Thank you for looking up.

Why am I thanking you for doing something that you probably do every day? At the ASP, we work with people of all ages from across the education and economic spectrums. You might be surprised how many we help look up for the very first time, and how this simple effort can change the path of someone’s life.

As the ASP’s director of development and communications, I have the pleasure of being in regular contact with our members and donors who share a commitment to the wonder, excitement, and learning opportunities unique to astronomy (unique to looking up). People like you who believe that astronomy is the gateway to science literacy — that this is not only our mission, it is our collective mandate. And the stakes have never been higher. Because “science literacy” no doubt means something different to everyone, we can all probably agree about what the world would look like in its absence.

So thank you for looking up. Thank you for being part of this vital endeavor.

As Earth’s Northern Hemisphere is shaking off winter — and the Southern one is heading into it — it is customary for the ASP to reach out and seek your financial support via our Spring Appeal. We come to you as a partner in science literacy, with the understanding that you do not give to us, you give through us. In case you ever wonder about the impact your support has on astronomy education and science literacy, through the years and thanks to you:

- Some 3,000 teacher/astronomer teams have been trained to provide hands-on astronomy lessons to an estimated 350,000 school children at sites around the country.
- More than 1,000 informal educators have been trained to increase astronomy education capacity at 700 museums, nature centers, and national parks serving an estimated annual audience of 117 million people.
- Publications of the Astronomical Society of the Pacific (PASP) has published 924 issues to benefit the professional astronomy community.
- The ASP Conference Series has published 467 volumes to benefit the wider scientific community.
- We support a network of 425 astronomy clubs, and provide training and materials to enhance their public astronomy outreach activities — logging 23,000 events reaching 2.4 million people.

Thanks to you — and together with you — we can ensure a science literate world. Please visit www.astrosociety.org/support to make your gift online, or keep an eye out for a letter from ASP executive director Jim Manning.

Please consider my office a resource for you, and do not hesitate to contact me with any questions or feedback. Thank you for believing in the ASP, and thank you for working with us to achieve a science literate world – today and tomorrow.

Kathryn Harper
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415-715-1406
The James Webb Space Telescope
JONATHAN P. GARDNER AND HEIDI B. HAMMEL
After many years the James Webb Space Telescope is well on its way to becoming a worthy successor to the Hubble Space Telescope.

The Digital Planetarium: A Modern Astronomical Wonder
SHAWN LAATSCH
Today’s digital dome has dramatically altered the role of a planetarium in its community.

Pinning Down the Universe
ESA AND NASA; EDITED BY PAUL DEANS
While confirming previous observations made by WMAP, Planck has revealed some interesting cosmic anomalies.

Astronomy in the News
Opening a window into Europa’s ocean, Kepler’s smallest ‘habitable zone’ planets, and new insights on how spiral galaxies get their arms — these are some of the discoveries that recently made news in the astronomical community.
So Long, and Thanks for all the Columns

It’s always hard to say goodbye, but I must…to three of Mercury’s excellent columnists.

I knew she had been a Mercury regular for a while, but I was surprised to learn that Katherine Bracher has been writing “Echoes of the Past” for 30 years — almost as long as she taught astronomy at Whitman College. What I liked most about her columns was that they weren’t just a rehash of some historically significant cosmic discovery. Instead, to quote from Kate’s final column, she wanted to: “…take items from ASP publications, either the PASP or the Leaflets, summarize them with appropriate quoted bits, and bring them up to date.” It was the “bring them up to date” idea that made her column unique. In just a few hundred words, Kate illustrated how science works, because while many of the updates showed how today’s knowledge followed from some initial find or theory, some revealed that the path to understanding didn’t always follow a straight line.

After nearly a decade of exploring “Planetary Perspectives,” columnist Daniel Durda thinks it might be time for a different perspective on all things planetary. And for his final column, he managed to go out with a bang — by somehow arranging to have a small asteroid blaze over the Russian city of Chelyabinsk this past February! Dan has a particular interest in small solar system bodies, so it’s fitting that his final column deals with something small that could have a big impact when it happens again.

About three years ago I decided that an organization dedicated to education and public outreach needed an E/PO column in its magazine. And thus was born “Reaching Out.” In the process of seeking a columnist, I found two: Bethany Cobb and James Lochner. I’m hoping Bethany will continue with Mercury for some time, but Jim has completed his assignment as program manager for education programs within NASA’s Science Mission Directorate and is moving on. I’ll miss his perspective on how we should be engaging our audiences after we’ve reached out to them.

Paul Deans
Editor, Mercury
last December, we lost, at the age of 89, one of the great icons of astronomy popularization: Sir Patrick Alfred Caldwell-Moore. The writer of dozens of books, an accomplished xylophone player, and the host of the BBC television program *The Sky at Night* that ran for more than 50 years (with Sir Patrick hosting right up until his death), Sir Patrick was arguably responsible for igniting an interest in astronomy for more people — including future scientists and educators — than perhaps any other single person in the modern era. (A very entertaining biography of Sir Patrick, warts and all, can be found at [http://tinyurl.com/csyyxq3](http://tinyurl.com/csyyxq3).)

The reason he’s an icon to me is very personal, but it’s probably a similar story to the one that many others could tell. An eon ago when I was in grade school, Moore’s *A Guide to the Moon*, checked out from the school library, was one of the first serious astronomy books I read. It caught my imagination at a time when my interest in astronomy was awakening, and this book and a few others were pivotal in turning that early interest into fascination, into action, into a career.

I never forgot that book, and decades later I was thrilled to have an opportunity to meet its author in person. It was the summer of 1991, and I and countless others had descended on the Baja peninsula of Mexico to witness the iconic total solar eclipse of that year. One evening I spotted Sir Patrick in a hotel lounge in San Jose del Cabo; I saw my moment and walked up and introduced myself. And then — like many who suddenly meet one of their childhood heroes — I babbled.

I went on about how wonderful it was to meet him, and how his Moon book had had such a big influence on me as a child — and then made it all worse by sputtering that of course, I didn’t mean to imply that he was old. And Sir Patrick, hair disheveled, dressed in a tropical shirt, smiled at me and in that trademark stentorian voice, proclaimed with great good nature, “But I am old!”

Not so old that he couldn’t continue to write, and broadcast, and passionately spread the joy of astronomy for another two decades and change. And I’ve always treasured that moment, now many years removed, when I had a chance to tell one of my personal heroes, however inadequately, how he had made a difference in my life.

I’ve collected many Moore volumes in my personal library over the years, including a copy of *A Guide to the Moon*, given to me some years ago by another iconic personage: a wonderful woman...
aptly named Urana Clarke from Livingston, Montana. She was also a musician — a teacher of piano — and an avid amateur astronomer like Patrick Moore, who wrote astronomy books of her own, shared her passion with young people, and penned a beloved sky column in the local newspaper — her own version of *The Sky at Night*. And she also lived to a great age, well into her 90s. She was giving me a tour of her home library one day when we were visiting on other business, and I spied the Moon book. I commented to her about how it brought back such fond memories of my youthful interest in astronomy, and she made a gift of it to me on the spot. The volume is a prized possession, still with an honored place on my bookshelf, a reminder of my own journey under the stars — and of two people whom I was privileged to meet, who had done so much to bring a love of the sky to so many.

We all have our icons — the Patrick Moores and Urana Clarkes who, one way or another, nurtured an interest, offered a hand, provided some spark that helped to send us on our life’s journey or to keep us there. It is a role your Society strives to fill today, through its programs, its publications, its tools, and its lessons — to be that spark in somebody’s life, to help teachers, scientists, museum educators, amateur astronomers, parents, and others start and guide the journeys we all take. And we thank you, all of you who support our work, for helping us to make a difference in the lives of others, and for making such a big difference in our Society’s life as well.

Next time you are under the stars and looking up, think back to whomever it was who helped to nurture your own interest in the sky, the person who may have struck that spark, played some iconic role. And ask yourself if you can serve that role in the life of another. Then pass it on!

**JAMES G. MANNING** is the Executive Director of the Astronomical Society of the Pacific.
The first “Echoes of the Past” column appeared in *Mercury* for July/August 1983. At that time the ASP had formed a History Committee to consider ways in which the Society might celebrate its upcoming centennial in 1989 and make its members more aware of its past. I suggested a column in *Mercury* of 50 Years Ago, 100 Years Ago etc., such as you find in many newspapers. The Committee said, “Fine; why don’t you do it?” And so it began. Other committee members wrote a handful of columns, but I have written most of them. Now, 30 years later, I’m going to retire from it, after a very enjoyable run and nearly 150 columns.

From the outset my idea was to take items from ASP publications, either the *PASP* or the *Leaflets*, summarize them with appropriate quoted bits, and bring them up to date. These could be items related to the Society itself, or astronomical material. The latter would be either one of the first mentions of something that has gone on to become a major idea in astronomy, or a publication of a theory that has since proved to be completely wrong. For the first several years there were often two or three brief items per column; more recently I’ve tended to cover a single topic in a little more detail.

That very first column, by Helen Wright, concerned the 1883 cornerstone laying for the main observatory building of the Lick Observatory. Wright wrote a number of historical astronomy books, including biographies of George Ellery Hale and Maria Mitchell, and an account of the building of Lick. She died in 1997 at the age of 82. The Lick Observatory was closely tied to the founding of the ASP, through its director Edward Holden.

In the next column I included a 75-Years-Ago item from the *PASP* in 1908, of George Ellery Hale’s first detection of magnetic fields in sunspots. There was also a note that...
Henry Norris Russell (later to become famous for the Hertzsprung-Russell Diagram) had been promoted to assistant professor of astronomy at Princeton. Sunspot magnetism is now known to be connected to the eleven-year sunspot cycle and to the origin of the spots themselves. Russell went on to a distinguished career at Princeton, making major contributions to the study of stellar structure and evolution such as the distinction between giant and “dwarf” or main sequence stars. His important students included Harlow Shapley, Donald Menzel, and Lyman Spitzer.

Solar System Topics
Some topics, such as Mars, came up a number of times in Echoes columns during the years. In the first of these, in 1984, I wrote about a search in 1909 for water vapor in Mars’ atmosphere. Such a search is difficult because we look through our own atmosphere, which has lots of water vapor in it. W.W. Campbell of the Lick Observatory went to the top of Mt. Whitney (14,501 feet) to get above much of it, and from his spectroscopic observations concluded that Mars had little, if any, water vapor. Since that 1984 column we have learned much more about Mars from various space probes, and we now know there is water on Mars, both in thin clouds and in frozen form below the surface of the Martian north pole, though the amounts are still fairly small.

In 1985 I discussed the canals on Mars, famously described by Percival Lowell as evidence for an advanced civilization on the planet. Robert Aitken of Lick had given a lecture to the ASP in 1910, supporting the view that the canals were natural markings instead. This too has been amply borne out since. A 1991 column, based on an ASP Leaflet by Carl Sagan in 1966, described the Mariner 4 flyby of Mars. To everyone’s surprise, its photos showed a heavily cratered surface. In 1997 a column noted that later probes had revealed a complex geology, with huge volcanoes, deep canyons, and apparent dry stream beds and erosion channels. And in a 2006 column, written as the rovers Spirit and Opportunity were exploring the surface, I concluded: “Clearly much remains to be learned about this neighboring world.” As this is written (2013) Opportunity has been working for nine years (it was supposed to last three months), and Curiosity is also studying Mars, with new results arriving almost daily.

Another topic that appeared fairly frequently was comets. Of course Comet Halley was a topic in 1985, 75 years after its impressive return in 1910. But other bright comets came in for their share of attention: Comets Arend-Roland and Mrkos (1957) in a column 40 years later in 1997, the sun-grazing Comet Ikeya-Seki (1965) in a 1995 column, and the infamous Comet Kohoutek (1974), billed as the “Comet of the Century,” which barely got bright enough to be seen with the naked eye (a 1999 column).

