The Astronomical Society of the Pacific Invites Nominations for the Society’s 2012 Awards

AMATEUR ACHIEVEMENT AWARD
significant observational or technological contributions to astronomy by an amateur astronomer

THOMAS J. BRENNAN AWARD
dedication to teaching astronomy at the high school level

RICHARD H. EMMONS AWARD
dedication to teaching introductory astronomy at the college level

KLUMPKE-ROBERTS AWARD
contributions to the public understanding and appreciation of astronomy

LAS CUMBRES AMATEUR OUTREACH AWARD
educational outreach by an amateur astronomer

MARIA & ERIC MUHLMANN AWARD
innovative advances in astronomical instrumentation, software, or observational infrastructure

ROBERT J. TRUMPLER AWARD
PhD research considered unusually important to astronomy

Further details, submission information, and past recipients can be found on our website:
http://www.astrosociety.org/membership/awards/awards.html
ASP Posters from Baltimore: A Sample

Here are five of the 71 posters that were presented at the 2011 ASP Conference in Baltimore. All the conference posters, oral presentations, and workshops, will appear in the Conference Proceedings, available by mid-2012.

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Thinking and Acting Like Scientists: Inquiry in the Undergraduate Astronomy Classroom
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That First Telescope

A number of years ago I edited SkyWatch (an annual publication of Sky Publishing). Some issues included a hefty telescope-buyer’s guide with more than 100 scopes. The market has grown even more crowded since then, and these days, there’s a tremendous amount of choice when it comes to telescopes.

Regardless of this variety, there’s a basic philosophy that should be adhered to when buying a scope for a first-time user, and it has nothing to do with a telescope’s price or power or size. Specifically, the best telescope for a budding astronomer is...(drum roll, please)...the one that will be used most often.

Okay, maybe that’s a little anti-climactic and obvious, but consider. How many “can’t miss” Christmas presents from your past have ended up permanently residing on a shelf in a closet, or in the garage, or packed into the car heading for a Goodwill store? I rest my case.

But seriously. What’s the point of giving a 14-year-old a 50-pound scope that requires assembly and disassembly each time it’s used? And a long-tube refractor or a beautiful but oversized reflector isn’t much good to somebody living in an apartment with a small balcony. (Remember, it’s a first scope for an inexperienced user.)

What will get used? A reasonably portable, good quality, go-to (a.k.a. computerized) telescope. That computer will help the novice find sights to see, especially in a light-polluted sky.

How do you find such a gem? If there’s a telescope shop in your town (or a camera store that sells them), find a clerk who knows about scopes. Or enlist the aid of someone at your local astronomy club, planetarium, or science center. Whatever you do, do not buy blind from an online retailer or cheaply (in a case of the wobbles when trying to observe sky sights. And if you do order a scope (vs. buying one in a store), be certain the company has a good return policy.

Very important: ensure the mount is solid. There’s nothing worse than a mount with the case of the wobbles when trying to observe sky sights. And if you do order a scope (vs. buying one in a store), be certain the company has a good return policy.

Still not sure? Consider buying quality binoculars, especially image-stabilized ones. They’re expensive but are also great for terrestrial purposes.

Yes, I have a bigger scope, but this portable 4.5-inch reflector is the one I use most.

Reflector (mirror) vs. refractor (lens)? It doesn’t matter. Choose based on aperture (the size of the main lens or mirror), price, and portability. What’s portable? A scope that can be carried outside in one or two pieces and quickly assembled.

Very important: ensure the mount is solid. There’s nothing worse than a mount with the case of the wobbles when trying to observe sky sights. And if you do order a scope (vs. buying one in a store), be certain the company has a good return policy.

Still not sure? Consider buying quality binoculars, especially image-stabilized ones. They’re expensive but are also great for terrestrial purposes.

Paul Deans
Editor, Mercury
Reaching

Does our reach no longer exceed our grasp?

I live in Pacifica, California, which boasts of being the “fog capital of the world” — and I believe it. The summer climate pattern especially keeps a marine layer of fog and clouds just off the coast and sweeping inland for long stretches. It means that we don't have many starry nights in July and August.

So it was a treat one evening, driving home along the coast at the very beginning of September, to actually see a clearing sky. To my delight, just as I cleared a stand of cypress along the road, I suddenly spied a breath-catching crescent Moon, pure white, over a long, leaden cloud stretching out to sea. Such crescent moons, suddenly seen in the deepening sky of dusk, never cease to startle and please me.

This time, the sight also made me think of an exercise the education staff was conducting with our Astronomy from the Ground Up (AFGU) network of informal educators at museums and science centers. In anticipation of the International Observe the Moon Night, scheduled for October 8th (for which the ASP was partnering with a group of other organizations, engaging AFGU and the Night Sky Network to hold Moon-observing sessions), they had been asking the group what the Moon meant to them — personally. Answers had flooded in — it was the first object they'd seen through a telescope, its changing phases had turned them on to astronomy as children, and so on.

It was a question that I pondered myself, and one that came back to me several times that same lunation.

A little more than a week later, the Moon had waxed to nearly full, and I was in Yellowstone National Park on a brief camping trip. And the question popped up again as I wandered the boardwalks one night at Midway Geyser Basin, where moonlit gouts of steam rose from Excelsior Geyser and Grand Prismatic Pool, like incense rising to heaven. And again just two nights later, as I watched dusk deepen from the roaring brink of the Lower Falls at the head of the Grand Canyon of the Yellowstone, and caught the full Harvest Moon peep golden over the forested rim of the canyon, itself golden in the fading light of day.

And I had my answer. To me, the Moon has always been a companion — not just to the Earth, but to me, punctuating my nights like an old friend, shining down with its Mona Lisa smile, a regular if cycling fixture in my own industries and adventures on this Earth.

But that's a very personal perspective; I also think it means much more.

"Ah, but a man's reach should exceed his grasp, or what's a heaven for?" wrote Robert Browning. And he was right. The Moon keeps us looking up, keeps us reaching, aspiring for something beyond ourselves. Would humanity's reach toward space have happened as quickly had not the Moon floated in our nighttime sky, a new world almost within our grasp?

It wasn't considered an easy prize. The Indonesians had a saying, "Like an owl craving for the moon," meaning to wish for something impossible. It was a widely held sentiment. Frederick Shackelford, in his 1934 book Earth and Sky Trails, wrote, “I think you will agree with me that a trip to the moon is quite a fantastic idea with things as they are now. It is extremely doubtful if man with all his ability to overcome difficulties will ever be able to make this journey.”

But things changed. Thirty-five years after Shackelford's pronouncement, we planted the first human footprints on its dusty face. And everything seemed possible.

But then, things changed again. Next year, it will be 40 years since we last planted footprints on the Moon (Apollo 17), and the US space program currently seems in a state of pause. There are no longer plans to return to the Moon. Mars has been put off for a generation. The shuttles are permanently grounded, access to the International Space Station is threatened by recently balky Russian
Soyuzes, the James Webb Space Telescope and its proportionate chunk of the NASA science budget is threatened by a balky US Congress, and while there are still plans, US space policy seems to change on a dime with every election.

Other nations — Russia, China, India, Japan, the Europeans — may continue their own quests. But what's happened to the US? The words of Shakelford come back to haunt us: “I think you will agree with me that a trip to the moon is quite a fantastic idea with things as they are now.” The Moon has become both familiar and remote once again.

Yet it still shines, reminding us that science and technology are the drivers of both economies and civilizations. And that the nations that continue to advance these enterprises, and continue to inspire and raise science and technology workforces, will be the ones at the forefront of our species' advance. Despite the current economic and politic climates, which we must presume are temporary, we should ask ourselves if this is the time we should be pulling back on our investment in the future.

For several days after Yellowstone, lingering in Montana before returning to the cloudy skies of Pacifica, I watched the Moon continue to display its quick-rise Harvest Moon effect each evening. They say that farmers used the light of the Moon at this time of year to continue their labors in the field after sunset.

I see that as a metaphor for the ASP as well. We continue our labors every day, as long as we have the light, to use astronomy to communicate, educate, and inspire others about the value of science in our lives, and to encourage greater science literacy and consideration of science careers among the young. Why? To do our part to secure the future for us all. We thank you for your support in this endeavor, and for making a difference.

So what does the Moon mean to you? Take time to look the next time it’s up on a clear night. Its changing phases may mimic our changing fortunes on the Earth, but remember that while the Moon may wane, it always waxes back to full. It reminds us to keep reaching.

JAMES G. MANNING is the Executive Director of the Astronomical Society of the Pacific.

This Lunar Reconnaissance Orbiter image of the Apollo 17 landing site shows the tracks laid down by the lunar rover (LRV), along with the last foot trails left on the Moon. The images also show where the astronauts placed some of the scientific instruments (ALSEP) that provided the first insight into the moon’s environment and interior. For more views of the Apollo landing sites, see NASA’s Apollo Revisited webpage.
30 Years Ago: Our Bigger and Better Galaxy

Our view of the Milky Way has changed dramatically since 1981.

In *Mercury* for Sept.-Oct. 1981, Bart Bok wrote an article about our Milky Way galaxy. He described recent studies of the Milky Way and concluded that: “our Galaxy is bigger and better — and certainly even more interesting — than we had suspected.” Thirty years later, this continues to be true.

Born in The Netherlands, Bart Bok (1906–83) was widely known for his work on the Milky Way at Harvard, Mount Stromlo Observatory in Australia, and the Steward Observatory in Arizona. In 1952 he became involved in radio astronomy, as well as continuing his support for optical astronomy and large telescopes. He was also known as an outstanding popularizer of astronomy, and his book *The Milky Way* (co-authored with his wife Priscilla in 1941) went through five editions, the last in 1981.

The general picture of our Galaxy that had emerged by around 1975 was of a flat system of stars, gas, and dust, with a central bulge of old red giant stars, and spiral arms containing the younger stars and star-forming material. The total mass of the Galaxy was about 200 billion solar masses. The Sun was one of about 100 billion stars, located in a spiral arm about 30,000 light-years from the center. Surrounding this flat disk was a spherical halo of globular star clusters. But as Bok reported in his article, “soon after [1974], the rumblings of changes to come started to be heard.”

In 1976 Jeremy Ostriker and colleagues found that our Galaxy was unstable, and that in order not to fall apart, “it had to be encased in a vast, possibly very rarified, outer halo — what we may call a corona.” They suggested “that the diameter of the corona would be three or more times that of our traditional Home Galaxy and that its total mass might well exceed the old estimated mass of 200 billion suns by a factor of 5 to 10!”

Other studies on the motions of stars in our Galaxy (and in other galaxies) suggested the presence of unseen matter in the outer regions. Both radio and optical results showed that the speeds of stars and hydrogen clouds increased out to about 20 kiloparsecs (65,000 light-years), rather than decreasing as would be expected if most of the galactic mass were concentrated near the center. So there must be a lot of mass out there, and the revised figure for the mass of the Galaxy became 2,000 billion solar masses, or about 10 times the previous value.

Bok concluded by asking: “What is the stuff that populates the thin outer parts of our Galaxy?” And he answered, “Frankly, I do not know, and I do not think that anyone has a clue.” He mentioned various speculations (tiny, faint old stars, or possibly little black holes, or many neutrinos left over from the Big Bang), but “we seem reasonably certain that there is a lot of hidden stuff between distances of 15,000 to 100,000 parsecs from our galactic center.”

Since that time, much more has been learned about the Milky Way. The center seems to harbor a supermassive black hole (of about four million solar masses), as do many galaxies. It is also now thought that our Galaxy is a barred spiral, with a nuclear bar (outlined by red giant stars) between 3,000 and 16,000 light-years long. This is surrounded by a ring, which contains a lot of hydrogen gas and is an active star-forming region. Beyond this is the disk of complex spiral arms, outlined by bright, hot, blue stars and more gas and dust. In all there are probably 200 to 400 billion stars in the Galaxy.

Surrounding the disk is the visible spherical halo, with globular star clusters extending up to 200,000 light-years or more from the center. As Bok noted, the speeds of stars indicate unseen mass in the outer regions, which is one of the strong arguments for the existence of dark matter. We now believe that the Galaxy has a spherical halo of dark matter — its nature is unknown, but its total mass is greater than the visible mass of the Galaxy. Also, the disk of the Galaxy is warped by gravitational interaction with its neighboring small companion galaxies, the Magellanic Clouds.

So Bok was indeed right about how interesting the Galaxy is and will continue to be.}

*KATHERINE BRACHER* taught astronomy at Whitman College in Walla Walla, WA, 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.
annals of astronomy

by Clifford J. Cunningham

Hevelius at 400

Ignored for centuries, Hevelius should be remembered as one of Europe’s greatest astronomers.

Loyal readers of this column, which I have been writing for a decade, will know that I enjoy marking the birthdays or deaths of celebrated astronomers. These have included the 300th birthday of Euler in 2007, the 400th anniversary of the death of John Dee in 2008, and the 500th birthday of Reinhold earlier this year. The year 2011 also marks a 400th birthday — that of the great Polish astronomer Johann Hevelius.

Aside from trips to Holland, England, and France in the early 1630s, Hevelius spent his entire life in Gdansk, Poland. His job as a city councilor gave him sufficient funds to build an observatory in the early 1640s. It’s not unusual today for wealthy people to build their own observatories, but this one was special — it was the very first telescope observatory in Europe!

With money inherited from his father in 1649, Hevelius went on to build telescopes of a size no one had ever imagined before. His telescopes started at six- to 12-feet long, then 20-, 60-, 70-, and eventually 150-feet long! They looked unlike anything recognizable today, because they had no tubes — the objective lens of the 150-foot was mounted on a mast 90 feet high.

He first turned his instruments on the Sun, deriving a rotation period based on sunspot observations from 1642–45. Next Hevelius took on the Moon, producing a book (Selenographia) in 1647 with 250 descriptions of lunar features and 133 copper plates made by his own hand. Terms such as “mare” and “sinus” seen on modern lunar maps are words he used first.

By the 1660s he had turned his attention to comets, producing two books that listed every comet observed up to 1665. Next Hevelius took on the Moon, producing a book (Selenographia) in 1647 with 250 descriptions of lunar features and 133 copper plates made by his own hand. Terms such as “mare” and “sinus” seen on modern lunar maps are words he used first.

By the 1660s he had turned his attention to comets, producing two books that listed every comet observed up to 1665. He discovered Nova Cygni 1670 and four comets, and theorized cometary paths are typically parabolic — another novel idea. His greatest work came in 1673 — Machina Coelestis contains an outline of the entire history of astronomy.

With all these accomplishments, one would think Hevelius to be the most celebrated astronomer in Europe, but jealousy was afoot. Most of his astonishingly accurate observations were done with metallic instruments such as quadrants that employed no lenses at all. Could these results be real, or was he faking it? The prominent English scientist Robert Hooke had no doubt it was fakery, and as Secretary of the Royal Society, his attacks were seriously considered.

The Royal Society dispatched its best man — none other than Edmond Halley — to find out. Halley stayed at Gdansk for two months in 1679, and in a series of observations made with Hevelius, his accuracy of one-half minute of angle was fully vindicated.

But just two months after Halley departed and as Hevelius was basking in his victory, his entire observatory and his home burnt to the ground. The disaster destroyed almost all records of his scientific efforts. Arson has always been suspected as the cause. Remarkably, Halley never sent Hevelius a letter of regret for what had transpired, and actually criticized Hevelius’ last published work in 1685 — a summary of his 49 years of labor in the service of astronomy.

