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The Day We Found the Universe
MARCIA BARTUSIAK
The discovery of the modern universe is a story filled with trials, errors, serendipitous breaks, battles of wills, and brilliant insights — a book excerpt by the winner of the ASP’s 2010 Klumpke-Roberts Award.

Learning How to Build a Solar System
JOEL D. GREEN
I’m in the planet-construction business, though only as an observer. It’s a hard job, because new stars are shrouded in dust and gas. But we’re finally beginning to uncover a few of their long-held secrets.

NASA’s New Airborne Observatory Sees “First Light”
NICHOLAS A. VERONICO
After more than a decade of hard work (and numerous funding challenges), a unique telescope finally takes to the air to seek out the secrets of the infrared universe.

Astronomy in the News
Spectacular first-light images of the Sun, a planetary system out of tilt, and a vast reservoir of intergalactic gas 400 million light-years away — these are some of the discoveries that recently made news in the astronomical community.
The Moai, the Eclipse, and the Milky Way

Travel can be a very enriching experience, and sometimes you don’t have to go very far to acquire that special feeling. Some of the best trips I’ve taken have been to the Rockies, a few hours away by car.

I have also been fortunate to visit some remote destinations, often in search of astronomical sights. I’ve traveled (as a tour leader) several times to Iceland in search of the northern lights, and I’m always enthranced by the otherworldly vistas that little island presents. Eclipse tours have also taken me to far-off lands where sometimes — though the idea is sacriligious to die-hard umbraphiles — totality is merely one of the highlights of the trip and not necessarily the be-all and end-all of the journey.

And so it was in Chile this July. The total solar eclipse of July 11 passed primarily over the waters of the South Pacific. Eclipse chasers converged on the few spots of land available, while tour companies chartered cruise ships and even an airliner in order to catch totality in mid-ocean.

My group was based on Rapa Nui (Easter Island), and we spent several days moai gazing. These statues, created to honor the Islander’s ancestors, were destroyed during the civil wars that raged in the late 1700s. Some have been restored, many remain as rubble, but all provoked much thought and inevitable comparisons to our own society.

On the 11th, totality blossomed forth without the waters of the South Pacific. Eclipse chasers converged on the few spots of land available, while tour companies chartered cruise ships and even an airliner in order to catch totality in mid-ocean.

For some of our group, this grandeur was reinforced a few days later when we traveled to the Atacama Desert for three nights of star-gazing (and several days of sightseeing). On our first night out, as we tumbled out of the bus that brought us to our dark-sky site, each of us paused and gaped skyward. High overhead, the core of our galaxy literally blazed forth. The dark dust lanes running through the starfield gave the galaxy a three-dimen-sional appearance. Many of us (myself included) had never seen our galactic home from a light-free environment in the Southern Hemisphere, and even those in the group who were not keen observers were in awe at the sight.

It’s expensive to visit the moai in Rapa Nui, and total solar eclipses are rare. But I’d encourage one and all to find the darkest sky possible close to home and take an enriching journey through our galactic home.

Paul Deans
Editor, Mercury
Last autumn, while in New York City on business, I found myself with a couple of hours to kill between meetings and decided to put them to good use by going stargazing. It was late November, shortly before Thanksgiving, and a light rain was falling as I walked the streets of Midtown. Viewing bleachers were going up along Central Park West for the big Thanksgiving Day parade. At Rockefeller Center, workmen fussed with the giant Christmas tree just days before the big lighting ceremony, while skaters practiced their spins on the ice rink below. A pair of Rockettes, adorned in festive red regalia for their high-kicking holiday review, scurried from a curbside cab in front of me into Radio City Music Hall.

As the city prepared for the onrushing Yuletide season, my own destination that rain-slick afternoon was the Museum of Modern Art on West 53rd. Once inside, I shook off my umbrella and headed for the upstairs galleries where the museum boasts a fine collection of French impressionists and post-impressionists and avant-garde of the early 20th century. There were Monets and Manets and Pissaros and Cezannes and Matisses and Bracques and Picassos galore decorating the spaces, but my objective was quite specific. I held my breath, rounded a corner, peeked into a modest-sized gallery, and there it was — in all its impastoed glory: Vincent van Gogh’s signature work, The Starry Night.

Is there a painting more widely reproduced than this, or better known? (Perhaps da Vinci’s Mona Lisa excepted on the latter point.) And there it was, the original — glassed in a gilded frame — just hanging on the wall.

As the museum-goers who clustered in front of the famous artwork drifted off to other paintings, I slid into a spot directly in front and leaned in, peering closely at the masterpiece of one of my favorite artists. I could see every paint-laden stroke of the palette knife on canvas, crafting the dark, foreground cypress, the drowsy village, and the universe at play above, the golden Moon and stars caught in the swirling blue currents of some cosmic breeze — or of van Gogh’s mind in those final creative years before the anguish took him.

It was a singular moment.

Icons in the popular sense tend to fill the space available, to grow larger-than-life, to inhabit some place beyond our ability to touch. And yet here was just such an icon a foot in front of my face, not a half-arm-span wide, hanging on the wall of an art museum on a rainy afternoon in New York. One could almost smell the paint, feel the strokes as Vincent applied them, and imagine his thoughts as he interpreted the universe through the filter of his mind. And an
encounter with an icon became an unexpectedly personal and impactful experience.

Since that extraordinary afternoon, I’ve wondered if *The Starry Night* was van Gogh’s attempt to make tangible the universe for himself. For what fills the available space and resists our ability to grasp it more than space itself? Perhaps Vincent was striving for what the rest of us strive for whenever we’re lucky enough to behold a dark night sky bristling with stars: to render it reachable, to somehow bring it a foot in front of our face and make a personal experience of it. And to share that experience with others.

At the Astronomical Society of the Pacific, we strive to do that every day — through the arts of education, outreach, professional development, and publication. And in an interesting coincidence, the ASP has done so since 1889 — the very year in which Vincent painted his famous painting. We two — the ASP and *The Starry Night* — have a concurrent provenance, each in our own way working to inspire people to the possibilities of what lies above, to help them craft their own personal and impactful experience with the sky, and to join in the adventure of discovering the natural world anew. It’s important work, and we thank you for your support as we strive together to advance that noble mission.

If you get to New York City, by all means view it from the top of the Empire State Building. Visit Times Square, and the Statue of Liberty. See a show on Broadway, and stroll through Central Park. But if you have a couple of hours to kill, consider a visit to the Museum of Modern Art to see a very special painting by a very special artist, for a very personal experience with it.

I can wish you no better stargazing in the Big Apple than to wish you *The Starry Night*.  

*James G. Manning* is the Executive Director of the Astronomical Society of the Pacific.
80 Years Ago: The Asteroid Eros

Astronomers have found Eros to be a very useful asteroid.

In September 1930, Seth B. Nicholson of the Mount Wilson Observatory published an A.S.P. Leaflet entitled "The Near Approach of Eros." Karl Gustav Witt discovered this asteroid, No. 433, in 1898 in Berlin. Its orbit was unusual for an asteroid — bringing it inside the orbit of Mars, and thus potentially closer to the Earth than any other solar system object known (at that time) except for the Moon and a few comets. Nicholson noted that its close approach on January 30, 1931, would provide an excellent opportunity to measure the distance from the Earth to the Sun (called the astronomical unit or a.u.)

Astronomers had long been able to construct scale drawings of the orbits of planets and comets. But "until some distance is determined in known units, such as the mile, the actual dimensions of planetary or stellar space are unknown. If, however, any one distance can be determined in miles, the scale of the whole planetary and stellar system is known. The simplest method of measuring one of these distances is by triangulation." This means taking observations of a celestial object from two points whose distance apart is known, and measuring the difference in position (parallax). But since the planets are very far away, their parallax angles are very tiny, and also they show large disks, which are hard to measure accurately.

However, "the asteroids are small, and accurate measures can be made on their star-like image." Furthermore, since Eros "would sometimes be much closer to the Earth than any other planet... measures of its parallax would give a very accurate determination of the distance to the Sun." This had been attempted at the previous close approach in 1900, when Eros came within 30,000,000 miles of Earth. The 1931 approach would be much closer, at 16,200,000 miles, affording a better chance to measure its parallax.

Besides this, Nicholson hoped that observations of Eros itself would help clarify the reasons for its variation in brightness. "The obvious explanation is that such asteroids are not spherical...and that they have an axial rotation. The rotation period of Eros is 5 hours and 16 minutes, and during this interval its brightness passes through two unequal maxima and minima."

A campaign to observe Eros in 1931 did lead to an improved value of the a.u. (92,950,000 miles), which was the best known value until more recent space-based observations. The rotation period was also confirmed, and the brightness variations suggested the asteroid was shaped rather like a potato, about 20.5 by 8 by 8 miles. But it still just looked like a point of light, with no visible surface or surface features.

The closest approach of the 20th century was on Jan. 23, 1975, when Eros came within 14 million miles of Earth. The next one will be in 2012. (It can never collide with us, since its orbit does not bring it as close to the Sun as we are.) But the most exciting and productive recent studies of Eros took place with the NEAR Shoemaker spacecraft, which went into orbit around Eros in 2000 and eventually landed on its surface.

The Near Earth Asteroid Rendezvous (NEAR) mission was launched in February 1996, and in June 1997, the spacecraft came within 800 miles of the asteroid Mathilde. It then carried out other maneuvers, including a gravity boost from a pass by Earth in January 1998. The first attempt to enter orbit around Eros failed, but a later attempt in February 2000 was successful. NEAR then spent a year taking images from various altitudes, including an approach to within 3.3 miles of the surface in October.

In January 2001 controllers began guiding NEAR in a slow descent toward the surface of Eros, and the spacecraft made a gentle touchdown on Feb. 12, 2001. This marked the first time a spacecraft had landed on an asteroid. It continued to transmit data from the surface until it was shut down on Feb. 28; an attempt to contact it on December 10, 2002 was unsuccessful.

The images confirmed the shape and dimensions of Eros, and showed a surface covered in impact craters, with lots of large rocks thrown around. Most of these rocks are probably the result of a meteorite impact about a billion years ago that generated a single large crater near the center of the asteroid, and also wiped out nearby smaller craters. Back in 1930, Nicholson would not have believed it possible to get such images, or to actually to land on an asteroid!

KATHERINE BRACHER taught astronomy at Whitman College in Walla Walla, WA, for 31 years. Retired in 1998, she currently lives in Austin, Texas. Her research focuses on eclipses and the astronomy of the ancient world; her other principal interest is early music.
Tales From the Crypt

Finding tombs, even those of famous astronomers, can be a grave matter.

Archimedes (287-211 BC) — the greatest mathematician of antiquity — was killed by a Roman soldier during the sack of Syracuse in Sicily. He had already planned his tombstone: it was to be set with a cylinder circumscribing a sphere, to celebrate his discovery that a sphere contained within a cylinder will always have an area two-thirds that of the cylinder.

In 75 BC, 136 years after Archimedes’ death, the philosopher Cicero was serving on the Roman governor’s staff in Sicily. He decided to try to find Archimedes’ grave. Cicero says he remembered some verses written on the tomb claiming that it was decorated with a sphere plus a cylinder on top. Locating the tomb was not easy, since the graveyard was large and overgrown, but eventually he spotted in the distance a column with the monument on top. He sent slaves with sickles to clear the path to it.

“When a passage had been cleared,” wrote Cicero, “we approached the pedestal in front of us. The epigram could be traced, though only about half the lines were legible, the latter portion being worn away.”

I was reminded of this ancient tale during a recent visit to Paris. One object of my visit was to locate the grave of one of the most famous astronomers of all time, Joseph Jerome Lalande (1732–1807). He held the chair of astronomy at the College de France for an amazing 46 years and became director of Paris Observatory in 1795.

In an age when astronomy was already beginning to split into specialties, Lalande made his mark in a wide range of astronomical endeavours. As a writer, he helped popularize astronomy. As editor of a major journal for 33 years, he was instrumental in advancing science. As an observer, he compiled a chart of more than 47,000 stars, and he incorporated perturbations into planetary tables that were widely used for years.

So where is the tomb of this astronomer who was showered with honors during his life? The clues are in a recent French-language biography of Lalande by Simone Dumont.

In his will, Lalande instructed that his body be interred below the instruments of the l’Observatoire de l’École militaire (the Military College observatory) in an excavation that he had made for this purpose. This did not happen, as it would have required the authorization of the Minister for War, and in any case the observatory ceased to exist in 1835.

Lalande was buried in Ste Catherine’s cemetery, since it was the closest to the College de France. The cemetery was closed in 1824 and was wiped away by road works in the 1850s. Relatives of those buried were warned to remove remains in 1852. A relative removed Lalande’s bones and reburied them at Père Lachaise Cemetery on April 6, the anniversary of his death.

Père Lechaise is a huge cemetery, and one of the most famous in the world. A host of stellar characters are there, including Oscar Wilde and Jim Morrison. But where, in this huge cemetery, should Lalande be buried?

