Making an Impact

Since our inception in 1889, and thanks to donors like you, the ASP has provided educators with the support and tools they need to help them engage young learners in science.

I’m asking for your support during this Fall Appeal so we can continue to innovate, expand our work, and make an impact in classrooms around the country. We know we’re making a difference because our members and supporters tell us that our programs matter.

From Palo Alto Unified School District, for instance, comes this note from teacher Nikole Manou:

_The first day at my new school a student...asked me, ‘Mrs. Manou, what causes nuclear fusion?’ Right then I knew I needed help!_

Nikole came to the right place. Our programs proved a perfect fit for her needs.

_I received an email from the Astronomical Society of the Pacific. They were organizing new teacher/scientist partnerships in the classroom. The ASP promised to train us together in order to create a rich curriculum concentrating on astronomy._

Astronomy can spark a child’s curiosity and motivate investigation, critical thinking, and problem solving. That’s why the ASP first developed Project ASTRO, a unique initiative that brings astronomers into the classroom to support teachers and engage young minds.

_I was paired with Roy Hayter, and it has been such an amazing experience. Roy and I have been working together for 12 years and have developed curriculum in the areas of astronomy, physics/rocketry, and chemistry, and we have organized a yearly star party._

Educators work hard to make learning exciting and relevant in the classroom. With the help of donors like you, the ASP is making a real difference for teachers as they strive to inspire students and foster science literacy.

_I have received so many benefits from this program. I have a science partner who...helps me plan, organize lessons, mentor students, and answer questions that are testing my limits of knowledge._

Nikole’s experience is not unique. The ASP has worked in partnership with educators across the United States, and in more than 40 countries around the world, for more than 25 years.

_We know in teaching that if we are excited about a subject, then that excitement transfers to the children. This is the same idea with having a professional scientist in the classroom. The students see the value and the excitement the scientist has and they become excited....We need everyone involved!_

Parents and caregivers trust children’s learning to teachers. Teachers trust the ASP for support. Please help us deliver on the promise of science literacy by introducing the next generation to the excitement and wonder of the universe.

We appreciate every donation! Your support really does make a difference. You can make your tax-deductible gift securely online at [www.astrosociety.org/donate](http://www.astrosociety.org/donate). For donations of $100 and up, you’ll receive a limited-edition 2015 ASP Commemorative Pin in thanks for your support. This special pin glows in the dark! — our way of commemorating the IAU International Year of Light.

Linda Shore, Ed.D.
Executive Director
Posters from the ASP’s 2014 Meeting

Here are reprints of five of the 55 posters that were on display at the 2014 ASP Conference in Burlingame, California.

Finding Habitable Worlds Around Other Stars
GEOFF MARCY
Astronomers are getting a first glimpse of the possibilities of life elsewhere in the universe.

Flying the Infrared Skies: An Authentic SOFIA Educator Experience
JAMES MANNING
I’ve long been associated with the Stratospheric Observatory for Infrared Astronomy, so it was great to finally partake in a flight.

Astronomy in the News
Rosetta arrives at a comet, clear skies and steamy water vapor have been found on an alien planet, and the distance to the Pleiades is recalibrated — these are some of the items that recently made news in the astronomical community.

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on the cover

Front: The Seven Sisters, also known as the Pleiades or M45, seem to float on a bed of celestial feathers in this infrared image from NASA’s Spitzer Space Telescope. Astronomers have recently resolved a controversy over the distance to this famous star cluster; see page 50 for the details. Courtesy NASA, JPL-Caltech, J.Stauffer (SSC/Caltech).

Back: A close-up view of Comet 67P/Churyumov-Gerasimenko, in a color-reconstructed image, as seen by Rosetta in early September. The comet’s surface reflects, on average, about 4% of the light striking it, making it as dark as coal. Go to page 45 for more. Courtesy ESA/Rosetta/MPS for OSIRIS Team; MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA. Additional Processing & Copyright: Elisabetta Bonora & Marco Faccin.
New Wonders to Behold

Even as you’re reading this, scientists from the European Space Agency’s Rosetta mission are making final preparations for the landing of little Philae onto the surface of Comet 67P/Churyumov-Gerasimenko on November 12th. See page 45 for an update on the landing site.

It’s always tremendously exciting seeing a new world (large or small) up close for the first time. Watching the comet’s nucleus grow ever larger as Rosetta approached reminded me of the heady days of discovery when Voyagers 1 and 2 flew past the four giant outer planets and their retinue of moons.