More general discussion of the nature of comets came up also. In a 1988 Echoes, I presented a summary of what was known about comets in 1928, according to an article by Nicholas Bobrovnikoff. Comets were then believed to be non-solid swarms of meteoric particles and gaseous molecules, sometimes described as a “flying gravel bank.” But a 2002 column reported on the theory of Fred Whipple in 1952 that a comet nucleus was a “dirty snowball,” whose outer layers melted when the comet neared the Sun, generating the material for the coma and tail. In 1986 the Giotto spacecraft flew into Comet Halley’s coma and provided images of the nucleus; these supported this model, which is now generally accepted.

Beyond Our Neighborhood
The wider universe was not neglected. In several columns I dealt with the nature and structure of our galaxy, and in others discussed the spiral nebulae or “island universes.” As long ago as 1891 some
research suggested that the Milky Way was a separate system of stars, as reviewed in a 1991 Echoes column. The same column noted that 40 years later, it was believed the Milky Way resembled other great spiral systems like M31 in Andromeda, and that we were out toward one edge of a flat disk. But it was not yet clear in 1931 that ours was really a spiral system. W.W. Morgan demonstrated the existence of spiral arms in 1952, as described in my most recent column (Winter 2013).

In 1989 a column described an 1889 article by Edward Holden about the “helical nebulae.” He was curious to figure out why some nebulae had a spiral appearance, and what sort of three-dimensional shape this implied. So he experimented with bending a piece of wire into various curves and spirals, and then looking at it from different angles. He concluded that a curve rather like a loose figure 6 would match many existing drawings of these nebulae, though he cautioned that photographs were really needed. This was true, since several of his “nebulae” turned out to be star clusters or elliptical galaxies, and only five of his 37 examples are actually spiral galaxies.

The question of whether these systems were, in fact, other galaxies was much discussed in the early 20th century. Echoes columns in 1992 and 1994 reported on items by Harlow Shapley in 1917 and 1919, concerning the “island universe” theory of spirals. Shapley had several arguments against this idea, including his own recent conclusion that our Milky Way was at least 300,000 light-years across. If other spirals were this big they would have to be at enormous distances, and then their rotational velocities (recently measured by van Maanen) would be close to the speed of light. (We now know van Maanen’s data were flawed, and our Milky Way is only about 100,000 light-years across. Shapley’s error in this was due to not accounting for the dimming of stars by interstellar dust.) It was also argued that the novae observed in other spirals would have to be incredibly luminous; we now know that this is in fact the case, and they are now called supernovae.

But Shapley persisted, and had a famous debate with Heber D. Curtis of Lick in 1920, in which Curtis defended the island universe idea and Shapley argued against it. Soon thereafter, Edwin Hubble discovered Cepheid variable stars in M31 and showed it was at least a million light-years away. By the end of the 1920s, the island universe theory had won out.

A related idea was the expansion of the universe of galaxies, signifyed by the red shifts in their spectra — the farther galaxies are rushing away from us faster than nearer ones, indicating that the entire universe is expanding. Hubble also discovered this, as discussed in a 1988 Echoes column, though he did not at first believe it. But when the 200-inch Hale telescope came into use on Mt. Palomar in 1948, it helped confirm this idea, and no one now doubts it. More recent discoveries show that the expansion is accelerating with time, and explanations for this are still being debated.

In the past 30 years of Echoes columns I have discussed many other things — solar eclipses, meteor showers, novae, stellar evolution, new observatories on Earth and in space, and several anniversaries of the ASP, among others. I have had a lot of fun looking back at old Leaflets and Publications to pick out interesting topics. I hope readers have enjoyed it as much as I have, and that the history of astronomy and the ASP will continue to thrive.

KATHERINE BRACHER taught astronomy at Whitman College in Walla Walla, Washington, for 31 years. Retired in 1998, she currently lives in Brunswick, Maine. Her research focuses on eclipses and the astronomy of the ancient world; her other principal interest is early music.
To the Moon in 1638

Using fantasy to promote a new view of the solar system.

An Englishman landed on the Moon in 1638.

“I do seriously, and upon good grounds affirm it possible to make a flying-chariot; in which a man may sit, and give such a motion to it, as shall convey him through the air.” So wrote John Wilkins more than three centuries before Neil Armstrong and Buzz Aldrin landed on the lunar surface.

There were three great books about lunar voyages published between 1634 and 1640: Dream by Johannes Kepler, The Man in the Moone by Francis Godwin and a Discovery of a World in the Moone by John Wilkins (first published in 1638 and republished in 1640 under a slightly different title with additional material).

Kepler imagined going to the Moon in four hours. Understanding that the effort of leaving Earth’s surface will be “a severe shock, for he is hurled just as though he had been shot aloft by gunpowder,” Kepler thinks the Moon traveler will have to be sedated to withstand what modern astronauts understand as the G-forces of a rocket launch.

Kepler used Dream to show that the worldview of Nicolaus Copernicus was correct — the Sun really was at the center of the solar system, and Earth and the other planets revolved around it. He used the method of a fictional account to propound the astronomical hypothesis of Copernicus.

At this time Copernicus’ idea was still regarded by many, if not most people, as pure fiction. Galileo was under house arrest by the Catholic Church for writing that it may be true. The sentence against him had just been passed the year before (1633).

“In a dream,” Kepler wrote, “it is necessary to have the freedom sometimes to invent even that which was never perceived.” By placing a person on the Moon, he sees that the Moon is immobile and Earth turns on its axis. By shifting the viewpoint from the Earth to the Moon, Kepler shows that the idea of an immovable Earth is false.

He then reveals that the motion of the planets is a composite of their own motion and terrestrial motion, which explains Earth’s annual revolution around the Sun. Thus, Copernicus is correct.

Four years after Kepler’s book, Godwin penned his. But unlike Kepler, he did not believe the Sun was the center of the solar system. Even so, Godwin’s fable transforms the incredible idea of a lunar flight into a possibility.

Wilkins takes the idea further, embracing the notion of going to the Moon seriously. “That ‘tis possible for some of our posterity, to
find out a conveyance to this other world; and if there be inhabitants there, to have commerce with them. “The scientists and engineers of the 1960s were that posterity, and the conveyance they created was the Saturn V rocket that sent men to the Moon.

Wilkins proposes making both Copernican astronomy and Galileo’s telescopic discoveries better known to a wide readership. The frontispiece of his book juxtaposes two maps — one geographical, the other heavenly. It emphasizes Wilkins’ argument that the Moon is another Earth, another celestial body that can be explored and mapped. He says studies of Galileo are thereby confirmed. In this passage, he compares Galileo to Lynceus, an ancient Greek said to have eyesight so keen he could see through trees and walls, and underground.

“So that what the ancient Poets were faine to put in a fable, our more happy age has found out in a truth, and we may discern as farre with these eyes which Galileo hath bestowed upon us, as Lynceus could with those which the Poets attributed to him.”

Twenty years after writing about a lunar voyage, Wilkins became one of the founding members of the Royal Society, the spark that set alight experimental science that has led us from the shackles of religion that bound Galileo to the broad, sunlit uplands of reason that have seen humans walk on the Moon.

In 2010 the Linda Hall Library of Science hosted an exhibition of books entitled Thinking Outside the Sphere: Views of the Stars from Aristotle to Herschel. A PDF version of the exhibit includes Wilkins’ 1640 book, putting it in a broader context.

CLIFFORD CUNNINGHAM was recently seen chatting with Tony Mendez, the real-life spy mastermind behind Argo, the Oscar-winner for Best Picture of the Year.

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Progenitors of Short Gamma-Ray Bursts

Are we any closer to an answer after nearly 50 years?

Gamma-ray bursts were discovered back in the 1960s — by US military satellites looking for terrestrial gamma rays that might indicate Soviet violations of nuclear treaties! For nearly a half-century, astronomers have slowly chipped away at the mystery of what these highest of energy cosmic emissions are and where they come from.

Gamma-ray bursts (GRBs) come in two “flavors”: bursts lasting less than two seconds are classified as short-duration (SGRBs), while those lasting from two seconds to as long as thousands of seconds are classified as long-duration (LGRBs). Observational evidence suggests that LGRBs result from the core collapse of massive stars (i.e. supernovae or hypernovae), whereas SGRBs apparently result from the merger of a compact binary star system.

Exactly how is an SGRB produced? The generally accepted mechanism is the merger of either a binary neutron star (BNS) system or a neutron star-black hole (NS-BH) binary that produces a spinning...

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astronomer’s notebook

by Jennifer Birriel
black hole surrounded by an accretion torus. The properties of progenitor systems were inferred from observations of SGRBs. Theoretical simulations showed that the combined magnetic fields of two merged neutron stars can power the relativistic jets that produce the SGRB. But what about a NS-BH binary system?

Bruno Giacomazzo and colleagues studied a complete sample of SGRBs and coupled these observations with theoretical models to examine the nature of SGRB progenitors. They selected a sample of SGRBs with known redshifts that were observed by NASA’s Swift satellite. The group calculated the mass of each SGRB’s torus. Assuming that all the mass of a torus is converted to energy would be a simple application of Einstein’s famous mass-energy relationship, E=mc².

However, this extreme case of 100% efficiency of mass-to-energy conversion only happens in the case of rapidly spinning black holes. In reality, the conversion efficiency depends on the rotation rate of the black hole, the strength of the magnetic field, and the thickness of the disk. To simplify things, Giacomazzo and colleagues assumed a conversion efficiency of 10% for all mergers. Then they had to estimate how much of this energy is in the form of gamma rays.

Previous studies led the group to assume that an average of 50% of the energy shows up as gamma rays. So, they estimated a total efficiency of up to 5%. Using the observed gamma-ray spectrum, they were able to compute a mass based on special relativity.

In two previous studies, researchers used general relativity to simulate BNS and NS-BH mergers. Each of these studies produced gravitational mass equations for SGRBs. Giacomazzo and his team compared their computed masses from observed energy outputs to the general relativistic model masses. They found that binary neutron star mergers can easily produce their sample of SGRBs. However, a neutron star-black hole merger cannot produce even the most energetic of their SGRBs unless the black hole is spinning at extreme speeds! The group is quick to point out that the NS-BH merger scenario cannot be completely eliminated as progenitors, but these would be rare.

Giacomazzo and his colleagues note that gravitational wave observations are critical to confirm the nature of SGRB progenitors. Gravitational waves are expected to result from BNS and NS-BH mergers. Binary neutron stars close to the maximum neutron star mass will rapidly collapse into a black hole after merging and the gravitational waves should be produced simultaneously with the SGRB. Their results indicate that most SGRBs result from BNS systems that are high mass and therefore would collapse directly into a black hole. Smaller mass BNS systems would produce a “long-lived” (up to a few hundred milliseconds!) hypermassive neutron star, which would then collapse to a black hole. These types of systems should exhibit a time delay between the gravitational wave signal and the subsequent SGRB signal.

What we really need are simultaneous observations of SGRBs and gravitational waves. Observations of the SGBR will provide information on the mass of the torus, and gravitational wave observations will reveal important information about the mass of the progenitor BNSs. So, future observatories like the Einstein Telescope will play a key role in finally pinning down the nature of SGRB progenitors.

JENNIFER BIRRIEL is an Associate Professor of Physics in the Department of Mathematics, Computer Science & Physics at Morehead State University in KY.
The Chelyabinsk Affair

A window-shattering reminder that the impact threat is very real indeed.

The big story on February 15, 2013, was supposed to be the very close approach of asteroid 2012 DA14. Discovered a year earlier at La Sagra Observatory in Spain, the 40-meter-long near-Earth asteroid flew past our planet just inside the orbits of our geosynchronous satellites. This was the closest predicted pass by an asteroid that large since we’ve been surveying our planetary neighborhood for potentially hazardous objects, and leading up to the flyby itself, many were heralding the flyby as a wake-up call to the danger of asteroid impacts.