His right-hand man was Michel Lefrançais, a cousin who had married Lalande’s daughter. Michel was always referred to as Lalande’s nephew. Michel was already buried at Père Lachaise, so that is where Lalande was finally laid to rest — not just his bones but his heart, too. It was common practice at the time for the heart to be removed at death and given to the family.

Dumont identifies the grave as midway between those of François Arago and Jean Baptiste Delambre, who became Director of Paris Observatory in 1804. That was my only clue to the location when I arrived at Père Lechaise earlier this year.

Finding the grave of Arago was easy. He was not only an astronomer, but became Prime Minister of France in 1848. A map at the entrance of the cemetery gives the approximate location of many graves, including that of Arago, but Delambre is not listed. After a half hour of fruitless searching, I asked a staff member at the cemetery, who kindly led me to Lalande’s grave.

Like the ancient tomb of Archimedes, “only about half the lines were legible, the latter portion being worn away.” The top portion under the arch reads “Familie Le Francais de Lalande” and underneath is written “Here reposes Michel Jean Jérôme Lefrançois de Lalande, astronomer.”

I was lucky enough to find the grave of Delambre just across the pathway from the Lalande grave. Like the grave of the German astronomer Franz Xaver von Zach at Père Lechaise, it too has a barely readable inscription.

CLIFFORD J. CUNNINGHAM was recently seen dining in the rooftop restaurant of the Reichstag in Berlin.
Understanding Ozone

Historic stellar spectra may ultimately lead to a better understanding of Earth's ozone shield.

It is widely known that Earth's tenuous layer of stratospheric ozone provides our biosphere with crucial protection from the catastrophic effects of solar ultraviolet radiation. On the other hand, it is a little-known fact that astronomers are credited for the first detection of atmospheric ozone. In 1890, the husband and wife team of William and Margaret Huggins discovered molecular absorption bands (now known as the Huggins bands) in the near-UV spectrum of the hot star Sirius. By 1917, these same bands had been observed in the solar spectrum as well. Using follow-up observations of both the Sun and Sirius, astronomers Fowler and Strutt identified atmospheric ozone as the source of the Huggins bands.

In the 1920s, Prof. G. M. B. Dobson pioneered the instrumentation and techniques needed to measure ozone from observations of the Huggins bands in the solar spectrum. From measurements at different sites across Europe, Dobson found that ozone concentrations vary considerably with local weather conditions and with the season. One of Dobson's original sites (Arosa, Switzerland) has been in operation since 1926 and represents the longest continuous set of ozone measurements. By the 1970s, scientists were using weather balloons to measure the height profile of ozone. Satellite measurements of ozone from space commenced slightly more than 30 years ago.

Since the discovery of the Huggins bands, astronomers have developed various techniques to extract and remove all of the pesky atmospheric absorption features that confound our studies of astronomical objects. Several years ago, however, one astronomer decided to turn astronomical "trash" into atmospheric science "treasure." In 2005, Elizabeth Griffin developed a technique to measure levels of terrestrial ozone levels from photographic stellar spectra and is currently pioneering an effort to document ozone levels in the first half of the 20th century using historic stellar spectra.

Griffin first performed a "proof-of-concept" using a total of ten high-dispersion photographic spectra of Vega and Sirius taken between 1977 and 1992. The technique is limited to early A-type and hotter stars with narrow lines to ensure that telluric Huggins bands are relatively unambiguous. She digitized each spectrum, and then performed an intensity calibration to correct for the non-linear response of the photographic emulsion, and then fit the absorption profiles of the Huggins bands using a template derived from published laboratory ozone cross-sections! (This is a rather simplified overview of her analysis. For full details consult her discovery paper.)

Griffin compared measured ozone levels derived from the nighttime stellar spectra with contemporaneous satellite measurements made with the Total Ozone Mapping Spectrometer (TOMS). TOMS measurements were made during the daytime from 1978-93. Since ozone levels vary from day to day at a given location by as much as 10-15%, Griffin used the average value of two TOMS measurements flanking the nighttime measurements. She found that the results derived from nighttime stellar spectra agree with the daytime TOMS measurements to within 2%!

Having established the validity of her technique for extracting ozone measurements from nighttime stellar spectra, Griffin then applied the technique to historic spectra from the pre-satellite era. The first difficulty was identifying the existence of appropriate spectral plates. She required high-resolution spectra of early A-type and hotter stars. Since ordinary glass is opaque to UV, spectra for the study needed to have been captured with quartz prism and optics.

After searching the plate archives of several observatories around the world, she found a collection of suitable spectra taken at Mt. Wilson Observatory between 1935 and 1942. This period is well before the release of anthropogenic CFCs into Earth's atmosphere and offers a new method, independent of Dobson's, to examine the natural variability of ozone. From the available spectra, Griffin identified a total of 16 viable spectra. Her analysis revealed that ozone measurements from the Mount Wilson spectra clearly exhibit seasonal variations. These variations are generally consistent with measurements obtained during the same time period at the Arosa site using the Dobson device.

Griffin's work represents a promising, cross-disciplinary application of astrophysical data. In fact, her research was supported by a grant from the Canadian Foundation for Climate and Atmospheric Sciences, and she consulted with a number of atmospheric scientists. In the future, she plans to examine a possible link between increased ozone concentration and abnormally intense El Niño events. In addition, Griffin hopes that this unusual application of astronomical data will encourage the scientific community to digitize historic astronomical data for future scientific investigations of all kinds.

Jennifer Birriel is an Associate Professor of Physics in the Dept. of Math, Computer Science and Physics at Morehead State University in KY.
It's the time of year again here in Boulder for thunderstorms. I love the smell of a good storm rolling in and the light show it can bring (as long as it doesn't zap my computer!). The power of those storms can be pretty frightening and downright destructive, though. The typical peak power in a single bolt of lightning can be as much as a trillion watts. One Trillion. A thousand megawatts! Not too shabby for a bunch of hailstones and water droplets bumping electrons around.

Of course, Earth is not the only planet known for these kinds of meteorological fireworks. When Voyager 1 flew past Jupiter in 1979, it captured images of the nighttime clouds of the gas giant showing the distinct flash-illuminated hearts of enormous thunderstorms. So-called 'whistler waves,' the radio-frequency ghosts of lightning propagating through the planet's magnetosphere, are an additional sign of the atmospheric electrical discharges. The measured output of Jupiter's storms suggests a frenzy of a bolt per second in the polar regions, and some estimates of the power output of Jupiter's flashes point to discharges equal to one hundred times the jolt of their terrestrial kin.

The same kind of lightning-induced radio emissions detected at Jupiter have been heard at Saturn and Neptune as well, though the more direct optical evidence of lightning there has not been as forthcoming. One might even wonder if some electrical charges might build up in the convective clouds seen in Titan's polar regions. With methane drizzling down and surrounding temperatures of -290° F, it would be like no thunderstorm we know, that's for sure!

Back here in the inner solar system, our neighbor Venus, with its thick atmosphere and opaque screen of clouds, seems a natural place to expect lightning. Indeed, radio science instruments on the Pioneer Venus Orbiter, which entered orbit around Venus in December 1978, did detect telltale signatures of lightning. Intriguingly, those suggestions of lightning have been interpreted as being roughly localized around regions of the planet where radar studies of the surface geology indicated volcano-like features. Lightning is often triggered in the eruptive plumes of terrestrial volcanoes.

Can we actually see Venusian lighting flashes? Seth Hansell and colleagues at the University of Arizona analyzed image data they obtained of the night side of Venus in 1993, looking for lightning in coronagraphic images taken at nearly video-frame rates. Laboratory simulations of lightning in a Venus atmosphere show that lightning should show a strong emission line at a wavelength of 777.4 nm due to excitation of neutral oxygen. Hansell's images of Venus showed several flashes that looked like lightning; their data suggest that there ought to be a visible flash of lightning somewhere on the night side of Venus every 27 minutes or so.

We'll get a good chance to finally confirm once and for all the existence of lightning on Venus within the next year. On May 21, Japan successfully launched their Akatsuki mission to Venus. Formerly known as the Venus Climate Orbiter, Akatsuki will arrive at Venus in December with a primary mission of studying the circulation patterns in the blistering atmosphere of our sister planet, focusing five different cameras on various levels of the atmosphere.

One of those cameras, the Lightning and Airglow Camera (LAC), will snap 30,000 pictures a second to try to catch some Venusian bolts in the act. LAC will operate at the same 777.4 nm wavelength that Seth Hansell and colleagues used nearly two decades ago, but it will be able to detect feeble flashes only 1/100 as strong as typical lightning here on Earth.

I'm eagerly awaiting the verdict on Venus lightning. I'd like to know whether it really exists or not (I'm betting it's there), but I really look forward to knowing more about the circumstances of its formation. Are there cloud dynamics, and collections of the right particulates in the atmosphere, that allow the kind of charge transfer and buildup which create the massive discharges in summer thunderstorms in Boulder? Even more intriguing for the implications for Venusian geology, will we find localized centers of lightning indicative of ongoing volcanic eruptions?

Stayed tuned to the results from Akatsuki. A lot of fundamental questions about the workings of Venus' atmosphere promise to be answered during the next few years.

DANIEL D. DURDA is a Principal Scientist in the Department of Space Studies at the Southwest Research Institute in Boulder, Colorado.
Astronomers Find Trigger for the Biggest, Baddest Black Holes

While black holes are menacing enough, capable of warping the very fabric of space and bringing time to a virtual halt, about 1% of them can far outshine their entire host galaxy. How such a small majority can muster this strength to emit the energy of up to 10 billion suns has been a long-standing mystery — until now.

NASA's ever-versatile Swift satellite has produced the most complete census of galactic black holes to date. The Swift team has found that most of these monster black holes — the famous quasars and others with esoteric names such as blazars or Seyferts — are in galaxies either merging or about to merge with other galaxies. The details are still unclear, but it seems that the commotion of galaxy mergers fuels a hungry central black hole with copious amounts of interstellar gas to burn.

There are two broad families of black holes. Stellar-size black holes form from the collapse of massive stars or, sometimes, from the merger of neutron stars. Our galaxy likely contains millions. Most of these are dark and quiet, visible only when a companion star feeds the black hole a little fuel. That fuel can heat to extreme temperatures as it falls towards the black hole and can emit X-rays and other forms of radiation.

The Swift finding concerns supermassive or galactic black holes. Most galaxies, including our own, possess a single, supermassive black hole at their core containing the mass of millions to billions of suns. How they form is a mystery, but it's likely from the collapse of interstellar gas during the galaxy's formation.

Collectively these kinds of energetic black holes are called Active Galactic Nuclei, or AGN, so named because that great outpouring of energy seen clear across the universe originates from a compact, central region in a galaxy. Technically an AGN refers to a region, not an object. No one has actually seen a black hole, remember, just the handiwork of a black hole. Nonetheless, an AGN is synonymous with the biggest, brightest, and baddest black holes.

Theories on black hole feeding abound, but the basic idea is that local interstellar gas spirals in and heats to higher and higher temperatures as it approaches the black hole's event horizon. More gas, more heat, and more radiation spewed out.

The Swift team has confirmed what some theorists have suspected: Galaxy mergers dislodge interstellar gas and fan the flames. Confirming this has not been so straightforward, though. The trick was to combine a thorough black hole census based on hard X-ray data with optical galaxy observations.

Swift's day job, mind you, is hunting for gamma-ray bursts. Swift has detected more than 500 bursts since its launch in 2004, some originating from the earliest days of star formation. The mission has been a phenomenal success. During its free time, Swift conducts a hard X-ray survey of the universe and takes what scientists call a "true" census of black holes. These hard, or highest-energy, X-rays can penetrate the dust that shrouds many black hole systems and stops lower-energy X-rays, ultraviolet radiation, and visible light from leaving.

Infrared radiation from warm dust near the black hole can pass through the material, but it can be confused with emissions from the galaxy's star-forming regions. So only a hard X-ray survey can accurately count all the black hole systems — albeit in the local universe, which is the best that the current generation of hard X-ray detectors can offer. The Swift survey is sensitive to AGN only as far as 650 million light-years away. Still, Swift has uncovered dozens of previously unrecognized systems.

Michael Koss, a graduate student at the University of Maryland, College Park, led his colleagues in a ground-based optical-telescope follow-up of 260 AGN identified by Swift. He found that 25% of the AGN were inside a galaxy in the process of merging with another galaxy, and an additional 60% were destined to merge soon — well, within a billion years, which is an astronomer's concept of soon.

NASA described the finding as a "smoking gun" for the galaxy-merger theory of AGN. The Swift team has convincingly associated galaxy mergers with AGN. To understand the details of how gas gets into a black hole, scientists might need to wait for the once-canceled, now-resurrected NuStar mission. NuStar would be the first space telescope to focus on hard X-rays and might peer back as far as six billion years ago.

Fortunately, NuStar is scheduled for launch in 2012. That's still within the billion-year window to observe galaxy mergers — though given NASA's budget uncertainties, still light-years away for some eager astronomers.