In the “old days” of the Voyager flybys, reporters (and faux reporters like me) traveled to the von Karman auditorium at the Jet Propulsion Laboratory in Pasadena, CA. Each morning we’d gather for a press briefing to learn of the latest discoveries. Shortly after, we’d queue outside the press office where PI officer Jurrie van der Woude, the keeper of the holy visuals, would dispense images (mostly black and white) to the print media, images and film clips to the television stars, and audio clips to the lowly radio people. Everyone would take their precious goodies, head to their assigned desks, and pound out their stories. The rest of the day was often spent in the auditorium, watching b&w images slowly appear in real time on monitors — literally scan line by scan line.

Meanwhile, the public would see one or two images on the nightly news or in the science column (remember them?) of the local newspaper. Months later, more images would appear in magazines or (in my case) be incorporated into planetarium shows.

Today I can go to the Rosetta website and learn about its mission, read about the science, and see whatever images have been released by the Rosetta team. There’s still plenty of room for interpretation of results, and that’s where good science reporters come in. But these days everyone can participate in a voyage of discovery, and the same should hold true next near when New Horizons zips past Pluto.
Every September, my attention focuses on baseball and the playoffs that are just a few weeks away, and this year is no different. Allow me to confess to one of my late summer baseball fantasies. My dream is to lead an astronomy activity with 30,000 fans attending a night game at a major league stadium (it also happens to be a Boston Red Sox game at Fenway Park, but that’s completely irrelevant I suppose).

In this fantasy, everyone attending the game has received a set of binoculars as a promotional gift. It’s the seventh inning stretch, and the stadium announcer says, “Ladies and gentlemen, it is our pleasure to welcome Linda Shore of the Astronomical Society of Pacific, who will lead us all in some stargazing. Please take your seats and get out your binoculars as we turn off the stadium lights.”

Once 900,000 watts of ballpark lights are extinguished, some of the brighter stars would become visible, and the fans might be able to spot a planet or two. Had this opportunity been possible this summer, I would have taken advantage of “International Observe the Moon Night” on September 6th. I would have instructed fans to take a close look at the terminator along the lower portion of the Moon’s disk. The binoculars would have afforded the fans an astounding view of some of the Moon’s surface features that are much easier to appreciate near the transition line between lunar day and night. I would have helped fans locate the 84-kilometer-wide Wargentin Crater, the elongated crater Schiller, and the spectacular rays of ejecta that emanate from the crater Tycho.

While I may have missed my opportunity to bring “International Observe The Moon Night” to a major league stadium in 2014, as we
often say in baseball, “there's always next year.” Of course this begs the question, what do I think can really be gained if, at the end of a baseball game, 30,000 people left a ballpark with a belly full of hotdogs and beer, a pair of binoculars, and a momentary glimpse at the face of the Moon.

I believe that doing astronomy at a major league baseball game would achieve a very small but powerful victory in the campaign to improve science literacy. Let me explain.

What does it mean to be “scientifically literate”? This question was the major theme of this year's ASP 126th Annual Meeting (“Celebrating Science: Putting Education Best Practices To Work”) and was discussed in almost every session. There was general agreement that a scientifically literate person knows more than just facts. While knowing the age of the solar system, expressing the diameter of the Milky Way galaxy in both light-years and parsecs, and describing the chemical composition of the stars are all important astronomy facts that people should know, understanding how astronomers came to this knowledge in the first place is as important.

The public also needs to learn to “think like scientists.” Because science involves a logical analysis of the natural world, literacy is the ability to ask researchable questions, weigh evidence, question the validity of assertions, and develop sensible conclusions. In other words, a scientifically literate person would have what Carl Sagan described as “a built-in baloney detector” that would make it impossible for people to be swayed by false claims or unconvincing evidence. The truth is, scientific literacy involves all of these abilities. People need to know key concepts and the big ideas of science, understand how scientists arrived at this knowledge, and possess the ability to analyze information critically.

The much bigger question is how do we motivate people to want to learn any of this in the first place? That brings me back to the baseball game. People need transformative experiences to ignite their curiosity and spark an interest in engaging in science. These experiences can take many different forms: getting a simple circuit to light, finding a fossil on a hike, looking a grey whale in the eye, or seeing the craters of the Moon in a pair of binoculars can all capture the imagination.

It's even more powerful when science experiences are shared with friends, family, or with tens of thousands of strangers at a baseball game. Science rarely occurs in isolation; it is a fundamentally social experience that brings groups of investigators together to share what they have observed. This is why so many of us lead star parties at venues — schools, museums, shopping centers, public parks, and city sidewalks — that attract large crowds.

