Catalogue," which he would publish in 1847 — sending one of the first copies to Caroline in Hanover (she died a year later). By then, he felt his work was almost complete in the field of observational astronomy — with the production of larger instruments, like the 72-inch telescope at Birr Castle in England, built by William Parsons, 3rd Earl of Rosse — taking over. His only remaining contribution was to complete his work on the *General Catalogue*, now with more than 5,000

objects, and his double-star catalog, which numbered some 10,300 pairs.

But by then Herschel's influence on astronomy and other sciences was concrete. It's amazing when you consider just how much the son achieved that his fame does not equal his father's. John Herschel's groundbreaking work on the energy output of the Sun is widely regarded as the foundation of modern solar physics. An 1819 paper he wrote on the discovery that sodium thiosulfate dissolves silver salts later helped his friend William Henry Fox Talbot fix his issues with early photographic processing. And although he might not be the sole person to name the process "photography," Herschel did define two terms in the field: *positive* and *negative*.

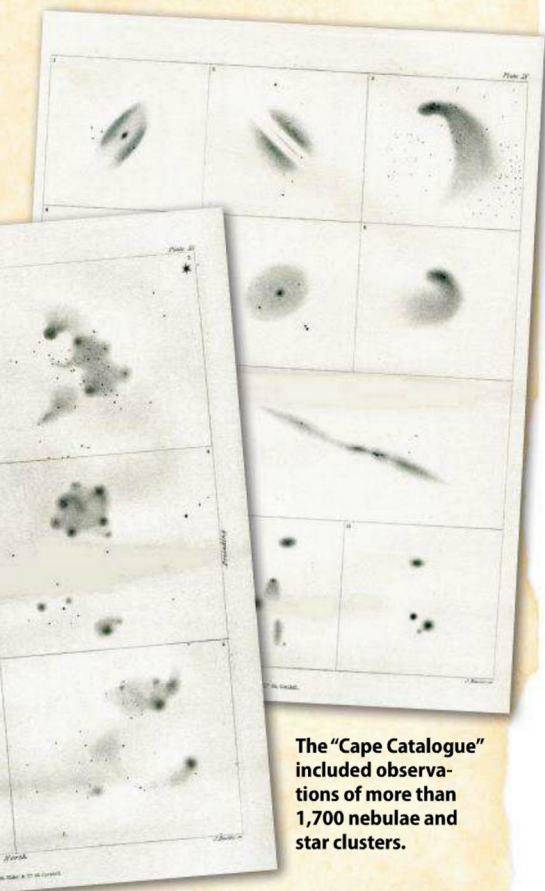
Herschel even became a longtime friend of his eventual portrait artist, Julia Margaret Cameron (see her work on p. 44) through his keenness to pass on the science he studied. He introduced Cameron to photography, so

the opportunity to take Herschel's portrait was a deeply significant moment. In her 1874 autobiography, *Annals of my Glass House*, Cameron wrote: "When I have such men before my camera my whole soul has endeavoured to do its duty towards them in recording faithfully the greatness of the inner as well as the features of the outer man. The photograph thus taken has been almost the embodiment of a prayer. Most devoutly was this feeling present to me when I photographed my illustrious friend, Sir John Herschel. He was to me as a teacher and High Priest. From my earliest girlhood I had loved and honoured him, and it was after a friendship of 31 years duration that the high task of giving his portrait to the nations was allotted to me."

But his impact didn't stop there. Herschel's 1830 *Preliminary Discourse on the Study of Natural Philosophy*, which provided basic surveys on various physical sciences, was a leading influence on the work of English naturalist Charles Darwin, who would later visit him in Cape Town on one of his excursions. Upon finishing his now famous work *On the Origin of Species*,

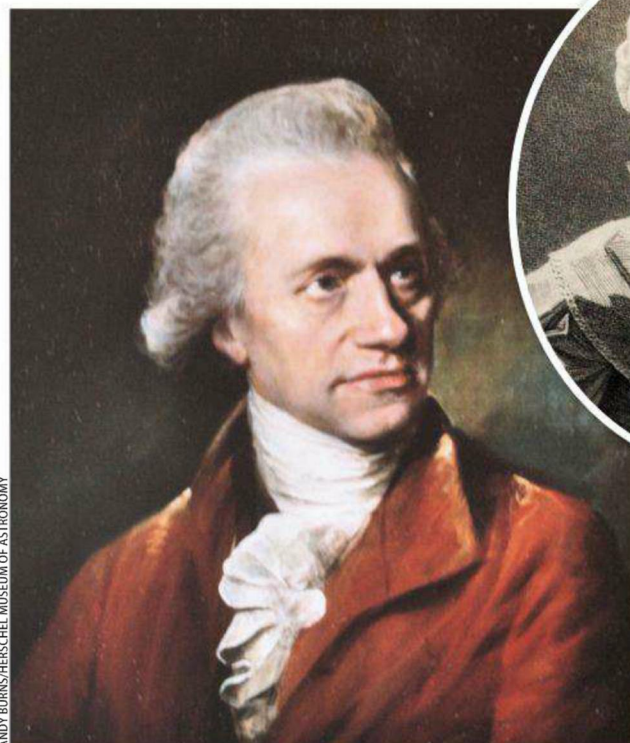
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The "Cape Catalogue" included observations of more than 1,700 nebulae and star clusters.

ANDY BURNS/HERSCHEL MUSEUM OF ASTRONOMY



▶ Sir William Herschel (left) and his sister, Caroline, both famous for contributions to astronomy, ultimately inspired John to pursue studies in the field. He went on to revise and extend William's list, which Caroline had compiled.

Darwin sent Herschel a copy with a note of praise: "I know that I ought to apologise for troubling you with the volume & with this note (which requires no acknowledgment) but I cannot resist the temptation of showing in this feeble manner my respect, & the deep obligation, which I owe to your Introduction to Natural Philosophy. Scarcely anything in my life made so deep an impression on me: it made me wish to try to add my mite to the accumulated store of natural knowledge."

Beyond such contributions, for amateur astronomers reading this article, the invention of the Herschel wedge, which allows for safe solar observations, may be one of his most pertinent legacies. All in all, Herschel's work influenced many facets of modern scientific knowledge, not just astronomy.

A quiet brilliance

In later life, Herschel became Master of the Mint, introducing new standards for plate printing of paper money to the United Kingdom, as well as the purity of gold and

silver (essentially the basis of the carat system). But he didn't enjoy the position, as he wrote in his diary in 1853: "Any man having anything to do with the Public Service under the Treasury who can do anything else is a fool. Though it is writing my own condemnation." Herschel finally retired in 1856 due to his health and the Mint's location away from his beloved family, which by then included 12 children.

Ultimately, Herschel attempted to de-emphasize his astonishing accomplishments. He spent his later years outside a small village in Kent working on his all-sky catalogs and writing, notably books on natural history and familiar scientific subjects including light and meteorology. He also produced works to popularize astronomy with the educated public, including many editions of his *Outlines of Astronomy*, which science writer Agnes M. Clerke called "perhaps the most completely satisfactory general exposition of a science ever penned."

On May 11, 1871, this gentle, brilliant, and modest man went to his death certain that he was only a pale shadow of his father and aunt. In the end, though, many said that's the way he wanted things to be.

Herschel was laid to rest next to Isaac Newton and Charles Darwin in the hallowed confines of Westminster Abbey in London — possibly the greatest honor he

could have received. His list of awards fills several pages, and when you consider the mountains in Antarctica, the asteroid, and the craters on the Moon and Mars named after him, along with the plethora of international citations concerning his work, it is a wonder his name is not better-known.

Herschel's obituary in 1871 read, "British science has sustained a loss greater than any which it has suffered since the death of Newton, and one not likely to be replaced." So next time you hear the name Herschel, hopefully you'll consider the extraordinary life led by one of the world's great polymaths and look on in wonder and admiration at what John Herschel gave the sciences and mankind. 🌌



Sir John Herschel is entombed in Westminster Abbey in London next to Charles Darwin, an indicator of the great importance his work played in our understanding of the universe. ANDY BURNS



READ EXCERPTS OF JOHN HERSCHEL'S DIARY AT www.Astronomy.com/toc.

CORONA LIGHT

Q: WHY IS THE SUN'S CORONA SO HOT?

Stacey Gaines, Philadelphia

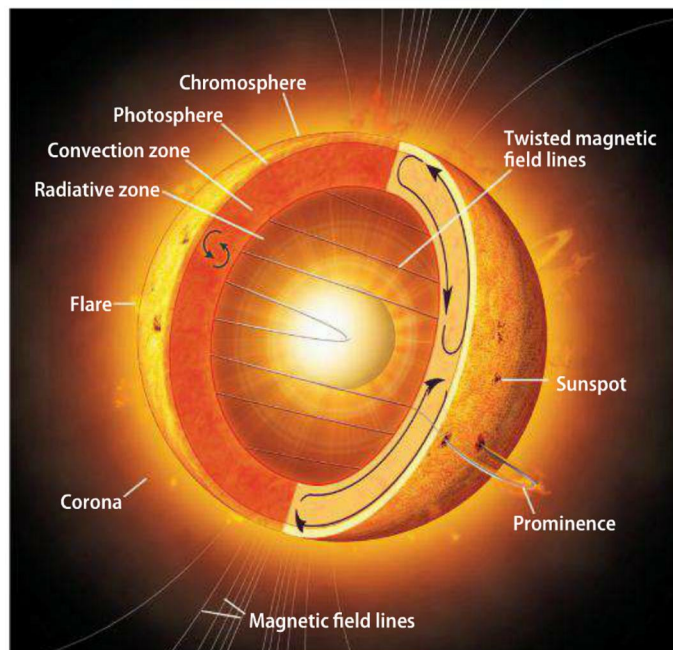
A: The Sun's radiative interior extends to about two-thirds of the solar radius and is the source of our star's rotation; photons and other particles carry heat in this region of the solar interior. This, in turn, feeds convection, which stirs the plasma under the Sun's visible surface (called the photosphere). The interaction between convection and rotation in the upper third of the Sun's interior creates strong magnetic fields, which rise through the interior and thread through the surface, making sunspots, prominences, and all kinds of beautiful structures.

We think the balance between the pressures (or forces) of magnetism and convective plasma motion is critical in heating the Sun's outermost atmospheric layer, the corona. In our star's interior, the pressures of plasma motions are typically much larger than those exerted by the magnetic field; in the corona, however, the opposite is true, and the magnetic field dominates the plasma

motions. Just above the Sun's surface is a layer called the chromosphere where these forces nearly balance each other. In that "transition" layer, plasma motions can drive magnetic fields, and vice versa.

The Solar Dynamics Observatory and Hinode have given us clearer-than-ever observations that show rapid heating events like fast jets of hot material triggered in or just above the chromosphere. The convection within the Sun generates small but violent changes to the magnetic field, which then create these jets. We see in these jets some portion of the hot plasma that fills the coronal loops — one component of the coronal heater.

Another likely component of the heater comes in the form of magnetic (or Alfvén) waves. The convective motions also generate these waves, which "ride" on the same hot jets and roar into the corona at even higher speeds. The Alfvén waves likely dump their energy in the corona, too, but the



Interactions between the radiative and convection zones within the Sun's interior contribute to heating our star's corona. *ASTRONOMY: ROEN KELLY*

means by which that happens is a topic of great debate. So, we still don't know exactly why the Sun's corona is hot, but we are finding some of the components of the system. This helps us considerably in trying to understand how the complete coronal heater works.

Scott McIntosh

National Center for Atmospheric Research, Boulder, Colorado

Q: HAVE ASTRONOMERS SEEN ANY SPECTRAL LINES THEY CAN'T IDENTIFY?

John Wendler

Stow, Massachusetts

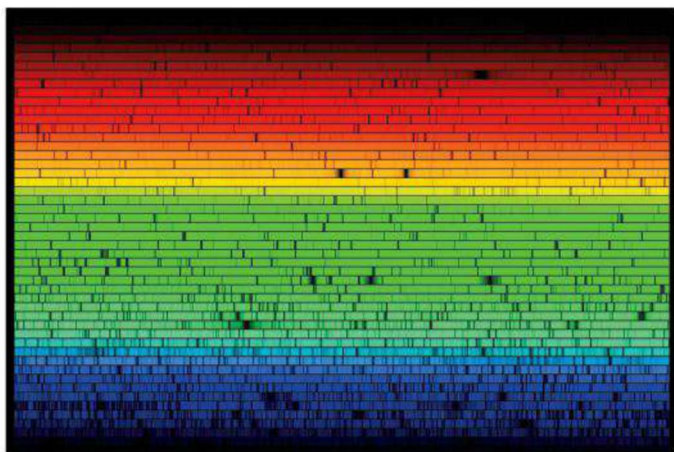
A: Yes. Each spectral line corresponds to a specific energy transition related to a particular atom — and thus, element. Astronomers analyze such lines to tell us what celestial objects are made of.