Baltimore-based science writer CHRISTOPHER WANJEK is chagrined to learn his AGN theory of alien trash incineration is not supported by the SWIFT results.
What is Your Theory?

A good theory can help you support student learning.

Physical theories shape how we, as scientists, view the universe, even as we devise new explanations or test previous ones. Theories enable us to create predictions of new phenomena and open doors to new areas of knowledge. Of greatest importance, theories unify our understanding of a subject.

But as instructors, we often enter the classroom without having a similar theoretical framework to fashion our insights into teaching. The result is an unclear idea of our goals and what circumstances best allow students to learn. K-12 teachers have an advantage over Astro 101 instructors, because learning theory is part of the teacher education curriculum. Although a quick summary of current theories follows, I suggest that your summer reading should include a book like Dale Schunk’s *Learning Theories*.

*Constructivism* says that individuals construct knowledge based upon their experiences. (Knowledge in this context means more than mere factual learning and encompasses deeper cognitive structures.) Constructivists hold that knowledge cannot be passed from person to person, but rather individuals must rediscover knowledge for themselves and develop their own cognitive structures. This model of learning recommends active learning in the classroom as a primary technique.

*Piagetian cognitive development* states that children go through four stages of cognitive advancement: sensorimotor, preoperational, concrete operational, and formal operations. Change from one level to another is not gradual but discrete and depends upon previous levels of attainment. Jean Piaget held that cognitive conflict was important for progression to the next stage, but recent research offers little support for that supposition. Further, additional research indicates that learning progresses gradually and not in the discrete leaps imagined by Piaget. While Piagetian theory has shrinking support, cognitive conflict does appear necessary for students to confront their physical misconceptions.

*Jerome Bruner* concentrated on how students represent knowledge: manipulating their environment, developing mental imagery, or devising symbolic systems. Instead of saying that students were not ready to learn certain concepts, Bruner held that the method of teaching was not attuned to students’ representation. He also introduced the idea of *spiral learning*: Ideas must be revisited several times with increasing complexity in place of encountering a topic once.

*Lev Vygotsky* emphasized the social nature of learning and suggested that social culture influences learning through available objects, language, and cultural symbology. That is, culture provides a set of tools by which students transmit knowledge and learn to regulate their thinking. Recent research seems to negate some of Vygotsky’s ideas, including the emphasis of environment over biological predisposition to develop certain learning skills. But the idea of cultural influence on learning seems to be well founded.

The idea of self-regulation of thinking is significant, and instructors need to provide classroom structures to support its development. For example, having students evaluate their knowledge periodically is crucial. So is *scaffolding*, where instructors control task elements. Nonessential task elements are reduced, while the elements necessary for developing a new concept are held in focus so students can master the critical part. Scaffolding is actually not part of Vygotsky’s theory — the *zone of proximal development* (ZPD) is — but scaffolding is an effective way of utilizing the ZPD.

Finally, research shows that learning takes place in a particular context and is connected to that environment. Students who learn about the melting of ice in a physics class may not have the cognitive structures to retrieve that information in an astronomy class. Research indicates that the structure does not reside solely within the mind but also within the *situation of learning*. Thus, the brain is not purely an information processor. One way to improve learning situations is to provide authentic learning experiences; i.e., the instructor should aim to have students do science instead of merely learning about scientific results.

In practice, no single theory is sufficient. Good instructors use multiple instructional theories to develop active learning environments that utilize collaborative activities. Activities should revisit topics as students engage concrete ideas, develop mental imagery, and then use symbols to describe their knowledge. Peer collaboration utilizes a social framework for learning, but specifically requires that cultural objects and language be used to transmit knowledge and share learning structures.

Opportunities and classroom structures should exist to enable self-evaluation of knowledge and to empower students to regulate their thinking. Reciprocal teaching starts with students asking questions of the teacher about an assignment. But as the students develop their understanding, the student/teacher roles reverse, and the teacher increasingly asks students to answer questions to evaluate and regulate their understanding of the topic.

Most importantly, instructors should spur students to focus on the process of learning and not on answers. With attention to the findings of educational research and theories, we can improve learning in our classrooms.

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Teaching Science to Adult Learners

Nothing beats engaging in teaching or public outreach with an eager audience! Alas, typical undergraduate students often have reasons for attending astronomy classes besides a truly burning desire to understand the universe. How, then, to populate a classroom with willing learners?

Start by taking a look around at the next astronomy public event you attend. I’ve always noticed a few distinct groups of really enthusiastic participants. One of these groups contains the scary-smart 8-year-olds that can quote the distance to the nearest stars and want to discuss, in detail, how black holes form. Fortunately, there are many excellent school programs, museums, and outreach efforts focused on providing first-rate astronomy content to these K-12 students.

A second group I’ve noticed consists of older community members. While these adults actively participate in public astronomy events whenever possible, the professional astronomical community often overlooks this segment of the population while concentrating on K-12 and undergraduate students. Mature adults craving more information about astronomy are generally left to fend for themselves. While there are many excellent popular media resources, including books, articles and documentaries, there is a lack of more structured programs and access to real “live” astronomers.

Fortuitously, there is a growing movement of adults going “back to school” for the singular purpose of engaging in lifelong learning. This is particularly true for seniors who, in retirement, may finally have time to more fully explore subjects of personal interest. Lifelong learning is also becoming more popular because of the growing body of research that concludes that exercise for the brain — including learning and reasoning — provides a measure of protection against dementia, such as Alzheimer’s, for the aging brain.

This movement provides professional astronomers with a practical opportunity to reach out to a population that we currently underserve. We should recognize that this group supports astronomical research through tax dollars, and represents a large base of voters who can wield considerable influence on the future of science in America. It behooves astronomers to reach out!

While building a new outreach program can be a daunting task, in this case astronomers can easily capitalize on the infrastructure already built (and being developed for lifelong learning) at many public and private universities and in communities around the nation. Astronomers just need to reach out and develop new relationships with local lifelong learning institutes. These centers can provide the pool of students and the physical space required, so volunteers can focus on developing interesting and appropriate materials for the classroom.

For the past few years, I have been teaching astronomy at the Osher Lifelong Learning Institute (OLLI) at UC Berkeley. There are more than 120 OLLIs on university and college campuses throughout the United States. These institutes provide adults, age 50 and above, with both a diverse curriculum of study and a stimulating community of peers. The OLLI classroom can be challenging because of the wide range of student backgrounds — some have spent a career in science or engineering, while others have rarely considered science since high school — making it difficult to gauge the appropriate level at which to present material.

Despite this challenge, teaching at an OLLI is extremely rewarding, because mature adults bring to the classroom a vast array of life experiences, great curiosity, and immense independence of thought. They are the ideal students. They come to class eager to learn new things and gain new perspectives on the world around them; they are engaged and interested; and they are willing to speak up and ask questions. And no need for grading makes the classroom more enjoyable for everyone!

I hope that more astronomers will consider developing outreach initiatives geared toward adults and seniors. It can be as simple as seeking out the lifelong learning institutes in your area and volunteering to teach a course. It is a mutually beneficial proposition: you will have the opportunity to teach in a positive and enjoyable classroom, and your students will gain access to first-hand astronomy.

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Students at the Osher Lifelong Learning Institute at UC Berkeley discuss and debate topics such manned vs. unmanned space missions in the program: "Blast Off! The History and Future of Space Exploration."
“With her trademark mix of meticulous research and vibrant prose, Bartusiak weaves these discoveries into a narrative equal to the excitement of that convulsive decade.” — Seed Magazine
January 1, 1925

The twenties were not just roaring, they were blazing.

Moviegoers were flocking to the cinema to watch in amazement as Moses parted the Red Sea in Cecil B. DeMille’s silent film epic *The Ten Commandments*. Greece overthrew its monarchy and proclaimed itself a republic, the first dinosaur eggs were discovered in Mongolia’s Gobi Desert, and crossword puzzles became all the rage. It was the height of the Jazz Age, when Victorian ideals came tumbling down in a frenzy of flappers, Freudian analysis, and abstract art. While majestic ocean liners crossed the Atlantic in under five days, Clarence Birdseye introduced the public to the novelty of frozen food and a failed artist named Adolf Hitler published *Mein Kampf*. It was a world, wrote F. Scott Fitzgerald in his classic novel *The Great Gatsby*, “redolent of orchids and pleasant, cheerful snobbery and orchestras which set the rhythm of the year, summing up the sadness and suggestiveness of life in new tunes.”

It was also an era of immense scientific fervor. On December 30, 1924, some four thousand scientists descended upon Washington, D.C., to attend the annual conference of the American Association for the Advancement of Science. Taking advantage of the six-day gathering, the American Astronomical Society held its meeting in the capital at the same time, with nearly eighty astronomers attending from across the United States. They lodged at the Powhatan, a plush eight-story hotel located on the corner of Eighteenth Street and Pennsylvania Avenue, where a room with private bath cost $2.50 a night and weary travelers could relax in its rooftop garden. Two blocks away Calvin Coolidge opened the doors of the White House to the visiting AAAS members. While notorious for being a man of few words, the thirtieth president of the United States was uncharacteristically chatty the day of the reception. “It has taken endless ages to create in men the courage that will accept the truth simply because it is the truth,” Coolidge told his guests. “We have advanced so far that we do not fear the results of that process. We ask no recantations from honesty and candor…. Those of us who represent social organization and political institutions look upon you with a feeling that includes much of awe and something of fear as we ask ourselves to what revolution you will next require us to adapt our scheme of human relations.” Six months later high school biology teacher John Scopes would go on trial in Tennessee for illegally teaching Charles Darwin’s theory of evolution.

The astronomers, though, were scarcely aware that Washington was host to the largest number of scientists ever assembled for an AAAS meeting. Their interest was intent on the astronomy program, which included talks on the atmosphere of Mars, how fast celestial objects could move, the temperature of Mercury, and the latest computed orbit of the eclipsing double-star system Algol.

On Wednesday, the second day of the meeting, the astronomers were taken by glass-topped buses to the U.S. Naval Observatory, in the northwest sector of the town, for a tour of the facility and a buffet luncheon in its stately main hall. Later that evening, New Year’s Eve, “occurred an event which was marked on the program and celebrated by a number of the faithful,” *Popular Astronomy* recounted. As the clock struck twelve, astronomers happily changed to civil reckoning for determining the start of a day. No longer would the astronomical day begin at high noon, a tradition launched in the days of Ptolemy that often led to great bookkeeping confusion. Instead, it now began at midnight, just as it did for everyone else. “It will probably be remembered and noted long after other astronomical happenings of the current year are forgotten,” stated the magazine.

But a presentation made on Thursday, New Year’s Day, ultimately overshadowed all other events at the meeting. Looking out their hotel windows that inaugural morning of 1925, conventiongoers discovered a blanket of snow covering the city, enough to give holiday sleds a good tryout, reported the Washington Post. Despite the ongoing snowstorm, however, the astronomers kept to their schedule and walked the short distance to the newly constructed Corcoran Hall, on the nearby campus of George Washington University, for a joint session with the mathematicians and physicists of the AAAS. They first heard a talk on stellar evolution, followed by a lecture posing the question “Is the Universe Infinite?” which led to a lively discussion among the conferees. Then right before the noon break, a paper modestly titled “Cepheids in Spiral Nebulae” was presented to the assembled audience. Those not familiar with astronomy likely imagined it was a minor technical work, of interest only to a specialist. But the astronomers in the room immediately grasped its significance. For them, it was electrifying news. Despite its lackluster title, this paper was no less than the culmination of a centuries-long quest to understand the true nature and extent of the cosmos. January 1, 1925, was the day that astronomers were officially informed of the universe’s discovery.

The author of the paper was thirty-five-year-old Edwin Hubble, a staff astronomer at the Mount Wilson Observatory, in southern California. Hubble had aimed Mount Wilson’s 100-inch reflector, the largest telescope in its day, toward a pair of celestial clouds known as Andromeda and Triangulum, the only spiral nebulae in the nighttime sky that can be seen with the naked eye. By having access to significant telescopic power, Hubble was at last able to resolve individual stars in the outer regions of the two mistlike clouds, and to his surprise and delight some turned out to be Cepheids, special stars that methodically dim and brighten as if they were slow-blinking cosmic stoplights.

The signals revealed that our galaxy, the Milky Way, was not alone. The Cepheids were telling Hubble that the Andromeda and Triangulum nebulae were very distant, situated far beyond our galactic borders. Our celestial home was suddenly humbled, becoming just one of a multitude of galaxies residing in the vast gulfs of space. In one fell swoop, the visible universe was enlarged by an inconceivable factor, eventually trillions of times over. In more familiar terms, it’s as if we had been confined to one square yard of Earth’s surface, only to suddenly realize that there were now vast oceans and continents, cities and villages, mountains and deserts, previously unexplored and unanticipated beyond that single plug of sod. Hubble directed our eyes to billions of other galaxies—other Milky Ways formerly unknown—scattered like separate atoms through space and time, as far outward as telescopes could peer. Indications of the Milky Way’s true place in the universe had been cropping up for years, but the evidence was indirect, conflicting, and controversial. Hubble stepped into the fray and finally provided the decisive proof. He confirmed an idea...
to everyone’s satisfaction that beforehand had been on far shakier ground.