On Monday, August 21, 2017, astronomers will have a remarkable opportunity to help the public safely observe and marvel at a sky show that has captured humanity's imagination for millennia — a total eclipse of the Sun. The path of totality for this eclipse will cross the United States, travel from the Pacific to Atlantic coasts, pass through 12 states, and be visible to millions of people living along the path of totality. Many organizations, including the ASP, are already planning for what may be one of the greatest opportunities to inspire the public and spark the curiosity of a new generation of astronomy enthusiasts.

Sadly, the path of totality will not pass through any major league ballparks, though Kauffman Stadium, home of the Kansas City Royals, gets pretty close and will see 99% of the Sun obscured by the passing Moon. So Kansas City Royals — if you are reading this and want an astronomer to lead the fans in a “moment of science” on August 21, 2017, give me a call!

LINDA SHORE is the Executive Director of the Astronomical Society of the Pacific.
An 850-year-old “Dark Star”

This astronomical allusion has its origin in the writings of Claudius Ptolemy.

As stars go, 850 years is quite young, but the subject of this column lies not in the sky but in a German poem. Despite having been known for hundreds of years, it was only in 1979 that the true significance of this “dark star” was understood.

The use of astronomical allusions in poetry is nothing new. The problem lies not with the author, but with those who read his work and fail to understand its meaning. I encountered this myself earlier this year while reading John Milton’s *Paradise Lost*, a mere youngster of a tome at only 350 years of age. Even though it has been the subject of scholarly study for three centuries, I discovered an allusion to the aurora borealis in *Paradise Lost* that no one has ever written about. And that poem is in English! (My discovery will be the subject of a future column in *Mercury*.)

Consider the problem of understanding an allusion written in what is known as Middle High German, used from about 1050 to 1350. It was not a unified written language and had no standardized spelling. The author of the poem, Der von Kürenberg, is one of the first poets in this language whose name we know. He wrote between 1150 and 1170, but his works survive only in a manuscript written two centuries later. The beginning of one of these poems reads in translation:

The dark star hides itself.

Do likewise, beautiful lady, when you see me:

Let your eyes glance at another man
And no one will know how things are between us.

A delightful love lyric, but it is the translation that has bedeviled scholars for generations, with most of them translating “Der tunkel sterne” (the first three words in the poem) as “the morning star,” an allusion to the planet Venus. But as Professor Arthur Groos of Cornell University has convincingly shown, this is wrong. It really means “the dark star.”

But what exactly is a dark star? For this we have to go back to the time of ancient Greece when Claudius Ptolemy wrote the *Almagest*. Arguably the most influential astronomy book of all time, it held sway as the undisputed authority up to the time of Copernicus (and even beyond). It is well known that Ptolemy divided the stars into six major classes, which gave us our system of magnitudes. What is less well known is that he added two more classes: cloudy stars and dark stars. The cloudy stars are now known as nebula, most of which are in our Milky Way galaxy though the so-called Andromeda Nebula is actually another galaxy like our own. None of this was fully understood until the 20th century.

For Ptolemy, a dark star was one of faint or indeterminate magnitude. So how did this inform the poetry of Kürenberg? While the entire *Almagest* was not available to European scholars in the 12th century, important parts of it were well known. An abridged version
(written 600 years before Kürenberg) was available, and translations of Arabic texts during the intervening centuries made the eight class description of stars by Ptolemy widely known. In German, the term for Ptolemy’s dark star became “tunnel sterne” or “dunkel sterne.” The term was also used to help describe the appearance of a comet in 1472. A German chronicle said: “a new star, which looked like a dark star beneath a cloud and emitted a dark ray as long as a road.”

The concepts derived from Ptolemy had an even longer life than you might imagine. In 1672, only nine years after Paradise Lost was finished, the English author John Gadbury wrote this about the stars: “There are six several magnitudes of them, clearly to be seen, besides some that are obscure, and others, nebulous or cloudy.” In a list he cites of 1,022 stars, Gadbury notes that nine are obscure, while five are nebulous. Of the obscure ones (which are the dark stars we are considering here), he says they are “scarcely visible by the best perspective.”

So what of that lady 850 years ago? Kürenberg’s speaker was asking her to obscure her true feelings for him — the man of her desires — by looking at another man. Thus, like a dark star, only those with the very best perspective would suspect the truth. It is one of many elements over the centuries that have given us “the romance of astronomy.”

CLIFFORD J. CUNNINGHAM was appointed a contributor to the Encyclopedia Britannica during the summer of 2014.

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**Milky Way Satellites as Proxies for Galaxy Evolution?**

*by Jennifer Birriel*

A recent comparison of our galaxy’s companions to those of Andromeda suggests a need for prudence.