Hevelius died in 1687 but his contributions to astronomy did not end. Around 1690 his widow brought out an edition of the star atlas he had been working on at the end of his life. It became the first star atlas to give positions in equatorial coordinates, a system later universally accepted. He created the constellations Sextans and Scutum, still used today.

In modern times Hevelius has been commemorated with a lunar crater 115 kilometers in diameter, and asteroid 5703 Hevelius. But even in Poland his fame is not preeminent. At the site of his residence in Gdansk, a plaque records he was the “the most famous, after Nicholas Copernicus, astronomer in the Republic of Poland.” Attacked in his lifetime and largely ignored for centuries, he deserves to be remembered as one of Europe’s greatest and most dedicated astronomers. [RETURN]
Earth Analogs with Oceans

Can we detect the oceans of Earth-like planets using the “glint” effect?

Carbon-based life forms require liquid water. This means that our best chance of finding life is to look for planets that harbor large quantities of liquid water. One major goal of NASA’s Kepler Telescope is the search for Earth-like terrestrial worlds orbiting Sun-like parent stars. Kepler detects planets by looking for the dimming of a star’s light as a planet transits (or passes across) the stellar disk. This method will detect any planet in an orbital plane aligned with our line of sight. In order to identify terrestrial planet candidates, follow-up observations must be made to determine the radii, surface temperatures, and orbital sizes and periods of all transiting objects.

As of February 2011, Kepler has observed 150,000 stars and has identified 1,235 planetary candidates. Twenty of these have been confirmed as planets and the characteristics of these newly discovered planets are found on the Kepler’s discovery pages. Of the candidate exoplanets, 68 are Earth-sized and 288 are super Earths.

In a recent paper, Joseph Catanzarite and Michael Shao of the Jet Propulsion Laboratory used Kepler’s exoplanet candidate sample to calculate the occurrence of “Earth-analog” planets orbiting sun-like stars. They define an Earth-analog planet as a one located within the habitable zone of a star (between 0.75 to 1.8 Astronomical Units [AU]) and having a radius within the Earth to super-Earth range (0.8 to 2.0 times the radius of Earth). Extrapolating from Kepler data, Catanzarite and Shao conclude that between one and three percent of sun-like stars harbor Earth-analog planets.

Being an Earth analog does not guarantee that a planet has liquid water. Catanzarite and Shao point out that Earth would not have liquid water if its orbit were as close as 0.75 AU or as far as 1.8 AU from the Sun. The habitable zone is likely larger than that adopted by the pair if one considers planets with more greenhouse warming than Earth or clouds with higher reflectance properties than ones found on Earth. But their recent estimate is a good starting point.

If we find an Earth analog around a sun-like star, how can we determine if it harbors a vast ocean of liquid water? One idea, first put forward by Carl Sagan and colleagues in 1993, is to look for the specular (i.e. mirror-like) reflection of the parent star’s light off an exoplanet’s ocean. Just last year this “glint” technique was employed to confirm the presence of lakes on Titan using spatially resolved images.

We cannot resolve features on the surface of a distant exoplanet. However, as an exoplanet orbits its parent star, it goes through a cycle of phases as observed from Earth. In 2010, Tyler Robinson, Victoria Meadows, and David Crisp modeled infrared brightness variations as a function of exoplanet phase and concluded that the James Webb Space Telescope (JWST) may be able detect infrared “glint” for an exoplanet as it orbits its parent star.

The “glint” effect, while promising, does have some limitations as pointed out by Robinson and colleagues. It will be extremely difficult to detect in visible light, because ocean waves, atmospheric clouds, and absorption by atmospheric molecules can obscure the effect in this spectral window.

Furthermore, the JWST’s ability to detect infrared glint will be limited by the inclination of an exoplanet’s orbit. And finally, instrument constraints of the telescope will limit observations of this effect to exoplanets out to about ten parsecs from Earth.

Most recently, Pennsylvania State University researchers Michael Zugger and James Kasting and several colleagues asked the question: “Can we detect the ‘glint’ of exoplanet oceans with ground-based telescopes?” Their idea is that any telescope looking for water on the surface of an exoplanet will have to look through an atmosphere similar to Earth’s. They explored the feasibility of detecting an exoplanet ocean by observing through Earth’s near infrared windows at 1.1 to 1.35 microns, 1.55 to 1.75 microns, and 2.1 to 2.3 microns.

Zugger and colleagues modeled the glint effect for both ocean-bearing and desert exoplanets. They included atmospheric aerosols like those in Earth’s atmosphere and the effect of polarization, whereas Robinson’s group did not. Zugger’s “enhanced” model demonstrated that detecting “glint” in Earth’s near-infrared windows will be possible only for exoplanets with an aerosol layer that is very thin compared to Earth. So, while infrared instruments on future space missions will be useful for detecting absorption due to atmospheric water vapor, carbon dioxide, and methane, they won’t be particularly useful for detecting oceans of water!

JENNIFER BIRRIEL is an Associate Professor of Physics in the Department of Mathematics, Computer Science, & Physics at Morehead State University in KY.
The title phrase is often heard at award ceremonies of various kinds, and it’s a sentiment expressed at the conclusion of many a fund-raising campaign. But it also applies to the role of the citizen scientist in making real contributions to advancing the astronomical sciences.

I’m very fortunate to be able to live my professional planetary scientist life doing what I love. Like many in this field I started out with firm roots as an amateur astronomer. Some might be tempted to believe that those of us who have graduated into the lofty halls of professional research work forget about our mere hobbyist days and don’t have much time for or interest in interacting with our amateur brethren. I’m sure that most ASP members and readers of *Mercury* are instead very well aware that this couldn’t be further from the truth (and will recognize that I adopted a not-so-subtle artificial ‘us/them’ construction in the title and previous sentence).

While some scientific endeavors may be a little hard pressed to demonstrate cutting-edge projects where the interested layperson can make important direct contributions (high-energy experimental particle physics comes to mind), there are certainly many scientific disciplines that regularly benefit from the contributions of citizen scientists. (I can think of a lot of great paleontological discoveries, for example.) The astronomical sciences are a particularly fruitful area for real contributions to important projects by amateurs.

There are good reasons for this. Professional astronomers are very often burdened with the temporal overhead of raising funds to get or keep projects going, face fierce competition in prying loose precious time on big telescopes, and are sometimes publish-or-perish pressured into leaving behind some crucial but ‘less-sexy’ research projects. And, frankly, there is many an instance where the state-of-the-art in telescope automation, enabling important new work, lies not at the national observatories but in the backyard dome of the space-geek-turned-internet-millionaire. There’s a reason I often put ‘amateur’ in quotes.

A number of organizations exist to facilitate the desires of lay astronomers to make real and useful contributions to scientific research. The American Association of Variable Star Observers is one such organization, forging strong collaborations between amateurs and professionals to advance the study of variable stars. Members of the Association of Lunar and Planetary Observers routinely monitor everything under the Sun — quite literally! They promote and coordinate focused observations of the Sun, Moon, planets, asteroids, meteors, and comets.

I have worked with the International Occultation and Timing Association to deliver observations of asteroid occultations that help refine orbits and provide constraints on the sizes and even detailed shapes of asteroids. In fact, IOTA just helped coordinate a complex campaign of 42 observers at 91 observing stations across northern California, Nevada, and Idaho to obtain a remarkably detailed shape profile for both components of the binary main-belt asteroid (90) *Antiope*. Their new data will help better constrain the orbital parameters of the system and the density of its components.

One venue I like to frequent to enjoy the amateur-professional collaboration in real time is the unmannedspaceflight.com forum. On display there is probably one of the best examples of the palpable excitement and enthusiasm generated when citizen scientists actively participate in the joy of discovery, analyzing for themselves new imagery from ongoing missions like Cassini and MER. And this is the real thing — real discoveries are made by non-professionals who process, and then interpret, raw images distributed by some NASA missions. I’ve seen my professional colleagues actively discussing and following up on image products generated by the very talented and deeply interested amateurs in that forum. It shows the outreach power that can be unleashed when forward-thinking mission Principal Investigators open their spacecraft data to unfettered, real-time distribution via the Web.

The near-instantaneous exchange of information afforded by the Internet, coupled with the availability of affordable, cutting-edge observing technology, is revolutionizing the participatory experience for citizen scientists. We’re living in a truly golden age for ‘amateur’ astronomy.

**Daniel D. Durda** is a Principal Scientist in the Department of Space Studies at the Southwest Research Institute in Boulder, Colorado.
Scientists in recent years have come to realize that most galaxies, including our own, harbor a supermassive black hole at their core. As spectacular as that sounds, it might be only half the story. Using NASA's Chandra X-ray Observatory, Harvard astronomers have found that the bulge in spiral galaxy NGC 3393 is powered by not one but two supermassive black holes. At a mere 160 million light-years from Earth, this is the closest known pair of such black holes.

Paired supermassive black holes, typically containing the mass of millions of suns, are not unusual. They are the result of galaxy mergers, in which each galaxy contributes its own great central void of doom. But the pair in NGC 3393 is extraordinary for two reasons.

First, when two spiral galaxies merge, astronomers have thought it would result in the formation of single galaxy with a disrupted appearance and intense, new star formation, as exemplified in NGC 6240, located about 330 million light-years from Earth. But NGC 3393 is a well-organized spiral galaxy, and old stars dominate its central bulge.

Second, the supermassive black holes in NGC 3393 are only about 490 light-years apart — a half arc-second separation. Other known pairs are thousands of light-years or more apart. Detecting such a separation is like seeing a dime at the distance of five miles. While this is trivial for the best optical telescopes, this is the limit for X-ray telescopes, and the latter is what's needed to detect this kind of black hole activity because dust in galaxy cores obscure optical light. In fact, the observation required nearly 25 hours of Chandra observation time.

"If this galaxy weren't so close, we'd have no chance of separating the two black holes the way we have," said Pepi Fabbiano of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Mass., who led the study that appeared online in Nature on August 31. So if you can't judge by galaxy shape, and if you can't detect supermassive black hole pairs that are close to each other in more distant galaxies, "it makes us wonder how many of these black hole pairs we've been missing," Fabbiano said.

NGC 3393 might be a result of a so-called minor merger of a massive galaxy with a smaller one, which didn't result in too much collateral damage to the larger galaxy's structure. Theories say that minor mergers should be the most common way for black hole pairs to form; major, or massive, mergers are not as common. But good candidates for minor mergers have been difficult to find because the merged galaxy is expected to look so typical.

Evidence for this minor merger would lie in the precise mass of both black holes in NGC 3393, still unknown. If one black hole is much more massive than the other, astronomers have an open-shut case. Follow-up observations are needed in infrared spectroscopy to measure mass, said Junfeng Wang of the CfA, a co-author.

Finding a black hole pair in a spiral galaxy is an important clue in understanding how galaxies and black holes grow through collisions and mergers, said co-author Guido Risaliti of the CfA and the National Institute for Astrophysics in Florence, Italy. In this regard, NGC 3393 is probably a major yet "hitherto missing observational point to the study of galaxy/black hole evolution."

Colliding supermassive black holes also would be one of the "loudest" sources of gravitational waves — ripples in space and time predicted by Albert Einstein but not yet detected directly. So, a proper census of black hole pairs would help shape missions to detect gravitational waves.

The Laser Interferometer Space Antenna, or LISA, was one such mission, although NASA announced in April 2011 its plans to pull out of its partnership with ESA to build LISA. ESA is planning a full revision of the mission, now called the Next Gravitational Wave Observatory. No gravitational wave detector is expected to launch this decade, though.

Fortunately, the supermassive black holes in NGC 3393 won't merge for another billion years, so even NASA as a little time.

Baltimore-based health and science writer CHRISTOPHER WANJEK is now doubly annoyed that LISA has been cancelled.
Lots of reasons account for lack of student success: economic status, social structures, family health, the educational level of parents, and the perceived ability to get a job upon graduation. The latter is what 60% of high school dropouts express as the reason for leaving school. Often there are so many stressors acting upon a student that he or she has little chance of completing an education.

What signals the potential for success? The single, best explanation, according to Robert Samuelson (an economics writer for the Washington Post) seems to be cognitive motivation.

This does nothing to absolve teachers of a responsibility to teach using best practices; indeed, your teaching style does matter. We may not be able to change the behaviors of the students who come to college to party. But for students on the edge, can we improve their motivation?

A first step is to get students to understand that learning is work. While we can make some learning tasks less onerous, learning at its base takes effort. Educational reforms in lower grades often try to make learning into a game (Oregon Trail, computerized math games, etc). The result is that students have a low threshold for mental exhaustion. But when they reach college, we need to convince them that performing the hard work of learning is as much training for their future professional life as storing knowledge.

Part of the problem in getting students to work harder is that many of them have the idea that the ability to learn is a fixed trait. When the going gets hard, they believe they have reached the limits of their ability and often quit on the assignment or on school. Carol Dweck, a Stanford psychologist, tells us that students who hold onto the idea that innate intelligence equals achievement are less successful than students who understand that learning takes effort.

To get student buy-in for this idea of learning as work, we can turn to industrial psychology and what creates job satisfaction: variability in tasks, feedback about the quality of job performance, the opportunity to complete tasks, and the ability to apply creativity. A class activity that lasts too long can leave vulnerable students feeling unsuccessful if they cannot finish the assignment or if they do not get feedback about how they did. And the feedback needs to be such that they are recognized for what they get right as well as given hints about how to fix what was wrong.

Livescience.com reports that two-thirds of high school students profess boredom everyday, with half blaming a lack of interaction with their teachers. This problem only grows in a college lecture environment. What can we do in Astro 101 to capture their attention?

In Why Don’t Students like School? Daniel Willingham, a University of Virginia psychologist, claims that every student retains curiosity even when they seem to be bored. But curiosity is fragile: students will engage a problem but only if it is small enough for them to digest. Willingham also states that content is not enough to sustain curiosity, but success will. This is not about self-esteem but about conditioning learning.

Willingham also reminds us that we cannot expect students to think like scientists. It takes a person 10 years on average to gain expert status, and experts develop a higher threshold for mental exhaustion. And we should not expect students to learn by doing what experts do.

When you see your students acting bored, it’s not a signal that that they are bad students. Consider it a signal that content is being chunked into too large a dose, or that we are expecting students to think in inappropriate ways for a non-expert.

Viewing boredom in the correct light can help us guide students to success. David Bruning teaches astronomy at a Midwestern state university. He thinks nothing is intrinsically boring — students need to be taught to look for why anything can be interesting to them.
Connecting in the Twitterverse

To avoid looking like a twit with your tweets, you need content.

In my days as a storyteller, one technique I learned for perfecting a story was to take a 10-minute story and tell it in five minutes (without doubling my speaking rate, of course) and not as a paraphrase, but a complete story. Then tell it in three minutes, then one minute. How about 140 characters? Can you tweet your story?

The world is all a Twitter, and no less so astronomy. Astronomy educators and enthusiasts have always kept up with the new media. So there are now a few hundred Twitter accounts devoted to astronomy, ranging from large organizations and publications to astronomy educators and amateur astronomers.

Many NASA missions and education programs have them. They are used for a variety of purposes. Some provide tidbits of up-to-the-minute news and mission updates, with links to press releases, new images, and other websites. Some missions have education twitter feeds that specifically serve teachers, providing information and links to resources.