It was the astronomical news of the century and yet Hubble, astonishingly, was not present—at this, his moment of triumph. Instead, the staid and respected Princeton University astronomer Henry Morris Russell stood in for Hubble that morning and relayed his findings to the conferees. From all accounts, Hubble was neither sick nor detained by family matters. He might have been put off by the long and wearying cross-country train ride, but the reason for his absence was possibly more idiosyncratic. Hubble, a former legal scholar trained in weighing evidence, was concerned that by the time of the astronomy meeting he hadn’t countered every feasible argument against his finding. At his own observatory, in fact, a colleague had gathered the strongest ammunition against his conclusion, evidence Hubble couldn’t yet refute. This loose end bothered him immensely. What Hubble craved was an airtight case—no stone unturned, no question left unanswered—before stepping up to the podium himself. Being caught in a scientific error was Hubble’s greatest nightmare. Back in California the young astronomer was fretfully asking himself, Could I possibly be wrong?

With the stunning pictures of our resplendent cosmos now so widely circulated, such a part of the routine imagery that surrounds us daily, it’s difficult to remember that less than a hundred years ago astronomers’ conception of the universe was very different than it is today. There were no quasars, no distant galaxies, no exotic black holes or wildly spinning neutron stars. No one even knew for sure how the Sun could keep generating its tremendous energies over billions of years. What was called “the universe” consisted of a single, disk-shaped collection of stars that cuts a magnificent swath across the celestial sky. With Earth located within this great stellar assembly, we peer outward through the disk and perceive it as a band (much the way a plate looks viewed from its side). Known since ancient times as the Milky Way because of its ghostly white visage, our galaxy a century ago was not just the sole inhabitant of the cosmos. It was the cosmos—a lone, star-filled oasis surrounded by a darkness of unknown depth.

A few voices of dissent could be heard, arguing against this perspective. A growing number of small spiraling clouds were being sighted in the heavens; these faint celestial objects were lurking wherever a telescope gazed away from the Milky Way into deep space. Were these spiral nebulae close to us or were they farther off? No one knew, because at the turn of the twentieth century astronomers didn’t yet have the means to determine their distance with assured accuracy. The only thing they could do was speculate. Some looked at these nebulae, shaped like springs unwinding, and thought, “Ah, nearby solar systems in the making.” Others observed the same tiny clouds and imagined them as a host of Greek. 

The Triangulum celestial cloud (as it was called a century ago) was resolved into stars by Edwin Hubble in the 1920s. Today we know it as the Triangulum Galaxy or M33.
sister Milky Ways so distant that their stars melded into faint and misty whiteness. That would mean the Milky Way was not special at all but merely one island of stars caught in the midst of a far larger archipelago. But the majority of astronomers rejected this strange—even frightening—concept. That other galaxies existed seemed inconceivable, and so they fiercely clung to what they perceived to be their pivotal place in the cosmos. Nicolaus Copernicus may have moved Earth and its inhabitants from the hub of the solar system in the sixteenth century, but humanity remained comforted by the notion that it retained a privileged position in the very heart of the Milky Way, the sole galaxy. They rested easy knowing they resided in the very center of the universe. There was no hard-and-fast evidence to suggest otherwise.

That contentment was shattered, though, as astronomy underwent a spectacular transformation, starting in the waning years of the nineteenth century. “This was an era of extraordinary change in every phase of human life on this planet,” recalled Edwin Frost, an astronomer who had personally witnessed the transition at the Yerkes Observatory in Wisconsin. “[It] was truly a Victorian age drawn to a close with the end of the century.” When Frost was growing up in the 1880s, Europe was the touchstone in matters of literature, painting, and science. “Even steel rails for the trunk-lines were imported from Britain as late as my college days,” he said. “Then Andrew Carnegie and others found that rails could be made better and cheaper in America…. The child was rapidly getting out of its infancy.” Discoveries and inventions were on the rise. Seemingly overnight, there were electric lights, heating by coal, hot-air furnaces, indoor bathrooms, and automobiles smoothly traveling down asphalt-paved roads.

Astronomy blossomed within this atmosphere of teeming innovation. Cameras became standard equipment on telescopes, enabling observers to gather light over an entire night and so generate images of faint stars and nebulae never before seen. And spectroscopes, devices that separate starlight into its component colors, allowed astronomers to figure out what the stars and other celestial objects were truly made of. Suddenly the very chemistry of the heavens was in their grasp. Meanwhile, prominent industrialists, enriched by the bounty of the Gilded Age, provided the money that allowed big dreamers to construct the large telescopes they had so long desired.

Given the swift emergence of these technological improvements, dry textbook accounts, reduced to a discovery’s most essential elements, make it appear as if Hubble’s historic achievement had taken place overnight. He goes to the world’s largest and best-equipped telescope and, voilà, he reveals a cosmos populated with myriad galaxies spread over space as far as the telescopic eye could see. The Milky Way suddenly becomes a minor player in a much larger drama, and Hubble is anointed cosmology’s “prime architect” for making this astounding breakthrough. But that is not the case at all. In reality, Hubble stood on the shoulders of a series of astronomers farsighted enough to tackle a problem others had been ignoring. Answers did not arrive in one eureka moment, but only after years of contentious debates over conjectures and measurements that were fiercely disputed. The avenue of science is more often filled with twists, turns, and detours than unobstructed straightaways.

Astronomers trained in the older, classical ways, who dwelled on calculating the motions of the planets and measuring the positions of stars to the third decimal place, had not been distressed at all by the mystery of the spiral nebulae. They figured that once the matter was resolved it would not greatly change their perception of the overall structure and contents of the heavens. Simon Newcomb, the dean of American astronomy in the late nineteenth century, remarked at an observatory dedication in 1887 that “so far as astronomy is concerned … we do appear to be fast approaching the limits of our knowledge…. The result is that the work which really occupies the attention of the astronomer is less the discovery of new things than the elaboration of those already known, and the entire systemization of our knowledge.”

Within ten years James Keeler, director of the Lick Observatory, in California, proved Newcomb was exceedingly shortsighted. Against everyone’s advice, Keeler got a troublesome reflecting telescope—the first of its kind at high elevation—back in working order and demonstrated its power with singular panache. Even though the telescope’s mirror was relatively small, it allowed him to estimate that there were tens of thousands of faint nebulae arrayed over the celestial sky, ten times more than had been known before. In the 1910s Lick astronomer Heber Curtis followed up on Keeler’s findings and gathered additional evidence to suggest that these many spiraling nebulae were nothing less than separate galaxies. At the same time, a few hundred miles south at Mount Wilson, near Los Angeles, Harlow Shapley resized the Milky Way, measuring it as far larger than previously thought and shoving our Sun off to the side, away from the galaxy’s hub. As Shapley liked to put it, “The solar system is off center and consequently man is too.”

The story of our universe’s discovery centers mightily on Shapley and Hubble, scientific knights who jousted with each other for years over the universe’s true structure. Their work took place during a crucial moment of transition. While European astronomers were diverted by World War I and its resulting turmoil, American astronomers were free to push forward on the question of the spiral nebulae. Figuring out the universe’s exact configuration became an American obsession, its participants drawn from the Lick, Mount Wilson, and Lowell
observatories, newly built in the western United States. The world’s older observatories had no chance at all, for at the Lick and Mount Wilson observatories, in particular, astronomers had access to advanced telescopes situated on prime high-elevation sites, a combination essential to cracking the mystery.

Hubble gets deserved credit for providing the last, painstaking turn of the lock. “Hubble’s drive, scientific ability, and communication skills enabled him to seize the problem of the whole universe, make it peculiarly his own, contribute more to it than anyone before or since, and become the recognized world expert of the field,” wrote astronomer Donald Osterbrock, archivist Ronald Brashear, and physicist Joel Gwinn for a centennial celebration of Hubble’s birth.

“Although Hubble’s name is now strongly attached to the discovery of the expanding universe, he was never a vocal champion of that interpretation of his data.”

By 1929, just five years after his initial finding on the galaxies, Hubble made an even more astounding discovery. He and his colleague Milton Humason gathered the key evidence that opened the door to proving that the universe was expanding, with the galaxies continually riding the wave outward. Space-time was in motion! Half the work to reach this startling conclusion was actually performed on an Arizona mountaintop a decade earlier by Vesto Slipher, a Lowell Observatory astronomer whose vital role in arriving at this finding is now largely forgotten outside the halls of academia. Such is the power of Hubble’s legend. It pushed the contributions of others into the shadows as the years progressed. This book intends to shine the spotlight once again on the entire cast of characters who contributed to revealing the true nature of the universe and laid the groundwork for Hubble’s success.

Knowledge of the cosmic expansion was a transforming event. It allowed astronomers to escape the confines of their home galaxy, letting them explore a far larger cosmological vista. The Milky Way was now fleeing outward, giving theorists free rein to contemplate the universe’s very origin. They mentally put the cosmic expansion into reverse and imagined the galaxies drawing closer and closer to one another, until they ultimately combined and formed a compact fireball of dazzling brilliance. In this way, they realized that the universe had emerged in the distant past from an enormous eruption—the Big Bang. No longer was our cosmic birth a matter of metaphysical speculation or a biased whim; it had become a scientific principle that could be tested and probed.

This new cosmic outlook came about through a unique convergence—the perfect storm—of sweeping developments. Not only did a burgeoning economy provide the money—and new technologies the instruments—to make these discoveries, but newly introduced ideas in theoretical physics supplied some answers. No less a scientific figure than Albert Einstein had arrived on the scene with a novel theory of gravity that provided a unique explanation for the universe’s bewildering behavior.

A dynamism entered into the universe’s workings. Einstein’s equations introduced the idea that space and time are woven into a distinct object, whose shape and movement are determined by the matter within it. His general theory of relativity anticipated the universe’s expansion and turned its study into an intellectual and theoretical adventure. Early globetrotters had crossed the oceans in search of terra firma—solid land, new continents—which were previously unknown to them and ready for exploration. With his relativistic vision of space-time as a pliable fabric that can bend and stretch, Einstein allowed astronomers to recast the ancient search into a quest for cosmos firma. Glued together by the genius physicist, space and time became cosmic real estate to be appraised, mapped, and scrutinized, with Hubble serving as its first surveyor.

Hubble summarized his cosmological findings in a work titled Realm of the Nebulae, which is part history, part college textbook, and part professional memoir. This book was labeled a “classic” by his peers at the time it was published in 1936. And Hubble’s initial take still holds up in its broad outline. “[His] picture differs from today’s only in details,” Caltech astronomer James Gunn noted decades after its publication. “One looks through the pages almost in vain for things that are known to be wrong. One finds a few… [but] we still determine the distances of the nearest galaxies by methods described [by Hubble]. We still mostly use Hubble’s classification scheme. We still pay a great deal of attention to the questions Hubble asks.”

However, there is one glaring exception to Gunn’s statement. Although Hubble’s name is now strongly attached to the discovery of the expanding universe, he was never a vocal champion of that interpretation of his data. That was because there were other hypotheses in play in the 1930s and 1940s. Hubble was reluctant to choose sides, at a time when his newly mined data and Einstein’s theory were so fresh. Hubble always coveted an unblemished record: the perfect wife, the perfect scientific findings, the perfect friends, the perfect life. His observations that the galaxies were fleeing outward were to him always apparent velocities. He wanted to protect his legacy in case a new law of physics sneaked in and changed the explanation. So far, it hasn’t.

Hubble was lucky in a way. The Hubble Space Telescope could easily have been given another name had certain events turned out differently: if someone had not prematurely died (Keeler), if someone else had not taken a promotion (Curtis), or if another (Shapley) was not mulishly wedded to a flawed vision of the cosmos. The discovery of the modern universe is a story filled with trials, errors, serendipitous breaks, battles of wills, missed opportunities, herculean measurements, and brilliant insights. In other words, it is science writ large.

Combining her skills as a journalist with an advanced degree in physics, MARCIA BARTUSIAK has been covering the fields of astronomy and physics for three decades. The author of five books, she is currently an Adjunct Professor with the Graduate Program in Science Writing at the Massachusetts Institute of Technology. She is the 2010 winner of the ASP’s Klumphke-Roberts Award.
New stars are shrouded in dust and gas, but we’re finally uncovering their secrets.

by Joel D. Green
My bio may say “post-doc,” but I’m actually in the planet-construction business. It certainly sounds more exotic than “post-doc.” And since, in the “real world,” everyone I meet has a business card, I’m now designing one for myself — it’ll have a hardhat on it. This card might prove very handy should I ever run into Slartibartfast or anyone else from Magrathea.

Of course, in practical terms, what I actually do is study the construction and assembly of solar systems — how stars and planets are born from gas and dust inside giant stellar nurseries. And yes, for an astronomer, this is practical!