Due to their proximity, the satellite galaxies of the Milky Way are easy to observe and their properties are firmly established. Their well-resolved color-magnitude diagrams constrain both their star formation and dynamical histories. As a result, the Milky Way satellites are commonly used as population templates for dwarf galaxies in the universe at large, even though this has yet to be established.

Daniel Weisz and colleagues recently compared the satellites of the Milky Way (MW) and Andromeda (M31). The MW has about two dozen satellite galaxies whereas M31 has about 10. This is not exactly a large pool to compare against; however M31 is the only galaxy close enough to obtain detailed observations of satellite galaxies.

Using archival data from the Hubble Space Telescope’s Advanced Camera for Surveys, Weisz and his team obtained color-magnitude diagrams for two M31 satellites: Andromeda II (And II) and Andromeda XVI (And XVI). A color-magnitude diagram (CMD) is
simply one type of Hertzsprung-Russell diagram. These new CMDs extend below the oldest main sequence turn-off point, which enabled the team to determine the age and star-formation history of both And II and And XVI.

Previous studies suggested differences in both the size-mass relationship and large-scale structure of M31 and MW satellite galaxies. This new study indicates that And II and And XVI exhibit CMD features distinctly different from MW satellite galaxies. Their CMDs have a double split — one red and one blue — in the red giant branch. This means that there are either two distinct age groups and/or metallicity populations. In addition, both M31 satellites have a horizontal branch population that extends across a wide range of luminosities. Taken together, these features are indicative of a prolonged history of star formation in these two M31 satellites.

Using two different CMD fitting models, Weisz and colleagues found that the star-formation histories of both And II and And XVI appear to have occurred in two distinct epochs: before 12.5 billion years ago and between 12.5 and five billion years ago. Roughly 50% of And II’s stellar mass formed in the first epoch and the remaining 50% in the second. And XVI experienced formation of about 30% of its stellar mass in the earlier epoch and the remaining 70% or so in the later epoch. Star formation in both M31 companions was abruptly extinguished about five billion years ago, consistent with similar observations for other M31 satellites.

The team then compared the two Andromeda companions to Milky Way satellites with similar luminosities and distances from their host galaxy. Superficially it appears that all the satellites might simply span a continuum of star-formation histories independent of host-galaxy properties. In addition, MW companions exhibit roughly equal populations of both ancient and intermediate stars — as do And II and And XVI.

Despite these similarities and the small sample size, there are intriguing differences between the satellites of M31 and the MW. Fornax and Leo I, Milky Way companions of similar luminosity to And II, exhibit a constant rate of star formation until one billion years ago when star formation was quenched. Two other MW satellites, Sculptor and Leo II, with luminosities close to And II, also exhibit very different star-formation histories. And XVI appears to have no luminosity analog in the MW. Milky Way satellites with the same low mass as And XVI (such as Hercules) exhibit mainly old stars that formed some 11 billion years ago. The MW companions Leo T and Leo P have masses similar to And XVI, but both show recent star formation.

Although only two M31 satellites are included in this study, the results are suggestive. The similarity in star-formation histories between And II and And XVI, which have very different masses, may be a coincidence. However, it is a striking one given that none of the MW satellites of similar mass share such similar star-forming histories. This seems to be the first evidence that star-formation histories of similar-mass galaxies may vary substantially. So perhaps our Milky Way satellites are not really representative of the universe at large.

JENNIFER BIRRIEL is Professor of Physics in the Department of Mathematics, Computer Science, and Physics at Morehead State University in Kentucky.
A Close Encounter of a Cometary Kind

A comet recently brushed past Mars. What happened to the spacecraft orbiting the red planet?

Mars just had a close encounter. On October 19, comet Siding Spring — C/2013 A1 — came within about 84,000 miles of the red planet. In astronomical terms, this is a close shave: our Moon orbits us at less than three times this separation.

When Siding Spring was first discovered in January 2013, there was speculation that it would actually hit Mars. We soon learned enough about its orbit to know that it was going to scoot by and deny us that particular cosmic show. But it still offered nearly unprecedented opportunities and risks. Humanity’s Mars fleet (as an aside, how cool is it that we have a Mars fleet?) cost about $1.72 billion, an investment that needed to be protected. At the same time, we wanted to make the most of the chance to observe a comet at such close range with the wide variety of instruments we have on our orbiters.

The solid part of the comet (the nucleus) is less than a mile across, but it’s surrounded by a cloud of gas and dust (the coma) 12,000 miles across. Most of this dust is microscopic, but it travels some 35 miles per second, and at those speeds even microscopic dust can do a lot of damage to a spacecraft. Teams of researchers modeled the coma to make predictions of the size, speed, and number of particles expected. The results indicated that the red planet would lie toward the edge of the cloud, where there aren’t as many particles, so the risk to the various spacecraft was lower than first feared. Still, NASA took precautions. Mars passed through the thickest part of the anticipated dust cloud about 90 minutes after the comet’s closest approach to the planet. By then, the orbiters were all in hiding.