In the spectrum of the Sun, for example, our spectrographs (the instruments we use to study the spectrum) can resolve more than 15,000 lines just in

the range that our eyes can see. If we look at the entire electromagnetic range, the Sun has at least three times as many lines, and perhaps even more. We can identify many of them, but at least a few thousand remain unknown today. Many of the unidentified ones lie at ultraviolet wavelengths (shorter than what our eyes can see); these lines blend together, making it hard to distinguish one from the next, even with our best instruments.

The study of spectral lines is really just the study of the complex configurations and behaviors of electrons in atoms. As astronomers, we owe a large part of our success in identifying spectral lines in astronomical objects to laboratory spectroscopists. These scientists dedicate years, and sometimes entire careers, to studying the detailed spectroscopic signatures of atoms, molecules, and plasmas (hot ionized gases) in laboratories on Earth.

Thanks to this help on the ground, astronomers have been



Astronomers study the Sun's radiation spectrum to learn what types of gas make up our star; each element is responsible for characteristic lines. Researchers have observed a few thousand lines in the Sun's spectrum that they have not yet identified. *N. A. SHARP, NOAO/NSO/KITP PEAK FTS/AURA/NSF*

able to successfully identify tens of thousands of lines in all sorts of objects in space: stars, galaxies, nebulae, quasars, supernovae, comets, atmospheres of planets, and even the gas and dust between them all.

Ian Roederer
Carnegie Observatories,
Pasadena, California

Q: AS I UNDERSTAND, A STAR WILL “BLOW AWAY” ANY REMAINING GAS AND DUST IN THE IMMEDIATE AREA ONCE IT BEGINS FUSION. SO WHY CAN SOME STARS COLLECT BILLIONS OF TIMES MORE MASS BEFORE BLOWING AWAY THE REMAINDER OF THEIR EMBRYONIC MATERIAL?

Bill Abel
Aurora, Colorado

A: All stars are born in clusters out of cold molecular clouds. Within each cluster, the formed stars occupy a range of stellar masses. Typically, stars with the mass of the Sun outnumber those some eight times heavier by about tenfold. This distribution of stellar masses is called the initial mass function (IMF), and astronomers have found that it appears to be a universal value.

Not all star-forming regions, however, appear to be creating massive stars. Only the most giant molecular clouds that contain sufficiently high-density

“cores” show signs of massive stars. Inside these dense cores, the gas collapses under its own gravity. For massive stars, this process is significantly faster than for solar-type stars and occurs in a region where more material is available. Observations suggest that a large circumstellar disk of matter forms around the baby massive star. Such a disk could facilitate the continuing accretion of material onto the star, allowing massive stars to form despite the hostile environment of high-energy radiation and strong stellar winds. Astronomers are working to figure out the details of this process.

So what sets the upper limit to stellar mass of around 150 solar masses? We long thought the maximum value resulted from stellar instability above a certain mass (related to the “Eddington limit”). Now we recognize that only a certain amount of matter has time to fall onto the forming star through the disk before the increasingly hostile environment destroys the surrounding ring of material.

Kim Arvidsson
Adler Planetarium, Chicago

Q: WHY DOES THE ZODIACAL DUST CLOUD STILL EXIST AFTER BILLIONS OF YEARS? DOES SOMETHING REPLENISH IT?

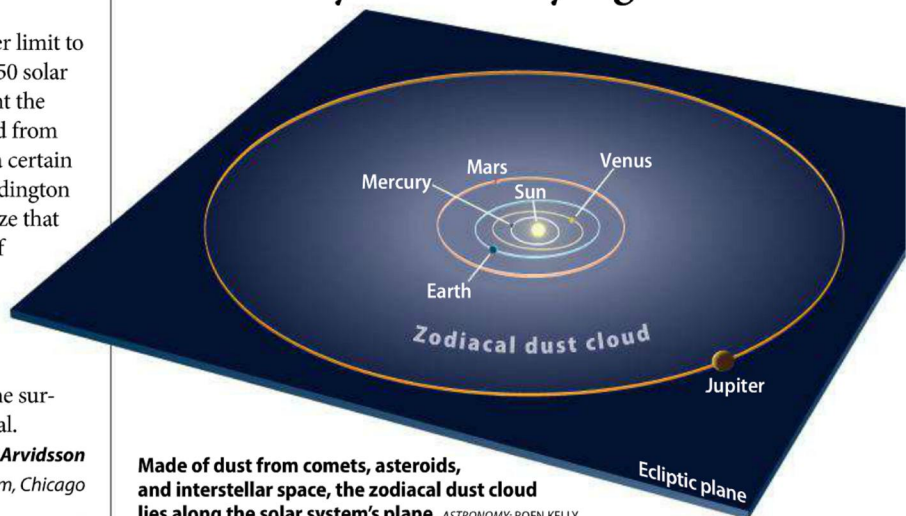
Art Humphrey
Oro Valley, Arizona

A: Astronomers have known about the zodiacal dust cloud for more than 300 years, since Giovanni Domenico Cassini drew attention to the phenomenon of the zodiacal light and gave the correct explanation for it as sunlight reflected from small grains of dust. Early space missions began studying the distribution of this dust in the 1960s. In 1983, the Infrared Astronomical Satellite detected



From Earth's surface, the zodiacal dust cloud looks like a triangular glow radiating from the horizon. You need to look up from a dark-sky site to see this phenomenon. ESO/Y. BELETSKY

The solar system's dusty region



Made of dust from comets, asteroids, and interstellar space, the zodiacal dust cloud lies along the solar system's plane. ASTRONOMY: ROEN KELLY

infrared emission from the zodiacal dust. Data from the spacecraft also demonstrated that both collisions between asteroids in the main asteroid belt (between Mars and Jupiter) and debris from comets contribute to the zodiacal dust cloud, in a proportion roughly one part asteroid to three parts comet. Asteroids sporadically collide and comets shed debris to make this dust.

The dust grains travel around the Sun in almost circular orbits, gradually spiraling inward toward our star. They take about 10,000 years to travel the distance from the asteroid belt to Earth.

Data obtained in the mid-1990s during the Ulysses mission to Jupiter helped astronomers identify a new component of the zodiacal dust cloud — interstellar dust. This material sweeps into the solar system as the Sun and planets fly through the local interstellar dust cloud on their journey around the Milky Way. While these grains contribute less than 1 percent of the zodiacal dust reaching Earth, they are traveling much faster than the asteroidal or cometary dust and traverse the whole solar system in about 50 years.

Michael Rowan-Robinson
Imperial College London

Send us your questions

Send your astronomy questions via email to askastro@astronomy.com; or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Al Nagler poses with his wife, Judi, in front of Tele Vue Optics' booth at the 2005 Photo Marketing Association Show in Orlando, Florida. ALL IMAGES COURTESY OF AL NAGLER

The life and times of Al Nagler

For 36 years, the man behind Tele Vue Optics has been a force in amateur astronomy. But there's a lot more to him than that.

by Michael E. Bakich

Many readers know Al Nagler as a giant in the field of telescopes — the developer of the revolutionary Nagler eyepieces, which offered amateur astronomers a much wider and sharper field of view of celestial scenes. As founder of Tele Vue Optics, he crafted many high-quality optical products that are well-known to observers: the Renaissance, Genesis, and Tele Vue Petzval lines of telescopes; accessories like the Starbeam, Paracorr, and Powermate; and the Nagler, Radian, and Panoptic eyepieces. He also supervised recent product lines such as Ethos and Delos.

But few people know the story of the man behind the products — the tale of a City College night-school-educated inventor who had many jobs, detours, and learning experiences on his path to success, and who today is an active 77-year-old who still describes himself as “a big kid.”

“I just kind of never grew up,” Nagler explains, “and I try to maintain that youthful enthusiasm as much as I can. I try to look at the positive side of things, if at all possible, and hope to engage with people, see where they’re coming from, and see what I can add to their experiences.”

Other pursuits

While known as an icon in our hobby, Nagler has interests that range far and wide, including art, classical music, and sound equipment. “I’m an audiophile,” he says. “In fact, I’ve almost been as crazy over that through the years as I have about astronomy.”

“When I was growing up, I thought I might become an artist,” he continues. “I used to do oil painting. Now the only artwork I do is sketching out new designs and imagining the way products might look. But

I actually applied to two high schools: One was the High School of Industrial Arts in New York City, and the other was the Bronx High School of Science. I was accepted to both, so I had to make a decision, and I chose Science. But I never got too far away from the art side.”

Indeed, Nagler’s art leanings find their way into some of Tele Vue’s products. “For example, if you look at the detail of our Starbeam red-dot finder [a telescope attachment that lets you center on an object],” he says, “you’ll see the back end has an odd curve in the tube. I often ask people what they think the purpose of that shape is, which puzzles them until I tell them it’s because I like it.

“Personal appeal is also why some of our products have slight bevels and tapers. I just think it adds to the aesthetic,” he laughs.

“That’s the way I vent my latent artistic desires nowadays.”

Childhood skygazing

Nagler’s interest in observing the heavens began, not surprisingly, in his youth. “My first real telescope,” he remembers, “was a 3.5-inch Skyscope reflector that I got as a kid. Before that, I had a spyglass, Roy Rogers binoculars, and a few other things to play with. I knew that by getting into the Bronx High School of Science, I could probably get to build my dream scope, and I devoted my junior and senior years to making an 8-inch reflector. The Scientific Techniques Laboratory (shop class) was a unique opportunity. I made the 8-inch mirror at home on my mother’s sewing machine top — my mom was very tolerant.”

The school displayed Nagler’s telescope on stage during his class’s graduation ceremony, and the principal presented him with the “Shop” award for the project. The prize was a micrometer he used for years.



Al Nagler’s parents, Isidore and Mildred (Cohen) Nagler, provided a stable home and a happy childhood for Al.

Michael E. Bakich is an Astronomy senior editor and author of *1,001 Celestial Wonders to See Before You Die* (Springer, 2010).





This 8-inch Newtonian reflector was Al Nagler's senior project in high school. Here it is at the 1958 Stellafane Convention, where it earned him third prize.



Charley Cafferella (left), Al Nagler's high school shop teacher, poses with his wife. Years later, Cafferella saw an ad (showing Nagler in the top of a lens) stating "A little Nagler goes into every Tele Vue Barlow." Cafferella thought, "I know that kid," and called Nagler, who gave him the telescope shown.



Even in youth, Al Nagler loved art. This oil painting is his re-imagining of Russian composer Modest Petrovich Mussorgsky's famous suite *Pictures at an Exhibition*. The music was itself the composer's tribute to a series of paintings by his friend the Russian architect and artist Viktor Hartmann.

Upon graduating from high school, Nagler had to work to support his mother and sister, since his father had died four years earlier. Nagler's first inclination was to be a machinist, so he took a job running a lathe in a lead factory. This, of course, was before the dangers of lead were widely known.

"I didn't really like the job, and after two weeks I was fired. But not for any reason you'd think," he says. "I got the job through an employment agency, but it turned out that the company hired me only as a two-week fill-in for a guy who was on vacation. And I still had to pay the agency!"

Nagler's next job also met an unusual end. Following his interest in machines, Nagler answered an ad for the Scientific Machine Corp. in Brooklyn. "What can get better than that for a guy who built a telescope in high school, right? And I got the job," he says. "What I did, however, was assemble a variety of mechanical arcade games we now call Skee-Ball machines and the giant toy cars that you used to see kids ride outside supermarkets."

But even this job was short-lived. "One day the owner, Jack Firestone, came up to me and said, 'You know, Al, you can do better

than this. You're fired,'" Nagler says. "And he meant it. And he knew. And he was right. It was a great lesson and a great favor, although I recall being unhappy at the time."

What's that smell?

Nagler's checkered job history continued with lab work at several chemical companies. The first, at National Starch Co., ended when he couldn't afford to move himself, his mom, and his sister to the company's new location in New Jersey. "My worst job," he says, "was at a plating plant in the Bronx where I tested chemicals, including acids and solvents. I had my own little laboratory on the second floor, but it didn't have any windows or ventilation.

"The conditions were intolerable, but when I complained, they ignored me," Nagler continues. "So, one day I cooked up a giant vat of hydrogen sulfide — otherwise known as 'rotten egg' gas — and I turned on a fan and blew it down into the main office. Well, I got even with them, but, of course, they fired me."

Right after high school, Nagler started night school at City College of New York. Because of work during the day, he had to decline a daytime-only scholarship. He studied music history, geology, chemistry, drafting (with the possibility of going into mechanical engineering), and, later, physics.

"And here's a story I've only told a few close friends," he says. "My first drafting job was for a company called S&S Industries in the Bronx." Since 1946, S&S has manufactured, among other things, brassiere wires and still controls 90 percent of that market.

"They had to make templates for the many underwire products so they could check the quality control," Nagler recalls. "My job — and I can already hear people laughing — was to make precision line drawings of the brassiere curves. I worked there for about a year."