**Studying Stars**
Stars form in clusters, and the light from star formation in other galaxies can be detected en masse by our telescopes. We can infer very broad characteristics of star formation from such observations. And the resulting large-scale questions are very interesting. What is the general rate of star formation? How is it distributed around a galaxy? Does star formation occur spontaneously wherever gas gathers (via some type of small-scale turbulence), or does it require a triggering event such as a giant supernova or a local shockwave?

But I don’t pay attention to other galaxies. I like to see individual stars and watch them develop. Of course I won’t live long enough to see any one star go through its entire life cycle — that takes millions or billions of years. (In fact, some stars are so small that they can survive to several times the current age of the universe.) So rather than watching a single star, I collect data on thousands of stars at different stages of their life cycle.

I focus principally on stars that are in their infancy — ranging from less than 25 million years old all the way down to stars that are in their first 10,000 years of life (stars born around the time of the development of agriculture here on Earth). Some of these suns are barely definable as stars. They’re more like slowly compressing agglomerations of gas and dust surrounded by slowly spiraling, infalling material.

I study star formation that occurs in our local region, within a mere kiloparsec of our Sun. A kiloparsec is 3,260 light-years, or about 19,000 trillion miles. I realize this sounds like a long way away but consider: our galaxy is about 100,000 light-years in diameter, our local group of galaxies is perhaps two million light-years in extent, and the observable universe is nearly 14 billion light-years across. We’re talking about studying stars that, cosmically, are a stone’s throw away. A kiloparsec hardly takes us out of our local spiral arm, the Orion Arm. So really, I work in our cosmic backyard.

The reason I (and other astronomers) look at nearby stars, rather than survey the galaxy, is simple: we want to be able to see them! Telescope time is precious, and we need to have as large a sample size as possible. The instrument we used to obtain this data, the Spitzer Space Telescope, completed its 5.5-year mission in May 2009 (though I should add that it’s returning excellent results during its new “warm-mission” phase). There is no other telescope (currently active or in the planning stages) that can examine the inner portions of nascent solar systems to the extent that Spitzer could, so we are left with a grand archive of Spitzer data with which to conduct our studies.
A Shocking Beginning

Anyone familiar with the beautiful artist’s renderings of the Milky Way might imagine our galaxy as a spinning, curved ceiling fan of stars, with the outer edges of the arms trailing off behind. The Great Galactic Ceiling Fan turns once 500 million years or so; the Milky Way is about 20 orbits old. In Galactic years, we are in our infancy!

Upon further consideration, this picture seems a little strange, because neither our ceiling-fan metaphor nor the artist’s concepts have stars between the arms. In fact, stars are there. We just don’t see them, because outside the spiral arms they’re not surrounded by compressed, glowing gas to help reveal their presence.

Spiral arms represent compression waves — shocks of great magnitude orbiting the central bulge of our galaxy. The arms are revealed thanks to star formation, which is the result of the great windmilling shock brushing the gas, causing compression and expansion, and stirring up the material. This compression cascades from the galactic arms, through clusters and associations, and down to individual star-forming regions known as molecular clouds — so-named for their abundance of molecular hydrogen gas (H₂). There are other less-abundant elements in these regions as well — interstellar dust in a pristine state plus dust and gas cast out by dying stars of earlier generations. These molecular clouds are the sites of stellar birth, with stars forming in groups of a few to a few thousand at a time.

When instabilities, shocks, or turbulence stir up a quiescent cloud, particles in small pockets of gas are forced closer together. As the particles draw near each other, gravity takes over. Gravity is an attractive force, and its strength grows as the number of adjacent particles rises. All it takes is an initial clump of gas and dust to start the process of accretion. The clump’s increasing gravity reaches out farther, draws in more particles, and accelerates them into downward-spiraling orbits that end in impact on the growing core.

As more material spirals inward and strikes the core, the core spins faster. It does so for the same reason that skaters can suddenly spin faster if they pull their extended arms back to their body: angular momentum is transported from afar (distant particles or outstretched arms) to the center (the spinning core or the skater’s body). If the core were to absorb all the energy raining down upon it from the infalling material without any release, it would spin up so quickly and violently that the core would blow itself apart, and star formation would be impossible. Fortunately, much of the momentum is carried off in the form of laser-like columns of jets shot out from the north and south poles of the spinning core, blasting rapidly moving, energetic particles into the surrounding environment.

Infall begets outflow — or perhaps both are the same phenomenon. Either way, a fraction of the material (somewhere in the
neighborhood of a few percent) fails to reach the central star, or be retained in orbit around the star in the form of a circumstellar disk, and is ejected in the previously mentioned jets. Some models indicate that the material in these jets is flung out directly along the poles of the central star. Others suggest that material could be ejected via a disk wind, or magnetic fields that thread the region between the inner edge of the disk and the star. In either case, careful analysis of the gas and dust flowing into space from newborn stars may provide a fossil record of the events leading to protoplanetary formation.

The end product of all this action is a protostar — the nexus of material clumped together by gravity into a hot core, around which planets might eventually coalesce. We cannot observe the development of stars directly, except during their most dramatic moments, because most of these stages last for thousands or millions of years. But we can look at a large number of stars in different stages and trace the pattern. (Similarly, you could examine dozens of people of different ages in your town, thereby indirectly determining the “life cycle” of a human.) Ultimately, by studying different newborn star systems hundreds of light-years away, we hope to gain insight into the history and development of our own solar system.

Planets Under Construction

So how do planets develop? As the surrounding dust and gas spirals into the central mass where the protostar is forming, some of the matter falling inward from all directions doesn’t make it to the new star. Instead, this material ends up swirling around the protostar in a preferred direction, forming a disk.

Early in the process, the cloud of infalling gas, ice, and dust veils the star. After a while (perhaps one hundred thousand years or so), the surrounding material is mostly cleared away. At this point the central star has reached something close to its final mass, though material is still spiraling into it from the disk. The disk itself is where much of the action is now centered, as particles heat up, collide, and are swept away or amalgamate into larger objects.

A nice analogy for the young star and its disk is a giant version of Saturn. Like Saturn’s rings, circumstellar disks are made of small dust grains, often with icy mantles. But unlike the Saturnian rings, these disk particles are much more densely packed and threaded with hydrogen gas, which tends to slow the movement of particles and pull them together. In fact, we suspect that early on in the process, there is one hundred times more gas than dust (in terms of total mass) in these young circumstellar disks.

The rings of Saturn contain obvious gaps. Inside these gaps lie shepherd moons, which corral small nearby particles, prevent them from escaping or slipping past, and maintain the stability of the system. A young star’s disk is far more tumultuous, with agglomerations of particles forming and being destroyed with semi-regularity. Sometimes enough material will stick together — initially by collisions or shear/drag forces and eventually by gravitational forces — to form a planetesimal, or a core. We think that even gas giants such as Jupiter may harbor rocky cores, but this has yet to be determined.
Now that planets are under construction in our new solar system, what effect do they have on the remaining dust and gas? What happens when the material in the outer solar system, which is still spiraling inward, encounters these clumps in the disk? Does this inward-falling matter reach the star, or is it blocked? The answers may lie in the record of these interactions contained in the composition and history of the dust that surrounds the star, dust that Spitzer and other telescopes can identify.

The Research Continues
How do we connect the pieces we have accumulated in this puzzle to see where our observations fit together, and where the mysteries remain? More research and analysis of everything is needed — from the big galactic picture to the minutia of what goes on as an individual star is born.

Galaxies are formed of stars, and large-scale considerations are important, but equally important are the stories of individual objects. We can learn both galaxy-wide and individual properties of star formation from studying protostars and their jets and outflows. One of the goals of the next decade is to bring into focus our knowledge of star formation at all levels.

Today we have new tools to study new stars. Although Spitzer’s initial mission has ended, a new generation of space telescopes is being built or are already in space to examine the cold dust, gas, and ice in the outer parts of young solar systems — areas that even Spitzer could not probe.

The European Space Agency’s Herschel Space Observatory will continue our exploration of young stars by examining them in the far infrared. We have already discovered new ices and dust features in young circumstellar disks, and we are beginning to determine, with great precision, the true mass of the disks and envelopes around young stars. Eventually, we will be able to combine all of our data to generate a new picture of star and planet construction throughout the galaxy.

The DIGIT (Dust, Ice, and Gas In Time) Open Time Key Project is an important backbone for this effort. I am part of this international team (with members in Texas, Massachusetts, Michigan, California, Hawaii, Germany, Spain, Belgium, and Holland) as the postdoctoral researcher dedicated to the DIGIT program. Initial data from Herschel-DIGIT has begun to appear, and we presented our first results at the American Astronomical Society meeting in January 2010. So far, we have discovered cold dust that may provide clues to the outer parts of stellar systems, and analyzed gas from shocks and outflows.

I know there are many more discoveries coming, and I can hardly wait. After all, since I’m in the planet-construction business, it behooves me to know as much about building new worlds as possible, in case I meet someone from Magrathea at a future conference.

JOEL D. GREEN is a Postdoctoral Researcher (in infrared astronomy) at the University of Texas at Austin. He uses all his DIGITs when studying new stars.
NASA'S NEW AIRBORNE OBSERVATORY SEES "FIRST LIGHT"

A unique telescope takes to the sky to help reveal the infrared cosmos.

by Nicholas A. Veronico
NASA’s Stratospheric Observatory For Infrared Astronomy, or SOFIA, reached its “First Light” flight milestone during the early morning hours of May 26, when the aircraft’s telescope and attached infrared camera collected light from celestial targets for the first time at altitude.

“With this flight, SOFIA begins a 20-year journey that will enable a wide variety of astronomical science observations not possible from other Earth- and space-borne observatories,” said Jon Morse, NASA’s Astrophysics Division director. “It clearly demonstrates that SOFIA will provide us with ‘Great Observatory’-class astronomical science.”

The flight was conducted from NASA’s Dryden Aircraft Operations Facility at the Palmdale Airport in Southern California. SOFIA is a highly modified Boeing 747SP fitted with a 100-inch (2.5-meter) diameter infrared telescope in the aft section of the plane, and is a joint program between NASA and the German Aerospace Center, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Bonn, Germany.

The First Light flight lasted nearly eight hours as the team of 10 scientists, engineers, and technicians from Universities Space Research Association (USRA), the German SOFIA Institute (DSI), and Cornell University tested the telescope assembly and other systems at 35,000 feet over the Pacific Ocean southwest of San Diego. Energy collected by SOFIA’s telescope was channeled into the Faint Object infraRed Camera for the SOFIA Telescope (FORCAST). FORCAST, built by a team from Cornell University, headed by Principal Investigator Dr. Terry Herter, is a mid-infrared camera that records images through filters in the wavelength range of 5 to 40 microns. (For comparison, the human eye sees light with wavelengths between 0.4 and 0.7 microns.)

SOFIA is a joint program between NASA and the German Space Aerospace Center, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Bonn, Germany. The SOFIA program is managed at NASA’s Dryden Flight Research Center, Edwards, California, and the aircraft is based at the Dryden Aircraft Operations Facility, Palmdale, Calif. NASA’s Ames Research Center, Moffett Field, Calif., manages the SOFIA science and mission operations in cooperation with the Universities Space Research Association (USRA), Columbia, Md., and the Deutsches SOFIA Institut (DSI) Stuttgart, Germany.

— N.V.

With its sliding door open wide to reveal its 17-ton infrared telescope, NASA’s Stratospheric Observatory for Infrared Astronomy soars over California’s snow-covered Southern Sierras during a test flight on April 14, 2010.
Using FORCAST, scientists recorded images of Jupiter and the galaxy M82 (located approximately 12 million light-years away in the constellation Ursa Major) at wavelengths unobservable by either ground-based observatories or current space-based telescopes. The composite Jupiter image shows heat pouring out of the planet's interior through transparent portions of its clouds. The composite M82 image peers through that galaxy's interstellar dust clouds to show three "starburst" knots in which stars are forming by the thousands.

"It's tremendous for me personally to see these images; this feels like the culmination of my career," said USRA SOFIA senior science advisor Eric Becklin. Becklin was the leader of the team that answered the original call for proposals from NASA and won the competition to develop and operate SOFIA. Becklin made some of the first infrared observations of planets and galaxies when infrared astronomy began in the 1960s.

The results, according to NASA SOFIA project scientist Pam Marcum, were gratifying. "Wind tunnel tests and supercomputer calculations made at the start of the SOFIA program predicted we would have sharp enough images for front-line astronomical research; a preliminary look at the first light data indicates we indeed accomplished that." The stability and precise pointing of the German-built telescope met or exceeded the expectations of the engineers and astronomers who put it through its paces during the flight.

Science Operations
When flying science missions, SOFIA will operate between 39,000- and 45,000-feet, which is above more than 99% of the water vapor in Earth's atmosphere. Research flights are planned to ramp up to an average rate of two to three times per week by 2015, equaling more than 900 science-flight hours per year. Using a suite of eight purpose-built instruments, one per mission, SOFIA will observe the universe in the infrared spectrum between wavelengths of 0.3 and 1,600 microns, a broader range than any other observatory on the ground or in space.