Celebrities tweet and have their followers. In his keynote at the Astronomical Society of the Pacific’s annual meeting in August 2011, Neil deGrasse Tyson shared his adventures in the Twitterverse. Once he decided that tweeting about what he was having for breakfast wasn’t going to be that interesting, he turned to connecting his audience to science and math. He poses thought-provoking tidbits and brings his own insight on the content, connecting to what his audience thinks and feels.

Twitter seems to be a combination of social media (in the old school definition of “the media”) and social networking. The former is about providing information, and the latter is about connecting. Content is king — no one will follow you if you don’t have something interesting and/or useful to say. But it’s also about engaging your audience — allowing them to respond and replying to them.

Some Twitter feeds engage their audience with Q&A sessions, contests, quick opinion polls, conversations, etc. Tweet-ups also build community, when a small part of the online community meets face to face for an event, and draws in a larger audience through their tweets.

I’ve written earlier about using storytelling to engage an astronomy audience. So I ask again: Can you tell your story in a tweet?

There are certainly examples of using Twitter for storytelling. There are microfiction Twitter sites, with each tweet a complete story. In 2010, a group of rabbis got together to tweet the Exodus. With different Twitter accounts taking different roles, they played out the story of the Exodus during the course of two weeks. In other cases, some online twitter fiction invites the readers to become participants in an extended story.

Our space missions have a story — a beginning, a middle, and a hopefully happy ending. A story also needs characters. The profile on a Twitter account tells a story of identity. Who is this? What’s most important to this person/mission/thing?

Remember the Mars rovers Spirit and Opportunity on Live Journal? Written by a third party, they were from the point of view of the rovers themselves. Opportunity was peppy and enthusiastic, while Spirit tended to be dark and gothic.

A number of missions have taken this approach in Twitter, among them the Lunar Reconnaissance Orbiter, Dawn, and New Horizons. Camilla, the mascot for the Solar Dynamics Observatory, has more than 2,500 Twitter followers.

Just as characters in a Twitter story tweet to each other, I can imagine missions tweeting to each other. Starting in the 1970s, gamma-ray burst detectors were placed on interplanetary satellites to form the Inter-Planetary Network. When each satellite detected the same burst, astronomers used a time-of-arrival technique to determine the location of the burst in the sky. These days, such satellites would be tweeting their data to each other.

Surely this needn’t be a universal approach, and not all missions need to take on personas. But consider: telling a Twitter story offers an opportunity to explore different ways to captivate the audience.

In oral storytelling, there is a non-verbal connection between the teller and the audience. But now our audiences demand dialogue and community building. Twitter offers an interesting venue. As Caitlin Burns, a transmedia producer, writes, “Twitter breaks the fourth wall by inviting the audience to reply, simply by using the platform.”

Jim Lochner is the Program Manager for the Science Mission Directorate’s Education & Public Outreach programs at NASA Headquarters.
More than one million clickers are in use nationwide, and more than 17,000 of them are at Colorado University. Data gathered during the past few years makes clear which uses of clickers lead to success, and which lead to failure. “Success” means both the faculty member and students report being satisfied with the results of using clickers. Clickers have many possible uses:

- find out if students have done assigned reading before class;
- measure what students know before you start to teach them and after you think you’ve taught them;
- measure attitudes and opinions, with more honest answers if the topic is personal or embarrassing;
- get students to confront common misconceptions;
- facilitate discussion and peer teaching;
- increase student’s retention of what you teach;
- transform the way you do demonstrations; and
- increase class attendance; improve student attitudes.

Of course, none of these outcomes are magically achieved by the clicker itself. They are achieved — or not — entirely by how you implement their use.

Practices that Lead to Successful Clicker Use

1. Have clear, specific goals for your class, and plan how clicker use can contribute to your goals. Do not attempt all the possible uses described above at one time!
2. You absolutely must explain to students why you are using clickers. If you don’t, they often assume your goal is to track them like Big Brother and force them to come to class. Students highly resent this.
3. Practice using the system before using it with students. Remember how irritated you get when A/V equipment fails to work? Don’t subject your students to this.
4. Make clicker use a regular, serious part of your course. If you treat clicker use as unimportant or auxiliary then your students will, too.
5. Use a combination of simple and more complex questions. Many users make their questions too simple. The best questions focus on concepts you feel are particularly important and involve challenging ideas with multiple plausible answers that reveal student confusion and generate spirited discussion. Show some prospective questions to a colleague and ask if they meet these criteria.
6. If one of your goals is more student participation, give partial credit (such as 1 point for any answer and 2 for the correct one) for some clicker questions. With some questions it’s appropriate to give full credit to all students, such as when multiple answers are valid or when you are gathering student opinions.
7. If your goal is to increase student learning, have students discuss and debate challenging conceptual questions with each other. This technique — peer instruction — is a proven method of increasing learning. Have students answer individually first, then discuss with those sitting next to them, and then answer again.

There are a number of key practices that lead to successful clicker use in the classroom.
8. Stress that genuine learning is not easy and that conceptual questions and conversations with peers can help students find out what they don’t really understand and need to think about further — as well as help you pace the class. Students tend to focus on correct answers, not learning. Explain that it is the discussion itself that produces learning, and if they “click in” without participating, they will probably get a lower grade on exams than the students who are more active in discussion. My students came up with the phrase, “No brain, no gain.”

9. Use the time students are discussing clicker questions to circulate and listen to their reasoning. This is very valuable and often surprising. After students vote, be sure to discuss wrong answers and why they are wrong — not just why a right answer is correct.

10. Compile a number of good clicker questions and exchange them with other faculty. The best questions for peer discussion are ones that roughly 30–70% of students can answer correctly before discussion with peers. This maximizes good discussion and learning. There is value in discussion even if a question is difficult and few students initially know the answer.

11. If you are a first-time clicker user, start with just one or two questions per class. Increase your use as you become more comfortable with the system and its uses.

12. Explain what you will do when a student’s clicker doesn’t work, or if a student forgets to bring it to class. You can deal with that problem as well as personal problems that cause students to miss class by dropping 5-10 of the lowest clicker scores for each student.

13. Talk directly about cheating. Emphasize that using a clicker for someone else is like taking an exam for someone else and is cause for discipline. Explain what the discipline would be.

14. Watching one class or even part of a class taught by an experienced clicker user is a good way to rapidly improve your clicker use.

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**Technical Considerations**

- Try to get your school to adopt only one clicker brand. Students hate being forced to buy more than one clicker!
- RF (radio) clickers are cheaper and easier to use than infrared ones.
- Simple clickers (such as iClicker) have fewer implementation problems.
- Test your registration system before the students do. Check early in the semester that all responses are getting credited. And deliberately make some mistakes to see what happens.

**Practices that lead to Failure**

1. Fail to explain why you are using clickers.
2. Use them primarily for attendance.
3. Don’t have students talk with each other.
4. Use only factual recall questions.
5. Don’t make use of the student response information.
6. Fail to discuss what learning means, or the depth of participation and learning you expect in your class.
7. Think of clickers as a testing device, rather than a device to inform learning.

*If you believe the teacher, not the students, should be the focus of the classroom experience, it is unlikely that clickers will work well for you.*

Be prepared. Effective clicker use with peer discussions results in a livelier and more interesting class — for you as well as the students. Expect good results immediately but better results as you become more experienced with clickers. This is the usual experience nationwide. Further information and references will be put on my [clicker-use webpage](http://clicker-use-webpage).

I’d like to hear about your experiences, good and bad, and perhaps include them in future editions of my book on how to teach with clickers. Feel free to get in touch with me at [dduncan@colorado.edu](mailto:dduncan@colorado.edu).

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**DOUGLAS DUNCAN** is the Director of Astronomical Laboratories, University of Colorado. Among his many accomplishments, he is the author of *Clickers in the Classroom: How to Enhance Science Teaching Using Classroom Response Systems* (Addison-Wesley, 2004). He is also the winner of the ASP’s Richard H. Emmons Award for excellence in college astronomy teaching for 2011.
This special section of *Mercury* features reprints of five poster papers, plus a transcript of a portion of David Blewett’s plenary talk “New Views of Diverse Worlds,” all part of the ASP’s Connecting People to Science conference held in Baltimore, MD, August 2011.

Clockwise from upper left: the poster paper venue in the Edinburgh Room; making a Sun funnel session; hallway in the Tremont Grand Conference Center in Baltimore; and a demonstration of planet transits in a workshop session.
Creative Writing and Learning in a Conceptual Astrophysics Course

by Rhoda Berenson, New York University/Liberal Studies Program

I often offer an optional assignment to the liberal arts students in my History of the Universe course that requires them to write an imaginative story incorporating specific scientific vocabulary. My goal has been to lessen student anxiety by providing an opportunity to submit a creative, at-home contribution to exams.

I have recently discovered that writing these stories also can have a positive effect on a student’s performance on the in-class exam. This would not come as a surprise to any of the proponents of the “Writing to Learn” movement, but it did come as a surprise to those students who told me how much the assignment helped them understand the concepts.

The Study
This study compares the results on two in-class exams for two groups of students. The first exam, in class, consisted of a mix of multiple-choice questions, true/false with explanation, numerical calculations, and short essays. There was no optional assignment for the first exam.

The in-class portion of the second exam was similar in format to the first, but students were given the opportunity to submit a take-home assignment that would count as 25% of the exam with the in-class portion as 75%. This resulted in two groups — one that chose to do the writing assignment and one that chose not to do it. Results were combined for seven classes over four semesters.

The Assignment
Although this assignment is similar to those suggested in some astronomy textbooks, the requirement for incorporating specific vocabulary guides the student in writing a more detailed and comprehensive story.

Tell the life story (biography or autobiography) of a sun-like star starting with its formation within a nebula to its final days. Your story must be creative, but it should also demonstrate your scientific understanding of the many stages in the star’s life. It should be understandable to someone who never studied the evolution of stars or the laws that govern that evolution. It must include 18 of the terms in the table below plus any additional scientific terms that are relevant to the story. All scientific terms must be used correctly and defined in context. It must also include two numerical evaluations.


Grades: Creativity: 5 points. Correct use of scientific ideas and terms: 18 points. Correct numerical evaluations: 2 points.

The Results

Table 1: Comparison of Grades on the First Exam Between the 2 Groups Based on Choice made for the Second Exam

<table>
<thead>
<tr>
<th></th>
<th>Chose not to Write</th>
<th>Chose to Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>84.5</td>
<td>81.2</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>12.5</td>
<td>10.9</td>
</tr>
<tr>
<td>Number of Students</td>
<td>116</td>
<td>101</td>
</tr>
</tbody>
</table>

Table 1 provides a comparison of the grades on the first exam for the two groups. The results of the pooled-variance t-test indicate that the two groups had performed significantly differently on the first exam ($t = +2.01; p\text{-value} = 0.045$). Both groups included students with grades ranging from very high to very low on the first exam. However, on average, the grades were significantly lower for those who opted to write the essay on the second exam, as might be expected from students who are looking to improve their grades.

Table 2: Comparison Between the 2 Groups of Grades on the Second Exam

<table>
<thead>
<tr>
<th></th>
<th>Chose not to Write</th>
<th>Chose to Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>84.9</td>
<td>85.2</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>11.8</td>
<td>10.3</td>
</tr>
<tr>
<td>Number of Students</td>
<td>116</td>
<td>101</td>
</tr>
</tbody>
</table>

Table 2 summarizes student performance on the in-class portion of the second exam, broken down by group. Using the pooled-variance t-test, the null hypothesis of no difference in performance cannot be rejected at a 0.05 level of significance ($t = -0.23; p\text{-value} = 0.815$).

It is clear that those who opted to do the writing improved their scores to match those of the initially stronger group who chose not to write the essay.

Table 3: Comparison of Change in Grades

<table>
<thead>
<tr>
<th></th>
<th>Chose not to Write</th>
<th>Chose to Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference</td>
<td>0.39</td>
<td>3.98</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>9.17</td>
<td>8.45</td>
</tr>
<tr>
<td>Number of Students</td>
<td>116</td>
<td>101</td>
</tr>
</tbody>
</table>

In fact, as seen in Table 3, using the grades on the first exam as a baseline, when examining changes in grades between the first and...
second exam, the writing group significantly outperformed those who did not opt to write, raising their grades, on average, by 3.98 points as compared to 0.39 points.

**Conclusion**

A creative writing assignment can improve students’ understanding of concepts of astrophysics as evidenced in their performance on exams. As a bonus to the instructor, the stories are a lot of fun to read. 

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**Sample Story Segments**

"Hello and welcome to the Solar Flare retirement facility…. To the right we have the spa. We have a full-time facialist on staff for those of you seeking to remove any signs of sunspots, those small patches that showed on our surface in our heyday because they were cooler than the rest of our face. Remember those good old days when all we worried about was emitting photons those particles of light and energy, expelling charged particles through solar wind that could affect the formation of planets. Some of us even played satellite to a larger star forming a binary system."

"It’s been nearly 10 billion years now that I have been working at Starlight Inc. and would like to take this opportunity to thank those protons who started with me in the early days when we were nothing more than some dust in the magnetic winds…. It was very early on when I started as just a messenger proton. I arrived in the cloud with nothing but the two up quarks on my back, one down quark in my pocket and a little dream."

"Once upon a time, in an interstellar molecular cloud far, far away, a foxy glob of Dust and a quite attractive-looking hunk of Gas got together in what was one of the most romantic nights in the universe. The evening (well, there really was no day or night in this region of space and, therefore, there couldn’t have been an evening, but for story-telling purposes, it was evening) began with an exchange of promiscuous glances and ended with scandalous accretion, the process of small objects uniting to form a larger one."

"My earliest memory is spinning. At first I turned in slowly meandering circles, my star stuff gathering itself together, full of youthful gravitational potential energy. As my matter became more and more concentrated, and I spun faster and faster, my gravitational potential energy decreased as my matter was inexorably pulled together at my center. I obeyed the universal law of conservation of energy turning my gravitational potential energy into the thermal energy that would eventually be responsible for the fusion in my core."

"STAR Army: Official Captain’s Log Year 1: Not too long ago, it finally happened. I don’t know how my forces and I didn’t see it coming, the first strike of the enemy…. Right now our main source of power comes from our Hydrogen division. The unit has been working in assembling proton-proton chains, partially disassembling itself, but working to redefine itself as the Helium unit through nuclear fusion. The thermal energy that is made in this practice gives my troops the abundant provisions (thermal energy) they need to maintain the pressure in the ranks and defend our perimeter."

"The Ballad of a 1.0M-sun Star (to the music of Don Maclean’s “American Pie”)"

Millions, millions years ago
I can still remember
How that Nebula did give the star breath.
And as it gathered rock, helium and hydrogen,
A cloud of dust collapsed at gravity’s demand,
Who know it’d be such a journey ’til its death."
Engaging in inquiry in the classroom is an extraordinary way to increase student interest in science and to improve student understanding of how authentic scientific research is performed. However, effective and practical inquiry activities can be challenging (and time consuming!) to develop and implement.

Fortunately, there are many excellent resources available for undergraduate-level educators who are interested in bringing inquiry into their classrooms. Some of these resources provide fully developed inquiry activities that can be put to use immediately in your classroom, or can be modified easily to fit your particular classroom needs. Other resources provide instructions for developing inquiry activities that require significant pre-class instructor preparation, such as building models for in-class use. These resources can also provide you with just pure inspiration — so that you can develop new inquiry activities suitable for your particular classroom situation.