Little did we know that Mother Nature had arranged for another, far louder, wake-up call that morning. Just hours before 2012 DA14 swept past from the south, another small westbound asteroid blazed through the dawn twilight over the Russian city of Chelyabinsk. My first impression from the single dashcam video linked in the first e-mail I read was that this was simply a particularly impressive example of one of the once-every-few-months bright bolides that streak across the sky somewhere in the world. As the multitude of videos poured in though, and the extent of the damage to buildings and injuries to hundreds of people filled the world’s news, it became quite evident that this was a significant event indeed.

The basic astronomical facts of the event took only a day or so to sort out after an initial flurry of some interesting, if inaccurate, speculation. With much focus that week on the impending close pass by 2012 DA14, and perhaps partially fueled by a puzzling penchant of Hollywood film and television documentary visualizations to depict threatening asteroids as accompanied by swarms of associated smaller fragments, many immediately wondered if this brilliant meteor was somehow linked to 2012 DA14. That speculation was fairly quickly dashed, as an initial determination of the meteoroid’s eccentric, Apollo NEA-like orbit showed it to be wildly different than
DA14’s more Earth-like, and inclined, path through near-Earth space.

Microbarograph data from a global infrasound network provided a quantitative verification of the qualitative impression, from deafening sonic booms and blasted-out windows, that this was no monthly-scale event. With a blast-energy equivalent to 440 kilotons of TNT (that’s nearly three dozen times the yield of the atomic bomb that devastated Hiroshima!) bolides like this are literally once-in-a-lifetime events.

The 55-foot-wide rocky asteroid plowed into the atmosphere on a shallow trajectory, was catastrophically crushed to bits by the increasing dynamic pressure of a Mach 60 entry, and showered countless meteorite fragments (some of the largest estimated to weigh nearly a half ton) over hundreds of square miles. The meteorites recovered so far suggest that this object was an L-type ordinary chondrite, among the class of rocky meteorites that are the most common to fall on Earth. It was a very similar chondritic body, albeit four or five times larger, that blazed through the Russian sky slightly more than a century ago, leveling more than 1,600 square kilometers of Siberian taiga. The Chelyabinsk event was, in many respects, a ‘mini Tunguska.’

The shattered windows and collapsed walls in Chelyabinsk have provided the impact-hazard community with a very tangible example of the damage that can be caused by even a relatively small NEA impact. Although at times there seems to exist a certain academic, dispassionate approach to discussing the event, characterizing the blast effects and relating this to larger potential impacts in the future, I’ve tried throughout the subsequent discussion to remind us of the very real human story of this event. Someone’s brother got glass in his face, or someone’s grandmother had to figure out where she would stay for the next week while windows in her now very cold home could be repaired. And this was, remember, just an extremely small event in scheme of things NEA-impact-wise — it could have been far, far worse.

Perhaps now many can better understand that this is why we survey for NEAs, this is why we devise techniques for deflecting larger potential impactors, and this is why it is important to maintain a planetary perspective. ❧

DANIEL D. DURDA is a Principal Scientist in the Department of Space Studies at the Southwest Research Institute in Boulder, Colorado.

As important as it is to maintain a planetary perspective, it is also a good idea to occasionally gain a fresh one. My first Planetary Perspectives column, in the September-October 2003 issue of Mercury, was titled “Minor Planets, Petite Moons” and examined some of the new discoveries of asteroid moons that were providing clues to the origin and evolution of small bodies. I’d forgotten this, and I find it fitting that my final column has a similar small-bodies theme.

And so after nearly a decade writing Planetary Perspectives for Mercury, I think it’s time to hand over the reigns for a bit of change and the opportunity for a different trajectory in planetary science commentary. During the past 10 years, I’ve thoroughly enjoyed the chance to share with you some amazing research results from my friends and colleagues, and I look forward to ‘dropping in’ from time to time to continue contributing to this wonderful publication.
If black holes make your head spin, try thinking about spinning black holes. What's spinning? Well, spacetime itself. If you were at the black hole's event horizon, you would be carried round and round this void on the coattails of nothing in particular, just the little spot of nothingness you're standing on.

Most astronomers are convinced that black holes rotate...fast. Now an international team using two X-ray satellites claims to have accurately measured, the first time, the spin of a supermassive black hole in the heart of NGC 1365, the Great Barred Spiral Galaxy, about 60 million light-years away in the southern constellation Fornax. Scientists used NASA's NuSTAR and ESA's XMM-Newton satellites to do the measuring. The spin, for the record, was measured at 84% light-speed.

"This is hugely important to the field of black hole science," said Lou Kaluzienski, NuSTAR program scientist at NASA, in two of three press releases accompanying the article in the February 28, 2013, issue of *Nature*. Sounds impressive. But some scientists aren't certain whether this is really black hole spin or just NASA PR spin.

At a fundamental level, it is easy to understand that stellar-size black holes will spin if the collapsed stars forming them spin. Although scientists aren't sure how supermassive black holes form, this likely involves stuff rotating and collapsing, preserving angular momentum.

As for measuring spin, the devil is in the details. Remember that black holes themselves aren't visible. Scientists infer their presence by observing gas around a black hole heated to extreme temperatures from the enormous tug of gravity. NGC 1365's core, for example, packs the gravitational punch of two million suns, confined to a region only 3.2 million kilometers across. (Our sun's diameter is 1.4 million kilometers.)

But the region around supermassive black holes — in this case, one classified as an AGN, or active galactic nucleus — can be chaotic, characterized by a flat accretion disk of gas flowing toward the black hole and close to the event horizon, plus a surrounding halo of gas and dust. And this sets the stage for the schism among scientists measuring black hole spin.

Some scientists — in particular Guido Risaliti of Osservatoria Astrofisico di Arcetri, Italy, the lead author on the *Nature* report — subscribe to the so-called disk model. This model states that the...
X-rays scientists detect are first ultraviolet photons that collide with electrons to create X-rays, which then reflect off the accretion disk, carrying with them the fingerprint of the effects of strong gravity near the black hole.

Other scientists subscribe to the cloud model, in which X-rays are reflected not off the disk but rather off the surrounding clouds. So the X-rays don’t carry information from the disk about extreme gravity — or, in the case of NGC 1365, the black hole’s spin.

Using a combination of XMM-Newton’s lower-energy X-ray detectors and NuSTAR’s higher-energy X-ray detectors, Risaliti’s group could, for the first time, study an AGN across nearly the entire X-ray spectrum. The scientists said the higher-energy data rule out the cloud model, because the emission source would need to be 100 times stronger if the X-rays were just bouncing off clouds instead of getting ramped up in the disk by the black hole’s spin.

But proponents of the cloud model, such as Jane Turner of University of Maryland, Baltimore County, argue justifiably that Risaliti’s group’s calculation for NuSTAR data is based on models only suitable for lower-energy X-rays.

Accounting for the scattering of X-rays is important for the physical conditions that must exist in the absorbing clouds in NGC 1365, “but that process is not included in the particular models that form the basis of the Risaliti paper,” Turner said. “Extending the use of [the models] beyond the valid regime will mean you get meaningless results.”

Turner and Lance Miller, a colleague at the University of Oxford, hope to analyze the data themselves, believing that the hype from the first big result from NuSTAR is premature. What is clear on all sides, however, is that we are getting increasingly closer to a black hole event horizon, and that everyone wants to go along for a spin.

Baltimore-based writer Christopher Wanjek is the author of the novel Hey Einstein!, his spin on the nature-versus-nurture debate.

Is Constructivism Dead?

The jury is in. Discovery or inquiry-based learning should be discarded because direct instructional guidance is more effective.

Science progresses through inquiry, so one might ask whether we should use the same method for astronomy instruction as for the construction of the knowledge in the first place. Problem-based learning, in particular, is intriguing because much astronomy can be expressed in terms of grand problems, which can be used to motivate understanding of background information (known as backward-directed reasoning).

However, a recent meta-analysis by Richard Clark, Paul Kirschner, and John Sweller (Putting Students on the Path to Learning) has not only called the ideas of discovery, inquiry, and problem-based learning into doubt, the authors have pronounced these methods dead. Because this is such a bold statement, questioning 100-year-old

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**education matters**

by David Bruning
teaching methods, we should look at what constructivism means. Consider the story “Fish is Fish” as mentioned in the National Research Council book *How People Learn*. A frog visits land and then returns to its pond to tell a fish friend about birds, people, and cows. The fish, hearing about the adventure, imagines each animal as a fish but with wings, two legs, or four legs. This story highlights Paige Schulte’s definition of constructivism: “learners construct meaning by fitting their ideas into reality.” But constructivism is often stated more narrowly than Schulte’s suggestion.

Constructivists Jean Piaget, Lev Vygotsky, and Jerome Bruner are commonly held to be the founders of discovery learning. Bruner believed that students better remember an idea if they learn it by themselves. This is sometimes stated, in a more restrictive form, as the only way students should learn is through their own construction of knowledge rather than having knowledge presented, modeled or shown to them by a teacher (e.g. Tom Loveless in *Education Policy*, edited by Diane Ravitch). This restrictive form is the one at issue in this column.

The definition of discovery learning varies between authors, but the restrictive form says that there should be no intervention by the teacher beyond a statement of the learning objective. This means that the instructor can pose no guiding questions nor provide feedback on students’ exploratory directions. Ton De Jong and Wouter Van Joolingen contend that computer simulation is a good match for discovery learning, with the learners’ main task being to infer, through experimentation, characteristics of the model underlying the simulation.

Indeed, many computer-aided instructional systems use inquiry learning, and many claims are made about their efficacy. For example, the *ThinkerTools* project claims to be effective at reducing differentials between high- and low-performing groups of students. But others say these studies are flawed because they do not use demonstrably similar comparison groups, and the reported gains are questionable.

In a study comparing direct and discovery learning modes in 3rd and 4th grade science classrooms, David Klahr and Milena Nigam found that direct learning is not only more efficient but also more effective. More children learned using direct instruction and the quality of learning was as high — and discovery learning did not produce deeper or richer knowledge as is usually suggested. Students learned the ideas of the scientific method equally well using direct versus discovery learning, refuting the idea that self-discovery produces learning more in line with the methods of science.

José Arocha and Vimla Patel found in their study of problembased learning that students retained backward-directed reasoning but did not acquire the forward-directed reasoning that is the hallmark of expertise. This lack of expertise persisted after training. In addition, a related study found that students failed to separate general science knowledge from that associated with individual problems, creating difficulties when new problem sets were presented, especially post-instruction.

Peter Airasian and Mary Walsh warn that constructivism is not an instructional approach but a model of how the brain works. For a prescription on how to help students learn, Clark, Kirschner, and Sweller recommend that we use explicit instruction.

That sounds like a relapse back to the days of teacher-centered lecture, but it is not. Explicit instruction merely means that concepts and skills are explained fully before students engage these ideas on their own. This instruction can be achieved through classroom activities, tutorials, modeling, demonstrations, and, yes, lecture — as long as the required information is provided to the students.

All the ideas about active learning representing best practice in
astronomy education continue to hold. Active learning is part of social constructivism (which sounds like constructivism but isn’t), which holds that students must be communal participants in learning rather than passive receivers.

Cast off your self-image as a constructivist, because that methodology does not benefit our students. And we should probably eschew using social-constructivist to avoid confusion with the other

You know, Orion always comes up sideways.” So begins Robert Frost’s poem *The Star Splitter*. I often think of this on autumn evenings as I see Orion rising. Orion provides a focal point for me. It is a relatively simple pattern of bright stars, arranged in a rectangle outlining his body, within which are the straight lines of his belt and sword. Orion is my focus when life gets complicated, reminding me why I’ve pursued astronomy.