The flying observatory's suite of instruments will enable astronomers to look at (among other sights) galaxies and the Milky Way's galactic center, focusing on starburst history and the motions of stars around supermassive black holes; the Milky Way's interstellar medium including the environs of star-forming regions, organic molecules in space, and how interstellar material is recycled; details of the formation of stars and planets, especially massive stars, and the chemistry and dynamics of planet-forming disks; and planetary science observations of comets, near-Earth asteroids, the planet Venus, and Saturn's moon Titan.

The observatory's first science program will begin in October 2010, with researchers Mark Morris (University of California at Los Angeles) and Paul Harvey (Colorado University, Boulder) collaborating with the FORCAST team to study several star-forming regions. The FORCAST instrument will be used to develop high-resolution, mid-infrared views of the star-formation process. Additionally, Harvey will work with the FORCAST team to interpret those data to carefully characterize SOFIA's imaging capabilities for future users.

David Neufeld (Johns Hopkins University, Baltimore, Md.) was selected to study the chemistry of the interstellar medium using data obtained by SOFIA's second instrument, the German Receiver for Astronomy at Terahertz Frequencies (GREAT). The instrument is a spectrometer developed for SOFIA by a consortium of German research institutes, led by Rolf Güsten at the Max Planck Institute.
Infrared radiation from celestial objects enters the telescope cavity and is reflected from the primary mirror up to the secondary mirror. From the secondary, the infrared rays are bounced to a mirror that sends the radiation down the light tube into the pressurized compartment of the aircraft, and then to an instrument (for example an infrared camera or spectrometer). Visible light reflected by the secondary passes the infrared mirror, is reflected by the visible-light mirror into the light tube, and then is captured by a visible-light instrument — typically a camera. This allows SOFIA to take Hubble-like photos as well as make infrared measurements.

The visible light (left) and infrared (right) images of the constellation Orion, the Hunter, are of the exact same area. These images dramatically illustrate how features that cannot be seen in visible light show up very brightly in the infrared.
10-inch telescope and instruments observing at wavelengths between 0.3 and 250 microns.

From 1974 to 1995, NASA flew a civilian version of the Lockheed C-141 Starlifter, known as the Kuiper Airborne Observatory (KAO). The KAO was named for astronomer Gerard P. Kuiper, who first suggested that an airborne observatory could be a best-of-both-worlds facility, combining the virtues of ground- and space-based observatories. The KAO was fitted with a 36-inch (0.9-meter) diameter infrared telescope, mounted forward of the wing, which was capable of studying objects at wavelengths from 0.3 to 1,600 microns (the same as SOFIA). Using its 36-inch scope, scientists on board the KAO learned a great deal about the universe, discovering such phenomena as the rings around the planet Uranus, water in Jupiter's atmosphere and in the interstellar medium, and early evidence for the black hole at our galactic center.

Based on the KAO's exciting results, researchers envisioned a larger telescope and could only imagine what revelations it might bring. To that end, in 1995 the KAO was sidelined to channel its funds into the development and construction of a more capable instrument that would become known as SOFIA.

**SOFIA is Born**

The Boeing 747SP (Special Performance) that would become SOFIA made its first flight on April 25, 1977, from Boeing's factory at Everett, Washington, and was subsequently delivered to Pan American World Airways on May 6 of that year. Fourteen days later, on the 50th anniversary of Charles Lindbergh's solo crossing of the Atlantic, Charles' widow, Anne Morrow Lindbergh, christened the jetliner Clipper Lindbergh in his honor. After nine years of service, Pan Am sold the jetliner to United Air Lines, which flew the plane until 1994, when it was put into storage.

The Boeing 747SP was 55 feet shorter than a standard 747 (fuselage length: 177 feet/53.9 meters), yet maintained the aircraft's wing span (196 feet/59.7 meters) and fuel load (300,000 pounds/44,776 US gallons) giving the SP a range of 6,625 nautical miles. The SPs operated on long-haul routes such as New York to Tokyo, or New York to Johannesburg. Boeing built 45 of the 747SP models, and approximately 14 are still flying today.

NASA acquired the Clipper Lindbergh on October 27, 1997, and began the modification process that was optimistically planned to take only three years. After years of conceptual tests (wind tunnel tests and fluid dynamics predictions using supercomputers), metal began to be cut. The physical modifications to the aircraft included major reconstruction of the fuselage pressure bulkheads, rerouting the aircraft's control cables, and upgrading the aircraft's engines — just a few of the items from a tremendously long list of modifications.

Once ready to soar again, SOFIA made her first post-modification flight on April 26, 2007, from Waco, Texas. The aircraft program then moved to NASA's Dryden Flight Research Center in California, and later to its Palmdale aircraft operating facility. Further modifications and envelope expansion flights (the “envelope” is the combination of speeds and altitudes at which SOFIA was tested and OK'd) were conducted during the balance of 2007 and for the two years following. On December 19, 2009, the airborne observatory made its first flight with the telescope cavity door fully open. Operational rehearsals and another series of flight tests were made in the opening months of 2010, culminating with the Telescope Assembly Characterization and First Light flight on May 25/26.

At the conclusion of the First Light flight, SOFIA Program Manager Bob Meyer said, “We're seeing the result of many years of hard work by hundreds of inspired and dedicated people to develop this fantastic facility for the world scientific community.”

**Inspiring the Next Generation**

SOFIA is a tremendous platform for expanding the horizons of students from all age groups. To accomplish this goal, the SOFIA team has expanded upon the successful Flight Opportunities for Science Teacher EnRichment (FOSTER) — the “educators in the stratosphere” program initiated with the Kuiper Airborne Observatory. During the last five years of the KAO’s operation, more than 70 teachers were matched with astronomer teams to assist with actual science observations in the stratosphere. In addition, the teacher teams were paired with a reporter from one of their local news media outlets, which enabled the educators and journalists to take their experiences back to the classroom and to share their inspiration with the local community through print and electronic media outlets, at science museums, and with the general public.

SOFIA is now gearing up for its Airborne Astronomy Ambassadors (AAA) program, which is expected to roll out in 2013. Each year (when fully operational), the AAA program will have as many as 80 educators working side-by-side with astronomers on board SOFIA. Following their flight experience, SOFIA’s Ambassadors will make multiple visits to classrooms, youth groups, and other public events as master teachers to share their inspiring astronomy experiences. The AAA program and SOFIA’s other education and public outreach activities are managed by a partnership between the SETI Institute and the Astronomical Society of the Pacific.

Looking toward the future, USRA SOFIA Mission Operations Director Erick Young said, “SOFIA’s First Light flight ushers in a new era of airborne astronomical discoveries. We’re at the dawn of 20 years of new infrared observations that will expand our knowledge of the universe.”

NICHOLAS A. VERONICO, SOFIA Science Center Public Affairs Officer, holds a journalism and a business management degree, and is the author or co-author of more than 25 books on subjects including aviation, military, and local history.
astronomy in the news

Excerpts from press releases that describe an assortment of recent astronomical discoveries.

First Light for the Solar Dynamics Observatory

NASA Science News

At an April 21, 2010, press conference in Washington DC, researchers unveiled “First Light” images from NASA’s Solar Dynamics Observatory, a space telescope designed to study the Sun.

“SDO is working beautifully,” reports project scientist Dean Pesnell of the Goddard Space Flight Center. “This is even better than we could have dreamed.” As soon as SDO’s telescope doors opened, the spacecraft began beaming back scenes so beautiful and puzzlingly complex that even seasoned observers were stunned.

One of the most amazing things about the observatory is its “big picture” view. SDO is able to monitor not just one small patch of the Sun, but rather the whole thing — full disk, atmosphere, surface, and even interior. (Click on the “More Information” link for several SDO movies of the Sun in action.)

More information

Venus is Alive — Geologically Speaking

European Space Agency

ESA’s Venus Express has returned the clearest indication yet that Venus is still geologically active. Relatively young lava flows have been identified by the way they emit infrared radiation. The finding suggests the planet remains capable of volcanic eruptions.

It has long been recognized that there are simply not enough craters on Venus. Something is wiping the planet’s surface clean. That something is thought to be volcanic activity but the question is whether it happens quickly or slowly? Is there some sort of cataclysmic volcanic activity that resurfaces the entire planet with lava, or a gradual sequence of smaller volcanic eruptions? New results suggest the latter.

“Now we have strong evidence right at the surface for recent eruptions,” says Sue Smrekar, a scientist at NASA’s Jet Propulsion Laboratory in California.

That strong evidence comes in the form of compositional differences compared to the surrounding landscape in three volcanic regions. The data were collected by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on ESA’s Venus Express spacecraft, which has been orbiting the planet since April 2006.

Dr. Smrekar and her colleagues targeted three regions that geologically resemble Hawaii, well known for its active volcanism. They show that the regions on Venus have higher emissivities than their surroundings, indicating different compositions.

On Earth, lava flows react rapidly with oxygen and other elements in the atmosphere, changing their composition. On Venus, the process should be similar, though more intense because of the hotter, denser atmosphere, chiefly of carbon dioxide.

More information

This figure shows the volcanic peak Idunn Mons. Bright areas are rough or have steep slopes. Dark areas are smooth. The colored overlay shows the heat patterns derived from surface brightness data collected by ESA’s Venus Express spacecraft. Red-orange is the warmest area and purple is the coolest. The warmest area is situated on the summit.
Phoenix Mars Lander is Silent; New Image Shows Damage
NASA / JPL

NASA’s Phoenix Mars Lander has ended operations after repeated attempts to contact the spacecraft were unsuccessful. A new image transmitted by NASA’s Mars Reconnaissance Orbiter shows signs of severe ice damage to the lander’s solar panels.

“The Phoenix spacecraft succeeded in its investigations and exceeded its planned lifetime,” said Fuk Li, manager of the Mars Exploration Program at NASA’s Jet Propulsion Laboratory in Pasadena, Calif. “Although its work is finished, analysis of information from Phoenix’s science activities will continue for some time to come.”

Last week, NASA’s Mars Odyssey orbiter flew over the Phoenix landing site 61 times during a final attempt to communicate with the lander. No transmission from the lander was detected. Phoenix also did not communicate during 150 flights in three earlier listening campaigns this year.

An image of Phoenix taken this month by the High Resolution Imaging Science Experiment, or HiRISE, camera on board the Mars Reconnaissance Orbiter suggests the lander no longer casts shadows the way it did during its working lifetime.

“Before and after images are dramatically different,” said Michael Mellon of the University of Colorado in Boulder, a science team member for both Phoenix and HiRISE. “The lander looks smaller, and only a portion of the difference can be explained by accumulation of dust on the lander, which makes its surfaces less distinguishable from surrounding ground.”

Apparent changes in the shadows cast by the lander are consistent with predictions of how Phoenix could be damaged by harsh winter conditions. It was anticipated that the weight of a carbon-dioxide ice buildup could bend or break the lander’s solar panels.

More information

Mars Orbiter Penetrates Mysteries of Martian Ice Cap
Jet Propulsion Laboratory

Data from NASA’s Mars Reconnaissance Orbiter have helped scientists solve a pair of mysteries dating back four decades and provided new information about climate change on the Red Planet. The Shallow Radar, or SHARAD, instrument aboard the Mars Reconnaissance Orbiter revealed subsurface geology allowing scientists to reconstruct the formation of a large chasm and a series of spiral troughs on the northern ice cap of Mars.

“SHARAD is giving us a beautifully detailed view of ice deposits, whether at the poles or buried in mid-latitudes, as they changed on Mars over the last few million years,” said Rich Zurek, Mars Reconnaissance Orbiter project scientist at NASA’s Jet Propulsion Laboratory in Pasadena, Calif.

One of the most distinctive features of the northern ice cap is Chasma Boreale, a canyon about as long as Earth’s Grand Canyon but deeper and wider. Some scientists believe Chasma Boreale was created when volcanic heat melted the bottom of the ice sheet and triggered a catastrophic flood. Others suggest strong polar winds carved the canyon out of a dome of ice.

Other enigmatic features of the ice cap are troughs that spiral outward from the center like a gigantic pinwheel. Since the troughs were discovered in 1972, scientists have proposed several hypotheses about how they formed.

Data from Mars now points to both the canyon and spiral troughs being created and shaped primarily by wind. Rather than being cut into existing ice very recently, the features formed over millions of years as the ice sheet grew. By influencing wind patterns, the shape of underlying, older ice controlled where and how the features grew.

More information
**The Shocking Size of Comet McNaught**  
*Royal Astronomical Society*

British scientists have identified a new candidate for the biggest comet measured to date [using] data from the ESA/NASA Ulysses spacecraft to gauge the size of the region of space disturbed by the comet’s presence.