Another drafting job followed, at Lightolier in New Jersey, where his drafting skills were applied to track lighting. This finally moved Nagler into the field that would transform his life.

High-level optics

"At that point, I had some real-world drafting experience, along with the article I wrote for *Mechanix Illustrated* in December 1955, where I described building my telescope in high school," Nagler says. "I also happened to know that the editor for *Sky & Telescope's* amateur



Albert Nagler married Judith Pearlman on June 25, 1961. His wife co-founded Tele Vue Optics and was the company's first full-time employee.

► **This 12-inch scope Al Nagler built was the first-prize winner at the Stellafane Convention in 1972.**

telescope-making column, Earle Brown, also was the chief project engineer at an R&D company, Farrand Optical, in the Bronx.

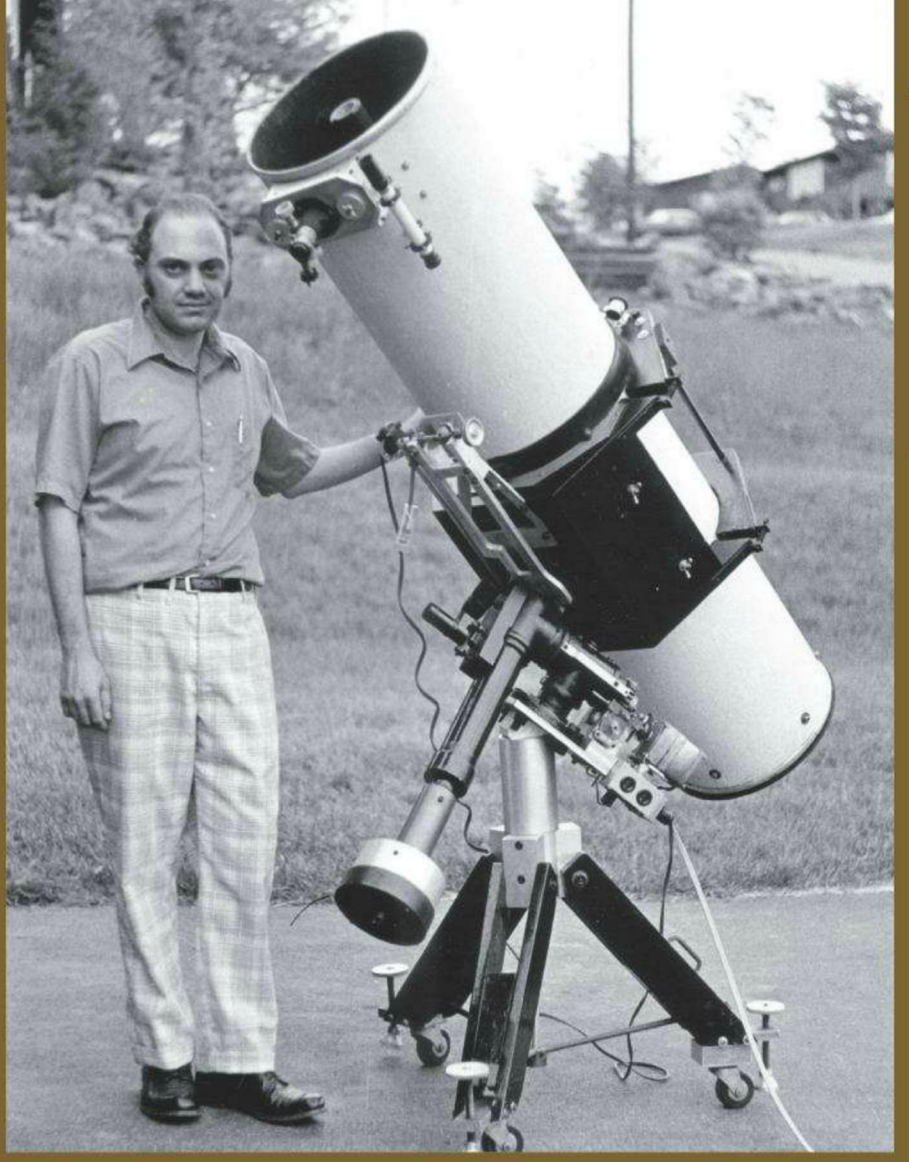
"So, in 1957, I just walked in and got a job as a draftsman. And that, of course, worked out well because after a year they asked if I would like to join the optical design department, where I eventually became senior optical systems designer."

Nagler worked at Farrand until 1973. Under Grumman Aerospace Corp.'s contract with NASA, the company developed visual simulators for the astronauts. Nagler himself designed the infinity displays for the Gemini program and the Apollo Lunar Module spacecraft. The simulators used large mirrors to project images of Earth orbit, docking, star fields, and lunar landing.

A complex optical probe created real-time landing images. The probe acted like a television camera mounted on a boom that "flew" down onto a scale model of the lunar surface. He also worked on eyepieces for night-vision goggles and mirror-type "heads-up" displays for aircraft (which later gave him the idea for Tele Vue's Starbeam red-dot pointer).

Nagler got his B.S. in physics in 1969, after 16 years of night school. The degree allowed him to take a position as chief optical engineer at Keystone Camera Co., a division of Berkey Photo, Inc. There, he designed a zoom lens for the firm's pocket camera. That task took him to Japan, where his contacts with the optical industry later proved invaluable: One of the Japanese companies he worked with remains a major supplier to Tele Vue today.

When Nagler left Farrand in 1973 to join Keystone, he also toyed with starting a company with a Farrand friend, Matt Baum, to make stereo reverb units. "Then I realized I'd be competing against companies like Sony that could take an idea and do anything they wanted to with it," he says. "So I went in a different direction."



Baum had invented an electronic motor brake that worked well, so the two men started a company, Ambi-Tech Industries, making products that combined electronics and mechanics.

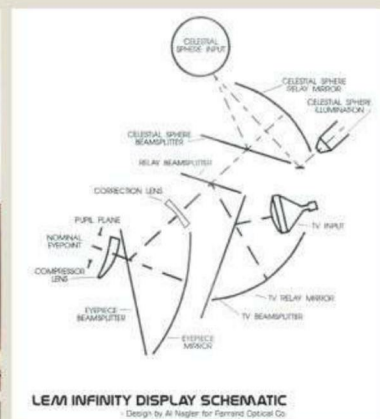
"I worked part time with Matt until I left Keystone in 1976, joining Ambi-Tech full time," Nagler says. "I did optical consulting in the evenings and started Tele Vue with my wife, Judi, in 1977. Judi managed it in the daytime while I designed optics for it at night."

"Matt and I built Ambi-Tech into a full-time business and had lots of fun developing products, mainly for safety on woodworking machines. My main functions were in product development and marketing. For 20 years, that's how I supported my family as I developed Tele Vue part time," Nagler says.

"Matt and I sold Ambi-Tech in 1996, and after my support work for the new owners ended in 1997, I finally went to Tele Vue full time," he continues. "My having another job was great because it let Judi and me build up Tele Vue slowly, without the need to borrow money or for additional investors. It also allowed my son, David, to join the company in 1988 as my 'eyes and ears' operations manager and become immersed in manufacturer relations, product development, quality control, advertising, and marketing."



In 1973, Al Nagler, then the chief optical engineer at Keystone Camera, designed the zoom lens for this small pocket camera.



A Farrand technician (left) tests the Infinity Display system Al Nagler designed for the Lunar Module simulator (middle). During the test, the triangular lens opening shown fit against one of the module's windows. In the schematic of the Infinity Display (right), the small triangular "compressor

lens" (bottom left) is that window. That lens provided a 110° field of view, had eye relief of 1 foot (30.5 centimeters) from the window, and included an exit pupil 1 foot in diameter. That way the astronaut could have his whole head near the window, with both eyes open, and move around.

Nagler had met Judith (Judi) Pearlman in 1959, taking her on their first date to Hayden Planetarium and then to a concert by the Bronx Symphony Orchestra.

"I took her to these two venues to see her reaction," Nagler says. "Of course, she wasn't into astronomy and classical music to the extent that I was, but at least she was able to tolerate both of my passions. Once we were married, she not only tolerated all my hobbies, she supported them."

Judi taught grade school until retiring to bring up David and daughter Meryl. "Later, when they were older and I had the idea for Tele Vue, she willingly became co-founder and its first full-time employee," Nagler says. "She managed the company and its growing staff alone from 1977 until the time when David joined in March 1988. Tele Vue would have gone nowhere without her. Sandy, David's bride-to-be, was hired by Judi as a 'surprise present' later that year for David's return from a business trip to Japan."

Personal ups and downs

Nagler recalls that his biggest optical inspiration came from looking at the 110°-wide view through the simulator window in the

Lunar Module and "flying" over the Moon's surface. "Later, I was the optical designer for Farrand's team that created an optical probe for Wright-Patterson Air Force Base," he says. "It had a 140° field of view and 45 lens elements. All that stayed with me, so when I started Tele Vue, I thought the probe's objective principle could be the basis for developing a wide-angle eyepiece with a 'spacewalk' view. About a decade later, I was able to apply all that experience to designing the Nagler eyepiece."

His involvement with so many businesses offered opportunities. "In the mid-1970s, projection television sets were becoming popular," Nagler says. "I knew how to correct the out-of-focus images due to the convex television tubes and lenses borrowed from overhead projectors being used. So, I started Tele Vue with Judi."

"I named it Tele Vue (for television viewing) knowing I might also use it for 'telescope viewing.' At the 1977 Consumer Electronics Show, the show magazine had an article titled 'NASA Scientist Designs Projection TV Lens.' By 1978, Edmund Scientific was selling its '5-inch Super Projection Lens' with a booklet I wrote on how to build a cabinet for the set. We sold these lenses until 1985, when large, flat, rear-projection screen TV sets took over the market."



Amateur astronomer and artist Hulan Fleming painted a family portrait of the Naglers observing at Stellafane. From left to right: Sandy and David Nagler, Michael and Meryl (Nagler) Budnick, and Judi and Al Nagler. (The cat is Grey Cat.)



Apollo 12 astronaut Alan Bean (standing), the fourth human to walk on the Moon, spoke at the 2009 Stellafane Convention. Al Nagler gave a brief introduction, and later the two talked about the Apollo simulator Nagler worked on.

"I learned a lot about business from this venture, including lessons in being careful about with whom you do business."

Aside from one particular nasty business snafu, Nagler recalls with some emotion what he considers his biggest personal mistake: "My father came from Austria. He was a physical therapist and chiropractor who spoke seven languages. He was a loving but stern father. My biggest mistake was failing to ask him about our family history before he came to the U.S.

"He passed away when I was 15," Nagler continues. "But before he did, at least he learned that I had been accepted into the Bronx High School of Science. So at least he had that.

"Besides being in a friendly manufacturing business with my good friend Matt, I can say that having a great family cooperating the way we do at Tele Vue is the reward of a lifetime. Judi worked full time on the business side until retiring in 2008. We had the joy of our son, David, asking us if he could join in 1988, and having Sandy join with us to follow in Judi's footsteps.

"With David's background in communications from Syracuse University, he moved the company forward in marketing, advertising, Internet, and, best of all, as my partner on virtually all technical matters. He developed the 100° Ethos concept and got the project going with Paul Dellechiaie, a longtime employee and my protégé in optical design. My name may make the headlines, but without such an ideal partner as David, along with a great staff, we could never have gotten where we are."

A standout event

At this point in his life, Nagler can reminisce about a great many things, but one event stands out to him as an example of how his professional work came full circle.

"In 2009, which was the 40th anniversary of the first Moon landing, the organizers of Stellafane [a major telescope show] invited Alan Bean [one of the moonwalking astronauts] to speak," he says. "Stellafane is my favorite place in the whole world. It's where I won third prize in 1958 for my high school telescope and first prize in 1972 for a 12-inch scope.

"So, before Alan's talk, there was a dinner held for him. The people at Stellafane asked me to say a few words because they knew of my work in the space program, especially on the Apollo simulator.



Tele Vue's initial product was the Tele-Kit projection system, which was the first to correct the backward-curving field of the television. Al Nagler designed the cabinetry as well as the lens system, which remained in production from 1977 to 1985.



Al Nagler presented a special guest lecture at the 2012 Astronomischer Tausch und Trödelmarkt European Astronomy Show in Essen, Germany.

"Alan Bean doesn't know me from Adam, but I gave a short talk for which he thanked me afterward. While we were speaking, I handed him a little booklet I had made that told the story of the Apollo simulator. It also contained a picture that I'd gotten from NASA of Bean in the simulator. On the booklet, I had written 'Dear Alan, glad it worked!'

"Now to me," Nagler says, "that was the perfect representation of how the things I did at Farrand, at Tele Vue, even as far back as high school and at Stellafane all worked together and brought me to that 'full-circle' moment."

Final thoughts

Nagler is quick to remind anyone that he has not retired. He still works largely full time, but his move to CEO in 2005, when his son David became Tele Vue's president, does allow him the opportunity to take more time off to travel.