Astronomy education and outreach can sometimes seem rather complicated.

NASA’s Science Education and Outreach efforts have come a long way in 15 years, when it was a collection of individual efforts scattered across centers and missions. Under Jeff Rosendhal’s direction, the Education Forums and the Broker Facilitators engaged in a “great experiment” to coordinate efforts and to build partnerships between and within the science and education communities. Coupled with the dedication of 1% of mission budgets to E/PO, many building blocks were slowly set in place — our own sense of community, working with outside experts, and expanding the communities being served.

The NASA E/PO community is now mature and still growing. The current Forums continue to build and improve community resources, including the new NASA Wavelength online catalog, many hours of professional development webinars, the community workspace, collaborative projects such as NASA’s Science4Girls during Women’s History Month, and welcoming new community members working on NASA E/PO grants.

But it’s all gotten complicated. The *Explanatory Guide* for SMD E/PO grants and E/PO programs describing the various required criteria was originally 34 pages. Combined with the accompanying *Help Guide*, it has grown to 65 pages. The *Guide* was initially motivated by the reasonable desire to have exceptional programs, but
the criteria have also become a means of assuring accountability for the taxpayer’s money. The NASA requirements for reporting results also stems from this need for accountability. All this is in addition to the many pages of NASA and Federal rules and regulations for grants and programs. So it’s time to focus on Orion, and consider the good work being done.

During my time at NASA HQ, I’ve had the pleasure of meeting many people who are doing great work. Dick Pugh, a retired high school science teacher, has a traveling hands-on meteorite show that he takes to eastern rural Oregon. He is often “the scientist” who visits these rural communities, with audiences ranging from 4 to 400. Born a city boy, but having spent much of his time in the country, he speaks their language — he relates to them and they to him. Dr. Jörg-Micha Jahn developed an interactive research campaign where hearing-impaired students in San Antonio, Texas, interacted directly via Skype with a scientist studying the aurora in Venetie, Alaska. Unplanned was the connection these students made with students in the village school, and though separated by 4,000 miles, they found that they had much to talk about — the aurora, their schools, and their communities, which brought them together. Each group of students created posters for the other school. These are just two of many examples of science conversations bringing people together.

We find it rewarding to understand and know this complicated universe. But it’s also a matter of beauty, not only inspiring in its images and workings, but in how it brings us together. It allows us to have conversations that matter — where we’ve come from, where we are, and where we’re going. Our ultimate endeavor is to share this science with students, educators, and the general public. But we also improve understanding of science, and encourage young people into rewarding careers. We make connections with people, and we change lives, including our own.

In The Star Splitter, a farmer burns his house down for the fire insurance so he can buy a telescope. After getting “a good glass for six hundred dollars,” he takes the narrator out “on a night of broken clouds,” and then:

\[
\text{We spread our two legs as it spread its three,}
\text{Pointed our thoughts the way we pointed it,}
\text{And standing at our leisure till the day broke,}
\text{Said some of the best things we ever said.}
\]

Here’s hoping you have many a night under the stars and your favorite constellations, saying the best things you ever say.

**JIM LOCHNER** has completed his two-year assignment as program manager for education programs within NASA’s Science Mission Directorate and is embarking on a new phase of his astronomy career — working at USRA (Universities Space Research Association) with universities performing space science research. As he will no longer be directly “engaging” students and the public, he has decided this will be his final Reaching Out column.
The James Webb Space Telescope

After many years the James Webb Space Telescope is well on its way to becoming a worthy successor to the Hubble Space Telescope.

By Jonathan P. Gardner and Heidi B. Hammel

Artist’s concept of the completed James Webb Space Telescope. Webb will be 100 times more powerful than the HST, and its science will range from studying cold objects in our own solar system to studying the first galaxies that formed in the universe.

[Spacecraft illustration: NASA. Background (Helix Nebula): NASA/NOAO/ESA/Hubble Helix Nebula Team/STScI/NRAO.]
Editor's note: The ASP continues its inside look at the James Webb Space Telescope (JWST) with this Mercury feature by two scientists who have been intimately involved in the project for many years. JWST Senior Project Scientist John Mather described the early history of the project in issue #110 of Astronomy Beat; he provides a detailed current status report on the project in Astronomy Beat #111 (May 14, 2013).

Jonathan: I started working at NASA’s Goddard Space Flight Center (GSFC) in 1996. I was excited about the upcoming installation of an infrared camera on the Hubble Space Telescope (HST), which I wanted to use to study galaxy evolution with deep surveys. Not long after I started work, I ran into one of my colleagues, who told me about a new telescope that was going to be the successor to the Hubble — larger and optimized for the infrared. One of its main science goals was to do deep surveys for galaxy evolution. I realized right away that if NASA was going to build a space telescope designed for my research interests, then I needed to get involved! Fast-forward 16 years. The mission is the James Webb Space Telescope, currently under construction, and I am the Deputy Senior Project Scientist for the mission at Goddard.

Heidi: My experience with space telescopes literally started with a bang, when the fragments of Comet Shoemaker-Levy 9 plowed into Jupiter in 1994. I was head of the Hubble Team that imaged Jupiter in response to the impacts. I was pretty young, and had nothing to do with the creation of the HST, but I recognized that it was an incredible tool. Some years later, I was asked to participate in an ad hoc science working group to study a new type of space telescope. The telescope was later named for James Webb, the architect of NASA’s Apollo Moon landings and also a staunch advocate for space science. I jumped at the chance to work on building a telescope for the next generation of young scientists, and a few years later I was
officially selected to be one of the six Interdisciplinary Scientists for the program. That was more than a decade ago, so it has been a pretty long, strange trip.

**Mirror, Mirror**

**Jonathan:** A telescope requires mirrors, and the good news about Webb’s mirrors is that they are all finished. The primary mirror consists of 18 segments, each made of beryllium and coated with a microscopically thin layer of gold. Beryllium was selected because of its very stable thermal properties, and the coating is gold because that has the best reflective properties in the infrared. The gold coating is so thin that it comes to a little more than the mass of a dime for each mirror segment. All 18 mirrors work together as a single optical surface and are adjustable. The back of each mirror segment is supported with actuators, mechanisms arranged so that we can move the segment in many different ways. There is an additional actuator that pokes the middle of the mirror segment to adjust its curvature. We plan to re-align the mirrors every two weeks through the lifetime of the mission.

**Heidi:** Most of the primary mirror segments are still at Ball Aerospace in Colorado where they were made, but several have been shipped to the Goddard Space Flight Center. The mirrors will be installed onto the main framework of the telescope using a robotic arm on a huge structure called the Ambient Optical Assembly Stand (AOAS). The AOAS is 100,000 kilograms of welded steel built within the largest class-10,000 clean room in the world at Goddard. (A class-10,000 clean room has less than 10,000 particles larger than 0.5 micrometers per cubic foot. In comparison, normal room air has one million particles, so a class-10,000 clean room is 100 times cleaner than a normal room.) Goddard’s clean room has a webcam.
which updates live images of the activity every 60 seconds, so you can watch Webb being built.

**Jonathan:** To see the first galaxies that formed in the early universe, we need to go fainter than Hubble can and see further into the infrared. So Webb’s mirror is larger than Hubble’s — 6.5 meters in diameter compared to Hubble’s 2.4 meters — and it will be cold, operating near 50 kelvin or -370°F. To keep the temperatures down, the Webb telescope itself will be shielded from sunlight by a multi-layer sunshield the size of a tennis court. The sunshield consists of five layers of Kapton, a flexible plastic material. Heat escapes between each of the five layers (each about one foot away from the next), so every layer is colder than the next. If we wanted to give the “Sun Protection Factor” of Webb’s sunshield, it would have an SPF of 1,000,000!

**Heidi:** Webb will have four main science instruments, a mix of imaging systems and spectrographs. The imagers will provide amazing pictures, just like Hubble. The spectrographs will allow us to analyze the light from distant planets, stars, and galaxies to determine their chemical make-up, temperatures, pressures, distances, and many other properties. Two of the instruments are already at Goddard. The Mid-Infrared Instrument (MIRI, pictured at upper right on the previous page), which has a mixture of imaging and spectrographic capabilities, arrived from Europe last year. Soon after, the Canadian Space Agency delivered the Fine Guidance Sensor, which also has

The sunshield will be launched wrapped around the telescope. This picture shows the first of five template sunshield layers installed on a mock-up of the telescope back plane (a full-scale structural facsimile of the real observatory) to test the deployment sequence. [Northrop Grumman]
a Near-Infrared Imager and Slitless Spectrograph sub-system (FGS/NIRISS).

Jonathan: The remaining two instruments should be completed this year. The main camera will be the Near-Infrared Camera, or NIRCam. The European Space Agency, in addition to providing the Ariane 5 rocket on which Webb will launch, also contributed a Near-Infrared Spectrograph (NIRSpec).
On to Launch

Heidi: Since both the primary mirror and the sunshield are larger than the Ariane 5 rocket’s five-meter-diameter cargo area, they will be folded up and stowed for launch. Unfurling the sunshield just after launch will be one of the most exciting parts of the mission.

Jonathan: Webb will be launched in 2018. Although we have many of the pieces nearly complete, the big task of putting it all together remains; we call this process “integration.” We also need to make sure it is all going to work when it gets into orbit. That means a lot of testing. The instruments will be tested at Goddard while the mirror is being assembled in the clean room. But to test...
them together, we have to use a giant vacuum chamber at the Johnson Space Center. The full end-to-end optical test of the telescope and instruments together on the ground will ensure that it all works correctly after launch.

**Heidi:** This telescope is big, and so shipping it around the country is not trivial. Its penultimate trip will be from the US to the launch pad in French Guiana. NASA has built a giant transport carrier to keep the telescope safe during its travels.

**Jonathan:** Like Hubble, Webb is a general-purpose observatory and will address nearly every aspect of astronomy. Much of the amazing science to come from Webb will be things that we — the scientists who are helping to building this incredible machine — have not even thought of yet. One of the most important lessons we learned from Hubble was to expect the unexpected: fully half of the most amazing results were never even considered when Hubble was being built. Therefore, each year scientists from around the world will submit proposals to use Webb, and a review committee will select the best ideas. We expect a lot of competition among scientists to use this powerful telescope. Hubble is awesome, and Webb will be better.

**Heidi.** Better than awesome. That’s NASA!

**HEIDI B. HAMMEL** is a planetary astronomer and one of the six Interdisciplinary Scientists for the James Webb Space Telescope. She is currently the executive Vice President of the Association of Universities for Research in Astronomy (AURA, Inc.) in Washington DC. Heidi is best known for using the Hubble Space Telescope to study giant planets and impacts on Jupiter, as well as for her award-winning public outreach.

**JONATHAN P. GARDNER** is the Chief of the Observational Cosmology Laboratory and the Deputy Senior Project Scientist for the James Webb Space Telescope at NASA’s Goddard Space Flight Center. He studies galaxy evolution using the Hubble Ultra-Deep Field and other galaxy surveys and looks forward to the day when Webb will find the first galaxies that formed in the early universe.
The Digital Planetarium: A Modern Astronomical Wonder

Today’s digital dome has dramatically altered the role of a planetarium in its community.

By Shawn Laatsch

The author at the console of the Imiloa planetarium, with 3-D images surrounding his audience. [Imiloa Astronomy Center]
The word “planetarium” conjures up visions of a huge, insect-like machine in the center of a circular room that projects stars on a dome overhead. During the last century, planetarium presentations wove together cultural stories of the constellations with their locations in the night sky, and showed generations of visitors how to “find their way” around the heavens. These magnificent machines could speed up time to reveal the motions of the Sun, Moon, and planets during the passage of days, months, or even years.