In January and February 2007, Comet C/2006 P1 McNaught became the brightest comet visible from Earth for 40 years. Serendipitously, Ulysses made an unexpected crossing of Comet McNaught’s tail during this time, one of three unplanned encounters with comet tails during the 19-year mission. The other encounters included Comet Hyakutake in 1996, the current record-holder for the comet with the longest measured tail.

Ulysses encountered McNaught’s tail of ionized gas at a distance downstream of the comet’s nucleus more than 1.5 times the distance between the Earth and the Sun. This is far beyond the spectacular dust tail that was visible from Earth in 2007. Dr Geraint Jones [of UCL’s Mullard Space Science Laboratory] said, “It was very difficult to observe Comet McNaught’s plasma tail remotely in comparison with the bright dust tail, so we can’t really estimate how long it might be. What we can say is that Ulysses took just 2.5 days to traverse the shocked solar wind surrounding Comet Hyakutake, compared to an incredible 18 days in shocked wind surrounding Comet McNaught. This shows that the comet was not only spectacular from the ground; it was a truly immense obstacle to the solar wind.”

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**Triton’s Summer Sky of Methane**  
*European Southern Observatory*

According to the first-ever infrared analysis of the atmosphere of Neptune’s moon Triton, summer is in full swing in its southern hemisphere. The European observing team used ESO’s Very Large Telescope and discovered carbon monoxide and made the first ground-based detection of methane in Triton’s thin atmosphere. These observations revealed that the thin atmosphere varies seasonally, thickening when warmed.

“We have found real evidence that the Sun still makes its presence felt on Triton, even from so far away. This icy moon actually has seasons just as we do on Earth, but they change far more slowly,” says Emmanuel Lellouch, the lead author of the paper reporting these results.

On Triton, where the average surface temperature is about minus 235° Celsius, it is currently summer in the southern hemisphere and winter in the northern. As Triton’s southern hemisphere warms up, a thin layer of frozen nitrogen, methane, and carbon monoxide on Triton’s surface sublimates into gas, thickening the icy atmosphere as the season progresses during Neptune’s 165-year orbit around the Sun. A season on Triton lasts a little over 40 years, and Triton passed the southern summer solstice in 2000.

Based on the amount of gas measured, Lellouch and his colleagues estimate that Triton’s atmospheric pressure may have risen by a factor of four compared to the measurements made by Voyager 2 in 1989, when it was still spring on the giant moon. The atmospheric pressure on Triton is now between 40 and 65 microbars — 20,000 times less than on Earth.
Out of Whack Planetary System

STScI

Astronomers recently reported the discovery of a planetary system way out of tilt, where the orbits of two planets are at a steep angle to each other. This surprising finding will impact theories of how multi-planet systems evolve, and it shows that some violent events can happen to disrupt planets’ orbits after a planetary system forms, say researchers.

“The findings mean that future studies of exoplanetary systems will be more complicated. Astronomers can no longer assume all planets orbit their parent star in a single plane,” says Barbara McArthur of The University of Texas at Austin’s McDonald Observatory.

For just over a decade, astronomers have known that three Jupiter-type planets orbit the yellow-white star Upsilon Andromedae. Similar to our Sun in its properties, Upsilon Andromedae lies about 44 light-years away. It’s a little younger, more massive, and brighter than the Sun.

Combining fundamentally different, yet complementary, types of data from Hubble and ground-based telescopes, McArthur’s team has determined the exact masses of two of the three known planets, Upsilon Andromedae c and d. Much more startling, though, is their finding that not all planets orbit this star in the same plane. The orbits of planets c and d are inclined by 30 degrees with respect to each other.

Several different gravitational scenarios could be responsible for the surprisingly inclined orbits in Upsilon Andromedae. “Possibilities include interactions occurring from the inward migration of planets, the ejection of other planets from the system through planet-planet scattering, or disruption from the parent star’s binary companion star, Upsilon Andromedae B,” McArthur said.

More information

Hubble Catches Stars on the Move

NASA / ESA

By exploiting the exquisite image quality of the NASA/ESA Hubble Space Telescope and comparing two observations made ten years apart astronomers have, for the first time, managed to measure the tiny motions of several hundred young stars within the central cluster of the star-forming region NGC 3603. The team was surprised to find that the stars are moving in ways that are at odds with the current understanding of how such clusters evolve. The stars in the cluster have not “settled down” as expected.

With a mass of more than 10,000 suns packed into a volume with a diameter of a mere three light-years, the massive young star cluster in the nebula NGC 3603 is one of the most compact stellar clusters in the Milky Way and an ideal place to test theories for their formation.

A team of astronomers from the Max-Planck Institute for Astronomy in Heidelberg and the University of Cologne led by Wolfgang Brandner (MPIA) wanted to track the movement of the cluster’s many stars. Such a study could reveal whether the stars were in the process of drifting apart, or about to settle down.

Brandner and his colleagues found good data in the archives for the NGC 3603 cluster from a July 1997 observing run with the Wide Field Planetary Camera 2 (WFPC2), and then made their own follow-up observations in September 2007, using the same camera and the same set of filters as in the original observations. It then took the team two years of very careful analysis to extract reliable estimates for the motions of stars in the images.
Details in Structure of a Distant Quasar

Max-Planck-Institut für Radioastronomie (Bonn)

Both, the Max-Planck-Institut für Radioastronomie (Bonn) and the Max-Planck-Institut für Astrophysik (Garching), run stations of the International LOFAR telescope (ILT), coordinated by ASTRON, the Netherlands Institute for Radio Astronomy. By connecting the German LOFAR stations with the central stations in the Netherlands, an international group of scientists led by Olaf Wucknitz from the Argelander Institute of Astronomy (AIfA) at Bonn University has now produced the first high-resolution image of a distant quasar at meter radio wavelengths.

After first tests of the individual antennas, the observations now bring together eight stations of the “LOw Frequency Array” (LOFAR). Five stations in the Netherlands were connected with three stations in Germany: Effelsberg near Bonn, Tautenburg near Jena and Unterweilenbach near Munich. All antennas were targeted at the quasar 3C 196, a strong radio source at a distance of several billions of light years. “We chose this object for the first tests, because we know its structure very well from observations at shorter wavelengths,” explains Olaf Wucknitz (AIfA). “The goal was not to find something new but to see the same or similar structures also at very long wavelengths to confirm that the new instrument really works. Without the German stations, we only saw a fuzzy blob, no sub-structure. Once we included the long baselines, all the details showed up.”

X-Ray Discovery Points to Location of Missing Matter

Chandra X-ray Center

Using observations with NASA’s Chandra X-ray Observatory and ESA’s XMM-Newton, astronomers have announced a robust detection of a vast reservoir of intergalactic gas about 400 million light years from Earth. This discovery is the strongest evidence yet that the “missing matter” in the nearby universe is located in an enormous web of hot, diffuse gas.

This missing matter — which is different from dark matter — is composed of baryons, the particles, such as protons and neutrons, that are found on the Earth, in stars, gas, galaxies, and so on. A variety of measurements of distant gas clouds and galaxies have provided a good estimate of the amount of this “normal matter” present when the universe was only a few billion years old. However, an inventory of the much older, nearby universe has turned up only about half as much normal matter, an embarrassingly large shortfall.

The mystery then is where does this missing matter reside in the nearby universe? This latest work supports predictions that it is mostly found in a web of hot, diffuse gas known as the Warm-Hot Intergalactic Medium (WHIM).

To look for the WHIM, the researchers examined X-ray observations of a rapidly growing supermassive black hole known as an active galactic nucleus, or AGN. This AGN, which is about two billion light years away, generates immense amounts of X-ray light as it pulls matter inwards. Lying along the line of sight to this AGN, at a distance of about 400 million light years, is the so-called Sculptor Wall.

In this artist’s impression, a close-up view of the so-called Sculptor Wall is depicted. Spiral and elliptical galaxies are shown in the wall along with the newly detected intergalactic gas, part of the so-called Warm Hot Intergalactic Medium (WHIM), shown in blue. An X-ray spectrum of the background source is given in the inset.
News and information for Society members.

2010 Winners: Pricilla and Bart Bok Award
Bart Bok was an outstanding research astronomer who made important contributions to our understanding of the Milky Way and of star formation. He received the ASP’s Bruce Medal for lifetime achievement, and in 1982 the Klumpke-Roberts Award for the popularization of astronomy. Throughout his life, and especially as an ASP Board member, Bok was a strong advocate for outreach and education in astronomy. Upon his death in 1983, the Society established the Bart Bok Memorial Fund to support educational projects.

At the suggestion of the American Astronomical Society (AAS), the activities supported by the Bok Fund were expanded to include the joint sponsorship (with the AAS) of an astronomy award at the Intel Science and Engineering Fair. The main criterion for selecting the Pricilla and Bart Bok First and Second Awards is scientific merit. Observational, instrumental, or theoretical projects are all eligible, as are interdisciplinary projects involving physics, mathematics, computer science, and engineering, etc. The Pricilla and Bart Bok First Award is a $1,000 scholarship; the Second Award is a $500 scholarship. The awarded funds are intended to be used by the recipients to further their education and research efforts.

In 2010, the First Award went to Andrei V. Nagornyi (18) Stuyvesant High School, New York, New York, for: “New Morphological Features for Automated Classification of Galaxy Images Obtained from Deep Space Surveys.” The Second Award went to Evan H. Fletcher (17), Kalamazoo Area Mathematics & Science Center, Galesburg, Michigan, for: “Reducing the Computation Time of an N-Body Galactic Simulation.”

Have You Heard the News?
Astronomy Behind the Headlines is a podcast for informal science educators produced by the Astronomical Society of the Pacific. The series offers a look behind the headlines in astronomy and space science, and provides links to related resources and activities so you can interpret these exciting topics for your audiences.

Did you know there are now seven episodes available? The latest is: Gamma-Ray Bursts with guest Dr. Dale Frail from National Radio Astronomy Observatory. You can listen to the podcast, download a transcript, and link to further activities and resources.

Past episodes include: Kepler and the Sun-like Stars, with Dr. Natalie Batalha Astrobiology with guest Chris McKay; Cosmic Debris with guest Peter Jenniskens; Water on the Moon with guest Brian Day; Impact on Jupiter with guest Heidi Hammel; and Measuring the Black Hole with guest Shep Doeleman.

You can find these episodes, with more to come, at Astronomy Behind the Headlines.

Travel With Us
Astronomy travel has moved beyond taking an eclipse trip every couple of years. Travel companies have discovered what many of us already know — there’s a huge interest in things astronomical.

For example, you can take a seven-day cruise up the coast of Norway in search of the aurora borealis (northern lights). From November 2nd to 10th, join us and MWT Associates aboard the m/s Midnatsol as it weaves along Norway’s breathtaking coastline from Bergen to Kirkenes. The ship features a two-story observation lounge with panoramic views, two saunas, a fitness room, a bar and a large sundek. Dave Eicher, Astronomy magazine’s editor, will lead the search for the aurora.

If you’re feeling more adventurous, why not meet us in the desert to hunt for meteorites? From March 19 to 29, 2011, join Chris McKay, planetary scientist and Mars Researcher with the Space Science Division of NASA Ames, and Astronomy magazine editor Dave Eicher, in Tunisia for an unforgettable experience. Tunisia is where great traders and warriors have walked over its marbled floors for centuries. It is the murmur of springs amidst date-palm oasis and the star-studded desert nights. It is Carthage, with aged ruins near the turquoise blue sea. And Tunisia is the receiver of rocks from space.

For more details (and to learn about other tours being offered), go to the ASP’s Astronomical Tours webpage. All tours feature astronomical enrichment programs, and revenue from these tours helps support the ASP’s mission and education programs.

Two Websites of Educational Interest
Mars Spacecraft Snaps Photos Chosen by Public. The most powerful camera aboard a NASA spacecraft orbiting Mars has returned the first pictures of locations on the Red Planet suggested by the public. The High Resolution Imaging Science Experiment, or HiRISE camera, aboard NASA’s Mars Reconnaissance Orbiter, or MRO, is nicknamed, “the people’s camera.” Through a program called HiWish that began in January, scientists have received approximately 1,000 suggestions. The first eight images of areas the public selected are available online.

“This NASA’s Mars program is a prime example of what we call participatory exploration,” NASA Administrator
Charlie Bolden said, “To allow the public to aim a camera at a specific site on a distant world is an invaluable teaching tool that can help educate and inspire our youth to pursue careers in science, technology, engineering, and math.”

Since 2006, HiRISE has obtained approximately 13,000 observations covering dozens of square miles, including areas from a student-suggestion program called NASA Quest. However, only about one percent of the Martian surface has been photographed. The public is encouraged to recommend sites for the other 99 percent. To make a suggestion, visit: http://uahirise.org/hiwish.

Take Virtual Walk on Moon. More than 37 years after humans last walked on the Moon, planetary scientists are inviting members of the public to return to the lunar surface as “virtual astronauts” to help answer important scientific questions. No spacesuit or rocket ship is required — all visitors need to do is go to www.moonzoo.org and be among the first to see the lunar surface in unprecedented detail. New high-resolution images, taken by NASA’s Lunar Reconnaissance Orbiter Camera (LROC), offer exciting clues to unveil or reveal the history of the Moon and our solar system.