"I'm having too much fun to retire," he says. "I get to talk to fellow amateur astronomers all the time. And every one of them is not only a potential customer, but also a potential friend." Indeed, with an attitude like that, Al Nagler must have many friends. 🌟



Bernhard Hubl's

unusual universe

Often-overlooked galaxy groups, star clusters, and dark nebulae showcase this skysooter's best work.

text and images by Bernhard Hubl

When I was a boy, I was fascinated with the new images of Jupiter and Saturn captured by NASA's Voyager spacecraft. I

wanted to see those planets with my own eyes — so began my interest in astronomy. After a period of visual observing with 7x50 binoculars and a 6-inch Newtonian reflector, I knew I wanted to know more about the nature of astronomical objects. So while at school in Vienna, I began taking classes in astronomy in addition to studying technical physics. After graduating, I decided to work as an engineer and leave astronomy as a hobby, which was the right decision for me.

Astroimaging evolution

Some 20 years ago, my first steps into astroimaging were with black-and-white

chemical photography using my 6-inch telescope. Later, I gained experience in digital astrophotography using a homemade Cookbook charge-coupled device (CCD) camera and a Canon EOS 10D. Since 2004, my main instrument has been a cooled CCD camera from Santa Barbara Instrument Group (SBIG), the ST-2000XM.

In 2007, I built a small roll-off roof observatory in my backyard in Nussbach, Austria, in a flat valley on the north side of the Alps. There, my homemade 12-inch f/3.8 Newtonian telescope found its home. Today, I capture most images with a setup consisting of two telescopes. The ST-2000XM camera attached to the 12-inch constitutes the main imaging system. As this system autoguides and images the desired object, my second telescope, a 4-inch f/5.4 Tele Vue NP-101, simultaneously captures a wide-field image of the

same object using SBIG's ST-8300C. While the long-focal-length photo from the Newtonian scope provides details within the targeted object, the wide-field image delivers context through a better understanding of the surrounding environment.

Favorite targets

When I first started imaging, I, of course, captured brighter, well-known objects. Nowadays, however, targets far off the beaten path are my clear favorites. I like to identify the objects in my wide-field images and then learn more about their physical nature. When I inspect a photo carefully, I always have the possibility of detecting something new.

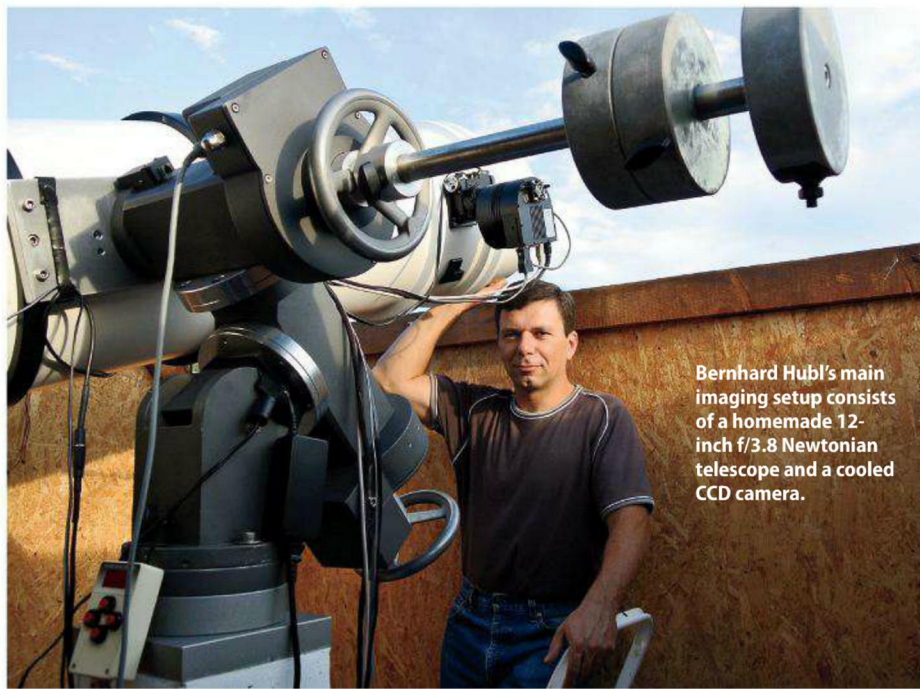
Beyond studying my wide-field images, though, I prefer to choose targets that other imagers often overlook. Take open star clusters, for example. This object class does not show extended structures like nebulae or fine details like galaxies, but the simplicity and elegance of open clusters that exhibit a huge diversity of star colors is wonderful.

Distant galaxy groups and galaxy clusters are a second favorite object class. I find it exciting to discover signs of interaction between galaxies and to realize the vast distances of these star cities.

My final favorite imaging targets are dark nebulae. The different amounts of star reddening due to strong variations of the dust density fascinate me.

Imaging techniques

When it comes to capturing such deep-sky objects, my image-processing philosophy is



Bernhard Hubl's main imaging setup consists of a homemade 12-inch f/3.8 Newtonian telescope and a cooled CCD camera.

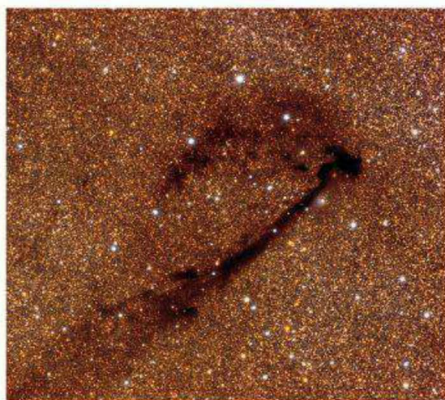
Bernhard Hubl frequently contributes high-quality astroimages to *Astronomy*.



A long-focal-length image of NGC 3227 in Leo the Lion shows clearly that this spiral galaxy is interacting with the dwarf elliptical galaxy NGC 3226 to its north (above in this photo). The interaction between the two galaxies has formed interesting structures: a looping tidal tail to the north and a faint tidal tail to the south. This system is collectively known as Arp 94. Capturing the interacting galaxies required 31 hours of LRGB exposure time through the author's homemade 12-inch Newtonian telescope at f/3.8.



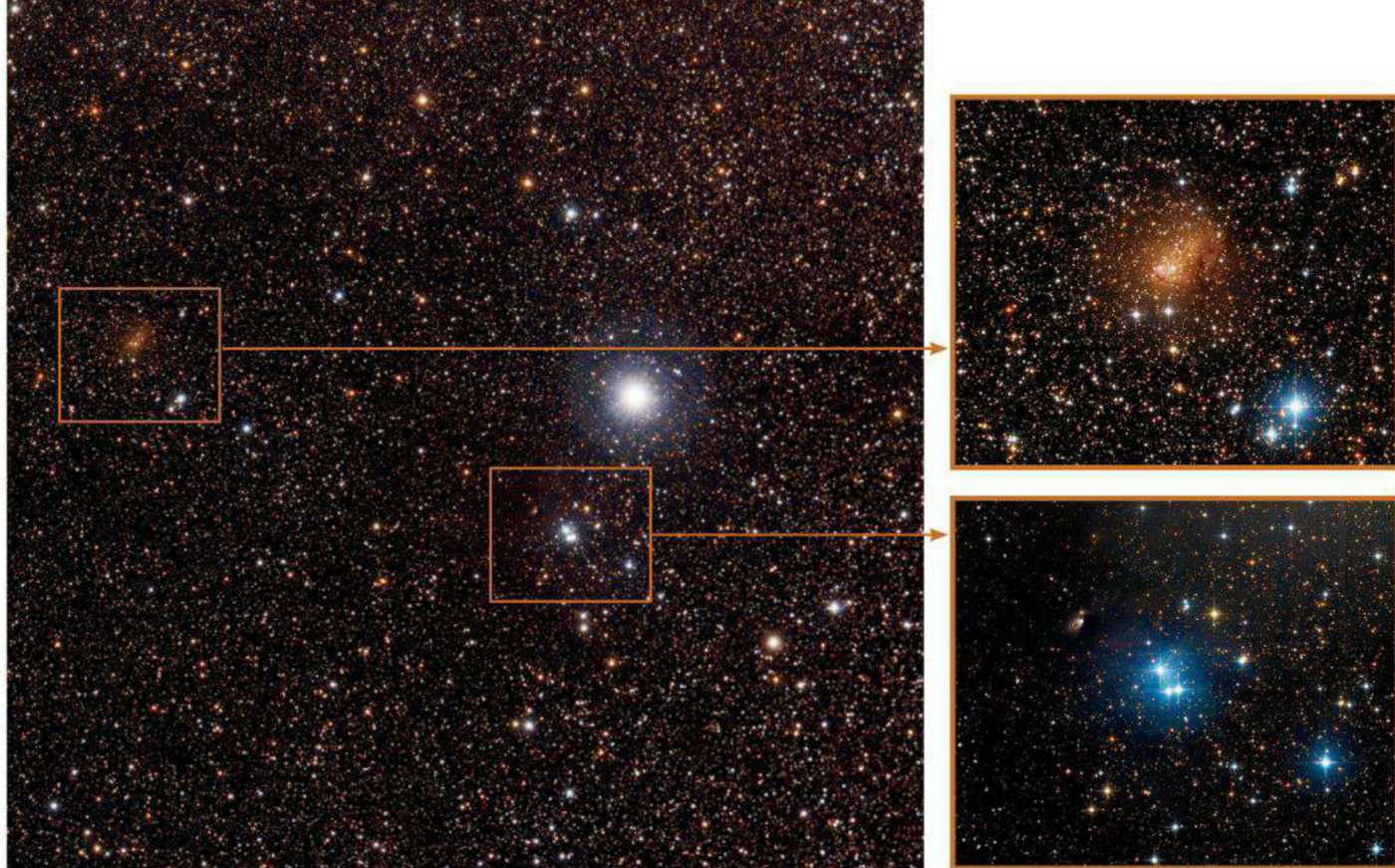
Abell 1314 is a galaxy cluster in Ursa Major that lies 450 million light-years distant. The brightest members of this cluster are IC 708, IC 709, IC 711, and IC 712. The two bluish galaxies near the top right corner are not members of Abell 1314, but foreground objects. This LRGB image required a total exposure time of 20.4 hours.



This dark nebula in Vulpecula is number 778 in Beverly T. Lynd's *Catalog of Dark Nebulae*. Such clouds are thick enough to obscure the light from background stars. The LRGB image required 10.8 hours of total exposure time.



NGC 2281 in Auriga is often considered a "poor" open cluster because it doesn't contain a rich field of stars. Such a description makes it a prime target for the author. This LRGB shot required a total exposure time of 212 minutes.



The wide-field image of the reflection nebula van den Bergh 1 (lower inset) also shows the bright star Beta (β) Cassiopeiae and the nearby reddish galaxy IC 10 (upper inset). One might expect the color of this star city to be bluish because IC 10 is a starburst galaxy. The wide-field image provides an explanation, though: A huge amount of dust in this region of Cassiopeia is responsible for IC 10's reddish color.



The dwarf spheroidal galaxy NGC 185 is a member of the Local Group of galaxies and a satellite of the Andromeda Galaxy (M31). This star city shows a considerable amount of gas and dust clouds in this LRGB image, which required 6.8 hours of total exposure time.



Barnard 174 is a dense dark nebula and active star-forming region that absorbs the light of the stars within it. Infrared observations show many young suns in this area. The author captured a tiny red nebula in the northeastern (upper left in this image) part of B174. This nebula is a Herbig-Haro object (HH354), a small patch of nebulosity associated with newly born stars. This LRGB image, captured through high clouds and fog, required a total exposure time of 8.2 hours.

quite simple. My main goal is a natural-looking image, so I am restrained with processing steps like smoothing (to reduce noise) and sharpening (to highlight details).

Still, I try to determine the normal-color (RGB) relative intensities of the field of view as carefully as possible. I base my color-balancing techniques on Richard Berry and James Burnell's 2000 book, *The Handbook of Astronomical Image Processing* (Willmann-Bell). The key is to measure the ratio of the three colors using a nearby type-G2 star (the same class as the Sun) and use this knowledge to balance the RGB filters without doing manual adjustments

(you can follow my step-by-step guide at www.astrophoton.com/tips.html).

Another important step in my workflow deals with the digital development processing (DDP), a powerful algorithm for enhancing deep-sky images. I must fine-adjust the DDP of the luminance data to that of the RGB data before creating the LRGB image. It is important not to lose any color information while producing the final astrophoto.

Helping others

My work in astrophotography is not limited to capturing beautiful images of deep-

sky objects, however. I also am involved in two projects that assist other astroimagers in their work.

First, I am an active part of the Central European Deepsky Imaging Conference (www.cedic.at), which has occurred every other year since 2009. As such, I am responsible for the agenda of this international meeting, ensuring that it satisfies the needs of beginners as well as advanced astrophotographers.