The best way to protect the orbiters was to make sure that Mars itself sat between them and the comet while it passed by. The teams for the three orbiters that have been at Mars for several years (Mars Express, Mars Odyssey, and Mars Reconnaissance Orbiter or MRO) have been preparing for this since the beginning of the year. They drew up plans to adjust spacecraft orbits with the lowest possible use of fuel, a scarce resource for the aging orbiters. NASA adjusted the orbits of Odyssey and MRO in a series of maneuvers in July and August. As we learned more about the predicted behavior of the comet, the European Space Agency adopted a wait-and-see approach with Mars Express, in part because the orbiter is low on fuel. Ultimately, no adjustment was made to the spacecraft’s orbit.

Two orbiters arrived just prior to the comet’s approach. The Mars Atmosphere and Volatile Evolution (MAVEN) reached Mars on September 21, and before it even began its science mission, it was reoriented to join its older compatriots on the far side of the planet. The other new arrival was the Mars Orbiter Mission (MOM) — India’s first-ever interplanetary probe (see page 59). About 10 days before the comet’s arrival, the MOM team burned about a kilogram of fuel to ensure the spacecraft would have a safe view of Siding Spring on nearly the opposite side of the planet from the comet.
Even while we arranged this cosmic duck-and-cover, we prepared to focus all the fleet’s scientific instruments on Siding Spring. In addition to coming so close to our tools, this comet is “fresh” — it has never before entered the inner solar system on its million-year-orbit, so it’s bringing us new evidence from the outskirts of our neighborhood. MAVEN inaugurated some of its instruments by studying the gases coming off the comet and watching for any changes in the Martian atmosphere. Odyssey turned its spectrometers and thermal imagers towards the comet’s coma and tail. MRO monitored the planet’s atmosphere for changes and took images of the comet’s surface. MOM’s color camera took snapshots.

For all of you Curiosity and Opportunity fans, there was never any worry! The Martian atmosphere is thick enough that any dust from the comet burned up before it reached our rovers. These particles became Martian meteors or “shooting stars” — and the cameras on both rovers were turned toward the sky to watch for them and observe the comet as it approached.

So…what happened? The good news is every spacecraft came through intact. The great news is we have enough observations to keep comet researchers busy for a long time. All of our spacecraft performed perfectly. The HiRISE camera on MRO snagged a close-up view. Both rovers got pictures of the comet from the Martian surface. All the orbiters emerged from behind the planet and started down-linking their data. Scientists are digging through it right now — who knows what they’ll find!

EMILY JOSEPH is a Research Assistant, with an emphasis on Mars studies, at the Planetary Science Institute. You can find her on Twitter @EmExAstris.

Takes Three to Tango?

A unique trio of orbiting black holes may be just two of them dancing with wild, flailing arms.

A single, supermassive black hole can wreak some serious havoc. So imagine, if you can, a dance of three of them. This is what a team of radio astronomers thinks it has identified in quasar galaxy SDSS J1502+1115. The finding, appearing online in Nature on June 25, excited the astronomy community with its implications for better understanding galactic evolution and detecting gravitational waves. More recently, however, excitement has turned to scientific debate. A second team of astronomers has poured through its data and concluded that it’s not three black holes but rather two — with one of them shooting off jets and creating hot spots. Either way, SDSS J1502+1115 is an interesting galaxy that now will be getting a lot more attention in the coming year.

This story started about three years ago when yet another research team identified SDSS J1502+1115 as a quasar. Nothing earth-shattering, but the observation had a double-peaked spectrum, suggesting binary black holes.

ARMCHAIR ASTROPHYSICS

by Christopher Wanjek
Quasars are galaxies that have very active supermassive black holes at their core, often containing the mass of millions to billions of suns. The active core, likely the result of the black hole sucking in copious amounts of interstellar gas, if not whole stars, can be seen at a distance of billions of light-years.

All galaxies are thought to harbor a central, supermassive black hole. Some are bigger and some are more active than others. This is one reason why a trio of black holes detected in SDSS J1502+1115 was so exciting: It provides evidence that the largest supermassive black holes grow through mergers of smaller supermassive black holes...particularly in the earlier universe. SDSS J1502+1115 is more than four billion light-years away; what we're seeing now happened at a time when our own solar system was just forming.