NEW MEMBERS — The ASP welcomes new members who joined between April 1 and May 31, 2010.

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Michael C. Smith, Fort Collins, CO

General Membership
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The Skies of August

This month’s feature constellation isn’t one that’s well placed for viewing as the Sun goes down. In fact, it’s actually highest in the sky after sunset around mid-December. But it is the “source” of this month’s Perseid Meteor Shower, so it’s an important one to know. The constellation is Perseus, the Hero, and in mid-August it’s rising above the northeastern horizon about midnight.

Perseus is part of the great Greek tale that features the constellations Cepheus, the King; Cassiopeia, the Queen; Andromeda, the Maiden (daughter of Cassiopeia and Cepheus); and Pegasus, the Winged Horse. If you’d like to read the legend, albeit without Pegasus in the story, check out Chapter 15 of Bullfinch’s Mythology.

The outline of Perseus (below) is almost human in shape, with two arms, two legs, and a tiny, pointy head! Between his head and the five bright stars that form the backward “E” shape of Cassiopeia is the Double Cluster, a pair of open star clusters that are a glorious sight in binoculars (and a naked-eye sight in a dark sky). This also happens to be the approximate location of the radiant of the Perseid Meteor Shower. All the Perseid meteors appear to speed away from this region of the sky, which is why the meteor shower is named after Perseus, the home constellation of the shower’s radiant.

Near the variable star Algol is Messier 34 (M34). While challenging to find in a city sky, this open star cluster is a fine sight in binoculars and is roughly the same brightness as the Double Cluster.

At the start of the month, brilliant Venus shines low in the west after sunset. To the planet’s upper left are dimmer Saturn and Mars. Venus slides under Saturn on August 8th, and for the next few days these two worlds form a small triangle with Mars to their upper left. On the 13th, the 3-day-old crescent Moon stands well to the left of these three planets after sunset. Venus will be the most obvious; Mars is to its upper left and Saturn to its right.

As the month progresses, all three planets sink lower into the west after sunset. On the 17th, dim Mars sits 2° above Venus. At month’s end, the star Spica slides past Venus.

Mercury is a challenge to find at the start of August. It’s low in the west after sunset during the first two weeks of the month. If you spot Venus early in the evening, use binoculars to scan to Venus’ lower right for a glimpse of dim Mercury. Wait until next month, when it’s an easier find at dawn.

Fortunately, Jupiter is much easier to spot. It rises in the east as twilight fades and is visible all night. The Moon, two days past full, passes above this giant world on the 26th.

The Perseid Meteor Shower peaks during the morning hours of (Friday) the 13th. It promises to be the best in several years, mainly because maximum activity occurs slightly less than three days after new Moon. As a result, the sky will be moonlight-free during the peak hours of this shower. Under a dark, clear night sky, careful observers may see upwards of 90 meteors per hour streaming away from the northern constellation of Perseus.

The Skies of September

With Jupiter and Uranus hovering next to each other in Pisces, the Fishes, perhaps it’s time to seek out this faint constellation. Fortunately, the Great Square of Pegasus serves as a handy signpost.

The chart on the next page shows Pisces and the Square as they rise in the east after sunset. The four stars of the Great Square are easy to spot, even from a city. Note that Pisces forms a very large “V” roughly parallel to two sides of the Square. In ancient times Pisces was imagined as a pair of fishes joined by a long ribbon. All of its stars are dimmer than those of the Great Square, making Pisces a challenge to see from a city.

The presence of brilliant Jupiter now serves as a convenient marker to help locate at least some of the stars of Pisces. Another way is to find part of the constellation is to look just below (due south of) the bottom of the Great Square. There you might spy the five dim stars that form the Circlet, which represents one of the two...
Venus continues to cling to the west-southwestern sunset sky, though it's low at the start of the month and gets lower every week. Dim Mars also hangs in, to Venus' upper right. But Saturn is pretty much lost in the solar glare. A very thin crescent Moon appears to the lower right of brilliant Venus on the 10th (though you'll need a low, clear western horizon to see it) and to Venus' upper left on the 11th.

Mercury pops into view in the morning sky during the middle two weeks of the month. Unfortunately, there's no nearby Moon to help guide you to this speedy little planet. The morning of the 19th is your best chance to see Mercury when it rises some two hours before the Sun and is well up in the east as dawn breaks.

Jupiter rises in the east as the Sun sinks into the west; opposition is on the 21st. It is high in the southeast before midnight and is nicely positioned for telescopic viewing. The full Moon stands well above the giant planet on the night of the 22nd/23rd.

This month, turn and face north to seek out Cassiopeia, the Queen, and Cepheus, the King. Cassiopeia is easy to spot — find 5 bright stars in the space of a backwards letter “E” and you'll be gazing upon the Queen. Finding the King is more of a challenge. Our chart below shows him looking a bit like an upside-down, peaked-roof house lying just west of Cassiopeia.

In the middle of the base of the King's “house” (opposite the pointy end), search out the star labeled Herschel's Garnet Star. This sun is a red supergiant and is one of the redbrest naked-eye stars visible from the Northern Hemisphere, though it's often described as being deep red or reddish orange. As such, its color makes it easy to spot when sweeping the area with binoculars.

Delta Cephei (δ Cep) is a binary star system approximately 890 light-years away. But it is not an eclipsing binary (where one star passes in front of, and dims the light of, a second star). Rather, Delta Cephei's variability is due to pulsation of the star. It varies from magnitude 3.5 to 4.4 in slightly more than five days (5.366341 days to be precise). This variability can be followed with the naked eye, though binoculars make estimating its brightness easier. On our chart, the magnitudes of two nearby stars have been marked (4.2 and 3.4) in case you'd like to track Delta's changing brightness. Delta also has a 6.3-mag. companion star that's an easy sight in a small telescope.

It's your last chance to spot Venus shortly after sunset. At the start of the month, and if you have a low southwestern horizon, see if you can find this bright planet once the Sun goes down. You'll not see it again until next month at dawn. Also gone from the sunset sky are Mars and Saturn. After all the action in the west this summer, the autumn sunset sky is barren of planets. Even Mercury is invisible, lost in the solar glare.

Fortunately, there's still Jupiter. It's well up in the southeast after sunset and is visible the rest of the night. On the 19th, the Moon stands high above this giant world.
Using Sky & Telescope’s Interactive Sky Chart

Thanks to Sky & Telescope magazine, Mercury readers have direct access to S&T’s online Interactive Sky Chart. While anyone can go to Sky’s website, registration is required to load and use the charts. Registration is free and has some advantages, but it’s not necessary for ASP members who just want to retrieve the monthly star chart.

Sky & Telescope’s Interactive Sky Chart is a Java applet that simulates a naked-eye view of the sky from any location on Earth at any time of night. Charted stars and planets are the ones typically visible without optical aid under clear suburban skies. Some deep-sky objects that can be seen in binoculars are plotted too.

Using the Chart: The Basics

When you launch Sky & Telescope’s Interactive Sky Chart applet in your Web browser, you should get a rectangular, naked-eye view of the sky on the upper left and a circular all-sky chart on the right. If the chart does not appear, see the “Tech Talk” section at the end of this article.

For instance, when you click on the link for the August Sky Chart, you should see, in a new window, a screen that looks like the image above. Each of the monthly links in Sky Sights will take you to a chart set for 40° north latitude and 100° west longitude (so it’s useful throughout the continental US) at 10:30 pm local time at midmonth in August, September, and October. The chart can be used one hour later at the start of each month and one hour earlier at month-end.

If all you want is a copy of the circular All-Sky Chart to take outside, press the “Create PDF” button, and then print the result. You’ll find the easy-to-use instructions included on the chart.

But Sky’s Interactive Chart offers much more. Click on any area of the circular All-Sky Chart that you’d like to see in more detail. The green frame will jump to where your cursor is pointing, and the scene in the Selected View window will now show this area.

Or click and hold down your mouse button within the green frame on the All-Sky Chart, then drag the frame around the sky. The scene in the Selected View window will change as the location of the green rectangle on the All-Sky Chart changes.

Finally, click and hold down your mouse button in the Selected View window, then drag the cursor to move to another part of the sky. The green frame in the All-Sky Chart will follow your movements.

Changing the Chart

Below the Selected View window you’ll find the latitude and longitude the chart is set for, as well as the date and time. These can all be changed.

To alter the date and time, click on the month, day, year, hour, or minute in the display at lower left, which will become highlighted. (You can change only one parameter at a time.) Then use the + or - button to increase or decrease the value you’ve selected. Each time you change a quantity, both the Selected View and All-Sky Chart will be updated instantly.

If you’d rather do a wholesale change, click the large “Change” button in the Date & Time display area. A pop-up window will appear. Here you can choose any date between January 1, 1600, and December 31, 2400, using the day and month pull-down lists and the year text-entry box.

To alter the location (and time zone), you’ll need to click the large “Change” button in the Location display area. A pop-up window will appear that will let you select a new location (be sure to enter data in just one of the three sections of this page). A follow-up page will let you select a time zone. But note that unless you register, the system will not remember your new location.

You’ll find more detailed instructions and hints for using the chart on the Help page. To really become familiar with this program, see the article: Fun with S&T’s Interactive Sky Chart.

Tech Talk

The applet should work properly in most Java-enabled Web browsers. For best results on a PC, use Internet Explorer 6 or Netscape 7; on a Mac, use OS X 10.3 (or higher) with Safari. If you’ve installed a “pop-up stopper” to block advertisements that automatically open in new browser windows, you’ll probably have to turn it off, as the Interactive Sky Chart needs to open in a new browser window.

If you have trouble getting the Sky Chart to open on your computer, please review Sky’s detailed system requirements to check whether you’re using a supported operating system. And don’t forget to also review the Help page.
Kids love to make things explode in science class. How about an entire star? Thanks to NASA, supernovas will soon be going off in classrooms around the country — no safety glasses required. It's done via a DVD called *Journey to the Stars*. Teachers can request a free copy along with supporting lesson plans and activity sheets on the *Journey* webpage.

“We want every classroom in the country to have a copy,” says Lika Guhathakurta of NASA’s Heliophysics Division in Washington DC. “Kids of all ages from K through 12 will enjoy the show — and never look at the night sky the same way again.”

*Journey to the Stars* began as a planetarium show produced by the American Museum of Natural History (AMNH) and supported by NASA’s Heliophysics Division. It surveys the mind-boggling variety of stars that dot the cosmos — exploding stars, giant stars, dwarf stars, neutron stars, even our own star! A *New York Times* reviewer called it “easily the most beautiful planetarium show I have ever seen.” *Journey* has been playing to packed houses at the Hayden Planetarium in New York since the summer of 2009 and, by popular demand, has now been copied to DVD.

The show is narrated by Academy Award-winning actress Whoopi Goldberg. “There it goes!” she calls out as a supernova explodes on the screen. “Talk about star power.” Her otherworldly voice propels the audience through time and space on a journey you soon forget is merely virtual. It is as immersive as a DVD can be.

Best of all, the show is dead-on accurate. Visuals depict stars using real data from NASA spacecraft and the finest theoretical models modern science has to offer.

“This is a solid combination of science and art,” says Ben Oppenheimer, an astrophysicist at the AMNH. “Scientists have been involved in the show from beginning to end, contributing to every step of the production process.”

“We went out and identified which of our colleagues were doing the best work in areas we wanted to cover,” recalls Mordecai-Mark Mac Low, Curator and Chair of Astrophysics at the AMNH. “We asked, can you bring models and observations to the table that will allow us to tell the story using the most current understanding that we have?”

The response was stellar. “We have data from roughly 40 different scientific research groups around the world,” says Oppenheimer. “In all, more than a hundred scientists pitched in to help.”

Emmy-award winning author Louise A. Gikow penned the script, turning the techno-speak of so many scientists into lucid prose. Other leading writers have praised the work as a model of science communication. Indeed, some say, reading the script is almost as good as watching the show, but that’s another story.

To kick off the release of the DVD on June 7th, NASA hosted more than three hundred VIPs from government, academia, and educational institutions at the Air and Space Museum in Washington DC. They saw the show on the dome at the Einstein Theatre and took home copies to their local schools.

Supporting materials that come with the DVD are every science teacher’s dream. A teacher’s guide offers tips for using the DVD as a classroom teaching tool. Activities for grade levels 3 through 12 are fun, innovative, and meet national science standards. It’s all written in plain language, beautifully illustrated with scenes from the show and new data hot off the presses from NASA’s Solar Dynamics Observatory.

Science class is just the beginning, points out Guhathakurta. “We hope teachers will request copies for each of their students, so they can take them home and watch with their families. Also, each disk contains the show in multiple languages — English, Spanish, French, Japanese, Hindi, Chinese and others. So they come in handy in language class, too!”

The journey begins [here](#).