These wonderful projectors, created by Zeiss, Minolta, Spitz, and GOTO, helped generations of children and adults discover Earth’s beautiful night sky. This was all done via a complex system of optics coupled with mechanical gears that set the sky and planets in motion while keeping it all in alignment. Although these machines created very realistic representations of the heavens, they were limited to presenting an Earth-centric view of the universe. But as our understanding of the cosmos expanded dramatically during the recent decades, these “traditional” planetariums struggled to accurately portray our current views of the universe.

All this is changing. Modern planetariums (sometimes no longer called planetariums) are going digital. Why? Because in a digital dome audiences can be transported to the surface of Mars, to an orbit around the potentially habitable exoplanets Kepler 62e and 62f, to a neighboring galaxy for a look back at our Milky Way, or to the first galaxies formed nearly 13 billion years ago. Best of all, today’s digital domes can illustrate the complex spatial relationships between astronomical objects near and far, and aid in revealing how these relationships influence the phenomena we observe. And yet, upon demand, these same theaters can still portray the stars and constellations of tonight’s sky.

A Brief History

For centuries we’ve tried to understand our place in the cosmos by creating models. Three-dimensional sculptures of celestial globes showed the heavens, but they did so from a god-like perspective — looking down through the crystalline sphere of stars that was believed to envelop Earth.

The first known large-scale attempt to correctly replicate the heavens and its motions was the Gottorp Globe, built between 1654 and 1664. It consisted of a hollow copper sphere 10 feet (3 meters) in diameter that was set on a tilted axis. The constellations were painted on the interior walls, two oil lamps placed at the center provided illumination, and the dome rotated to demonstrate the motion of the night sky. A circular interior bench provided seating for ten.

In 1913, Wallace Atwood constructed a 15-foot-diameter globe made from light galvanized sheet iron and mounted on electrically driven rollers so it could turn. He drilled 692 holes of various sizes into the globe to show stars (from 42° North latitude) down to 4th magnitude. The 17 spectators seated inside the Atwood Celestial Sphere saw the stars illuminated via light falling on the outside of the sphere. An electric lamp that moved along the ecliptic showed the position of the Sun, while the brightest planets were holes in the zodiac that...
could be uncovered and covered as necessary. Moon-phase disks, coated with luminous paint, were attached to the sky as required.

Projecting the Sky

In 1919, Walther Bauersfeld proposed a new idea to realistically replicate the night sky — the use of numerous small projectors to project the stars onto a fixed hemisphere. This concept led to the creation of the first fully functioning optical-mechanical planetarium by the Carl Zeiss company — the Zeiss Model I. A 200W lamp in the center of a small metal sphere (the star ball) shone light through a set of lantern slides made by photographing exact drawings of the night sky. The light passed through lenses and 4,500 pinpoints of light — the stars — illuminated a darkened dome. Rotating the star ball around its polar axis simulated daily motion. The Sun, Moon, and naked-eye planets were housed in individual projectors in a cage area below the star ball; each could move independently to show their apparent motions against the background of stars. However, like the Atwood Sphere, the Model I could show the sky for only a single latitude.

In August 1923, the Model I was installed in a temporary 16-meter dome on the roof of the Zeiss factory in Munich. When its stars lit up the dome’s interior, it was immediately dubbed “the Wonder of Jena.” Later it was permanently installed in a 10-meter dome in the Deutsches Museum in Munich.

Almost immediately the Zeiss Model II was designed and built, with two star spheres, copper-foil plates with holes for the stars, and a second motor so that the sky seen from any latitude could be shown. Non-Zeiss star projectors began to appear in the 1930s, though they were one-of-a-kind instruments. In the late 1940s, Armand Spitz demonstrated a simple, low-cost projector at Harvard Observatory, and Spitz Laboratories soon began selling his Model A pinhole projector. The Japanese followed with projectors from Minolta in 1958 and GOTO in 1959. Both were similar in design to the new Zeiss projectors — dual star balls and separate planet projectors.

During the 60 years following the appearance of the Zeiss Model I, optical-mechanical projectors improved to a point where they could show a night sky inside a dome that was almost indistinguishable from the real thing outside. (In fact, with light pollution extinguishing the stars in most major cities, planetarium skies often looked better than the real thing!) Starting in the early 1960s, special effects
and slide projectors began appearing in the dome so planetarium programs could expand beyond the basic night-sky lectures. Pre-recorded narration was added, as was automation to control the burgeoning number of projectors being installed. Film projectors made an appearance in the 1970s, and standard video projection began replacing film in the 1980s. With these additions, the planetarium program became a multimedia extravaganza, and topics other than astronomy began to be offered.

**The Digital Revolution: First Attempt**

Thirty years ago, Evans & Sutherland (E&S) produced Digistar I, the first digital planetarium projector. Moving an electron beam over the phosphor-coated face of a cathode ray tube created images composed of light points and lines (also known as a vector scan) that passed through a fish-eye lens and covered the entire planetarium dome.

The system was able to produce a digital version of the night sky, but there were significant limits. The sky was a green monochrome color and the resolution was poor, resulting in star fields that were not as crisp (or as bright) as optical-mechanical projections. However, on the plus side, Digistar I could show the sky from any location within the solar system or out to 650 light-years from the Sun, illustrate thousands of years of stellar proper motion, and generate wire-frame graphics.

**A Giant Leap Forward**

In 1996, during the International Planetarium Society (IPS) Conference in Osaka, Japan, GOTO debuted Virtuarium, the world’s first full-color, three-dimensional full-dome computer graphic projection system. Two years later, also at IPS though this time in London, England, Sky-Skan introduced SkyVision — the first true full-dome video playback system. SkyVision used six CRT projectors controlled by a cluster of high-end PC computers that aligned, masked, and blended the video to form one seamless, dome-filling image. Initially the system could only play pre-rendered video sequences. However, real-time capabilities were added a year later via Digital Sky, software that not only digitally replicated the stars, but did so in real time, giving the user complete control over the heavens. This allowed planetariums to show the cosmos from anywhere — be it a ground-based perspective or out at the “edge” of the universe.
Also in 1999, E&S launched StarRider, their first full-dome system. Although only video playback, it could be used in conjunction with their real-time monochrome Digistar II. In mid-2002 they showcased Digistar 3, a system that integrated real-time and video playback in full color, comparable to Sky-Skan’s Digital Sky/SkyVision system.

More than a decade later, digital theaters are now in full bloom. Optical-mechanical planetarium manufacturers have introduced their own versions of digital all-dome systems. All are generally comparable, with the main differences occurring in the user interface and the size of the real-time datasets. New vendors such as Digitalis and Global Immersion have entered the digital full-dome arena. Some companies offer stereoscopic projection systems as the latest option in planetarium display technology.

Small and midsize domes and portable planetariums haven’t been left behind in this digital revolution. New vendors and new systems have let the “little guys” keep pace. Considering there are many more small theaters than large, it’s a market that will likely continue to grow.

Despite these advances, the direct descendants of the Zeiss Model I continue to shine. Numerous facilities want the best of both worlds, so when they’re built or undergo expansion or remodeling, they opt for the combination of an optical-mechanical night-sky projector surrounded by a digital full-dome system.

**There’s No Dome Like Home**

It’s all very well and good to talk about this digital revolution in the planetarium field in general terms. But let me bring in a specific example: the digital dome where I work. It’s in the Imiloa Astronomy Center of Hawaii located at the University of Hawaii at Hilo at the base of Maunakea (the preferred Hawaiian spelling of Mauna Kea). As you may know, Maunakea is home to 12 observatories operated by a number of countries around the globe.

Open in February 2006, Imiloa was created to inspire the next generation of explorers by sharing the astronomical science conducted on Maunakea through a Hawaiian worldview. Its proximity to these great observatories has given us unique access to

*Left: The Imiloa Astronomy Center, a 42,000 square-foot facility that opened in 2006. [Photo by Macario, courtesy Imiloa Astronomy Center] Right: A Definiti 4k projector, similar to ones in the Imiloa dome. [Sky-Skan]*
astronomical discoveries and astronomical datasets, which are translated into unique visualizations in our dome.

The planetarium is a 16-meter, non-tilted dome with 120 unidirectional seats. It has a Sky-Skan Definiti stereoscopic projection system, tri-colored LED lighting, and 5.1 digital audio surround-sound. The Sky-Skan system was installed in November 2007 and consists of four Sony SXRD video projectors driven by a cluster of 18 custom-built PC computers with specialized graphics and storage capabilities. The system has 16 channels of video (four per video projector), a resolution of 4096x4096 pixels (4K), and a brightness of 40,000 lumens. Sky-Skan’s DigitalSky software controls all system features including playback programs and real-time astronomical datasets.

Astronomical Datasets: First Steps

During the installation of our operating system, we discussed with a number of observatories possibility of displaying their data in our dome. Dr. Jean Charles Cuillandre and Dr. Stephane Arnouts of the Canada-France-Hawaii Telescope (CFHT) were the first astronomers to propose a dataset. For seven years the CFHT conducted an extensive observing campaign to discover exploding stars in the distant universe. Using their MegaCam (a new generation, large CCD camera) four locations in the sky were regularly imaged, resulting in the detection of several hundred supernovae. As a bonus, when stacked together the observations revealed a large number of faint galaxies (roughly a half-million) spread across the four fields. Compared to the better known Hubble Deep Field (HDF) acquired by the Hubble Space Telescope, each CFHT deep field covers an area 400 times larger, making them particularly interesting to those who study the formation and evolution of galaxies.

After determining the distances to these galaxies, CFHT astronomers built a three-dimensional map showing their locations. Data from the four fields lets us travel 8.5 billion years into the cosmic past — roughly two-thirds the age of the universe. CFHT provided the data for these four fields to Imiloa and Sky-Skan, who then transformed it into visualizations capable of being displayed via the DigitalSky software. Using the 3-D stereoscopic capabilities of our dome, we can fly through this data and share it with audiences in a very dramatic way, showing the galaxies in their correct positions and orientations.

Different Ways to Use the Dome

Dr. Antonio Chrysostomou, then the Associate Director of the James Clerk Maxwell Telescope (JCMT) proposed showing a 3-D volumetric view of gas flows in the Whirlpool galaxy. Data collected by the HARP (Heterodyne Array Receiver Program) instrument on the JCMT shows M51 warped by interactions with its companion and gas-flow motion within this famous spiral.

HARP data required special formatting as the data shows the motion of gas as its third dimension (instead of distance, which is the
usual “z” point for data). HARP provides a volumetric cube of data, and those points were then converted into sprites (colored points, often used to denote positions of galaxies in 3-D space) for display. Colors were added to show gas flow moving toward and away from the galaxy. The result is a dramatic view of the Whirlpool that reveals the interaction between the main galaxy and its companion. This submillimeter view provides a new way of seeing a galaxy volumetrically.

Dr. Andy Adamson, currently at Gemini Observatory but formerly the Head of Operations at the United Kingdom Infrared Telescope (UKIRT), provided image tiles from the UKIRT’s galactic plane survey (GPS). These stunning images show the plane of the Milky Way in greater detail (16K resolution) than visible light can provide. The GPS covers the galactic plane to latitudes 5° above and below the mid-plane, and longitudes stretching from the galactic center in Sagittarius across to Cassiopeia.

The GPS has detected more than one billion objects, the great majority of them stars. The survey is being examined for new star clusters, new globular clusters, star formation areas, and galaxies hidden in the mid-plane extinction region. Imiloa worked with SkySkan to create a method for tiling these images, allowing us to zoom in and explore the scene in great detail. The methodology is similar to “tiling in” when viewing images of Earth features in Google Earth.