Intrigued by the double-peaked spectrum in SDSS J1502+1115, a team led by Roger Deane of the University of Cape Town, South Africa, conducted a follow-up observation with the powerful very long baseline interferometry (VLBI) technique. VLBI entails coordinated observations from multiple radio telescopes spread across continents to produce an image resolution comparable to a single telescope with a dish thousands of miles wide.

Deane's group determined that the galaxy contains two supermassive black holes only 450 light-years apart — by far, the tightest pair ever detected — orbiting a third black hole 24,000 light-years away, making this the first known trio of supermassive black holes. The binary tightness would make this a prime source of gravitational waves, or ripples in space-time, because such waves become more prominent as two massive bodies approach each other and merger. And the binary, so close to a third black hole, shows supermassive black hole and galaxy evolution in action.

But not so fast, says Joan Wrobel of the National Radio Astronomy Observatory. Wrobel's team was sitting on its own data on SDSS J1502+1115 for years, too busy to analyze it. Wrobel's data from the US Very Long Baseline Array (VLBA) was comparable to Deane's from the European based VLBI network.

In a paper published in Astrophysical Journal Letters, Wrobel says the tight binary is just one black hole with bipolar jets creating a “double hotspot” and the illusion of a double black hole. If true, this could have interesting implications for how matter, shot in jets from black holes, interacts with the interstellar medium.

Deane's interpretation, if true, more so than Wrobel's, would put SDSS J1502+1115 on the map as one of the most interesting sites for studying extreme gravity. Time will tell who's right.

CHRISTOPHER WANJEK is a Baltimore-based science writer whose dance moves leave everyone confused.
The NASA Night Sky Network (NSN) was launched in 2004 in response to a survey conducted by the Institute for Learning Innovation for the Astronomical Society of the Pacific (ASP). That broad survey gave us information on club demographics, members’ public outreach efforts, and the barriers faced in engaging in effective astronomy outreach.

In the past 10 years, the ASP has grown the NSN to include more than 450 clubs, and has developed and distributed 11 outreach ToolKits on a variety of topics. NSN services and resources have been evaluated on an ongoing basis, indicating that they have been embraced by the active clubs as high quality and extremely useful in all the kinds of outreach that they conduct. An indication of their usefulness is the 28,000+ events logged, reaching almost three million people across the United States.

In 2014 two surveys were initiated to assess the current club landscape and assess future club needs. One survey revisits some of the questions posed in the 2002 survey, with an eye to how club membership and outreach practices have changed. A second survey polls an elusive audience: public visitors to club events and “star parties” to measure their reasons for, expectations of, and reactions to these events. Our initial results are shown along with a brief analysis of the impacts the amateur astronomy community has had on their target audience and how the NSN can evolve to better meet the needs of both clubs and the general public.

**Methods**

An anonymous online survey of 34 questions was set up to question amateur astronomers from around the US. The survey was split into several parts, with the first two parts focusing on the demographics of themselves and their clubs. The third and fourth parts were focused on their audiences and current outreach methods. The fifth section was focused on their challenges and needs found during outreach. An optional final section focused on what their interest would be in workshops focused on outreach training.

The survey of audiences was distributed to a subset of amateur astronomers to allow for basic surveys of their audiences, asking questions both before and after the events. It was made available as a PDF and via print, to easily allow audiences to fill out their impressions before and after the events. Data collection has recently been concluded on these surveys.

**Results**

Astronomy outreach by clubs serves a wide audience, with 78% of initial respondents reporting that their clubs helped usher their
initial forays into outreach. Schools and children are some of the main audiences for astronomers. Astronomers do report that they wish to reach formal educators more directly, including a very strong demand to better serve K-12 teachers as well as to reach community college professors. Interestingly, teenagers show up as an audience that amateur astronomers both widely serve and as an audience they wish to better reach. This may be due to more involvement with elementary and middle schools (51%) than high schools (35%).

Astronomers report that their two main obstacles to outreach are a lack of time and lack of support, and, to a lesser extent, a lack of resources. These obstacles make themselves known in the astronomers’ replies to the question of, “What kinds of support would encourage you to engage in additional outreach?” Outreach materials and supplies top their wish list, but notably additional help in the form of a partner or group is also very highly requested. 75% of respondents reported an interest in attending special astronomy education outreach workshops to help sharpen their skills.