In this poster, I describe my use of inquiry activities in my undergraduate astronomy classroom. These activities were adapted from, or inspired by, many different sources. Working in collaborative groups, students in my classroom perform inquiry activities using real or simulated astronomical data and/or models, which allows them to think like scientists. The students then get to act like scientists by presenting results and conclusions to their peers in scientific poster sessions. Students also have the opportunity to think and act like scientists by simulating the process of developing scientific proposals and critiquing these proposals as members of the review committee.

Using inquiry in the classroom is a great tool for improving student engagement and learning, and these resources will make it much simpler for you to bring inquiry into your own classroom.

Rethinking the Traditional Lab
In "traditional" labs, students typically follow step-by-step instructions to collect data and then analyze that data using methods prescribed in the lab manual. The results to be achieved in this process are often clearly laid out in the background/introduction section of the lab manual. Basically, students are given the answer, given the question, and then required to replicate the answer. This is, of course, not how "real" science is done and, therefore, provides students with no insights into the true scientific process.

In the inquire-based lab, students are required to take a more active role in determining what questions to ask and how to collect and analyze the data to answer those questions. This can be challenging for the students, as it requires more active thinking/creativity than simply following the steps in a traditional lab. However, these labs also allow students the thrill of making independent discoveries and engage them more thoroughly in the scientific process.

These labs can also be challenging for the instructor. The labs can be harder to supervise, and students lacking experience in this process may require significant coaching/assistance. Students may also fail to obtain a satisfactory answer to the question they posed — but that, too, is part of real science! Embracing this challenge, and adding even a few inquire-based labs to your curriculum, can significantly enrich the students’ experience of modern science.

Even if a lab cannot be fully inquire-based, slight modifications can allow students to solve problems more independently. Imagine a lab covering the inverse-square law of light. Instead of just telling the students that $F \propto \frac{1}{r^2}$ and then asking them to verify this by measuring flux from a light bulb at set distances, why not give the students the experimental setup and ask them to use the setup to determine how distance effects light? Let them independently develop the methods of data taking and analysis, and thus require them to think and act more like scientists.
Posters vs. Lab Reports

Traditional labs generally end with students turning in lab sheets (e.g., questions straightforwardly asked in the lab manual and then answered in a few sentences). In some cases, students may turn in more formal “lab reports.” These serve as the standard evaluation tools to confirm that students have completed the assignment and are building knowledge. Again, however, they require little independence of thought or creativity from the students.

A method of evaluating student learning that requires more independence from the students is to require them to present their methods, data, and conclusions in “poster” form (digital posters, paper posters, and posters on whiteboards/chalkboards can all work). Students can then present their posters to other groups in the class (or the class as a whole) allowing for immediate feedback from both peers and instructors.

Having to explain and defend their work both in written and oral form helps students internalize the material. Furthermore, immediate questioning can help students determine which parts of the material remain unclear to them. Students will also be exposed to novel thinking when they hear how other groups approached and tackled the problem at hand.

Inquire-Lab Examples & Resources/References

Transiting Planets: This inquiry lab was developed by N.J. McConnell et al. (“A College-Level Inquiry-Based Laboratory Activity on Transiting Planets,” 2010, ASP Conference Series, Vol. 436, 97-107); or arXiv, and the lab uses a relatively simple model (built from parts available at most craft/hardware stores) to simulate a transiting planet. Students use a light meter in the place of a telescope to answer student-developed questions such as: “Can the size of the planet be determined?” or “Can you tell if a planet has a moon?”

Engaging in Astronomical Inquiry: This lab manual by S.J. Slater, T.F. Slater, and D.J. Lyons (W. H. Freeman & Company 2010, ISBN: 1429258608) contains about a dozen inquiry-based labs based on digital data, and therefore the only equipment required to complete these labs is an Internet-connected computer. These labs explore some cutting-edge astronomy topics including the Hubble and Ultra Deep Field, Extrasolar Planets, and Galaxy Zoo. The labs employ a “backwards faded scaffolding approach” that breaks down the steps of scientific inquiry to introduce them to students one step at a time, e.g., students first develop the ability to draw conclusions from data before being asked to devise novel scientific questions.

Role Playing: Proposing Scientists & Review Committees: In this activity developed by B.E. Cobb (for more details e-mail the author) and inspired by an activity by C.D. Bailyn, students are given a scientific goal (for example, “detect a new extrasolar planet”) and a list of possible telescopes/instruments to build, and are then separated into teams at competing “universities.” A team member from each “university” makes a proposal to a review committee of classmates. The committee then decides how to allocate the funding “budget.” The activity cycles through several rounds so that each student plays the role of proposing scientist and committee member at least once. Data “obtained” from the funded telescopes/instruments is presented to the class at the end of each round, so for each new proposal cycle students must identify what new/additional data is required to make progress toward completing the scientific goal.

The Copernican Revolution & The Phases of Venus: In this lab developed by B.E. Cobb (for more details e-mail the author), students take on the role of pre-Galilean scientists. Using a very simple Sun/Venus model (light bulb and ping-pong ball), students ask questions about how the phases of Venus would appear from Earth in the Ptolemaic system vs. the Copernican system. They must develop a hypothesis, collect model data, and then compare the model data to Galileo’s actual observations of the phases of Venus in order to draw a conclusion about whether the heliocentric system or geocentric system best match the observational data.

Acknowledgments

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Spatial Sense and Perspective: A 3-D Model of the Orion Constellation

by Inge Heyer (U of Wyoming), Timothy F. Slater (U of Wyoming), and Stephanie J. Slater (Center for Astronomy & Physics Education Research)

If we take a close look at people who were successful in their field of endeavor, we will likely find that not only were they generally creative and able to think outside their field box, but also that they were able to make connections — mental, conceptual, physical — between things in ways that no one else had thought of before.

Archimedes took a bath and made the connection to volume displacement. Galileo thought of using a spyglass for something other than spying. A Persian mathematician thought that there should be a mathematical term for nothing, hence inventing the concept of zero, which allowed Newton to invent calculus. And it took a very creative engineer to think of using car air-safety bags to land the Sojourner rover safely on Mars.

Interconnections
Looking at any field of study, we will soon realize that it is inevitably related and connected to other fields, often even dependent on them. Without mathematics we could not do science, without science we could not practice medicine, without literature we would not know what people thought about and valued in ages past, and without history we would not be able to learn what mistakes to avoid today. It is this interconnection between fields that often leads to ideas from one field informing issues in another, and allows creative minds to make connections that enable problem solving.

The Greeks realized this, and in their schooling, mathematics, music, literature, philosophy, and sports all went together. We wonder why, in these modern times, we insist on separating the fields of study in school so rigidly, thereby denying our students the possibility of seeing the connections and dependencies that already exist, and preventing their minds being open to realizing new connections of their own.

In this professional development activity, we have employed astronomy, literature, mathematics, and art to create a three dimensional scale model of the Orion constellation.

Astronomy in Literature and Art
Science fiction and fantasy literature tends to contain a wide variety of references to astronomical phenomena. Therefore this genre is well suited to make a connection between literature and astronomy. Recent books turned into movies such as The Lord of the Rings, Harry Potter, and The Chronicles of Narnia already have a wide following among students of all ages, and hence could be used as a good teaser to get them to think about astronomy issues, both fanciful and very real.

According to Larsen and Bednarski (2008), “The Lord of the Rings (1955) draws heavily on Tolkien’s academic interests in language, culture, mythology, and science. The work contains an impressive litany of astronomical knowledge (pertaining to such concepts as constellations, motions and phases of the Moon, eclipses, and aurora), reflecting Tolkien’s childhood interest in astronomy and other sciences.” Not only have ideas like this been used successfully in various observatory EPO informal science education activities, but they can also be applied in the formal classroom.

Art and astronomy have a long historical connection, especially since before the age of photography when all observations had to be drawn by hand. But even today, there are many physical phenomena which we can infer from observation, but which we cannot image directly. We employ graphic artists and animators to visualize these phenomena (such as the gravitational and magnetic

Literature Paragraph
Aragorn smiled at him; then turned to Boromir again. “For my part I forgive your doubt,” he said. “Little do I resemble the figures of Elenilion and Isildur as they stand carven in their majesty in the halls of Denethor. I am but the heir of Isildur, not Isildur himself. I have had a hard life and a long one; and the leagues that lie between here and Gondor are a small part in the count of my journeys. I have crossed many mountains and many rivers, and trodden many plains, even into the far countries of Rhûn and Harad where the stars are strange.”

From The Lord of the Rings: The Fellowship of the Ring by J.R.R. Tolkien, Book 2, Ch. 2.
forces around a black hole), and inform the media, the public, and of course teachers and students.

Outcome Goals
This exercise was initially developed as one activity of a yearlong professional development class taught in astronomy for K-12 teachers on the Big Island of Hawaii during the 2009 International Year of Astronomy (IYA). It is designed to be appreciated by students of varying interests, so even if they hate math and love art (or vice versa), there should be something of interest for most students. Furthermore, connections between these fields are made, and hopefully the students will pick up on all of the parts by working together.

This activity is best for high school students (grades 9-12), but it can also be used for grades 6-8 (with more scaffolding) and for college introductory astronomy classes (with less scaffolding). The activity should take about two hours.

The outcome goals of this exercise are: recognize science-related content in literature; learn about perspective, line-of-sight, and relative distances; apply basic algebra to determine the relative distances from actual data; and apply artistic skills to construct and paint the parts of the Orion constellation model.

The subject areas addressed are astronomy, mathematics, literature, and art. The matching national science standards for grades 9-12 are understanding and science inquiry, objects in the sky, science as a human endeavor, science in society, and history of science.

The inspiration for this activity came from a FINESSE workshop at the January 2009 AAS meeting.

Needed Supplies
This activity is best done in groups of 3-6 students. For each group the following supplies are needed:

- Square Styrofoam boards (2): 12 x 12 x 0.5 inches
- Dowel Rods (4): 12 inches
- Beads (16): 0.25 inch
- Styrofoam balls (7): 1 inch
- Cotton balls (1)
- Strings (thick thread, fishing line, pipe cleaners) (8): 18 inches
- Scotch tape
- White sheets of paper (2): 8.5 x 11 inches
- Needle (1)
- Ruler (1)
- Pencils (2)
- Calculator (1)
- Student Handout (1)

Activity
1. Have one student read the literature paragraph. Ask the students to discuss in their groups what astronomical issues are being addressed (“the stars are strange”). Ask how and why stars would be “strange” in other places (here on Earth or elsewhere). Have the groups share their ideas.
2. Give each group a copy of the Orion template. Point out the seven major stars and the Orion Nebula. Ask the students if they think Orion looks the same wherever you are. Why? Let them speculate, but don’t give them the answer yet.
3. Hand out the rest of the supplies to the groups.
4. Take the first sheet of paper and mark off 0.5-inches from the top and bottom. Pick which side represents your view from Earth and

Hawaiian teachers building a scale model of the Orion constellation.
mark it as such. Put the Orion template half on top of it, so you can trace the position of the eight objects (seven stars, one nebula) onto the “starting line” (the view from Earth). Be sure to mark your tick marks with the names of these objects.

5. From the table of stars pick the one furthest away (ε Ori, 1,342 light-years), and mark that on the far side from Earth (at the 10-inch distance) exactly opposite the corresponding tick mark on the Earth side. Now we are ready to do some math. We need to figure out the relative distances of the other seven objects. For example: If 1,342 light-years correspond to 10 inches, one light-year corresponds to 10/1342 inches. Therefore, 427 light-years (α Ori) correspond to 3.18 inches. This requires proportional reasoning, which might present a challenge to students with lesser math abilities.

6. Do this for all the objects, and mark their positions on the paper exactly opposite their tick marks on the Earth side. Then put this paper onto one of the Styrofoam squares, put the other paper underneath, and the second Styrofoam square under that. Now take the needle, and punch one hole at each of the eight object positions through both papers and squares. Be sure to mark the orientation of the squares.

7. Meanwhile, other members of the group can paint the stars and nebula appropriate colors. One could even paint the Styrofoam boards with a space background.

8. At the same time, someone else can knot one bead at the end of each string. Once we have made the holes, use the needle to put one thread through each hole of the bottom paper/Styrofoam combo. Then, put one painted Styrofoam ball onto each string for the stars and the cotton ball for the nebula.

9. Have one person hold up the Orion template on the far side from Earth, so that we can determine how high up the objects should be. Determine the height (eyeball it), then put a bit of scotch tape under each object to keep it in place. Next put the dowel rods in each corner. Be very careful of the orientation of the top paper/Styrofoam combo (the paper should be on top). Then use the needle to put the top of each thread through the appropriate hole in the top plate. Finish by tying a bead to each thread to keep things in place.

10. We now have a distance scale model of the Orion constellation. When looking at this model from the Earth side, we see the familiar constellation. But when looking at it from the side, it looks very different. The stars that appear next to each other in the constellation are, in reality, nowhere near each other. So when viewed from any-place but Earth, folks would see something very different. Refer the students back to the discussion at the beginning. Why does Orion look different from another point of view? (Differing distances of stars.)

11. Have each group design a new constellation from the Orion stars based on the different viewpoint. Create a new name and write a new mythology for this new name, based on an invented culture. Here’s where the creative writers get to shine. And the artists can contribute by painting the new constellation character (similar to the one of Orion, the Hunter, as seen from Earth).

Ask the groups to share their new constellation stories and pictures. This exercise can be done for other constellations as well; there are 88 to choose from.

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**Table of Major Stars in the Orion Constellation**

<table>
<thead>
<tr>
<th>Object</th>
<th>Distance (ly)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betelgeuse (α Ori)</td>
<td>427</td>
</tr>
<tr>
<td>Rigel (β Ori)</td>
<td>773</td>
</tr>
<tr>
<td>Bellatrix (γ Ori)</td>
<td>243</td>
</tr>
<tr>
<td>Mintaka (δ Ori)</td>
<td>916</td>
</tr>
<tr>
<td>Alnilam (ε Ori)</td>
<td>1,342</td>
</tr>
<tr>
<td>Alnitak (χ Ori)</td>
<td>817</td>
</tr>
<tr>
<td>Saiph (κ Ori)</td>
<td>721</td>
</tr>
<tr>
<td>Orion Nebula (M42)</td>
<td>1,270</td>
</tr>
</tbody>
</table>

When looking at Orion from Earth (top), we see the familiar constellation. But when seen from 90° away (bottom) it looks very different.
Teachers must encourage [students] to see and use mathematics in everything they do... Only by encountering the elements and expressions of numeracy in real contexts that are meaningful to them will students develop the habits of mind of a numerate citizen. Like literacy, numeracy is everyone's responsibility. (The Case for Quantitative Literacy)

Motivation
The National Assessment of Adult Literacy surveyed 26,000 American adults in the areas of prose, document, and quantitative literacy in 1992, with a follow-up in 2003. This NALS defined quantitative literacy as "the knowledge and skills required to apply arithmetic operations, either alone or sequentially, using numbers embedded in printed materials; for example, balancing a checkbook, figuring out a tip, completing an order form, or determining the amount of interest from a loan advertisement." Key results:
1. More than 20% of American adults performed at the lowest level of proficiency with another 25% at the next level.
2. Quantitative proficiency of younger adults was lower than that of older adults, suggesting that general proficiency is declining with time.
3. Individuals with the highest numerical proficiencies were more likely to be employed and to earn 2-3x higher salaries.
4. Non-white adults were more likely to be in the lower two levels.
5. The proficiencies of men were somewhat higher than those of women.

Other studies confirm conclusions 4 and 5, and show that women are more susceptible to math anxiety, minorities are more likely to leave college with deficits in numeracy, and students with learning difficulties are particularly likely to struggle with applied mathematics.