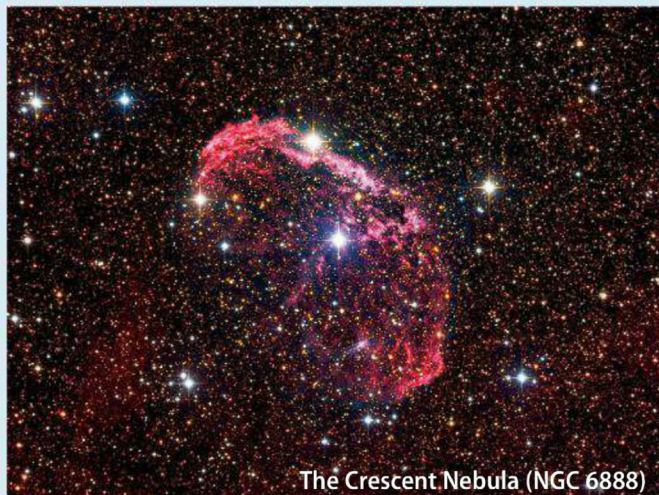
For the past two years, I also have been the project manager of *CCD-Guide* (www.astronomie.at), a venture of a local Austrian astronomy club. Each year, we release a

CAPTURING POPULAR TARGETS, TOO

Just because astrophotographer Bernhard Hubl prefers to image objects “off the beaten path” doesn’t mean he hasn’t produced fantastic images of more iconic targets.



Comet C/2009 P1 (Garradd)



The Crescent Nebula (NGC 6888)



The Butterfly Cluster (M6)



The Pinwheel Galaxy (M33)



The Iris Nebula (NGC 7023)



Globular cluster M22

DVD with more than 3,000 astrophotos from 30-plus well-known European imagers. The product includes special software to assist users in searching reference photos, image data, and object information, as well as helping them plan to-do lists and showing them how to archive their images.

Looking forward

I’m not sure where I will go in the future in terms of my astrophotography, but one thing is fixed: I always will search for targets that are too often overlooked. My wish, though, is to go deeper, so one day I will need to upgrade my already nine-year-old

camera. I also might push the limits of my imaging by using a remote telescope to capture neglected targets in other parts of the sky. Astrophotography provides me with hours of fun each time I’m out under the stars or inside processing data, and I’m sure this will not change for the rest of my life. ☿



BROWSE MORE OF BERNHARD HUBL’S IMAGES AT www.Astronomy.com/toc.

Shoot easier with the Nightscape CCD camera

This Celestron camera offers the bells and whistles of more expensive models at a much better price.

by Craig and Tammy Temple

Having been avid astroimagers for more than six years and having used camera models as different as a DSLR, a one-shot color CCD, and a monochrome CCD, we realize that choosing what equipment to photograph the sky with can be a daunting task. Imagers have to consider many factors: how well the unit cools, its quantum efficiency (how much of the total light the system captures), megapixels — and don't forget price.

Finding the right combination can take a bit of time and research. Knowing this, we were excited to have the opportunity to test a camera that offers a nice balance of features and price, Celestron's Nightscape CCD.

Opening the box

When the camera arrived, we were surprised at its size. It is bigger, but lighter, than we expected. The housing is all metal and quite rugged. One nice feature was evident immediately: Celestron grouped all of the control and power ports together on one side. That helps at the telescope

because you can keep the cables in one tidy bundle.

The box also included them — a USB cable and the power cord, each 10 feet (3 meters) long. One side plugs into the camera while the other has an automobile-type (cigarette-lighter) connector, which powers the camera on 12 volts DC. A brief instruction manual and the Windows-compatible software installation CD complete the package.

Features abound

The Nightscape CCD is a camera with plenty of features that won't break the bank. At its heart is a Kodak KAI-10100 color sensor. This chip features 4.7-micrometer pixels in an array measuring 17.9 by 13.5 millimeters. That produces an image with 10.7 megapixels. It also has the capability of binning (combining) pixels. You can do this either as 2x2 or 4x4 groups without losing the color data.

The camera employs a mechanical shutter that allows exposures as short as 0.01 second unbinned or 0.001 second binned. A single-stage thermoelectric cooler chills the sensor to approximately 36° Fahrenheit (20° Celsius) below the ambient temperature. The built-in cooling fan has three speeds to offset warmer nights and

yield maximum cooling. The Nightscape isn't overly heavy either, weighing in at 2 pounds (0.91 kilogram).



Celestron's Nightscape CCD camera

PHOTO COURTESY OF CELESTRON

One clever feature Celestron built into the camera is the 2" nosepiece. It has T-threads on both ends. What is so special about that, you ask? The distance from the top of the nosepiece to the sensor is 55mm, the same as the distance of a standard DSLR camera. This means you won't need additional spacers for readily available coma correctors and field flatteners. Also, you can remove the nosepiece entirely, exposing the T-threads directly on the camera's face. This will let you attach other accessories such as an off-axis guider.

Under the stars

We found the Nightscape and the included AstroFX software easy to use. Launching the software accesses the camera through



The AstroFX software that Celestron provides has lots of features and is easy to use. CRAIG AND TAMMY TEMPLE

Craig and Tammy Temple image celestial objects from Hendersonville, Tennessee. Many of their shots have appeared in *Astronomy*.

PRODUCT INFORMATION

Celestron Nightscape CCD camera

Imaging sensor: Kodak KAI-10100

Color Sensor

Sensor size: 17.9mm x 13.5mm (22.5mm diagonal)

Pixel size: 4.75 microns square

Resolution: 10.7 megapixels
(3760x2840)

Exposure range: 0.01 second to 24 hours

Mounting: 2" barrel and T-thread

Cooling: Regulated thermoelectric with fan

Weight: 2 pounds (0.91 kilogram)

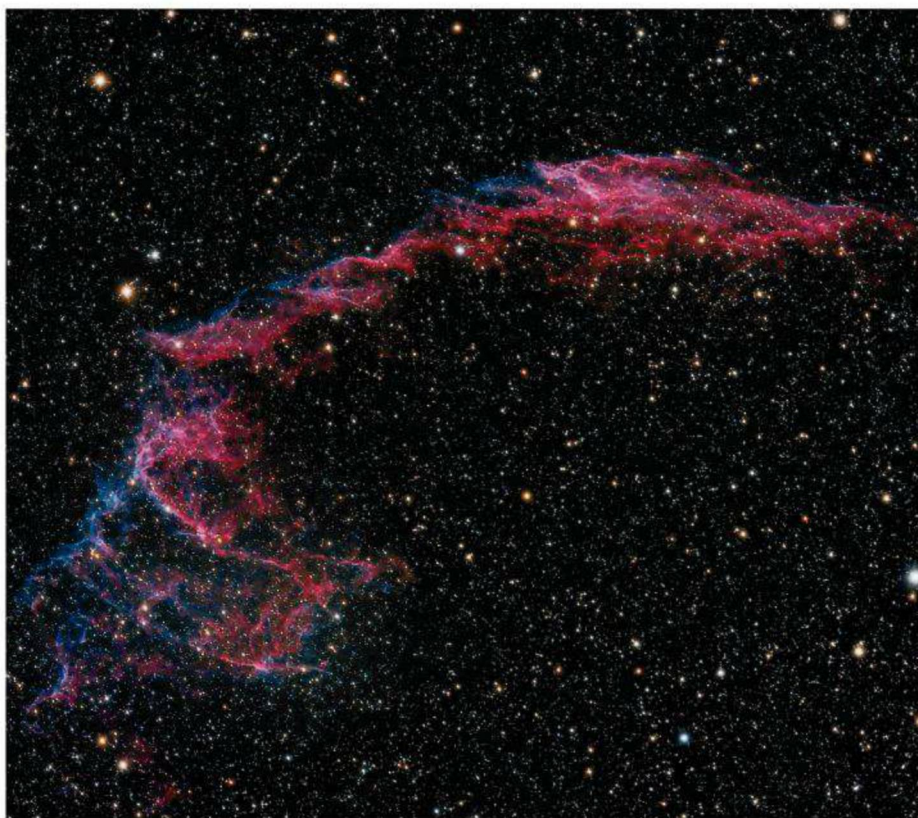
Power requirements: 12-volt DC
2.5-amp, tip positive

Includes: 10-foot (3 meters) USB and power cables, instruction manual, *AstroFX* software for Windows

Price: \$1,499

Contact:

Celestron
2835 Columbia Street
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com



NGC 6992 helps form the eastern part of the Veil Nebula in the constellation Cygnus the Swan. The authors took this image by attaching the Nightscape CCD to their 4-inch refractor. They shot and stacked eighty-four 5-minute images at f/7. CRAIG AND TAMMY TEMPLE

your computer. The interface is intuitive, with clear options to select a destination directory, exposure type (light, flat, dark, flat-dark), exposure time, frame size (binning), and number of exposures.

To cool the sensor, simply enable the cooler in the software, select a fan speed, and specify a set-point temperature. After the temperature has stabilized, a notification will display and you can start imaging. Output files are saved in astronomy's

standard Flexible Image Transport System (FITS) format for portability across various software packages. In addition, the software installation includes an ASCOM driver, which allows other applications to control the camera.

After attaching the camera to our 4-inch refractor and cooling the CCD to 32° F (0° C), we began to focus by setting the *AstroFX* software to "Focus" mode. This process automatically looped, taking exposures at a set interval, until we canceled it. We moved or resized the displayed focus image as desired.

Focusing was quick and simple. We used a focusing aid called a Bahtinov mask. Even without it, however, this step was easy because the software kept updating the image, which let us focus in real time.

Once focused, we slewed to our target and used the "Looping exposure" (focus) mode to frame the image. This extended the value of that feature because we were able to frame the object in real time.

We completed the imaging session without any problems, and the cooler held the CCD's temperature stable throughout the night. Full-frame images downloaded in less than seven seconds, as indicated by the *AstroFX* status window. That speed

impressed us, given the 20.3-megabyte size of each FITS file the camera produces.

The mechanical shutter also was top notch. Taking calibration frames was easy, and we saw no shutter artifacts (image irregularities) when we took relatively short (1.5-second) flat frames. (Flat frames allow you to correct for errors in the illumination across any CCD chip.)

For two additional nights, we repeated the same sequence of activities. On the third night, we noted that the camera's cooling specifications were spot-on. The ambient temperature was 77° F (25° C) and the cooler could not reach 32° F. After waiting for the ambient temperature to drop and using the "High" fan setting, the CCD reached 32° F and held steady for the remainder of the session.

A great choice

Without a doubt, the Celestron Nightscape CCD is one of the simplest cameras we have used. The control software is straightforward and easy to operate, and both it and the camera performed without a hitch. If you are looking for a one-shot color CCD camera that offers high-quality features and simplicity without your having to sell the farm, this camera will not disappoint you. ☼



The Nightscape CCD camera attaches to any 2" focuser. This image shows the authors' setup.



Galaxy rising, part two

Here's a second way to put the Andromeda Galaxy or any other celestial image right where you want it.

In last month's column, I showed you how to bring in the image of the arch on top of the Andromeda Galaxy (M31) as a layer, select the blue sky, and delete it from the stack. This process allowed us to see M31 underneath.

Now let's go about this in a different way. Starting in *Photoshop* from the same layer stack (without deleting the sky), select the blue sky once again, but this time go to "Layer," then "Layer Mask," and then "Hide Selection." What you've just done is

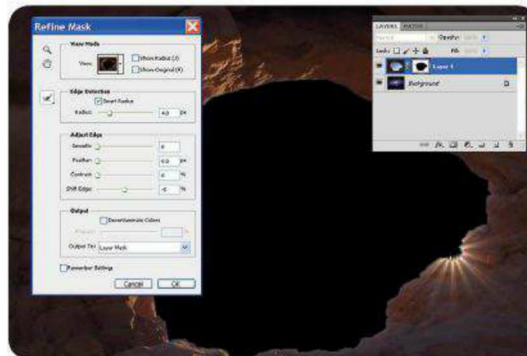
to turn the selection into a layer mask that is holding back the blue sky. The advantage of using a mask is that you can refine it.

So, right-click on the mask icon and choose "Refine Mask." Once this palette opens, note "View Mode" at the top. Click in this icon box, and notice all the ways that you can view the mask. For this exercise, choose "On Black." This will let you see any trace of the sky remaining within the masked area.

Next and below this option, you'll see the "Edge Detection"



With the image of the arch lying on top of the Andromeda Galaxy (M31) image, select the blue sky and choose the "Hide Selection" option. This allows M31 to come through.



Right-click on the mask icon and select the "Refine Mask" dialog box. Doing this opens up many options, including being able to see any trace of the sky remaining by turning the mask black.

dialog box. Here, you'll find ways to improve your selection. One tool I suggest you become familiar with is the "Brush" tool that you can use to refine spots in the selection. Continue to do this until there is no sky showing. Then click "OK."