These were the first times astronomers used a domed theater to present their data in 3-D stereo. These first steps launched Imiloa on a path that brought this information to the public, and we are currently discussing ways of releasing this data for other planetariums to use and display in their domes. One way the Imiloa Astronomy Center is using this data is during our regular presentation 3D Hitchhikers Guide to the Universe. This hour-long tour from Earth to the edge of the universe as we know it incorporates these datasets. We also offer a monthly program called Maunakea Skies, during which we do an in-depth sky tour followed by a presentation by one of the observatory astronomers. This program now includes flying out (in 3-D stereo) to some of their discoveries.

**Awesome Light**

Imiloa has also produced three programs on the observatories of Maunakea — our Awesome Light Series. These are stereoscopic digital dome productions that explore the latest astronomical discoveries using real footage from the observatories, which makes the audiences feel as if they are actually with the astronomers at the telescopes. The first one has an optical theme featuring the CFHT, Gemini North, Keck, and Subaru observatories. The second looks at submillimeter and radio astronomy with JCMT, the Caltech Submillimeter Observatory, the Harvard Smithsonian Submillimeter Array, and the Very Long Baseline Array. The final installment chases celestial mysteries with the UKIRT, the NASA Infrared Telescope Facility, the University of Hawaii 2.2-meter telescope, and Hoku Kea (the teaching telescope for the University of Hawaii at Hilo).

Each of these programs features time-lapse photography acquired using digital SLR cameras. While this seems like an easy shoot, the two cameras must fire in synch to provide left- and right-eye views for the stereo 3-D effect. The spacing between the camera lenses is...
critical as it should be as close as possible to the interocular distance. The camera lenses need to parallel, perfectly aligned, and critically focused. Complicating things further, all of this must be done at 14,000 feet at the summit of Maunakea, where the air is thin and cameras and computers (and human operators) sometimes behave a bit differently than they do a sea level.

No matter how we do it, audiences need to be wowed by the 3-D — and they are. Most comment that the show made them feel as if they were inside these observatories, and that they could reach out and touch these incredible instruments of discovery.

In addition to the time-lapse footage, datasets from the observatories are used in the program and highlight the discoveries made at these amazing facilities. The datasets are also used for live presentations, and even for special presentations to observatory staff for research purposes. All this is possible thanks to the modern digital planetarium, and in Imiloa’s dome by our Sky-Skan Digital Sky software coupled with the Definiti hardware system.

An Exceptional Transformation

The modern digital dome has dramatically altered the role of a planetarium in its community. It allows us to teach and entertain in new ways. These systems enable live presenters to take audiences on voyages of discovery to astronomical objects, explore positions and motions of objects in the sky, reveal spatial relationships in a dynamic way, and share real astronomical data from observatories.

Of course digital planetariums can playback “standard” astronomical programs, and program sharing (and purchasing) is far more prevalent than it was in the past. But these domes can also offer a great variety of science programming including shows about Earth, life sciences, natural history, music, culture, mathematics, and (of course) pure entertainment.

The digital dome is transforming the planetarium from a place to visit a few times in a lifetime, to one that audiences want to return to again and again. Astronomers and observatory staff have commented that this new technology “now makes the planetarium useful to astronomers...compared to when all planetariums could do was show the constellations.”

If you haven’t been to a digital planetarium, you are missing an exceptional way to explore and learn about our universe. So visit one near you, or come over to the Big Island and check us out!

**SHAWN LAATSCH** is the planetarium manager at the Imiloa Astronomy Center and an officer in the International Planetarium Society. He installed and implemented the world’s first stereo 3-D digital planetarium and is part of the team that develops the 3-D programs that bring the cosmos to life.
Pinning Down the Universe

While confirming previous observations made by WMAP, Planck has revealed some interesting cosmic anomalies.

By ESA and NASA; edited by Paul Deans

This map shows the oldest light in our universe, as detected with the greatest precision yet by the Planck mission. The ancient light, called the cosmic microwave background, was imprinted on the sky when the universe was 370,000 years old. It shows tiny temperature fluctuations that correspond to regions of slightly different densities, representing the seeds of all future structure: the stars and galaxies of today. [ESA and the Planck Collaboration]
In March 2013, scientists with the Planck space mission released the most accurate and detailed map (previous page) ever made of the oldest light in the universe, revealing new information about its age, contents, and origins.

The map results suggest the universe is expanding more slowly than scientists thought and is slightly older than previous estimates. The data also show there is less dark energy and more matter, both normal and dark, in the universe than previously known.

The map is based on the mission’s first 15.5 months of all-sky observations and reveals tiny temperature fluctuations in the cosmic microwave background (CMB), ancient light that has traveled for billions of years from the very early universe to reach us. The patterns of light represent the seeds of galaxies and clusters of galaxies we see around us today.

**Planck Results: The Highlights**

- The universe is 13.82 billion years old, about 100 million years older than previous estimates. Several years ago the WMAP spacecraft provided the best estimate so far: 13.73 +/- 120 million years old. Planck’s data is within WMAP’s uncertainty range, but Planck’s data is considered more accurate.

- The universe is expanding slightly slower than expected. The newly estimated expansion rate, known as the Hubble constant, is 67.15 +/- 1.2 kilometers/second/megaparsec. (A megaparsec is roughly three million light-years.) This is less than prior estimates derived from space telescopes, such as NASA’s Spitzer and Hubble, using a different technique (including Type Ia supernovae) — see page 38.

- The content of the universe has been slightly revised. The new estimate of normal matter (everything we can see) is 4.9%, up from 4.6%. The dark matter content (an invisible substance that can only be seen through the effects of its gravity) is 26.8%, up from 24%. Dark energy (which acts like a pressure, increasing the expansion rate of the universe and pushing the cosmos apart) falls to 68.3%, down from 71.4%.

- The universe appears to be slightly asymmetrical in the average temperatures on opposite hemispheres of the sky. This runs counter to the prediction made by the standard model that the universe should be broadly similar in any direction we look.
“As that ancient light travels to us, matter acts like an obstacle course getting in its way and changing the patterns slightly,” said Charles Lawrence, the US project scientist for Planck at NASA’s Jet Propulsion Laboratory in Pasadena, Calif. “The Planck map reveals not only the very young universe, but also matter, including dark matter, everywhere in the universe.”

The age, contents, and other fundamental traits of our universe are described in a simple model developed by scientists called the standard model of cosmology. These new data have allowed scientists to test and improve the accuracy of this model with the greatest precision yet. At the same time, some curious features are observed that don’t quite fit with the simple picture. For example, the model assumes the sky is the same everywhere, but the light patterns are asymmetrical on two halves of the sky, and there is a spot extending over a patch of sky that is larger than expected.

“One hand, we have a simple model that fits our observations extremely well, but on the other hand, we see some strange features which force us to rethink some of our basic assumptions,” said Jan Tauber, the European Space Agency’s Planck project scientist based in the Netherlands. “This is the beginning of a new journey, and we expect our continued analysis of Planck data will help shed light on this conundrum.”

The findings also test theories describing inflation, a dramatic expansion of the universe that occurred immediately after its birth. In far less time than it takes to blink an eye, the universe blew up by 100 trillion trillion times in size. By showing that matter seems to be distributed randomly, the new map suggests that random processes were at play in the very early universe on minute “quantum” scales. This allows scientists to rule out many complex inflation theories in favor of simple ones.

“Patterns over huge patches of sky tell us about what was happening on the tiniest of scales in the moments just after our universe was born,” Lawrence said.

**Cosmic Microwave Background**

Launched in 2009, Planck has been mapping the CMB, the afterglow of the theorized big bang that created our universe. This relic radiation provides scientists with a snapshot of the universe 370,000 years after the big bang. Light existed before this time, but it was locked in a hot plasma similar to a candle flame, which later cooled and set the light free.

The cosmic microwave background is remarkably uniform over the entire sky, but tiny variations reveal the imprints of sound waves
The Hubble Constant

Why the difference between Planck’s estimate of the Hubble constant and the current estimate based on various other methods?

Martin White, Planck Scientist, University of California Berkeley

This is one of the most exciting hypotheses of the data — the apparent tension between the different ways of estimating how rapidly the universe is expanding, and I suspect that this is going to drive a lot of attention from the [scientific] community during the next year or two. The hope would be that this is actually pointing toward some deficiency in the model, or some extra physics that we’re not aware of, and spark a whole new research direction.

One way of thinking about this is that the way we’re measuring how rapidly the universe is expanding is a little bit different than the way it’s been done previously. What you need to do to figure out how fast the universe is expanding is to measure its size at two different times, and measure the difference in size and the difference in time. We’re starting from the very early universe and trying to extrapolate toward the present. What the people who have published the larger value (73 kilometers/second/megaparsec) are doing is starting at the present time and trying to extrapolate backwards. We’re not quite matching in the middle, and that’s where things get really interesting.

The question then is: what are the assumptions we’re making that are causing this mismatch, and I think that’s something people are going to be investigating for quite some time.

I have a number of suspicions as to why this is so, but perhaps one of the most exciting things could be if the nature of dark energy that we think is causing the accelerated expansion of the universe is different than the simplest model. For example, if the amount of dark energy were somehow increasing with time in a given volume of space, then that would alleviate some of the tension. That’s a pretty radical thing to propose, so this is not something that we should take lightly. But this is the kind of direction one could imagine going to try to alleviate this tension, and that would be really exciting.

This illustration summarizes the almost 14-billion-year-long history of our universe. It shows the main events that occurred between the initial phase of the cosmos (where its properties were almost uniform and punctuated only by tiny fluctuations) to the rich variety of cosmic structure that we observe today, ranging from stars and planets to galaxies and galaxy clusters. [ESA/NASA]
triggered by quantum fluctuations in the universe just moments after it was born. These imprints, appearing as splotches in the Planck map, are the seeds from which matter grew, forming stars and galaxies. Prior balloon-based and space missions learned a great deal by studying these patterns, including NASA’s Wilkinson Microwave Anisotropy Probe (WMAP) and the Cosmic Background Explorer (COBE), which earned the 2006 Nobel Prize in Physics.

Planck is the successor to these satellites, covering a wider range of light frequencies with improved sensitivity and resolution. Its measurements reveal light patterns as small as one-twelfth of a degree on the sky.

Complete results from Planck, which still is scanning the skies, will be released in 2014. All the recent Planck papers can be found online (http://tinyurl.com/73j2y6x). A summary of the results is in Section 9 of Paper I.

Launched on May 14, 2009, as successor to NASA’s Wilkinson Microwave Anisotropy Probe (WMAP), Planck is a European Space Agency mission, with mission-enabling technology for both of Planck’s science instruments contributed by NASA. (ESA)

Planck’s CMB map has allowed scientists to extract the most refined values yet of the universe’s ingredients. Ordinary matter consists of detectable stars and galaxies, dark matter is detected indirectly by its gravitational influence on nearby matter, while dark energy is a mysterious force thought to be responsible for accelerating the expansion of the universe. [Before Planck: based on the WMAP nine-year data release presented by Hinshaw et al (2013). After Planck: ESA and the Planck Collaboration.]

PLANCK is a European Space Agency mission, with significant participation from NASA. European, Canadian, and US Planck scientists worked together to analyze the Planck data. The telescope is orbiting the second Lagrange point of the Earth-Sun system (L2), a point in space located 1.5 million km from Earth. After launch, it took Planck about 60 days to enter its final operational orbit around L2. The observatory settled into an orbit that resembles a halo around L2, with an average amplitude of 400,000 km.
Astronomers Open Window into Europa’s Ocean

With data collected from the W. M. Keck Observatory, California Institute of Technology (Caltech) astronomer Mike Brown and Kevin Hand from the Jet Propulsion Laboratory have found the strongest evidence yet that salty water from the vast liquid ocean beneath Europa’s frozen exterior actually makes its way to the surface.

The data suggests there is a chemical exchange between the ocean and surface, making the ocean a richer chemical environment, and implies that learning more about the ocean could be as simple as analyzing the moon’s surface. The findings were derived from spectroscopy delivered from the Keck Observatory.