Also, many (~15% according to initial survey responses) of our non-major students are pre-service teachers. Since many students learn 'math anxiety' from their teachers, leaving our future teachers with an improved attitude toward mathematics is a very important step towards mitigating math anxiety and improving quantitative literacy in future generations.

Why I Want to Go to Astronomy Camp
Astronomy Camp will be a fun and interesting way to introduce myself to science the way it is actually done... I have always heard a lot about science and math being related, but I have never actually used them together. I have finished an entire year of algebra, but never has there been any science in it. The same holds true in my science class. Frankly, I have never seen any connection between the two of them. Hopefully I will be able to use more advanced math and science together at Astronomy Camp....

Common Mathematical Misconceptions (and Deception)
We must instill in our students the skills necessary to distinguish nonsense from reality and help them reach the level of numerical sophistication needed to be discerning consumers, voters, and citizens!

Table 1: Common mathematical misconceptions encountered frequently in our classrooms.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Common Incorrect Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 + 5</td>
<td>0.5</td>
</tr>
<tr>
<td>0.5 =</td>
<td>5%</td>
</tr>
<tr>
<td>How many seconds in an hour?</td>
<td>60 sec/min + 60 min/hr = 120 sec</td>
</tr>
<tr>
<td>10^2</td>
<td>20</td>
</tr>
<tr>
<td>4.3 x 10^6</td>
<td>4.3000000</td>
</tr>
</tbody>
</table>

Workshop Series
One [difficulty in cross-curricular implementation of QL] is the notion of "special expertise"... A major challenge in implementing writing across the curriculum, for instance, is the fact that faculty do not all know automatically how to coach or assess writing effectively, so substantial efforts at faculty development are generally required. I believe the same level of effort is required for quantitative literacy. (Numeracy, Mathematics, and General Education)
We are developing a workshop called “Techniques, Tools, and Tips for Improving Quantitative Literacy in the Science Classroom” with these goals:

a) Raise awareness of the problem of serious deficits incoming college students have in the area of mathematical reasoning. Data verifying the problems of innumeracy and math anxiety abound in the literature, but many science instructors lack the time and/or inclination to keep up on the broader educational literature, and rely on workshops to boil it down to its important points. This has been very successful in the area of learner-centered teaching techniques, and we hope that these workshops will be met with similar enthusiasm by the community.

b) Share evidence-based tips, tricks, and curricular materials that we have collected and developed, which will be increasingly informed by our study.

We are compiling our materials and vetting new ones in our classrooms:

• Daily quantitative brainteasers;
• Quantitative supplements to questions in the very popular Lecture Tutorials in Introductory Astronomy workbook;
• Homework and test questions involving simple arithmetic reasoning;
• Labs in which students evaluate the reasonability of numbers presented in popular media;
• Labs in which students examine selection effects and how to recognize them in data;
• “Real life analogs” to astronomical formulae and graphical relationships;
• A variation of the very popular science vs. pseudoscience curricula espoused by experienced educators such as Doug Duncan (CU Boulder) with the additional component of how to recognize good mathematical data vs. bad.

c) Recruit instructors interested in further investigation to participate in our study.

Workshop participants will be asked to participate in the ongoing study. We hope that the workshop will convince them that whether (and how) numeracy should be emphasized in the science classroom is an open question worth pursuing.

Takeaways

Many Americans leave college with significant lingering deficits in numerical skills — especially women, minorities, and the learning disabled. Cross-curricular application of numerical skills is likely the only way to convince students of their usefulness. “Math is only useful to pass a test in math class.” (anonymous Honor student).

Introductory science classes for non-majors may be the last opportunity for many students to experience applied mathematics in context. Because of its broad appeal and large enrollment numbers, Introductory Astronomy is an important place to emphasize numerical skills.

YOU may be your students’ last chance to appreciate the role of arithmetic in science and the importance of quantitative thinking in their roles as consumers, voters, citizens, parents, and future educators! Join us to help understand and solve this problem.

Our QL Study

Science courses are a natural place to emphasize and reinforce numerical skills and quantitative literacy.

College students are generally required to complete one course in science. Based on data compiled in the last decade, more than 10% of college students (~300,000 students) eventually enroll in an “Astronomy 101” course. This large population is why we feel that introductory astronomy courses for non-science majors are a logical place to begin a study of the efficacy of science courses in improving quantitative literacy in the general college population.

We have begun to study, and improve, the numerical skills of our university and community college students.

Get Involved

Give the survey to your class! We’re still recruiting instructors for Fall 2011, and Spring 2012!

Provide feedback. Do you feel there are any necessary QL skills missing from our list? Which do you feel are the most important?

Share with us. How do you emphasize quantitative skills in your labs, lectures, homework, etc.? We will keep any materials you provide confidential or to add them to our resource database for the workshop series. And how do you connect quantitative skills to science, astronomy, and real life in your classroom?

Learn More

If you’d like to read more about this concept and what we’re doing, we have an article (of the same title) appearing in the next issue of Mercury (Winter 2012).
Computer-based simulations and virtual labs are valuable resources for science educators in various settings, allowing learners to experiment and explore “what if” scenarios. Educational computer games can motivate learners in both formal and informal settings, encouraging them to spend much more time exploring a topic than they might otherwise be inclined to do.

This poster is effectively a “literature review” of numerous sources of simulations, games, and virtual labs.

Although we have encountered several nice collections of such resources, those collections seem to be restricted in scope. They either represent materials developed by a specific group or agency (e.g. NOAA’s games website) or are restricted to a specific discipline (e.g. geology simulations and virtual labs).

This poster directs viewers to games, simulations, and virtual labs from many different sources and spans a broad range of Earth science and astronomy disciplines. The poster is also a sampler of a broader, more in-depth collection of such resources available online at a website dedicated to disseminating such items.

On My Website
I have a webpage called Computer Simulations, Games, and Virtual Labs for Earth Science and Astronomy Education. The list on that page accompanies a poster presented at the ASP Conference in Baltimore in August 2011. It contains a larger set of educational web items and often more detailed descriptions that what’s below. There is also a webpage called Games, Sims, and Virtual Labs spanning all of the STEM disciplines.

Examples in Detail
Below are two samples (Gizmos and PhET) of the listings found on my Earth Science and Astronomy Education webpage. These examples reveal the typical level of detail you’ll find on those pages. The screen-grab image is not usually from the opening page but from a screen that appears somewhere in the middle of the activity.

Gizmos Description: hundreds of simulations for math and science, primarily for students in grades 3-12 (also some college-level). Science simulations cover a range of subjects, with largest collections in physics.
URL: www.explorelearning.com
Creators: ExploreLearning
Cost: Commercial product; not free. Demo versions available. Pricing appears to depend on situation (# of students using, # of Gizmos used, etc.).

PhET (Physics Education Technology) Description: a large collection of Flash and Java-based simulations covering a range of scientific disciplines and mathematics. The main focus is physics for college students, but the project has expanded into chemistry, biology, and Earth science. Many of the simulations are suitable for K-12 audiences.
URL: phet.colorado.edu
Creators: University of Colorado at Boulder
Cost: free

The Rest of the Listings
Here are the other listings that were included in my Baltimore poster paper. They’re less detailed in this article, but there is more information about each sim on my website.

Asteroid/Comet Orbits Simulator
ssd.jpl.nasa.gov/sbdb.cgi
This Java applet from NASA/JPL generates interactive diagrams of the orbit of an asteroid or comet of the user’s choice.

Astronomy Applets
scatter.colorado.edu/STEM-TPSoft
Astronomy applets from the University of Colorado (Boulder) including Planet Finder, Planetary Transits, Radiative Transfer, etc.

Bill Nye’s ClimateLab
www.billsclimatelab.org
Climate science games and simulations from Bill Nye, the Science Guy, and the Chabot Space and Science Center.

BYU Virtual Earth Science
yscience.byu.edu
Extensive virtual labs for Earth Science, Chemistry, Physics, and Biology from Brigham Young University.
EdGCM
edgcm.columbia.edu
A research-grade Global Climate Model (GCM) with a user-friendly interface that is suitable for use by students and can be run on a desktop computer; from Columbia University (NY).

EPA Environmental Club: Games
www.epa.gov/students/games.html
Games and puzzles from the US Environmental Protection Agency, including Recycle City, Environauts Mission to Earth, and much more.

Gravity and Tides
sunshine.chpc.utah.edu/labs/tides/menu_tide.swf
Simulations from the University of Utah demonstrate the creation of tides by gravitational forces.

Jason Project: Digital Labs & Games
www.jason.org/public/whatis/games.aspx
Games and simulations from the Jason Project, including Operation: Resilient Planet, Coaster Creator, StormTracker, and Mini Labs.

Killer Asteroids
killerasteroids.org
Games about asteroids from the Space Science Institute, including Rubble!, Deflect an Asteroid, What If It Hit My Town, and more.

Kinetic City
www.kineticcity.org
Assorted science education games and simulations from the American Association for the Advancement of Science.

Math & Physics Applets
www.falstad.com/mathphysics.html
Java applets covering various math and physics topics including oscillations and waves, acoustics, electricity and magnetism, electrodynamics, quantum mechanics, linear algebra, vector calculus, thermodynamics, etc.

MESSENGER Mission
www.messenger-education.org/students/animations.php
Simulations related to the MESSENGER space mission to Mercury, including Gravity Assist Simulator, Planet Mass Comparison, Mosaic Postcards from Mercury, and more.

Molecular Workbench
mw.concord.org/modeler
The Concord Consortium’s Molecular Workbench (MW) provides visual, interactive computational experiments for teaching and learning physics, chemistry, biology, biotechnology, and nanotechnology.

My Own Biome
myownbiome.com
Four-player game simulates ten different biomes (license purchase required).

NASA Climate Kids - Games
climate.nasa.gov/kids/games
Climate science games from NASA including Go Green!, Mission to Planet Earth, Whirlwind Disaster, Wild Weather Adventure, Migration Concentration, Earthy Word Games, and more.

Nebraska Astronomy Applet Project
astro.unl.edu/naap
These online laboratories target the undergraduate introductory astronomy audience, from the University of Nebraska-Lincoln.

NOAA Games “Planet Arcade”
games.noaa.gov
NOAA’s games page features a variety of games from the EPA, the Jason Project, and PBS, as well as from NOAA.

Planet Families: Build a Solar System
www.alienearths.org/online/interactives/planet_families
Use this solar system construction kit from the Space Science Institute to build your own family of planets.

Reconstructors: Uncommon Scents
reconstructors.rice.edu
This environmental science mystery game from Rice University leads students through an investigation of a toxic chemical accident.

SClgames.org
www.sclgames.org
Assorted games from the Space Science Institute, including Magneto Mini Golf, Drive a Rover, Fly to Mars, Wrath of Ra, and more.

Thrill of the Catch
discoverylake.discoveryeducation.com
“Build” custom fish, learn about water quality, and take a virtual fishing trip in this game from the Discovery Channel.

Virtual Astronomy Laboratories
val.brookscole.com
Twenty virtual laboratories for an introductory astronomy course from the publisher Brooks/Cole.

WeatherWise
profhorn.meteor.wisc.edu/wxwise
These Java applets cover various weather-related topics (storms, temperature, humidity, precipitation, wind, clouds, radiation, climate, etc) from the University of Wisconsin-Madison.

Wiki Watershed
wikiwatershed.org
Various activities related to watersheds, including a watershed simulator. [RETURN]
Spacecraft exploration has revolutionized our understanding of rocky bodies in the solar system.

by David T. Blewett

Color differences on Mercury are subtle, but they reveal important information about the nature of the planet's surface material. The large, circular, light-colored area in the upper right is the interior of the Caloris basin.

Unless otherwise noted, all images are courtesy NASA / Johns Hopkins University Applied Physics Laboratory / Carnegie Institution of Washington.
The objects I’m going to be talking about today are Mercury, the Moon, and Vesta. The reason that these worlds are of great interest is that they allow us to investigate the fundamental forces that shaped all the solid-surface planets. On larger planets like Mars, Venus, and Earth, the surfaces have been greatly modified by water and wind, obscuring much of their history. But with these smaller rocky bodies, we have a chance to investigate the most basic geological processes.

Four Basic Geological Processes
What are those processes? First is accretion out of the solar nebula. Dust particles clumped together, growing and colliding to form larger and larger objects, until they reached the size of protoplanets. Some of those protoplanets melted from the heat of accretion and the energy released by radioactive nuclides, and consequently differentiated (or separated) into a core, mantle, and crust, with dense iron metal sinking to form the core.

Impact cratering is certainly another process that has profoundly affected all planetary surfaces. Two others are tectonism, the deformation of the surfaces of the planets due to horizontal or vertical stresses within the crust, and volcanism — whether it’s explosive volcanism of the kind that produced the cinder cones found at Haleakala in Hawaii, or effusive volcanism that resulted in the big basalt flows in places like Iceland, Hawaii, or Mare Imbrium on the Moon.

So we will embark on a tour of the inner solar system to see some examples of what scientists are learning about these forces and the ways they interact to produce the worlds that we see today. Let’s start with Mercury.

An Introduction to the Smallest Planet
Mercury is truly a planetary oddball. It’s the smallest planet, but it has the highest density. It has a huge iron core and a very thin mantle. The relative size of its core is much larger than those of Venus, Mars, or the Moon. Mercury is in the most eccentric orbit. It’s the only planet that’s in a spin-orbit resonance — Mercury’s globe turns on its axis three times for every two times it goes around the Sun.

Mercury has an actively generated internal magnetic field, even though two of its larger cousins (Venus and Mars) do not. It’s the closest planet to the Sun, and yet there is evidence that ice could be lurking in dark polar craters. This is quite counter-intuitive given Mercury’s scorching surface temperatures. Mercury has an enigmatic surface composition. We don’t yet know what type of rock forms the surface, though MESSENGER is providing us with an assortment of clues. Further, the innermost planet has very complicated interactions between the surface, the magnetosphere, the exosphere, the solar wind, and interplanetary space — it’s a dynamic and complicated system.

And of course, for a long time Mercury was quite lonely and neglected. Until 2008, it had been visited by only one spacecraft — Mariner 10 with three flybys back in the mid-70s. I don’t have enough fingers and toes to count the number of missions that went to Mars during the same time period!

MESSENGER
MESSENGER is a somewhat contrived acronym. It stands for (MErcury Surface, Space ENvironment, GEochemistry and Ranging), which is why we always put MESSENGER in capital letters. MESSENGER is a NASA “Discovery” mission — NASA’s small size of planetary mission. (Cassini, currently exploring Saturn, is one of the large ones, called “Flagship” missions; New Horizons, on its way to Pluto, is a medium-sized “New Frontiers” mission). At the time MESSENGER was selected, the cost for a Discovery mission was capped at about $300 million. That’s for the entire mission: design, development, the spacecraft, the instruments, launch, mission operations for eight years, and the data-analysis program. For Discovery, the time from start to launch can be no more than three years. MESSENGER was built and is operated by the Johns Hopkins University Applied Physics Lab (JHUAPL) in Laurel, Maryland.

One thing about traveling close to the Sun is that the solar panels for generating electric power don’t have to be very big. The intensity of sunlight at Mercury is about 10 or 11 times greater than it is at Earth, and going close to the Sun means the spacecraft could get very hot. Thus MESSENGER has a sunshade made of woven ceramic.
The computers that control the orientation of the spacecraft (and everything else it does) have, reinforced in their electronic brains, a very important Rule Number One: *Always keep the sunshade pointed at the Sun!* If the spacecraft were to roll or pitch or yaw too far in the wrong direction, allowing sunlight to strike parts of the spacecraft that it’s not supposed to, bad things would happen!