Materials designed for classroom use are also highly requested, not surprising considering astronomers’ commitment to outreach in classrooms and formal education settings. In addition, astronomers report the increased usage of information technology such as computers (50%), tablets (25%), presentation software such as PowerPoint (54%), and planetarium software (47%) in their outreach events. This should be kept in mind as future materials are developed for Night Sky network member clubs (of which 47% report usage of Night Sky Network ToolKits). Of course, 95% report that their telescopes are still their go-to tool for outreach events.
Conclusions
Amateur astronomers perform a large amount of outreach in formal education settings. They indeed have a need for materials and training designed for classroom use, to better serve the educational needs of both students and teachers. Special workshops and partnership programs, potentially along the lines of Project Astro, may prove very useful in this regard.

In addition, it is essential to find ways to optimize the Night Sky Network website to allow for easier and quicker access to outreach materials and potential outreach partners in order to allow astronomers to focus their time and efforts on their enthusiastic commitment to public outreach.

Quotes
“When they come to my events they are awestruck with what they see. This is a blast! So far feedback has been great. I tailor the program for the appropriate age and education of the participants and I get specific feedback from the classroom teachers.”
“The ToolKits are very well developed and work really well.”
“The number of requests for school groups have greatly decreased. This is due in a large part to the stress put on teachers dealing with the state and federal government mandated testing.”
“We are currently involved with the local middle school but would like to do more for the local high school.”
“Several schools ask the club to bring scopes at a specified night for observing by the kids and their families.”
“I worked with a middle school teacher and her two sixth grade classes in Project ASTRO for 8 years, ending in spring of 2013.”

Sources and Further Information
Night Sky Network Website

Partners and Acknowledgments
The primary Night Sky Network partners are the Astronomical Society of the Pacific (ASP) and the NASA Exoplanet Exploration Program (ExEP). Additional partners include:
• The NASA Origins Forum
• The Structure and Evolution of the Universe Education Forum
• The NASA Solar System Education Forum
• NASA’s Kepler Discovery Mission (NASA Grant NAG-2-6066 to SETI Institute)
• Center for Science Education at the UC Berkeley Space Sciences Laboratory
• NASA Science Mission Directorate under EPOESS Grant Number NNX10AE71G
• Virtual Planet Laboratory
• Space Science Institute for Interactive Learning
• NASA’s Wide-field Infrared Survey Explorer (WISE)
• NASA Solar System Exploration
• Space Telescope Science Institute
• NASA Education and Public Outreach at Sonoma State University: GLAST, Swift, and XMM-Newton
• Suzaku Mission E/PO Program at NASA/Goddard Space Flight Center

In addition, the National Science Foundation has provided $3 million in grant support for specific NSN initiatives, including research into club culture and for certain toolkits outside of NASA funding. This current study is funded by NASA’s Jet Propulsion Laboratory (JPL). For more information, please e-mail us.
This special section of *Mercury* features a transcript of Geoff Marcy's Sunday afternoon public talk "Finding Habitable Worlds Around Other Stars," an expanded version of James Manning's presentation "Flying the Infrared Skies: An Authentic SOFIA Educator Experience," and reprints of five poster papers — all part of the ASP's Celebrating Science: Putting Education Best Practices to Work conference held in Burlingame, California, in August 2014. [ASP/Paul Deans x7]
From Picas to Pixels: An Astro 101 e-book

Stephen Shawl (U Kansas), Gene Byrd (U Alabama), Susana Deustua (STScI), and Michael LoPresto (Henry Ford Community College)

What happens when a publisher discontinues publishing a textbook? That was the dilemma we were presented with. Given that we know we have a high-quality product that can contribute to student understanding of science in general and astronomy in particular, and that significant efforts had already been expended on the project, we decided to self-publish, even knowing that the challenges, and the gamble in terms of time and personal expense, were great.

Self-publication provides an opportunity to produce an updated edition at great cost savings to students — something faculty often says is an important consideration in their choice of a book. We discuss the many significant challenges, the greatest of which is marketing.

We present the end result: a completed publication in various e-book formats and with links to the Discovering Astronomy Concept Videos made for the book.

History:
  ° Goal: to provide an active learning and observing experience within the large lecture format class
  ° Contained activities integrated throughout the text that used simple instruments made by the student
  ° Contained packet with die-cut instruments for students to construct, plus lenses, diffraction grating
  ° In-text questions to have the student reflect on reading
• Second edition in 1988
• Third edition in 1995 added Stephen Shawl as coauthor. Goals for this edition were:
  ° Make a mainstream book
  ° Full color (previously B&W only)
  ° Separate activities into separate Activities Manual for significant cost-savings
  ° Addition of Discoveries — very short activities not requiring the instrument kit
  ° A major goal became an understanding of the nature of science
  ° Planets presented with a view toward comparative planetology
• Fourth Edition in 2000 with new publisher
• Fifth Edition in 2006
• In 2010, publisher cancelled contract for 6th edition and discontinued publication
• Authors decide to self-publish
Self-publishing:
• Advantages
  ◦ Complete control
  ◦ Lack of publisher’s costs (overhead, printing, warehousing) allows for significantly lower price to students
• Disadvantages
  ◦ No budget beyond coauthors’ contributions
  ◦ Must do page layout and compositing
  ◦ Need to obtain, pay for, and track image permissions (had previously been ~$9500) and credit-line information
  ◦ Self-publishing means self-marketing
    ▪ How to get the word out?
    ▪ How is purchase to be done by student?
    ▪ If, and how, to use social media?
  ◦ Difficulty of convincing faculty to change books even though cost to student will be low
  ◦ Extremely time consuming
• Conclusion: huge gamble