“We now have the best spectrum of this thing in the world,” Brown says. “Nobody knew there was this little dip in the spectrum because no one had the resolution to zoom in on it before.”

“We now have evidence that Europa’s ocean is not isolated — that the ocean and the surface talk to each other and exchange chemicals,” says Brown, the Richard and Barbara Rosenberg Professor and professor of planetary astronomy at Caltech. “That means that energy might be going into the ocean, which is important in terms of the possibilities for life there. It also means that if you’d like to know what’s in the ocean, you can just go to the surface and scrape some off.”

Using current technology on ground-based telescopes, Brown and Hand have definitively identified a spectroscopic feature on Europa’s surface that indicates the presence of a magnesium sulfate salt, a mineral called epsomite, that could only originate from the ocean below.

“Magnesium should not be on the surface of Europa unless it’s coming from the ocean,” Brown says.

Astronomers hypothesize that chloride salts bubble up from Europa’s global liquid ocean and reach the frozen surface where they are bombarded with sulfur from volcanoes on Jupiter’s largest moon, Io. This illustration of Europa (foreground), Jupiter (right) and Io (middle) is an artist’s concept. [NASA/JPL-Caltech]
A pair of newly discovered stars is the third-closest star system to the Sun, according to a paper recently published in *Astrophysical Journal Letters*. The duo is the closest star system discovered since 1916. The discovery was made by Kevin Luhman, an associate professor of astronomy and astrophysics at Penn State University and a researcher in Penn State’s Center for Exoplanets and Habitable Worlds.

Both stars in the new binary system are “brown dwarfs,” which are stars that are too small in mass to ever become hot enough to ignite hydrogen fusion. As a result, they are very cool and dim, resembling a giant planet like Jupiter more than a bright star like the Sun.

“The distance to this brown dwarf pair is 6.5 light-years — so close that Earth’s television transmissions from 2006 are now arriving there,” Luhman said. “It will be an excellent hunting ground for planets because it is very close to Earth, which makes it a lot easier to see any planets orbiting either of the brown dwarfs.” Since it is the third-closest star system, in the distant future it might be one of the first destinations for manned expeditions outside our solar system, Luhman said.

Astronomers have long speculated about the possible presence of a distant, dim object orbiting the Sun, which is sometimes called Nemesis. However, Luhman has concluded, “we can rule out that the new brown dwarf system is such an object because it is moving across the sky much too fast to be in orbit around the Sun.”

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Kepler Discovers its Smallest ‘Habitable Zone’ Planets
NASA/Ames Research Center

MORE INFORMATION: http://tinyurl.com/chr4793

NASA’s Kepler mission has discovered two new planetary systems that include three super-Earth-size planets in the “habitable zone,” the range of distance from a star where the surface temperature of an orbiting planet might be suitable for liquid water.

The Kepler-62 system has five planets; 62b, 62c, 62d, 62e and 62f. The Kepler-69 system has two planets; 69b and 69c. Kepler-62e, 62f and 69c are the super-Earth-sized planets.

Two of the newly discovered planets orbit a star smaller and cooler than the Sun. Kepler-62f is only 40 percent larger than Earth, making it the exoplanet closest to the size of our planet known in the habitable zone of another star. Kepler-62f is likely to have a rocky composition. Kepler-62e, orbits on the inner edge of the habitable zone and is roughly 60 percent larger than Earth.

The third planet, Kepler-69c, is 70 percent larger than the size of Earth, and orbits in the habitable zone of a star similar to our Sun. Astronomers are uncertain about the composition of Kepler-69c, but its orbit of 242 days around a sun-like star resembles that of our neighboring planet Venus.

“We only know of one star that hosts a planet with life, the Sun. Finding a planet in the habitable zone around a star like our Sun is a significant milestone toward finding truly Earth-like planets,” said Thomas Barclay, Kepler scientist at the Bay Area Environmental Research Institute in Sonoma, Calif.
Supernova Remnants Produce Cosmic Rays

NASA/Goddard Spaceflight Center

MORE INFORMATION: http://tinyurl.com/baoupj4

A new study using observations from NASA’s Fermi gamma-ray space telescope reveals the first clear-cut evidence the expanding debris of exploded stars produces some of the fastest-moving matter in the universe. This discovery is a major step toward understanding the origin of cosmic rays, one of Fermi’s primary mission goals.

“Scientists have been trying to find the sources of high-energy cosmic rays since their discovery a century ago,” said Elizabeth Hays, a member of the research team and Fermi deputy project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Md. “Now we have conclusive proof supernova remnants, long the prime suspects, really do accelerate cosmic rays to incredible speeds.”

Cosmic rays are subatomic particles that move through space at almost the speed of light. About 90 percent of them are protons, with the remainder consisting of electrons and atomic nuclei. In their journey across the galaxy, the electrically charged particles are deflected by magnetic fields. This scrambles their paths and makes it impossible to trace their origins directly.

Through a variety of mechanisms, these speedy particles can lead to the emission of gamma rays, the most powerful form of light and a signal that travels to us directly from its sources.

The Fermi results concern two particular supernova remnants, known as IC 443 and W44, which scientists studied to prove supernova remnants produce cosmic rays. IC 443 and W44 are expanding into cold, dense clouds of interstellar gas. These clouds emit gamma rays when struck by high-speed particles escaping the remnants.

Scientists previously could not determine which atomic particles are responsible for emissions from the interstellar gas clouds because cosmic ray protons and electrons give rise to gamma rays with similar energies. After analyzing four years of data, Fermi scientists see a distinguishable feature in the gamma-ray emission of both remnants.

This multi-wavelength composite shows the supernova remnant IC 443, the Jellyfish Nebula. Fermi GeV gamma-ray emission is shown in magenta, optical wavelengths as yellow, and infrared data from NASA’s Wide-field Infrared Survey Explorer mission is shown as blue (3.4 microns), cyan (4.6 microns), green (12 microns), and red (22 microns). Cyan loops indicate where the remnant is interacting with a dense cloud of interstellar gas. [NASA/DOE/Fermi LAT Collaboration, NOAO/AURA/NSF, JPL-Caltech/UCLA]
New Insights on How Spiral Galaxies Get Their Arms

Harvard-Smithsonian Center for Astrophysics

MORE INFORMATION: http://tinyurl.com/bvk4q2h

Spiral galaxies are some of the most beautiful and photogenic residents of the universe. Our own Milky Way is a spiral. Our solar system and Earth reside somewhere near one of its filamentous arms. And nearly 70 percent of the galaxies closest to the Milky Way are spirals.

But despite their common shape, how galaxies like ours get and maintain their characteristic arms has proved to be an enduring puzzle in astrophysics. How do the arms of spiral galaxies arise? Do they change or come and go over time?

The answers to these and other questions are now coming into focus as researchers capitalize on powerful new computer simulations to follow the motions of as many as 100 million “stellar particles” as gravity and other astrophysical forces sculpt them into familiar galactic shapes. A team of researchers from the University of Wisconsin-Madison and the Harvard-Smithsonian Center for Astrophysics reports simulations that seem to resolve long-standing questions about the origin and life history of spiral arms in disk galaxies.

“We show for the first time that stellar spiral arms are not transient features, as claimed for several decades,” says UW-Madison astrophysicist Elena D’Onghia, who led the new research along with Harvard colleagues Mark Vogelsberger and Lars Hernquist.

“The spiral arms are self-perpetuating, persistent, and surprisingly long lived,” adds Vogelsberger.

The origin and fate of the emblematic spiral arms in disk galaxies have been debated by astrophysicists for decades, with two theories predominating. One holds that the arms come and go over time. A second is that the material that makes up the arms is affected by differences in gravity and jams up, like cars at rush hour, sustaining the arms for long periods.
ASP Annual Conference Update
In 2013, the ASP celebrates our 125th premier gathering of educators and public outreach professionals from across North America and abroad. Via workshops, lectures, panels, discussions, and exhibits, more than 200 specialists from across the science spectrum will collaborate to explore best practices and research findings, trends, and professional development opportunities.

The conference will be held in San Jose, CA, the nation’s center of gravity for STEM literacy and industry. The conference will run from July 20–24, 2013, with the theme “Ensuring STEM Literacy.”

This year our conference features two streams. In one, professionals working in Education and Public Outreach (E/PO) and science communication in astronomy, Earth and space science, and related fields, are invited to consider how best to share the results of their work with each other and the public, how to improve their practice, and how to make connections across science disciplines. In the other, we ask: how can we do a better job with introductory astronomy, planetary science, astrobiology, and geoscience courses? Much of the symposium will be in the format of small-group sessions, where we will practice effective techniques for reaching students.

Here are the conference threads:

**Education & Public Outreach (E/PO) Conference**
- Employing 21st Century Media and Technology
- Developing Multicultural and Cross-Cultural Initiatives
- Addressing Misconceptions & Conceptual Change
- Evaluating and Assessing E/PO Programs and Products
- Using Authentic Science and Citizen Science
- Improving Our Professional Practice

**Cosmos in the Classroom**
- Managing Learning in Laboratories, Planetariums, and Observatories
- Developing and Delivering Online Courses
- Incorporating New Classroom Technology
- Sharing Education Research Studies
- Integrating New Science Discoveries into Courses
- Applying Innovations and Great Ideas for the Classroom

We are also pleased to announce that Dr. Natalie Batalha, Assistant Professor of Physics & Astronomy at San Jose State University, co-Investigator for NASA’s Kepler Mission, and Director of the Systems Teaching Institute at the NASA Research Park, will present the keynote plenary address on Monday, July 22.

Last but not least, the ASP will host a special “Sunday Science Talks” on the afternoon of July 21, preceding the Welcome Reception. Hear from leading scientists about the latest in their fields!

You can learn more about the conference, including information...
about registration and lodging, and sign up for further information and updates as they become available, on our 125th Annual Meeting webpage: http://astrosociety.org/meeting.

**Remembering Don Wentzel**
The staff and board of the ASP extends condolences to the family of Donat “Don” Wentzel (1934–2013), a 38-year active member of the organization, very generous donor, and past member of the ASP Advisory Council.

Don was an expert on the physics of the Sun, and authored the popular 1989 book *The Restless Sun*, named Book of the Year by the ASP. He taught the first Astro 101 course at the University of Maryland, and influenced generations of non-science majors as well as teaching assistants who learned to teach under his tutelage. Don became increasingly interested in astronomy education on a national level, and through his leadership and kindness, he served as a mentor for many people seeking to find a meaningful way to contribute to astronomy education. He obtained grants and encouraged a variety of projects around the country with funding and guidance. In the 1970s, when the ASP was growing and enhancing its education programs, Don spent time with Andrew Fraknoi and others on staff, freely giving advice, pointing to potential funding sources, and encouraging new ideas in reaching students and the public.

The ASP was an early participant in the AAS Astronomy Education Task Group that Don co-founded in 1972 and helped lead, which established the roots of the ASP’s success in today’s education and public outreach (E/PO) network.

Don was also an important voice at the beginning of ASP projects such as our syndicated newspaper column on astronomy, the first workshops on effective astronomy teaching (ultimately leading to our Project ASTRO program), and student reasoning ability. He was dedicated to encouraging and supporting the growth of astronomy around the world, especially in developing regions, and traveled to countries including China, India, Vietnam, and Egypt to lead summer schools and workshops.

The ASP is truly fortunate to have had Don in our universe for so many years. We are grateful that his spirited star shone brightly for as long as it did, and he will be missed. You can read more about Don in the [Washington Post](http://astrosociety.org/meeting).