Also notice that MESSENGER does not carry the type of dish antenna found on many spacecraft. Instead, it has an electronically steerable phased array antenna. The solar panels are about 50% covered with mirrors to help maintain them in the proper temperature range. The other half of the panel’s surface consists of photovoltaic cells.

After launch on August 3, 2004, the spacecraft did a bit of interplanetary pinball, using several planetary gravity assists to get to its destination. It went by Earth once, Venus twice, and Mercury three times (in 2008 and 2009) before finally entering orbit around Mercury in March of 2011. The flybys were very important for testing out the instrument sequences, affording the opportunity to practice for the challenge of being in orbit and having the equivalent of two flybys per day.

### A Visual Overview of Mercury

On the first MESSENGER flyby, the spacecraft returned a fabulous image [see the opening photo on page 28] — it’s a composite of images taken through three different color filters and is roughly what your eye would see if you were there. We saw for the first time the whole of the large impact structure called the Caloris basin (only the eastern third of the basin was sunlit during the Mariner 10 flybys).

The colors are subtle, but can be enhanced to bring out the differences. A digital image consists of a matrix of numbers, which can be manipulated mathematically, including via a statistical technique called principal components analysis (PCA). What PCA does is boil down all the color variation in a scene to a few factors that contain most of the variation. It does a really good job of highlighting the main sources of color variation. This is the enhanced color view *(right)*, which is really quite beautiful.

What we see on the surface are relatively bright, smooth plains (colored yellow) that fill the interior of the Caloris basin. There is a terrain with color properties like that of the “average” Mercury surface. Then there is dark material that has a bluish color, compared to the global average, in certain parts of the southern hemisphere and surrounding the exterior of the Caloris basin. Fresh impact craters dot the surface with their bright interiors and rays.

### Strange Sights

A lot of strange sights have been seen on Mercury, things that the MESSENGER team is still trying to understand. For instance, the images reveal certain craters that have dark rims; several are found within the Caloris basin. This rather surprising. The dark rim indicates that the impact dug up dark material from beneath the surrounding smooth plains, which have a higher albedo.

Another class of crater on Mercury (including Sander; see the image on the next page) has highly unusual bright stuff on their floors. Mariner 10 spotted a number of them, though at fairly poor spatial resolution, and few scientists at the time really thought much about the bright material. But now we’ve seen many more with MESSENGER — I’ll have more to say about them later on, but they’re turning out to be amazing.

There is clear evidence for volcanic vents on Mercury. The prime example is in the southwest corner of the Caloris basin, where there...
is an irregular depression that appears to be on a gentle rise. It’s surrounded by a velvet-textured, smooth, bright deposit that becomes more diffuse with distance away from the depression.

Features such as this are found on the Moon, and it is probable that they are pyroclastic deposits formed by explosive eruptions. On the Moon these deposits all appear dark, because the erupted material is rich in ferrous iron, causing it to appear dark against the lower-iron lunar highlands. But Mercury defies expectations, because its pyroclastic deposits are, instead, bright compared to the background surface.

**Troughs and Scarps**

With Mercury, the surprises just keep coming. For instance, Pantheon Fossae (*upper right*) is right in the middle of the Caloris basin. The Fossae consists of a collection of hundreds of troughs radiating out from a central point. The central impact crater is probably unrelated — it appears that the impact post-dates the formation of the troughs. It was a big surprise to discover such a group of troughs on Mercury. There's nothing like Pantheon Fossae on the Moon or on the part of Mercury seen by Mariner 10.

Troughs are produced by tension in the crust when the surface is pulled apart and a valley opens up. Most everywhere else on Mercury the crust is dominated not by tension but by contraction — squeezing together. Contraction produces a type of landform called a scarp (cliff), in which one block of crust is pushed or thrust up over another along a fault.

It appears that Mercury’s diameter shrunk by several kilometers (a result of cooling of the interior), producing contraction on a global scale. With all that contraction going on, it's curious to find evidence of tension in the form of troughs — forces working in the opposite direction. The timing and cause of the troughs are real puzzles that the structural geologists and geophysicists are working to solve. It also turns out there are many more scarps (*above*) than was originally thought, and some of them are huge. The presence of more scarps means that Mercury’s global contraction was probably even more extensive than initially suspected.
Hollows

Mercury’s surprises just keep on coming. From Mariner 10 and MESSENGER flyby images, we knew that certain craters and basins had unusually high-reflectance material in their floors, such as the crater Sander, mentioned earlier. The bright, bluish material is not limited to the floors of craters — it is also sometimes found in crater walls or on the peak rings of basins. Such deposits are unique to Mercury, with no counterpart on the Moon or any of the asteroids that have been imaged at close range.

Once the spacecraft entered orbit and was able to make high-resolution targeted observations, we found that that the bright stuff consists of very weird, irregular, shallow rimless depressions. Many of the depressions, which we have dubbed “hollows,” have bright interiors and bright halos. The hollows are tens of meters to a few kilometers in size. They have a fresh appearance and few if any small impacts have formed on the hollows — indicating a very young age compared to the majority of the planet's surface. The hollows are unlikely to be volcanic, because their locations don’t make sense for volcanism and the colors are different (hollows tend to be bluish whereas Mercury’s pyroclastic deposits tend to be reddish).

The MESSENGER team has had only a few months to think about this, but one hypothesis for the origin of the hollows is that sublimation or some other loss of volatile material is taking place. That is, a component of the rocks is unstable once it arrives at the surface of Mercury after being exposed by an impact, and is eroding (sublimating) because of high temperatures or as a result of the intense bombardment by micrometeoroids and solar wind particles to which the planet's surface is subjected.

The “Swiss-cheese” terrain that occurs on the south polar cap of Mars, formed by sublimation of carbon dioxide ice, has depressions that are very similar in appearance to some of Mercury’s hollows. No one would ever have predicted that a Martian polar cap could be an analog for anything on Mercury!

In Tyagaraja crater (lower left), as in Sander, a large number of hollows have coalesced to form terrain with an odd, etched appearance. The hollows are a major puzzle, and the composition of the bright material and the process that forms them will be engaging planetary scientists for quite a while.

MESSENGER’s sensors found that Mercury is not as depleted in potassium relative to thorium as expected. This reverses a trend (illustrated above) that shows potassium abundance decreasing the closer a planet is to the Sun.
Volatile Elements

MESSENGER carries a set of geochemical sensors. The gamma-ray spectrometer can measure the abundance of naturally occurring radioactive elements (chiefly potassium and thorium). Potassium is a volatile element, meaning that it has a relatively low boiling point. For Mars, Earth, and Venus, the trend is for decreasing potassium the closer the planet is to the Sun.

It was expected that during Mercury’s formation close to the Sun, potassium would have been driven off, and thus the planet would continue the trend and be depleted in potassium. But it turns out that Mercury has a high level of potassium — similar to the average value of Mars. This rules out some of the high-temperature models for

Ron Dantowitz and Copland Crater

Some 10 years before MESSENGER arrived at Mercury, amateur astronomers Ron Dantowitz, Scott Teare, and Marek Kozubal got time on the 60-inch telescope on Mount Wilson. They observed Mercury and used an image-stacking technique to combine 40 near-infrared images that were taken during the instances of best seeing. They produced an image of Mercury and published a paper about their observations in the Astronomical Journal in 2000.

The image showed a part of Mercury that had not been viewed by Mariner 10 and so represented newly seen territory. They identified what they thought was a dark impact basin and a bright crater. In 2008, Ron approached the International Astronomical Union (IAU, the organization in charge of naming features on the planets), because he wanted to name that crater for a composer whose music he enjoys: Aaron Copland. The IAU liked the idea but felt it was a bit premature to assign a name to something seen at such low resolution.

In 2009 MESSENGER flew by on its third pass and imaged that part of the planet. Indeed, the dark basin that Ron and his collaborators saw is present, and beside it is a bright spot. But it turns out that the bright spot is not a crater. Instead it is a pyroclastic vent surrounded by a bright deposit similar to the vent in southwest Caloris.

There are as yet no rules established for the naming of volcanoes on Mercury, but whatever it turns out to be, it won’t be the same convention that is used for naming craters. On Mercury, craters are named for artists, musicians, authors, and painters. Therefore I contacted Mr. Dantowitz and suggested that the name Copland be proposed for a large flooded large crater adjacent to the bright spot. He was agreeable to that and the IAU accepted the name. So that’s the backstory to how Copland got its name.

— D.T.B.
Mercury’s formation and suggests that the material from which Mercury formed may have come from a wider swath of the inner solar system than was previously suspected.

Fitting with the gamma-ray spectrometer result for potassium, the x-ray spectrometer has found higher-than-expected sulfur content on the Mercurian surface. Sulfur is another volatile element. Sulfur compounds may be involved in the formation of the hollows described earlier. Thus there is growing evidence that, contrary to the old prevailing wisdom, Mercury is not depleted in volatile elements, and thus models for the formation of Mercury need to be revised.

**Magnetic Field**

Mariner 10 discovered the planet’s magnetic field. MESSENGER has confirmed that the intrinsic field has a dipole configuration, which wasn’t quite clear from the Mariner 10 data. It looks like the strength of the field hasn’t changed since Mariner 10 flew past, and we don’t yet see any magnetized sections of crust (areas of magnetized crust are found on Mars and the Moon).

It has been determined that there is a shift in the magnetic equator relative to the geographic equator (see the illustration on the previous page). This offset, about 500 kilometers toward the north, is related to the nature of the internal dynamo that generates Mercury’s magnetic field. An interesting consequence of the northward offset is that more solar wind and magnetospheric particles are able to get in and bombard the area of the surface around the south pole. This has implications for generating Mercury’s thin atmosphere and also has implications for some of the processes that have happened to the rocks on the surface.

This illustration tries to summarize some of the complex interactions between the solar wind, the magnetic fields generated in a liquid outer core, the magnetosphere, the exosphere, and micrometeoroids bombarding the surface. It’s a complex, dynamic system, and there is much yet to be learned.

**A Strange World**

So the summary for Mercury is that it’s a strange planet, and it is radically different from the Moon. Even some planetary scientists say: “Ah, Mercury looks just like the Moon.”

At a cursory glance, yes. But in nearly every characteristic, Mercury and the Moon contrast sharply. Many aspects of this little planet are poorly understood, and MESSENGER is revealing numerous fundamental features about the planet that we don’t yet comprehend. Among other things, models for its formation need to be reconsidered.

Mercury is a planetary endmember, an “anchor” for the process of planetary formation close to the Sun. In order to fully comprehend how the Sun’s family of planets formed, we need to understand Mercury. Since many of the planets being discovered around other stars are “close-in,” Mercury likely has much to teach us about planet formation in general.

MESSENGER’s primary mission runs through March 2012. An extended mission proposal has been submitted to NASA, and we have enough fuel to maintain orbit for another Earth year. So hopefully, many more discoveries about Mercury are in store.

David T. Blewett is a member of the Senior Professional Staff, Space Department, at the Johns Hopkins University Applied Physics Laboratory. He specializes in remote sensing and geological studies of the Moon and Mercury. He is a MESSENGER Participating Scientist, and also serves as the MESSENGER Science Outreach Liaison.
Excerpts from recent press releases that describe an assortment of astronomical discoveries.

MESSENGER Reveals Lava Flows, Hollows, and Unprecedented Surface Details

The Lunar Mapping and Modeling Project website will also include data obtained from past lunar programs and missions including Apollo, Lunar Orbiter, Lunar Prospector, Clementine, Kaguya (Japan) and Chandrayaan-1 (India).

By making these data widely available to the general public, NASA seeks to provide engineers, scientists, mission planners, educators and students with a new resource that will allow them to view and analyze a wide array of lunar images and other data products in a way not previously available to such a diverse group, said Raymond French, integration lead for the Lunar Mapping and Modeling Project Office.

The website provides access to rich and highly complex products from previous missions such as images, digital elevation models, gravity models, local hazard assessment maps assessing slope, surface roughness, crater, and boulder distribution; and resource maps detailing such information as soil maturity and the presence and abundance of hydrogen and other elements.

The Lunar Mapping and Modeling Project website features an easy-to-use browsing tool, and provides access to two additional visualization and analysis tools.

Putting The Moon Within Reach

NASA has created a new interactive web-based tool that incorporates observations from past and current lunar missions, creating one of the most comprehensive lunar research websites to date.

The Lunar Mapping and Modeling Project has created an online set of capabilities and tools that will allow anyone with an Internet connection to search through, view, and analyze a vast number of lunar images and other digital products. The data and tools available through the project website will allow researchers to perform in-depth analyses to support mission planning and system design for lunar exploration and science missions. It will permit detailed scientific analysis and discovery and open additional educational and outreach opportunities.

The website is a one-stop location for finding, retrieving, and analyzing data about the Moon, including the most recent lunar surface imagery, altimetry, temperature, lighting and other data, as provided by the Lunar Reconnaissance Orbiter.

New data from orbit show a huge expanse of volcanic plains surrounding the north polar region of Mercury. These continuous smooth plains cover more than 6% of the total surface of Mercury.

Images collected by MESSENGER have revealed an unexpected class of landform on Mercury and suggest that a previously unrecognized geological process is responsible for its formation. Images collected during the Mariner 10 and MESSENGER flybys of Mercury showed that the floors and central mountain peaks of some impact craters are very bright and have a blue color relative to other areas of Mercury. “To the surprise of the science team, it turns out that the bright areas are composed of small, shallow, irregularly shaped depressions that are often found in clusters,” says David Blewett, a staff scientist at the Johns Hopkins University Applied Physics Laboratory. “The science team adopted the term ‘hollows’ for these features to distinguish them from other types of pits seen on Mercury.”

The Galileo spacecraft surveyed the Moon on December 7, 1992, on its way to Jupiter. The left part of this North Pole scene is visible from Earth.

The Lunar Mapping and Modeling Project website features an easy-to-use browsing tool, and provides access to two additional visualization and analysis tools.

More information
**NASA Spacecraft Data Suggest Water Flowing on Mars**

Observations from NASA’s Mars Reconnaissance Orbiter have revealed possible flowing water during the warmest months on Mars.

Dark, finger-like features appear and extend down some Martian slopes during late spring through summer, fade in winter, and return during the next spring. Repeated observations have tracked the seasonal changes in these recurring features on several steep slopes in the middle latitudes of Mars’ southern hemisphere.

“The best explanation for these observations so far is the flow of briny water,” said Alfred McEwen of the University of Arizona, Tucson, the principal investigator for the orbiter’s High Resolution Imaging Science Experiment.

Some aspects of the observations still puzzle researchers, but flows of liquid brine fit the features’ characteristics better than alternate hypotheses. Saltiness lowers the freezing temperature of water. Sites with active flows get warm enough, even in the shallow subsurface, to sustain liquid water that is about as salty as Earth’s oceans, while pure water would freeze at the observed temperatures.

“These dark lineations are different from other types of features on Martian slopes,” said Mars Reconnaissance Orbiter Project Scientist Richard Zurek of JPL. “Repeated observations show they extend ever farther downhill with time during the warm season.”

The features imaged are only about 0.5 to 5 yards or meters wide, with lengths up to hundreds of yards. The width is much narrower than previously reported gullies on Martian slopes. However, some of those locations display more than 1,000 individual flows. Also, while gullies are abundant on cold, pole-facing slopes, these dark flows are on warmer, equator-facing slopes.