Finally, with the M31 layer active (on the bottom), hold down the Control key and, using the mouse, move M31 until the galaxy's nucleus is where the sunburst was. As it turned out, the image of M31 was too small to fill the hole in the arch. In such a case, hit Control-T to transform the layer to a larger size. While you're doing this, rotate the layer so that the galaxy is at the proper angle. And by

"proper," I mean the angle you like best. Press Enter when you're happy with the proportions in the picture.

At this stage, take a final look at your image because this is the last point you will be able to independently adjust each of the layers. Do the rocks look correct? What about M31 in relation to the rocks? When you are satisfied with your results, save the layered image as a Photoshop (PSD) file in case you want to go back and change something. Then flatten it for regular use and turn it into a TIFF or JPEG image.

This technique works with a wide variety of images. In fact, I think you'll agree that the sky is the limit! ☼



The finished picture sports an exact match between the edges of the galaxy and the rocks. It also reveals the author's preferences for scale. Yours may differ.

ALL IMAGES: TONY HALLAS

FROM OUR INBOX

Questions about the Higgs

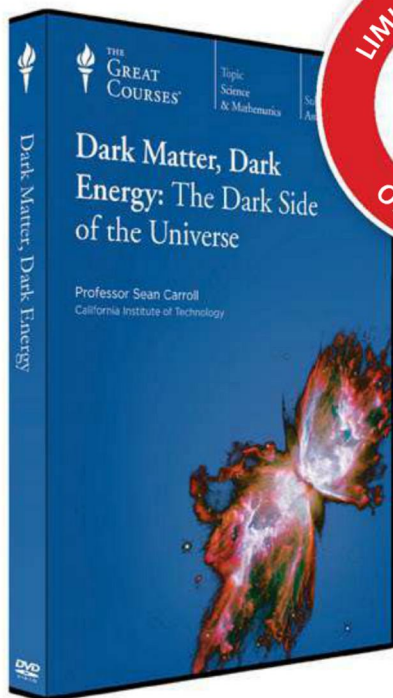
From reading "Why you should care about the Higgs boson!" (November 2012), I learned that the Higgs particle has not existed since right after the Big Bang — until scientists started to make them again at collider experiments. I also found out that a field associated with the particle permeates all of space and time and that the physical manifestation of this field is responsible for the masses of all the fundamental particles. If this field didn't exist, particles would have masses of zero and they would move at the speed of light.

What I did not learn from the article, however, is by what means the Higgs field imparts mass, how it chooses the masses it imparts, and why it still permeates space. I am hoping you can fill in the blanks. — **Herman M. Heyn**, Baltimore

Here's a way to think of the Higgs field imparting mass. Imagine the Higgs field as a lattice or grid. As a particle moves through this lattice, it creates a distortion that lends mass to the particle. This distortion contributes mass similarly to how a group of paparazzi surround a famous person — wherever she goes, the group will cluster and follow. That's the distortion.

As you mention, the Higgs field must still exist, or particles would become massless. Because one of the basic laws of physics is the conservation of momentum, mass, which is proportional to momentum, cannot just disappear. I hope this answers some of your questions. — **Liz Kruesi**, Associate Editor





What Is the Universe *Really* Made Of?

In recent years, scientists have discovered that 95 percent of the contents of the cosmos are invisible to all current methods of direct detection. Yet something is definitely there, governing the shape and fate of our universe. These phenomena, called dark matter and dark energy, are the most eagerly studied subjects in astronomy and particle physics today. And for good reason—what could be more exciting than cracking the mystery of the fundamental components and composition of the universe?

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Targeting galaxies

Spring and autumn are the seasons amateur astronomers observe galaxies. Because these distant star systems often are small with low surface brightnesses and subtle details, however, sketching them may present a bit of a challenge. Choose less complex targets to begin with, such as the featured galaxies in this month's column.

As a rule of thumb, large-aperture telescopes and jet-black skies provide the best views for galaxies. But galaxies emit light across the electromagnetic range, so filters (which let only certain

wavelengths through) don't improve their views.

When you set out to sketch a galaxy, you'll initially see a faint patch set against a field of stars. Be patient. Your eyes will become more sensitive to contrast variations the longer you remain at the eyepiece, especially when using averted vision (looking slightly away from an object to use a more sensitive part of your eye). To preserve your dark adaption (night vision) as you sketch, use a diffuse red light with a dimmer switch set as low as possible.

For galaxies, a blending stump makes a great addition to your sketch kit. You can use it to merge harsh pencil markings or to apply graphite to the paper. For the latter, rub a clean blending stump across a patch of graphite that you place off to the side of your sketch, and then use it to draw the galaxy. Lastly, an observing template from the PCW Memorial Observatory website is available for your use at www.tinyurl.com/PCWsheet.

NGC 3893 and NGC 3896

Within the Ursa Major Group of galaxies lie NGC 3893 and its companion, NGC 3896. This pair provides a wonderful opportunity to record two targets in a single sketch.

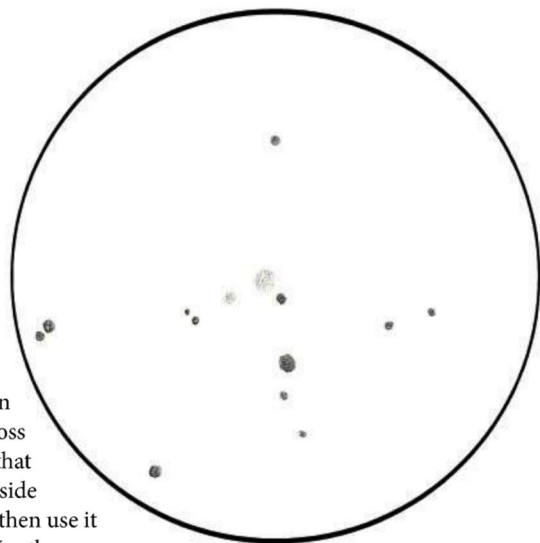
NGC 3893 is a barred spiral galaxy located 1° northeast of Chi (χ) Ursae Majoris.

It's one of the larger galaxies in this group, spanning 4.5' by 2.8' with a surface brightness of magnitude 12.9.

Through an 8-inch telescope, it appears as a diffuse oval stretched north-northwest to south-southeast. The galaxy structure really comes to light through larger scopes and averted vision. It shows a mottled (blotchy or dappled) surface with a bright core, a hint of spiral arms, and a magnitude 12.5 star at its northwest edge.

NGC 3896 is a barred lenticular galaxy with a magnitude 13.3 surface brightness. It lies 4' southeast of its larger companion. At only 1.4' by 1.0' in size, it

Bill Ferris from Flagstaff, Arizona, made this eyepiece sketch of NGC 3893 and NGC 3896 in Ursa Major. He sketched with graphite on white paper while observing through a 10-inch f/4.5 reflector at 63x. BILL FERRIS

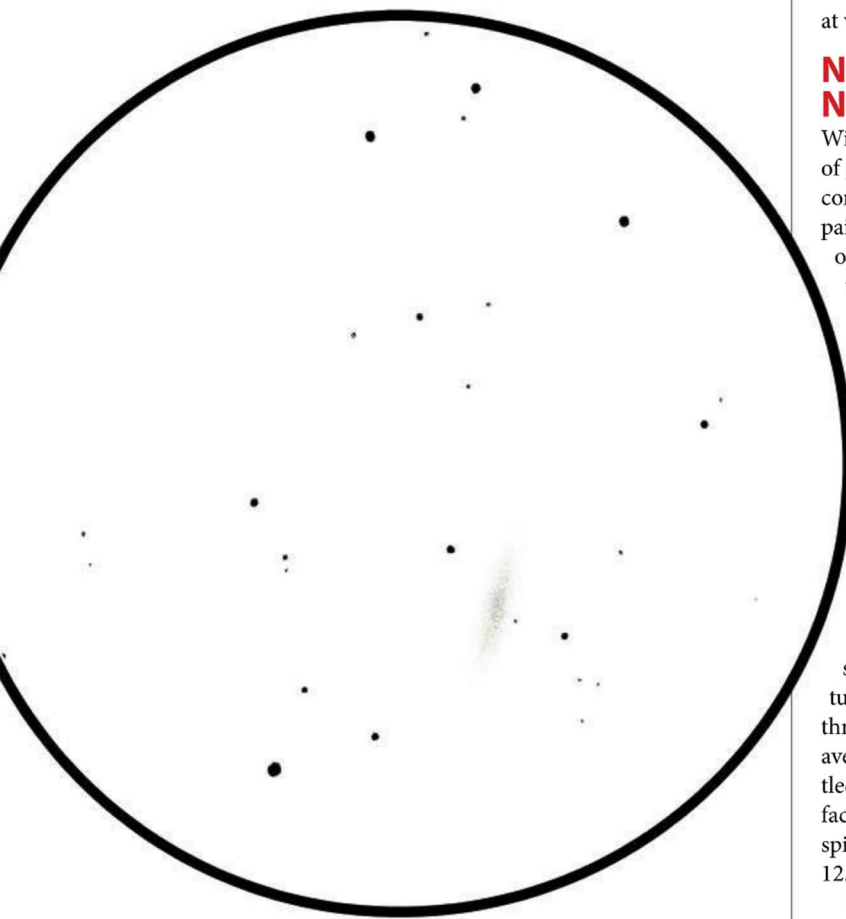


appears as a diffuse circular glow through a 6-inch scope. Through larger scopes, you'll see that it has a bright core, and with high powers, you'll spot the 13th-magnitude star that touches its northern edge.

NGC 6690

For a challenge, swing over to NGC 6690 in Draco. This little 3.8' by 1.3' treasure (also known as NGC 6689 because of a catalog error) is a faint edge-on barred spiral galaxy with a surface brightness of magnitude 13.7. It lies 1.5° southeast of magnitude 4.2 Phi (φ) Draconis, between a 12th-magnitude star to the north-northeast and a magnitude 12.5 star to the southwest. A 13th-magnitude star stands just off its western edge.

Through a 10-inch scope, it appears faint and elongated to the north-northwest and south-southeast with a brighter center along its axis. It becomes mottled with diffuse ends at the northern and southern tips through a 16-inch telescope at 150x. ■



The author observed through a 16-inch f/4.5 Newtonian reflector at 150x to make this sketch of NGC 6690 in Draco. She used a circular observing template on white paper, a #2 graphite pencil, a felt-tipped superfine Faber-Castell Pitt artist pen, a 0.5mm mechanical pencil, and a blending stump. ERIKA RIX

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SECURITY UPGRADE
New tech will soon let you carry big bottles on the plane again. Page 32

HOUSEHOLD MICROBES
It's a germ jungle in your home... especially on your pillow. Page 34

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Pheromones defeat a tiny forest killer. Page 78

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Cosmic Adventures



A new face joins the series

Since December 2010, Associate Editors Bill Andrews and Liz Kruesi have been sharing insights into the wacky and wonderful world of astronomy in *Liz and Bill's Cosmic Adventures*. In 19 episodes, the pair covered everything from black holes, observing, the lives of stars, and the speed of light to astro-themed foods, Albert Einstein's awesomeness, animals in the stars, and the craziness of end-of-the-world myths. But as Editor David J. Eicher shared in his March editorial, Andrews has taken his talents "across the hall" to *Astronomy's* sister magazine, *Discover*.

Now Kruesi has a new partner in crime for *Cosmic Adventures*, Associate Editor Sarah Scoles. Scoles previously had been making astronomy fun for students who visited the National Radio Astronomy Observatory in Green Bank, West Virginia, and she's ready to expand her audience. Kruesi and Scoles will cover such topics as paradigm shifts in astronomy and how much of the universe is dark, and even share some quirks of the *Astronomy* staff. Join the new pair on their upcoming adventures — and relive the best moments between Kruesi and Andrews — at www.Astronomy.com/cosmicadventures.

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OBSERVING TOOLS

Spring observing videos

Each season, *Astronomy's* editors provide you with three videos outlining showpiece objects currently in your night sky. This spring, Senior Editor Michael E. Bakich gears one video toward beginning observers and easy targets, such as Saturn and Comet PANSTARRS. In another, he focuses on spring objects you can see through a small telescope, including the Owl Nebula (M97) and the Whirlpool Galaxy (M51). And finally, Editor David J. Eicher shares 10 of his favorite springtime deep-sky objects, from Centaurus A to the Coma cluster of galaxies. Check them out at www.Astronomy.com/intro.



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Reader Photo Gallery

Visit www.Astronomy.com/readergallery to browse members' images of great celestial events, like this one of the November 2012 penumbral lunar eclipse by Bijan Pirzad.