**Fraknoi Wins Faraday Science Communicator Award**
Andrew Fraknoi, the chair of the Astronomy Department at Foothill College in Los Altos Hills, California, and a former executive director of the ASP, has won the 2013 Faraday Science Communicator Award from the National Science Teachers’ Association (NSTA), given each year to an individual who has inspired and elevated the public’s interest in science.
The award is named in honor of Michael Faraday (1791–1867), the British physicist whose pioneering experiments are the basis for our understanding of electricity, magnetism, and the relationship between the two. In addition to his work in basic science, Faraday was known as a clear writer and dynamic lecturer, who devoted much effort to explicating the scientific ideas and discoveries of his time to non-scientists.

“I am especially honored to receive this award because Michael Faraday is one of my scientific heroes,” Fraknoi said. “I teach about him in my ‘Physics for Poets’ evening class, and I have always admired his legendary dedication to explaining science to the wider public.”

Fraknoi has spent much of his 40-year career on both college-level teaching and the popularization of science. Before coming to Foothill College, Fraknoi served for 14 years as the executive director of the Astronomical Society of the Pacific. While there, he created Project ASTRO, a program that trains and links volunteer astronomers with 4th-9th grade teachers in regional centers around the country, and Family ASTRO, which provides games and kits that allows families with children to enjoy astronomy together. He also organized a series of workshops and conferences about the teaching of astronomy, both at the K–12 and college level, and developed a collection of classroom astronomy activities (The Universe at Your Fingertips), which is used in educational settings around the world.

For a more extensive description of Fraknoi’s work, go to the Foothill College press release.

Galileoscopes Now at the ASP
The Galileoscope is a high-quality, low-cost telescope kit developed by a team of leading astronomers, optical engineers, and science educators. No matter where you live, with this easy-to-assemble, 50-mm (2-inch) diameter, 25- to 50-power achromatic refractor, you can see the celestial wonders that Galileo Galilei first glimpsed 400
years ago and that still
delight stargazers today. 
These include lunar craters
and mountains, four moons
circling Jupiter, the phases
of Venus, Saturn’s rings, and
countless stars invisible to
the unaided eye. The Galileoscope is augmented with educational
activities and related materials for use by classroom teachers, plane-
tarium presenters, astronomy-club members, and anyone else eager
to share the treats of the telescopic sky with others. You can find the
Galileoscope for sale at the ASP’s AstroShop.

NEW MEMBERS — The ASP welcomes new members who joined between January 1 and March 31, 2013.

Technical Membership
Mark Biersack, Rocklin, CA
Gerald Grupsmith, Daly City, CA
Mark Hamel, Universal City, TX
Pascal Lee, Moffett Field, CA
Alice Peyvahouse, Pacifica, CA
Keith Wancowicz, Springfield, VA
Tom Wilbur, Arnold, MD

General Membership
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Timothy Dave, Hayward, CA
Julia DeMarines, Denver, CO
Natalie Finn, Chicago, IL
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Richard Gauthier, Santa Rosa, CA
Catherine J. Grier, Columbus, OH
Blythe C. Guvenen, Tucson, AZ
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Jennifer Jipson, Shell Beach, CA
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Shinonee Kadakia, Redondo Beach, CA
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Justin R. Mason, Chesapeake, CA
Scott McMillan, Templeton, CA
Bonnie K. Meinke, Baltimore, MD
Richard J. Mergen, Spring Branch, TX
Andi Nelson, Chicago, IL
Claire Raftery, Berkeley, CA
Jocelyn Read, Fullerton, CA
Mary Roach, Oakland, CA

Rikki Shackelford, Berkeley, CA
Linda Strubbe, Toronto ON, Canada
Nicholas Walton, Cambridge, United Kingdom

Family Membership
Stephanie Wright, Rehoboth, DE

Student Membership
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Yu (Sophia) Dai, Cambridge, MA
William A. Dawson, Dixon, CA
Shane Frewen, Los Angeles, CA
Or Graur, New York, NY
Sebastien Guillot, Montreal QC, Canada
Li-Wei Hung, Los Angeles, CA
Meagan Morscher, Evanston, IL
Mark Mozena, Santa Cruz, CA
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Abhijith Rajan, Tempe, AZ
Meredith L. Rawls, Las Cruces, NM
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Prabal Saxena, Fairfax, VA
Chelsea E. Sharon, Piscataway, NJ
Aomawa L. Shields, Seattle, WA
Julie N. Skinner, Hanover, NH
Kimberly R. Sokal, Charlottesville, VA
Allison L. Strom, Pasadena, CA
Johanna Teske, Tucson, AZ
Amy Tulay, Weatherly, PA
Kimberly D. Ward-Duong, Tempe, AZ
Elizabeth J. Young, Princeton, NJ

All proceeds from product sales support the mission
and education programs of the ASP
THE ASTRONOMICAL SOCIETY OF THE PACIFIC WISHES TO THANK the following organizations and individuals for their generous philanthropic support. This list reflects gifts and grants received between March 1, 2012, and February 28, 2013. Funds raised support the ASP’s mission to foster scientific curiosity, advance science literacy, and share the joy of exploration and discovery — to encourage tomorrow’s science, technology, and academic leaders.

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($5,000–$24,999)
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by Paul Deans

The Skies of May
After suffering through a paucity of planets in the sunset sky during the first few months of 2013, our patience is rewarded this month. Jupiter is rapidly sinking into the west, while Venus and Mercury rise up to greet it.

At the start of the month, Jupiter sets about three hours after the Sun. By month’s end, the Sun/Jupiter setting-time separation is a mere hour. Meanwhile, Venus is rising up from the solar glare, and by the 11th it sets about an hour after the Sun. The 11th is also when you might be able to spot — about 30 minutes after sunset — a very thin crescent Moon (approximately 40 hours old; you may need binoculars to see it) in between brilliant Venus (below it) and bright Jupiter (above). The next night the lunar crescent will be to Jupiter’s upper left.

During the next two weeks Venus climbs and Jupiter sinks. But wait. At dusk on May 24th, find brilliant Venus and look to that planet’s upper right. In the field of view of binoculars will be dim Mercury. On the 26th (start looking about 30 minutes after sunset), these three planets will create an equilateral triangle, roughly 2º on a side, low in the west.

Finally, on the 27th and 28th, Jupiter passes about 1º to the left of Venus. It’s too bad all this happens very low in sky — you’ll need a low, flat, and clear western horizon to catch all the action.

As for the other two naked-eye planets, Mars is still hidden in the Sun’s glare. However Saturn is high in the southeast at dusk and hangs around pretty much all night, setting near dawn. On the 22nd, Saturn is to the upper left of the nearly full Moon as darkness falls.

An annular eclipse of the Sun occurs on May 10th. The path of annularity (above) begins in northern Australia, touches some of the Solomon Islands, and then sweeps across the South Pacific. More information is available on this NASA eclipse website. Two weeks...
later, there’s a penumbral eclipse of the Moon. However, it’s so minor, with the Moon barely grazing the Earth’s outer shadow, that this eclipse is listed here merely for completeness. Even meticulous observers will notice nothing out of the ordinary at mid-eclipse (00:10 Eastern time on the 25th; 21:10 Pacific time on the 24th).

The Skies of June
As the month opens, Jupiter continues its slide toward the Sun, and by mid-month it’s lost in the glare of sunset. However, Venus manages to stay ahead of the Sun, setting in the west-northwest about 90 minutes after sunset for most of June. Even though it’s low, it’s impossible to miss if you have a decent western horizon — shining at magnitude -3.9, it’s a sparkling white beacon amid the colors of sunset.

And then there’s Mercury. It, too, was visible in late May, and as June opens, it’s still in the west-northwest as dusk descends. Look for it (as a dim point of light) about 4° to the upper left of Venus; binoculars will be needed during twilight. It’s best if you seek it out during the first week of June, when Mercury will be at its highest and brightest.

On the 10th, the two-day-old crescent Moon appears to the left of Venus — a beautiful sight indeed. On the 18th, 19th, and 20th, Mercury sits less than 2° to the lower left of Venus, but its brightness is fading rapidly. It is also sinking back toward the Sun, and it’ll be lost in the solar glare by month’s end.

This Mercury/Venus conjunction in the west is one of the better ones to come along in quite some time. The next nice conjunction of these inner planets doesn’t occur until early January 2015.

As for the remaining two naked-eye planets, Mars remains hidden by the Sun, but Saturn shines high in the south at dusk. These warm months of summer are a fine time to take out your telescope and explore Saturn, its rings, and as many moons as you can find. (Its largest moon, Titan, is easily spotted in a small telescope.) On the 18th Saturn is to the Moon’s upper left; on the 19th to Luna’s upper right.

The Summer Solstice occurs at 5:04 Universal Time on June 21st, which translates to before local midnight on the 20th in the Mountain time zone and points west, but after local midnight on the 21st in the Central time zone and points east.

The Skies of July
At last. For those who are early risers, there’s finally something to see in the morning sky. Both Jupiter and Mars have emerged from the glare of the Sun.

At the start of the month, Mars rises more than an hour before the Sun, but it’s faint and challenging to see. You might spot it on the 6th as dawn brightens, because it’ll be to the upper right of the thin crescent Moon. But Jupiter, to the Moon’s lower left, is brighter and likely more obvious. If you find and follow Jupiter, look carefully on the mornings of the 21st and 22nd. Dim Mercury will be less than 1° to the left of the giant planet — the pair can be seen together in the field of view of a low-power telescope.
And there’s a bonus: Mercury is rising. It hangings below Jupiter for the final two weeks of July. On the 30th it rises nearly 90 minutes before the Sun, and is about 10º high in the east-northeast 30 minutes before sunrise.

Meanwhile, Venus continues to brighten the dusk sky, though it never appears very high after sunset. It sets some 90 minutes after the Sun, but even at sunset it’s little more than 15º above the western horizon. Still, at a magnitude of -3.9, it’s impossible to miss if the western skies are clear. Look for a crescent Moon to the lower left of Venus on the 10th and to the far left of the planet on the 11th.

Finally, Saturn is still reasonably high in the southwest after sunset. This ringed planet is upper right of the Moon on the 16th.

**Looking Ahead**

And just a reminder, keep the August Perseid meteor shower in mind as you plan your summer vacation. The shower peaks during the night of August 12th; the best block of time is from 11 pm on the 11th until dawn on the 12th (that’s Sunday night to Monday morning). There’s no Moon to interfere with your enjoyment of this annual shower, so plan to be somewhere dark that evening to watch for the 60-plus meteors per hour that often grace the summer sky at this time. (The night of the 10th/11th is pretty good, too.) In 2014 the Moon is just past full on Perseid night (not good), so 2013 is the better year for these meteors.

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**S&T Sky Charts**

Thanks to *Sky & Telescope* magazine, *Mercury* readers have direct access to S&T’s online Interactive Sky Chart, which 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. If you have trouble getting the Sky Chart to open on your computer, please review S&T’s detailed system requirements and their Help page. Note that Java must be enabled on your browser.

**Links to Sky & Telescope’s Interactive Star Chart:**

May • June • July

These links will take you to a chart set for 40º north latitude and 100º west longitude (useful throughout the continental US) at 10:00 pm local time at midmonth in May, June, and July 2013. The chart can be used one hour later at the start of each month and one hour earlier at month-end.

You can alter the chart’s date, time, and location — detailed instructions and hints for using the chart can be found on the Help page. To really become familiar with this program, see the article: Fun with S&T’s Interactive Sky Chart.

**For iPad Users**

S&T’s Interactive Sky Chart does not work on the iPad; try the SkySafari 3 app (through iTunes). Here is a review. If ASP iPad users have another favorite, please tell me about it.

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Dishes in the Desert

On March 13, 2013, the Atacama Large Millimeter/submillimeter Array (ALMA), was inaugurated. This aerial view shows the Chajnantor Plateau, at an altitude of 5,000 meters in the Chilean Andes, where the 66 antennas of the ALMA array are located. [Clem & Adri Bacri-Normier/ESO]