**Dawn Science Team Presents Early Science Results**

Scientists with NASA’s Dawn mission are sharing with other scientists and the public their early information about the southern hemisphere of the giant asteroid Vesta.

Dawn, which has been orbiting Vesta since mid-July, has found that the asteroid’s southern hemisphere boasts one of the largest mountains in the solar system. Other findings show that Vesta’s surface, viewed by Dawn at different wavelengths, has striking diversity in its composition, particularly around craters. Science findings also include an in-depth analysis of a set of equatorial troughs on Vesta and a closer look at the object’s intriguing craters. The surface appears to be much rougher than most asteroids in the main asteroid belt. In addition, preliminary dates from a method that uses the number of craters indicate that areas in the southern hemisphere are as young as 1 billion to 2 billion years old, much younger than areas in the north.

Scientists do not yet understand how all the features on Vesta’s surface formed, but they did announce, after analysis of northern and southern troughs, that results are consistent with models of fracture formation due to giant impact.

Since July, the Dawn spacecraft has been spiraling closer and closer to Vesta, moving in to get better and better views of the surface. In early August, the spacecraft reached an orbital altitude of 1,700 miles (2,700 kilometers) and mapped most of the sunlit surface, during survey orbit, with its framing camera and visible and infrared mapping spectrometer. That phase was completed in late August, and the spacecraft began moving in to High Altitude Mapping Orbit.
**NASA’s Kepler Helps Update Census of Sun-like Stars**  
*Iowa State University*

NASA’s Kepler Mission has detected changes in brightness in 500 sun-like stars, giving astronomers a much better idea about the nature and evolution of the stars.

Prior to Kepler’s launch in March 2009, astronomers had identified the changes in brightness, or oscillations, of about 25 stars similar to our sun in size, age, composition and location within the Milky Way galaxy.

The discoveries are a big boost to asteroseismology, the study of stars by observations of their natural oscillations. Those oscillations provide clues about star basics such as mass, radius and age as well as clues about the internal structure of stars.

“This helps us understand more about the formation of stars and how they evolve,” said Steve Kawaler, an Iowa State University professor of physics and astronomy. “These new observations allow us to measure the detailed properties of stars at an accuracy that wasn’t possible before.”

The Kepler spacecraft is orbiting the Sun carrying a photometer, or light meter, to measure changes in star brightness. The photometer includes a telescope 37 inches in diameter connected to a 95 megapixel CCD camera. The instrument is continually pointed at the Cygnus-Lyra region of the Milky Way. It is expected to continuously observe about 170,000 stars for at least three and a half years.

Data from 500 sun-like stars gives astronomers a much better understanding of the stars, their properties and their evolution. It also gives astronomers data to test their theories, models, and predictions about the stars and the galaxy.

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**Fifty New Exoplanets Discovered**  
*European Southern Observatory*

Astronomers using ESO’s world-leading exoplanet hunter HARPS announced a rich haul of more than 50 new exoplanets, including 16 super-Earths, one of which orbits at the edge of the habitable zone of its star. By studying the properties of all the HARPS planets found so far, the team has found that about 40% of stars similar to the Sun have at least one planet lighter than Saturn.

The HARPS spectrograph on the 3.6-metre telescope at ESO’s La Silla Observatory in Chile is the world’s most successful planet finder. The HARPS team, led by Michel Mayor (University of Geneva, Switzerland), announced the discovery of more than 50 new exoplanets orbiting nearby stars, including sixteen super-Earths. This is the largest number of such planets ever announced at one time.

In the eight years since it started surveying stars like the Sun using the radial velocity technique, HARPS has been used to discover more than 150 new planets. About two thirds of all the known exoplanets with masses less than that of Neptune were discovered by HARPS. These exceptional results are the fruit of several hundred nights of HARPS observations.

Working with HARPS observations of 376 Sun-like stars, astronomers have now also much improved the estimate of how likely it is that a star like the Sun is host to low-mass planets (as opposed to gaseous giants). They find that about 40% of such stars have at least one planet less massive than Saturn. The majority of exoplanets of Neptune mass or less appear to be in systems with multiple planets.

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*More information*
How Single Stars Lost Their Companions
Royal Astronomical Society

Not all stars are loners. In our home galaxy, the Milky Way, about half of all stars have a companion and travel through space in a binary system. But explaining why some stars are in double or even triple systems while others are single has been something of a mystery. Now a team of astronomers from Bonn University and the Max Planck Institute for Radio Astronomy (also in Bonn) think they have the answer — different stellar birth environments decide whether a star holds on to its companion.

Stars generally do not form in isolation but are born together in groups within clouds of gas and dust or nebulae. These stellar labor rooms produce binary star systems, which means that virtually all newborn stars have a companion. Most of these groups of stars disperse quickly so that their members become part of the Galaxy. But why, then, are not all stars seen in the sky binaries, but only half of them?

Before the groups of stars disperse, binary stars move through their birth sites and the group studied how they interact with other stars gravitationally. "In many cases the pairs are torn apart into two single stars, in the same way that a pair of dancers might be separated after colliding with another couple on a crowded dance floor," explains Michael Marks, a PhD student and member of the International Max Planck Research School for Astronomy and Astrophysics. The population of binaries is therefore diminished before the stars spread out into the wider Galaxy.

Herschel Paints New Story of Galaxy Evolution
European Space Agency

ESA’s Herschel infrared space observatory has discovered that galaxies do not need to collide with each other to drive vigorous star birth. The finding overturns this long-held assumption and paints a more stately picture of how galaxies evolve.

The conclusion is based on Herschel’s observations of two patches of sky, each about a third of the size of the full Moon. These observations are unique because Herschel can study a wide range of infrared light and reveal a more complete picture of star birth than ever seen before.

It has been known for some years that the rate of star formation peaked in the early universe, about 10 billion years ago. Back then, some galaxies were forming stars ten or even a hundred times more vigorously than is happening in our Galaxy today.

In the nearby, present-day universe, such high birth rates are very rare and always seem to be triggered by galaxies colliding with each other. So, astronomers had assumed that this was true throughout history.

Herschel now shows that this is not the case by looking at galaxies that are very far away and thus seen as they were billions of years ago.

David Elbaz, CEA Saclay, France, and collaborators have analyzed the Herschel data and find that galaxy collisions played only a minor role in triggering star births in the past, even though some young galaxies were creating stars at furious rates.

By comparing the amount of infrared light released at different wavelengths by these galaxies, the team has shown that the star birth rate depends on the quantity of gas they contain, not whether they are colliding.
**How a Black Hole Devoured a Star**
*Max Planck Institute for Radio Astronomy*

The source now known as Swift J1644+57 is the result of a truly extraordinary event — the awakening of a distant galaxy's dormant black hole as it shredded and consumed an errant star.

Most galaxies, including our own, possess a central supersized black hole weighing millions of times the Sun's mass. The black hole in the galaxy hosting Swift J1644+57 may be twice the mass of the four-million-solar-mass black hole lurking at the center of our own Milky Way galaxy. As a star falls toward a black hole, it is ripped apart by intense tides. The gas is corralled into an accretion disk that swirls around the black hole and becomes rapidly heated to temperatures of millions of degrees.

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**Giant Space Blob Glows from Within**
*European Southern Observatory*

Observations from ESO's Very Large Telescope have shed light on the power source of a rare vast cloud of glowing gas in the early universe. The observations show for the first time that this giant "Lyman-alpha blob" — one of the largest single objects known — must be powered by galaxies embedded within it.

A team of astronomers has used ESO's Very Large Telescope to study an unusual object called a Lyman-alpha blob. These huge and very luminous rare structures are normally seen in regions of the early universe where matter is concentrated. The team found that the light coming from one of these blobs is polarized. This is the first time that polarization has ever been found in a Lyman-alpha blob, and this observation helps to unlock the mystery of how the blobs shine.

"We have shown for the first time that the glow of this enigmatic object is scattered light from brilliant galaxies hidden within, rather than the gas throughout the cloud itself shining," explains Matthew Hayes (University of Toulouse, France), lead author of the paper.

The team studied one of the first and brightest of these blobs to be found. Known as LAB-1, it was discovered in 2000, and it is so far away that its light has taken about 11.5 billion years to reach us (redshift 3.1). With a diameter of about 300,000 light-years, it is also one of the largest known, and has several primordial galaxies inside it, including an active galaxy.

There are several competing theories to explain Lyman-alpha blobs. One idea is that they shine when cool gas is pulled in by the blob's powerful gravity, and heats up. Another is that they are shining because of brilliant objects inside them: galaxies undergoing vigorous star formation, or containing voracious black holes engulfing matter. The new observations show that it is embedded galaxies, and not gas being pulled in, that power LAB-1.
New Society Board Members

Please welcome three new ASP Board members and one returnee. During a 20-year career in computer graphics technology, Chris Ford has managed most of the professional 3D software tools used in feature film special effects, animation, broadcast graphics, and scientific visualization. From 1997 to 2002 he was Senior Maya Product Manager at Alias|Wavefront (Silicon Graphics) where he introduced the Academy Award winning Maya software, now the industry’s dominant 3D digital media content creation software. Between 2002 and 2005, he was Director of Product Management at Autodesk for all 3D media and entertainment software products. Chris is the Business Director for Pixar Animation Studios (Walt Disney Co.) Academy Award winning RenderMan software. He is also President of the Mount Diablo Astronomical Association, and is a keen astrophotographer with a particular interest in the application of cinematic computer graphics visualization technology to astronomical imaging.

Wayne Rosing has training in mathematics, astronomy, and physics. He is a computer engineer by vocation, and has been programming, doing computer, electronics, and optical design, and telescope engineering since high school. His career has spanned leadership roles at Digital Equipment Corporation, Apple Computer, and Sun Microsystems. Most recently, Wayne was Sr. VP of Engineering at Google from 2000 through April 1, 2005. In 1992, Wayne founded what is known as ‘Las Cumbres Observatory Global Telescope Network, Inc.’ (LCOGT) now located in Goleta, CA. At LCOGT, he and his staff of engineers and scientists are currently developing scores of one- and 0.4-meter aperture telescopes to be placed in various locations around the world. These telescopes will be used for scientific research as well as be available for educational use by “learners of all ages.”

Chris Impey is a University of Arizona Distinguished Professor and Deputy Head of the Astronomy Department. His research interests are observational cosmology, gravitational lensing, and the evolution and structure of galaxies. He has 160 refereed publications and 60 conference proceedings, and his work has been supported by $20 million in grants from NASA and the NSF. As a professor, he has won 11 teaching awards, and he has been heavily involved in curriculum and instructional technology development.

Chris has also been an NSF Distinguished Teaching Scholar, a Phi Beta Kappa Visiting Scholar, the Carnegie Council on Teaching’s Arizona Professor of the Year, and a co-chair of the Education and Public Outreach Study Group for the American Decadal Survey of the National Academy of Sciences. He has written more than 30 popular articles on cosmology and astrobiology, and co-authored two introductory textbooks.

Judy Kass retired from her position as Senior Project Director with the American Association for the Advancement of Science in the fall of 2007 but continues to work as an independent consultant. As the Senior Project director for the AAAS’s Public Understanding of Science and Technology Programs, she developed partnerships with PBS stations, educators, scientists, and Community Based Organizations in various projects across the US. She was PI/Project Director of the NSF planning grant “Science and Mathematics Education Reform: What do Parents Need to Know to Get Involved?” that identified ways for parents to become more involved in their children’s science education. She currently is co-PI on an NSF-funded two-hour PBS special “The Mystery of Matter: Search for the Elements.” In October 2008, Ms. Kass received the first President’s Award from the Association of Science Technology Centers, recognizing her longstanding role in fostering AAAS/Science Centers relationships. She currently serves as Vice President of the Board of Directors of the ASP.

The ASP Invites Nominations for the Society’s 2012 Awards

The Astronomical Society of the Pacific is now accepting nominations for the Society’s 2012 awards honoring accomplishments in astronomy education and public outreach. Recipients receive a cash award and engraved plaque, as well as travel and lodging to accept the award at the Society’s 2012 Meeting next summer.

• The Richard Emmons Award celebrates a lifetime of outstanding achievement in the teaching of college-level introductory astronomy for non-science majors.
• The Klumpke-Roberts Award recognizes those who have made major contributions to the public understanding and appreciation of astronomy.
• The Thomas J. Brennan Award is given for excellence in the teaching of astronomy at the high school level in North America.
• The Las Cumbres Amateur Outreach Award honors outstanding educational outreach by an amateur astronomer to K-12 students and the public.
The Amateur Achievement Award recognizes significant observational or technical achievements by an amateur astronomer. The Robert J. Trumpler Award for a recent Ph.D. thesis considered unusually important to astronomy. Submission guidelines, and lists of past recipients can be found on the ASP's Annual Awards webpage. The deadline for nominations is December 15, 2011. You do not need to be a member of the Society to make or second a nomination.

The ASP's Transit of Venus page
The phrase "once in a lifetime" denotes a rare event. A transit of Venus is actually a "twice-in-your-lifetime" event, because these transits occur twice during an eight-year span, with each pair separated by more than a century. The current transit pair (2004 and 2012) concludes next year. Miss it, and you'll have to wait 105 years to see another.

So where will you be on June 5–6, 2012? And what will you be doing to observe the transit? To help you answer these questions, the ASP has assembled a growing list of items and links on the topic of the Venus transit. You can access this information on the ASP's Transit of Venus webpage.

Airborne Astronomy Ambassadors (AAA) Cycle 1 Application Opportunity
NASA's Stratospheric Observatory For Infrared Astronomy (SOFIA) is a 747SP aircraft carrying a 2.5 meter-diameter telescope dedicated to astronomical research. The telescope, associated equipment, and observing team are in the pressurized main cabin. AAA program participants will fly on overnight missions, at altitudes of up to 45,000 feet, in the main cabin. The 8- to 10-hour flight experience will be similar in environmental conditions (temperature, seating, turbulence) to a regular commercial airline flight, although interior noise level will be somewhat higher. Participants must be able to walk up a steep and narrow stairway unassisted, sit for an extended period of time in a pressurized cabin, and carry flight materials unassisted. AAA program applicants and members must be US Citizens or legal residents teaching in a US school.

Applications to become an Airborne Astronomy Ambassador (AAA) will be accepted until November 15, 2011. Cycle 1 science flights are expected to take place from mid-2012 to mid-2013. This is a unique opportunity for formal and informal educators to be involved in frontier astronomy research as partners with scientists on SOFIA flights.

Educators must apply as teams of two. One team member must be an active grade 6-12 classroom science teacher (formal educator). The second team member may be a science, math, or technology teacher at the elementary, middle or secondary level, or an informal educator (e.g. science museum, planetarium).

Applications will be accepted only via a website (with supporting documents to be uploaded). For further details, application requirements, and access to the application forms, please go to this Web address: www.seti.org/epo/SOFIA

Support Your Society
In today's world, where the things we do often seem to lead to unintended consequences, isn't it nice to know that generosity remains one of those acts where intended consequences can still result? It is to provide such intended consequences that we ask for your generous support in our annual fall appeal.

Let me tell you of one such consequence: his name is Aaron Leifheit. Aaron is the Environmental Education Program Director at Red Rock Canyon Interpretive Association near Las Vegas, and he attended last fall's ASP Sky Rangers workshop at Yosemite National
The program trains people like Aaron, who work at national parks and other outdoor educational venues, to effectively incorporate astronomy into their programs for the benefit of their visitors.