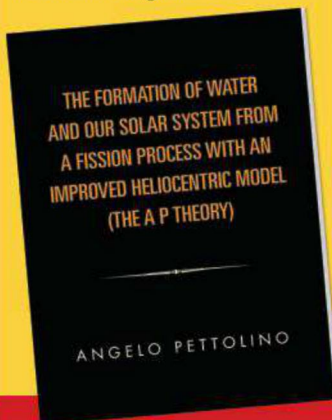
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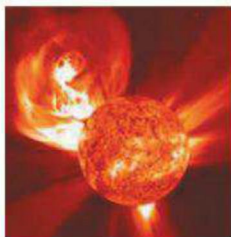
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The Formation Of Water And Our Solar System From A Fission Process With An Improved Heliocentric Model (The AP Theory)

Author: Angelo Pettolino



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Some of the most fundamental questions about the formation of water and our solar system are now answered for the very first time ever in this new, non-fiction, cutting edge, easy to understand book. The AP Theory is the most provable, must read book that directs our minds down new paths describing water and our solar system's formation. The AP Theory is the logical answer to the fundamental questions: how was water and our solar system formed? Grounded in science; it dispels the many myths and misconceptions surrounding water and our solar system's formation with a definitive description and chronological interpretation.

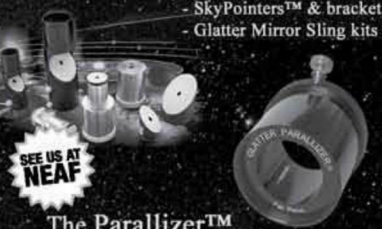
by presenting compelling evidence, to discredit the "gravitationally held (gas) atmosphere" theory. Internationally acclaimed for its controversial, courageous and "bold truth" statements this one of a kind, watershed book advances cosmology and science to a new level of enlightenment by using the latest scientific discoveries to help prove its position. The author's art series of 23 original cosmological 7"x10" prints depicting water and our solar system's formation 5 billion yrs. ago allows the reader to visualize what's being read and presents an improved heliocentric model. The AP Theory supersedes the present texts and library reference books.

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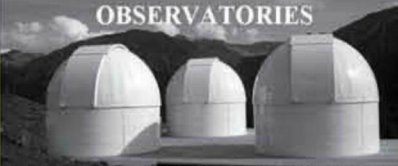
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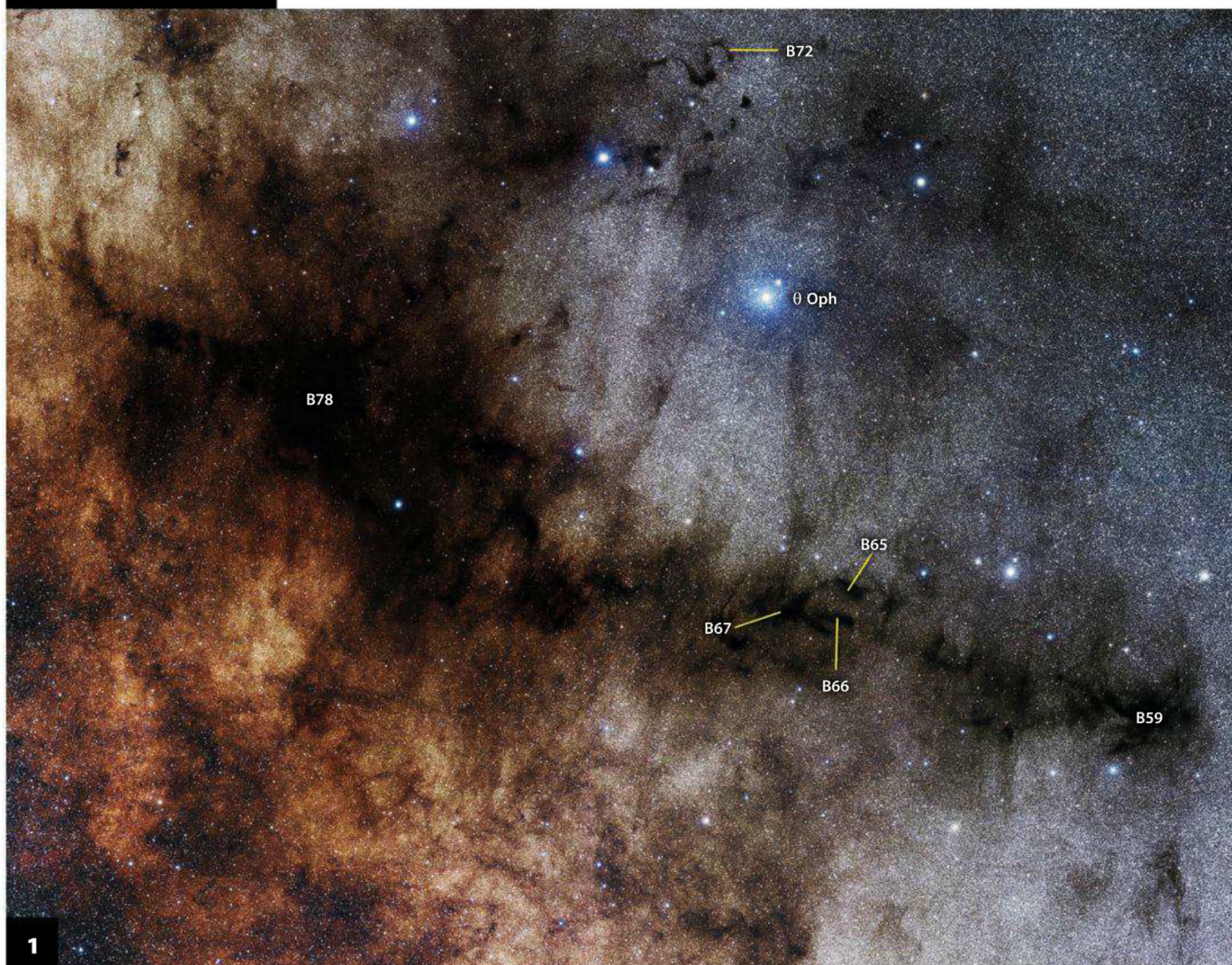
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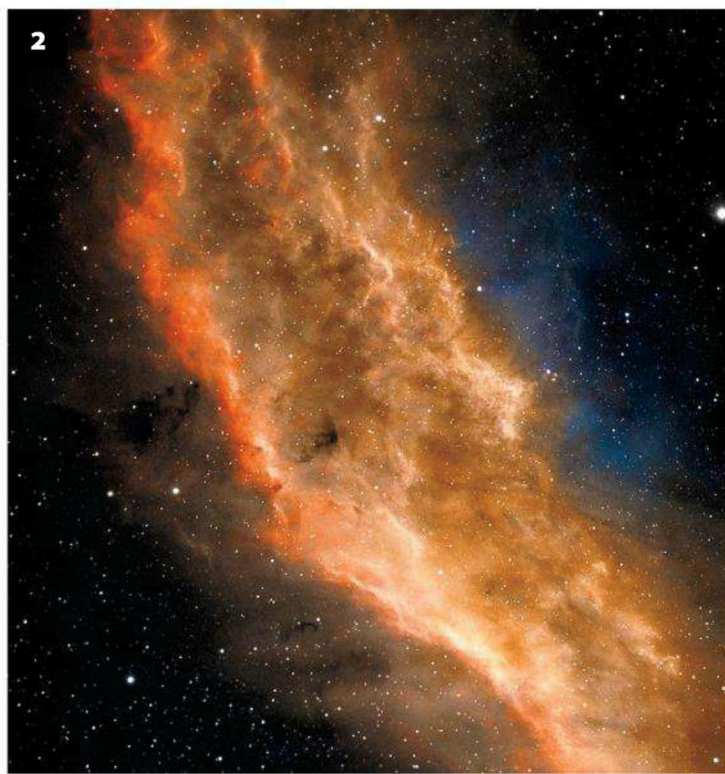


1. THE PIPE NEBULA

Five dark nebulae (Barnard 59, B65, B66, B67, and B78) make up this huge object, which lies in Ophiuchus the Serpent-bearer. It is part of the larger Dark Horse Nebula. The Snake Nebula (B72) is the small winding dark nebula at top center. (4-inch Takahashi FSQ-106ED refractor, FLI Proline 16803 CCD camera, RGB image with 8 hours of exposures through each filter) • *Yuri Beletsky*

2. THE CALIFORNIA NEBULA

NGC 1499 in Perseus is the only celestial object named for one of America's 50 states. It resides in an outer spiral arm of the Milky Way called the Orion Arm. The nebula's luminous portion spans 100 light-years. This entire region contains vast hydrogen clouds from which many bright, massive stars have formed. (3.2-inch Orion ED80T CF refractor, Atik 314L+ CCD camera, five-panel mosaic consisting of one hundred and ten 15-minute H α exposures stacked with twenty 15-minute OIII exposures and sixty-three 15-minute SII images) • *Warren Spren*





3. THE WIZARD NEBULA

NGC 7380 appears as an unevenly bright haze with an irregular border 0.5° long stretching from north to south. The northern part of the nebula glows more brightly than the southern part. Amateur astronomers began calling this object the Wizard Nebula in the early 2000s when long exposures of it began to circulate on the Internet. (17-inch Planewave Instruments CDK17 corrected Dall-Kirkham astrograph at f/6.8, Apogee Alta U16M CCD camera, H α /OIII/SII image with exposures of 140, 90, and 80 minutes, respectively)

• **Bob Finnigan and Tony Cellini**

4. THE SOLAR CORONA

For centuries, astronomers traveled to view total solar eclipses because those were the only times they could see the Sun's corona — its outer atmosphere. Even today, that "crown" visible during totality never fails to impress those who observe it. (Nikon D700 DSLR, Tamron 400mm f/4 lens set to f/6.3, composite image made by combining $\frac{1}{2},000$ -second to 1-second images at ISO 200 and a single $\frac{1}{2}$ -second image at ISO 1600, taken November 14, 2012, near Maitland Downs, Australia) • **Robert and Elisabeth Slobins**

5. MARS AND ANTARES

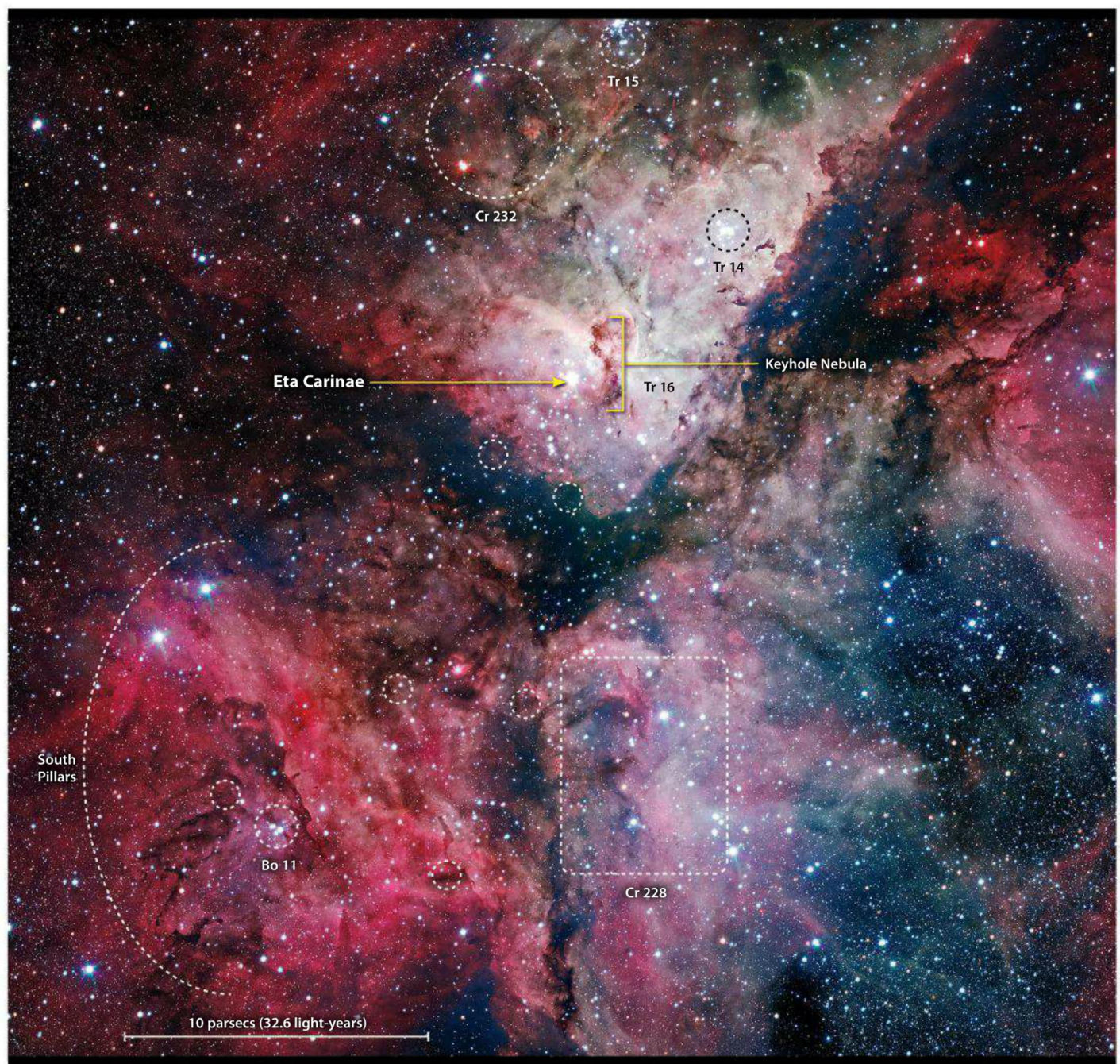
The constellation Scorpius the Scorpion's brightest star is Antares, a word that literally means "rival of Mars." This image shows the two objects near each other and proves why the name is true. Northern viewers should note that this is a Southern Hemisphere view, so Scorpius appears upside down. The slightly brighter star lies above and to the left of the planet. (Canon 5D Mark II DSLR, 35mm lens, fog filter stacked with a star filter, taken October 13, 2012, near San Antonio de Areco, Argentina) • **Luis Argerich**

6. SHARPLESS 2-1

This cloud of ionized hydrogen in the Milky Way is the first object in American astronomer Stewart Sharpless' catalog of 313 such regions north of declination -27° . He published the second and final version of the catalog in 1959. (Telescope Engineering Company TEC-140 refractor at f/7.2, FLI Proline 16803 CCD camera, two-panel mosaic with each being an H α LRGB image with exposures of 300, 250, 140, 110, and 120 minutes, respectively) • **Marco Lorenzi**

Send your images to:

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Inside the Carina Nebula

A spectacular new image from the European Southern Observatory (ESO) shows one of the greatest star-forming regions in the sky like never before. The amazing detail and color in this picture of the Carina Nebula (NGC 3372) comes from the VLT Survey Telescope at ESO's Paranal Observatory in Chile.

The brilliant red color in the gas is due to hydrogen being excited into luminescence by

ultraviolet radiation from stars nearby. The whole object is a stellar nursery, transforming gas and dust into infant stars. The circles on the picture mark the locations of embedded infrared sources, and other labeled features — Bochum 11, Collinder 228, Collinder 232, Trumpler 14, Trumpler 15, and Trumpler 16 — are all young star clusters.

The ferocious star Eta (η) Carinae lies above center; it is

one of the most luminous and massive stars known. Nearby lies an S-shaped dark nebula called the Keyhole. The southern area of the Carina Nebula contains numerous pillars of dust. The nebula lies about 7,500 light-years away. On this mind-boggling scale, our Sun and the nearest star system to it, Alpha (α) Centauri and companions, would be separated by a quarter of an inch. ☛

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June 2013: Saturn's grand show continues

As darkness falls in early winter, **Saturn** commands our attention. Although the planetary showpiece reached opposition and peak visibility in late April, it now appears much higher in the early evening sky. The planet stands approximately 70° above the northern horizon around 9 P.M. local time in mid-June.

Saturn moves slowly westward against the background stars of eastern Virgo all month. It resides a bit more than 10° due east of Spica, the Maiden's brightest star. As twilight fades, Saturn lies to Spica's lower right in the northeastern sky. Shining at magnitude 0.4, the planet appears slightly but noticeably brighter than the star.

You won't want to miss the view of Saturn through a telescope. The ringed planet's disk measures 18" across while the rings span 41" and tilt 17° to our line of sight. This large angle makes the dark Cassini Division, which separates the outer A ring from the brighter B ring, easy to spot even through small instruments. Also keep an eye out for 8th-magnitude Titan, Saturn's biggest and brightest moon, as it orbits the planet once every 16 days. Several smaller satellites show up through moderate apertures.

A trio of bright planets hangs low in the northwest shortly after sunset. On June 1, Jupiter, Venus, and Mercury form a straight line in the twilight sky. All three appear slightly higher the closer you live to the equator.

This will be your last chance to glimpse **Jupiter** during its evening apparition. The giant planet slips into the Sun's glare after June's first week. You likely wouldn't see it at all if it weren't so bright, gleaming at magnitude -1.9. Jupiter will return to view in the eastern sky before dawn during July.

Venus appears a bit higher but far brighter than Jupiter on June 1. The brilliant object shines at magnitude -3.8, some six times brighter than its neighbor. And unlike Jupiter, Venus' visibility improves throughout June. By month's end, it appears conspicuous in the northwest as darkness falls and doesn't set until after twilight concludes. When viewed through a telescope in late June, the planet spans 11" and sports a nearly full phase.

Venus serves as a guide to **Mercury** all month. The innermost planet reaches greatest elongation June 12, when it lies 24° east of the Sun and appears 12" high 30 minutes after sunset. Mercury passes 1.9° south (to the upper left) of Venus on June 21, although the two remain close for several days. Binoculars will help you locate Mercury, which glows about 100 times fainter than its companion.

The period after greatest elongation is the best for viewing Mercury through a telescope. Although no detail appears on its face, the disk's size and phase show up nicely. On the 12th, any scope reveals the planet's 8.1"-diameter disk and 40-percent-lit phase. By

the time of its conjunction with Venus, the inner world spans 9.6" and appears one-quarter lit.

Mars is the only bright planet visible before dawn. Although it starts the month hidden in the Sun's glare, it slowly emerges into the morning twilight. By the end of June, you can find the Red Planet about 5° above the northeastern horizon 45 minutes before sunrise. Look for its ruddy glow to the lower left of Orion. You might need binoculars to spot the magnitude 1.5 object. Don't bother aiming your telescope at Mars — its disk measures just 4" across and shows no detail.

The Moon occults Spica

June 18, and the event is visible in a dark sky from most of southern Africa and all of Madagascar. From Windhoek, Namibia, the star disappears at 20h58m UT and reappears at 22h03m UT.

The starry sky

The sky's largest constellation appears prominent in June's early evening sky. Hydra the Water Snake begins with a tight group of six stars that forms the beast's head. In mid-June, you can find this small collection about 30° above the northwestern horizon once darkness falls. Hydra's body extends almost straight up from the head and stretches so far that its tail passes nearly overhead.

I remember watching Comet C/1983 H1 (IRAS-Araki-Alcock) when it passed near Hydra's head in 1983.

This fast-moving comet drew many people's attention to the constellation. This month, however, I want to focus on Hydra's other end. There you can find one of the finest deep-sky objects in the southern sky: spiral galaxy M83.

This object ranks among the southernmost in French comet-hunter Charles Messier's famous catalog of celestial sights that might be mistaken for comets. Although Messier cataloged M83 in 1781, fellow Frenchman Nicolas Louis de Lacaille discovered it in 1752 while observing from South Africa. Of course, neither man recognized M83 as a galaxy separate from our own — the discovery that any objects existed beyond the Milky Way would have to wait until the 20th century. Still, M83 holds the distinction of being the first galaxy sighted beyond our Local Group.

You can find M83 fairly easily a few degrees southeast of 3rd-magnitude Gamma (γ) Hydrae. Even in these days of computerized telescope mounts, it's fun to track down the galaxy — just scan about two-thirds of the way from Gamma to the tight triangle of stars 1, 2, and 3 Centauri.

M83 glows at 8th magnitude and shows up through binoculars under a dark sky. When viewed with a telescope, the galaxy appears as a fuzzy patch with a strong central condensation. Larger apertures reveal evidence of M83's spiral arms, which are oriented nearly face-on to our line of sight. ☛

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:

9 P.M. June 1

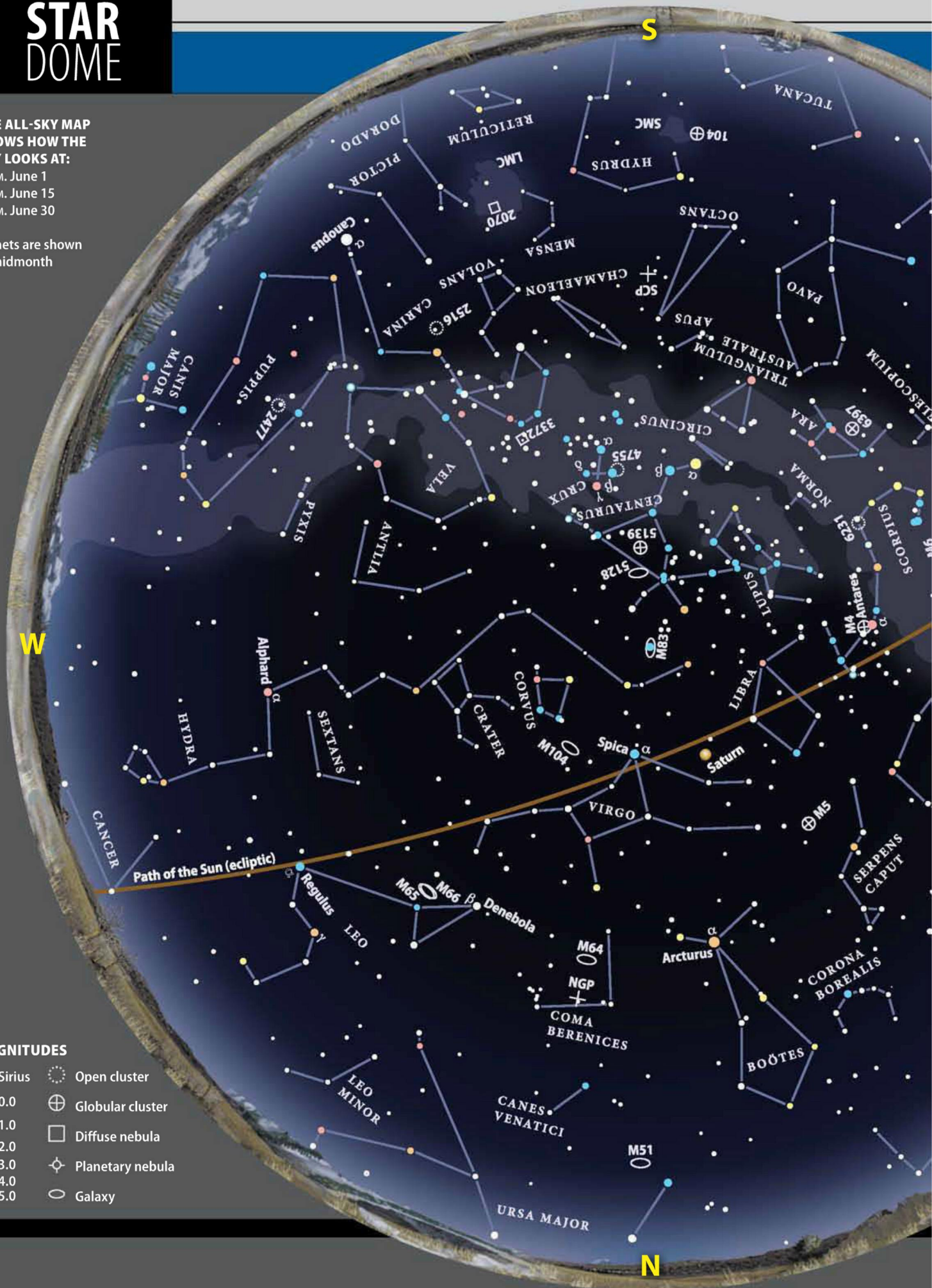
8 P.M. June 15

7 P.M. June 30

Planets are shown
at midmonth

MAGNITUDES

- Sirius
- Open cluster
- 0.0
- ⊕ Globular cluster
- 1.0
- Diffuse nebula
- 2.0
- ⊛ Planetary nebula
- 3.0
- Galaxy
- 4.0
- 5.0



HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



STAR COLORS:

Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by Astronomy: Roen Kelly

JUNE 2013

Calendar of events

- | | |
|---|---|
| 3 The Moon passes 4° north of Uranus, 8h UT | 20 Mercury passes 1.9° south of Venus, 18h UT |
| 7 Neptune is stationary, 18h UT | 21 June solstice occurs at 5h04m UT |
| 8 New Moon occurs at 15h56m UT | 23 Venus passes 5° south of Pollux, 1h UT |
| 9 The Moon is at apogee (406,486 kilometers from Earth), 21h40m UT | The Moon is at perigee (356,991 kilometers from Earth), 11h12m UT |
| 10 The Moon passes 5° south of Venus, 11h UT | Full Moon occurs at 11h32m UT |
| The Moon passes 6° south of Mercury, 23h UT | 25 Mercury is stationary, 23h UT |
| 12 Mercury is at greatest eastern elongation (24°), 17h UT | 27 The Moon passes 6° north of Neptune, 21h UT |
| 13 Asteroid Juno is stationary, 13h UT | 30 Last Quarter Moon occurs at 4h54m UT |
| 16 First Quarter Moon occurs at 17h24m UT | The Moon passes 4° north of Uranus, 15h UT |
| 18 The Moon passes 0.1° north of Spica, 20h UT | |
| 19 Jupiter is in conjunction with the Sun, 16h UT | |
| The Moon passes 4° south of Saturn, 17h UT | |

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