At the Yosemite workshop, Aaron received some Galileoscopes, developed during the International Year of Astronomy, to teach the principles of optics and provide a ready-made way for kids to explore their world as Galileo did. Aaron used his new telescopes for the After School Allstars program, in which a group of Las Vegas inner city kids came to the canyon for an overnight camping trip last November. Aaron taught a lesson on Galileo, who he was and what he did, followed by observations of Jupiter. He then gave the telescopes to the kids, who practiced using them on a night hike and again the next day. They went home the excited owners of a new way to study the world around them — perhaps to spark a life-long interest in science, and to consider becoming scientists themselves one day, making new discoveries all their own.

Aaron wrote: “These events would not have been possible without the kindness of the Astronomical Society of the Pacific’s generosity! Thank you!” What this really means is that these events — and so many others around the nation and beyond, sparked by Sky Rangers and other ASP programs — would not be possible without the kindness of your generosity.

Your gift, and the work it supports, has real impact, reaching into the classrooms of Project ASTRO teachers, into the public events of amateur astronomers, into the outdoor programs of people like Aaron Leifheit, who work every day to advance science literacy using the tools and training that our Society provides, even as we help to advance science through our professional publications, meetings, and other activities as well.

It’s important work at a time when public understanding and appreciation of science is urgently needed, when science education leading to new generations of scientists and science-literate citizens is crucial to our future. Astronomy has proven, time and again, to be an appealing and effective avenue toward these goals.

I ask you to help us advance these goals with an investment in the work of the ASP and in the science future of our national and global societies — to be generous as we work together to achieve the intended consequences of a future of science enlightenment and achievement. Thanking you in advance for your support, I remain,

James G. Manning
Executive Director, Astronomical Society of the Pacific

P.S. Please give generously so that we can, together, help more Aaron Leifheits introduce kids to science!  

Support the ASP through the Combined Federal Campaign

The ASP is a member of the Combined Federal Campaign (CFC) for federal employees (CFC#: 10651). Individual members’ and supporters’ CFC gifts to the ASP throughout the year directly support our many educational and outreach programs to advance science literacy. Please consider this convenient avenue as a way to support the Society. Thank you for being there for us, as we work together to continue the good work in which we all believe, inspiring and engaging the next generation thorough astronomy!

A Gift That Gives Back

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NEW MEMBERS — The ASP welcomes new members who joined between June 16 and September 30, 2011.

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AUTUMN 2011 Mercury 43
The skies of November

The two inner planets (Mercury and Venus) spend the first half of the month close together, but low in the southwest after sunset. Both set about an hour after the Sun, but because they are low, you’ll need a flat and clear horizon to spot them as darkness falls. By the time a very thin crescent Moon appears to the right of Venus on the 26th (and high above Venus on the next evening), Mercury has vanished into the twilight glow.

Jupiter is well up in the east-southeast at sunset and dominates the sky as the evening progresses. It’s right on the boundary between Aries, the Ram, and Pisces, the Fishes. On the 8th and 9th the Moon passes above this giant planet.

Mars in Leo, the Lion, rises just after midnight and is well up in the south by dawn. On the 11th and 12th the red planet passes slightly more than 1° from the star Regulus, which is almost as bright but not as red. On the 19th the Moon passes under star and planet.

Saturn (in Virgo, the Maiden) pops up about an hour before the Sun at month start; by month end it’s rising nearly three hours before Sol. Don’t confuse it with the star Spica, which is the westernmost of this pair of nearly equally bright objects (of course, Saturn is the one with the rings). At dawn on the 22nd, look to the left of the thin crescent Moon to see first Spica, then Saturn.

The Sky sights

by Paul Deans

The skies of December

The final eclipse of 2011 is a total lunar eclipse on December 10. The Moon’s orbital trajectory takes it through the southern half of Earth’s umbral shadow. Although the eclipse is not central, the total phase still lasts 51 minutes. The timings of the major eclipse phases are listed below.

At the instant of greatest eclipse (14:31:49 UT) the Moon lies at the zenith in the Pacific Ocean near Guam and the Northern Mariana Islands. The entire event is visible from Asia and Australia. For North Americans, the eclipse is in progress as the Moon sets, with western observers witnessing a larger fraction of the eclipse before moonset. Observers throughout Europe and Africa will miss the early eclipse phases because they occur before moonrise. None of the eclipse can be seen from South America.

The Moon’s centre passes south of Earth’s shadow axis. Thus, the northern half of the Moon will appear much darker than the southern half because it lies deeper in the umbra. Since the Moon samples a large range of umbral depths during totality, its appearance will change dramatically with time, and so it is difficult to predict how bright it will appear as brightness varies within in the umbra.

During totality, the winter constellations are well placed for viewing, so a number of bright stars can be used for magnitude comparisons. Aldebaran (magnitude +0.87) is 9° to the southwest of the eclipsed Moon, while Betelgeuse (+0.45) is 19° to the southeast, Pollux (+1.16) is 37° east, and Capella (+0.08) is 24° north. If you are short sighted, remove your glasses (or contacts) and compare the brightness of the (fuzzy) eclipsed Moon to the brightness of the (equally fuzzy) nearby bright stars.

The NASA JavaScript Lunar Eclipse Explorer is an interactive webpage that can quickly calculate the altitude of the Moon during each phase of the eclipse from any geographic location.

The times (below) listed in italic indicate that the Moon may well have already set in your area/time zone. You can calculate the exact time of moonset for your area at the USNO’s Sun/Moon data page.

<table>
<thead>
<tr>
<th>Eclipse Phase</th>
<th>UT</th>
<th>ET</th>
<th>CT</th>
<th>MT</th>
<th>PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial Eclipse Begins:</td>
<td>12:45:42</td>
<td>7:45:42</td>
<td>6:45:42</td>
<td>5:45:42</td>
<td>4:45:42</td>
</tr>
<tr>
<td>Penumbral Eclipse Ends:</td>
<td>17:30:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Feb 20, 2008, total lunar eclipse, when the Moon also passed through the southern half of Earth’s shadow.

**Venus** is very low in the southwest after sunset at the start of the month. It sets two hours after the Sun, but will be difficult to see because of its lack of altitude as darkness falls. But as the month progresses, Venus creeps higher in the sky as dusk fades. On the 27th, the 3-day-old crescent Moon sits above Venus at dusk. It’s a nice sight if you have a low southwestern horizon. **Jupiter** is well up in the southeast after sunset and is visible most of the remainder of the night. On the 5th the Moon is to Jupiter’s right; on the 6th to its left.

**Mars** rises around midnight; the last quarter Moon is to the red planet’s lower right on the 17th. **Saturn** rises during the early morning hours and is well up in the east by dawn. The crescent Moon sits below the ringed planet as they both rise on the 20th.

At midmonth, **Mercury** pops up about an hour before the Sun. If you have a good southeastern horizon, look for a very skinny crescent Moon to Mercury’s right on the morning of the 22nd.

The **Geminid meteor shower** during the night of the 13th-14th is often considered one of the year’s best. Unfortunately, this year the Moon (just a few days past full) rises at mid-evening and shines all night long, so moonlight will certainly reduce the number of Geminids visible to skywatchers.

**The Skies of January**

- Go to Sky & Telescope’s January 2012 Sky Chart
- How to use S&T’s Interactive Sky Chart

2012 will be a busy year for skywatchers. There is the usual assortment of meteor showers, planet-Moon alignments, and even two Jupiter-Venus gatherings (March 14, after sunset in the west, and July 15, before sunrise in the east, with the crescent Moon in attendance). But there are also four eclipses and one very rare event to look forward to.

The eclipses are a diverse lot. On May 20-21, an annular eclipse of the Sun races from southern China and southeastern Japan (on the morning of the 21st) across the Pacific to the western US (during the afternoon of the 20th). The path of annularity in the US stretches from northern California to northwestern Texas, but the accompanying partial solar eclipse covers much of Asia, western and northern Canada, and the US west and northwest.

On June 4th a slight partial lunar eclipse will be ongoing at moonset for much of the Americas and at moonrise for the Far East. A total solar eclipse occurs on November 13-14, but other than a sunrise appearance over northeastern Australia, the path of totality tracks across the Pacific Ocean. Finally, a penumbral lunar eclipse occurs November 28. This is a very subtle event, and seeing a little of the delicate shading across the northern limb of the Moon at mid-eclipse is a challenge.

The year’s very rare event is the transit of Venus. You’ll be hearing plenty about this celestial sight in the months to come because it occurs so infrequently. Miss this one and you’ll have to wait 105 years to see the next one! The ASP has created a Transit of Venus webpage, with articles and links to information that will help you observe this historic (and uncommon) event.

One thing that will not happen in 2012 is the end of the world. You can read all about this non-event in a free issue of the ASP’s Astronomy Beat.

**Venus** finally puts in a proper appearance in the southwest after sunset, not setting until about three hours after the Sun. On the 25th, the 3-day-old crescent Moon will shine to Venus’ right — a beautiful sight.

All month **Jupiter** is well-placed for viewing in the south after sunset. On the 2nd as dusk fades, look high into the southeast to see the 9-day-old Moon hovering above the giant planet. At month’s end (on the 29th), a crescent Moon joins Jupiter. If you can spot Venus after sunset, note how far it is from Jupiter. By mid-March, these two bright worlds will be blazing together in the west after sunset.

**Mars** now rises before midnight and is well past south at dawn. During the early morning hours of the 14th, the Moon sits beneath the red planet. **Saturn** rises in the east an hour or two after midnight and is nicely placed in the south at dawn. The last quarter Moon rises with Saturn and on its right on the 16th.

During the first eight months of 2012, follow the motion of Mars relative to Saturn. From mid-January through mid-April, Mars retreats from Saturn, moving farther west each night. But then Mars turns and speeds eastward, catching Saturn in mid-August when they’ll briefly meet, low in the west at sunset.

At the beginning of the month, hunt for **Mercury** low in the southeast before sunrise. Don’t delay; it’ll be somewhat visible for only a few days into the new year.

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

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

### Using the Chart: The Basics

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

For instance, when you click on the link for the November Sky Chart, you should see, in a new window, a screen that looks like the image above. Each of the monthly links in Sky Sights will take you to a chart set for 40° north latitude and 100° west longitude (so it’s useful throughout the continental US) at 9:00 pm local time at mid-month in November, December, and January. The chart can be used one hour later at the start of each month and one hour earlier at month-end.

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

But Sky’s Interactive Chart offers much more. Click on any area of the circular All-Sky Chart that you’d like to see in more detail. The green frame will jump to where your cursor is pointing, and the scene in the Selected View window will now show this area. Or click and hold down your mouse button within the green frame on the All-Sky Chart, then drag the frame around the sky. The scene in the Selected View window will change as the location of the green rectangle on the All-Sky Chart changes. Finally, click and hold down your mouse button in the Selected View window, then drag the cursor to move to another part of the sky. The green frame in the All-Sky Chart will follow your movements.

### Changing the Chart

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

To alter the *date and time*, click on the month, day, year, hour, or minute in the display at lower left, which will become highlighted. (You can change only one parameter at a time.) Then use the + or – button to increase or decrease the value you’ve selected. Each time you change a quantity, both the Selected View and All-Sky Chart will be updated instantly. If you’d rather do a wholesale change, click the large “Change” button in the Date & Time display area. A pop-up window will appear. Here you can choose any date between January 1, 1600, and December 31, 2400, using the day and month pull-down lists and the year text-entry box.

To alter the *location*, you’ll need to click the large “Chance” button in the Location display area. A pop-up window will appear that will let you select a new location. Use either the “USA or Canada” or the “World by City” box and your time zone will be automatically selected, but don’t forget to check the Daylight Saving Time box if appropriate. Do not use the “Worldwide by Latitude & Longitude” option — there are problems with its functionality (among other things; here’s an update from *S&T*).

You’ll find more detailed instructions and hints for using the chart on the [Help](https://skystar.com) page. To really become familiar with this program, see the article: [Fun with S&T’s Interactive Sky Chart](https://skystar.com#fun-with-s-t-s-interactive-sky-chart).

### Tech Talk

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

If you have trouble getting the Sky Chart to open on your computer, please review Sky’s detailed [system requirements](https://skystar.com#system-requirements) to check whether you’re using a supported operating system. And don’t forget to also review the [Help](https://skystar.com) page.
Book reviews are rarely included in *Mercury*, but some books call out to be an exception to this rule. Sue French’s *Deep-Sky Wonders* is one such volume.

Sue has been writing an observing column for *Sky & Telescope* since July 1999. It started out as “Small-Scope Sampler” and highlighted deep-sky objects (double stars, star clusters, nebulae, and galaxies) visible in small telescopes under moderately dark skies. Later the column name changed to “Deep-Sky Wonders,” and though spotting some of these sights now requires darker skies and larger scopes, the column’s philosophy remains the same.

In the interest of full disclosure, I should mention that while at Sky Publishing, I edited *Celestial Sampler*, Sue’s first collection of 60 celestial tours drawn from her *S&T* columns. I’m delighted to see that with the publication of *Deep-Sky Wonders*, more of her columns will reach a wider audience.

The core of this book is 100 of Sue’s *S&T* columns, selected from June 2000 to September 2010. Of these, 23 are “repeats” from her *Celestial Sampler* compendium, to which 77 new deep-sky tours have been added. There’s also a solid index, a short list of resources, and 12 monthly all-sky star maps that will at least show you where (and when) to find the constellations mentioned in the book.

The 100 installments of Sue’s *Wonders* are divided first by season and then by month. As per the original *S&T* columns, each article contains (in addition to the text) a detailed star chart of the region being discussed, a table that includes the names, types, sizes, locations (and sometimes star-atlas references) of the deep-sky sights being described, and one or two images. And I must say, the quality of the deep-sky images is outstanding — a tribute to the various photographers as well as the book’s printer.

But it’s the written word that will make or break a book like this, and Sue’s writing is superb. Not only does she tell you where to find an assortment of celestial sights and what they look like, she also describes their scientific significance and provides a little historical background when appropriate. These details make her columns splendid reading, particularly on nights when you can’t go out and observe the objects she’s describing.

Perhaps you live in a city, where light pollution reduces your night sky to a handful of bright stars. Does this mean *Deep-Sky Wonders* isn’t for you? On the contrary, binoculars and small telescopes help cut through the urban glow, and many of Sue’s columns include objects bright enough to see with basic optics under poor sky conditions.

Major complaints? None. Nits to pick? A few, though most are the type that only other editors really notice. But two are worth mentioning.

It’s a shame that different columns describing the same constellation are often separated by other constellation tours. The worst example of this is “Touring Orion’s Sword” on page 33 and “The Giant’s Shield” on page 37, which are split by a two-page tour of Auriga. In the book, each column is reprinted in the order (month and year) it originally appeared in *S&T*. But this adherence to order outweighs a common-sense approach of placing same-constellation columns back to back, which would make for more coherent reading and better stargazing.

The other annoyance is that many of the star charts lack any indication of scale. A circle representing the field of view of a 5° finderscope or a 1° eyepiece is really useful, especially for beginners. To be fair, this isn’t the book’s fault. It appears that *S&T* stopped including these fields of view in the charts in Sue’s columns. Still, it would have been a nice addition to the book.

But these are minor quibbles. If you’re looking for a gift for someone who is an occasional stargazer, a serious observer, or anyone in between, you won’t go wrong with *Deep-Sky Wonders*. 

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