Work Flow
• Divide chapters among four coauthors for updating and improving
  ◦ Suggest new or modified illustrations
  ◦ Find necessary updated images and owner of image; try to find free images to decrease permission costs
• Senior author reads and edits drafts; coauthors revise
• Senior author composites chapter into book’s design
• Coauthors proof layout version
• Layout all front and back matter — table of contents, author information, preface, information for students on how best to use book’s features, appendices, star charts, glossary, image credits
• Final proofing

Self-publishing Decisions:
• Cost containment requires book be available only electronically
  ◦ Advantages
    ▪ Lower cost
    ▪ Easy to purchase
    ▪ Easy to carry around
    ▪ Searching capability
    ▪ Note taking
    ▪ Bookmarking
    ▪ Inclusion of hotlinks to web and animations
  ◦ Disadvantages
    ▪ Some people still prefer hardcopy (they could print it out but at a high cost if done in color)
• Formats
  ◦ PDF
    ▪ Maintains layout deemed best by authors
    ▪ Looks like a “real” book
  ◦ Epub (for iPad and most other e-book readers and software) and MOBI (for Kindle)
    ▪ Authors have no control as to how it looks in different apps. Figures and tables can split across pages

The Latest Exciting Updates
• While not finalized, it appears we’re partnering with two companies
  ◦ The first will provide online access for purchase of the book along with online materials the student will purchase if wanted by the instructor. These online materials will include online testing and homework, along with a grade book.
  ◦ A low-cost printed version may be available. To keep the price low, it would be black & white, loose-leaf, 3-hole punched, and shrink-wrapped.
Discovering Astronomy is available for Fall 2014 adoption. The book, with online materials, will be available for Spring 2015. Details of the book, table of contents, a sample chapter, and other information and features are available at discoveringastronomy.weebly.com.

Engaging Scientists in Education and Public Outreach: Resources and Tools for Scientists

Jennifer Grier (Planetary Science Institute), Sanlyn Buxner (Planetary Science Institute), Bonnie Meinke (STScI), Nick Gross (Boston College), and Morgan Woroner (Institute for Global Environmental Strategies)

The NASA E/PO Forums help the Science Mission Directorate (SMD) support scientists involved in E/PO through resources, communications, opportunities for involvement, and professional development workshops. The Forums understand that scientists have a range of experience, time, and areas of interest in E/PO, and provide tools and opportunities for a variety of needs.

The Planetary Science E/PO Forum has conducted both surveys and interviews of space scientists regarding E/PO. Specifically, a recent series of semi-structured interviews with members of the American Astronomical Society Division of Planetary Sciences (AAS-DPS) has helped pinpoint specific areas where the Forum can provide support and resources to help scientists become engaged and to support their work in E/PO.

In response to this and other input, the Forums have produced, and continue to develop, a suite of resources that scientists can use in their E/PO endeavors. Some tools can help scientists early in the process to ‘get started,’ while other tools are useful for those who have long been engaged in E/PO to expand the impact of their work and to increase their efficiency.

SMD E/PO Forum Community Workspace

Connect directly with the Forum Community on the Workspace. This is a place to find out more about the latest events and news, as well as to engage in discussions about E/PO issues of interest, professional development, announcements, and projects in development.
Planetary Science E/PO Resources Sampler
The sampler contains a list of resources and activities selected for scientists who work with students, teachers, and the public. The resources are organized by thematic topics such as volcanism, astrobiology, and ice and water in the solar system.

Getting Started Guides
Addressing the scientist’s need for information guides that are brief and easy-to-use, we are developing a series of Guides to important E/PO topics. Topics cover a wide range from “The Quick Introduction to Education and Public Outreach” to “Increasing Your Impact and Efficiency.” Also in development are One Page Tips and Tricks to assist with situations commonly encountered during E/PO such as “Classroom Dos and Don’ts” and “Public Talks.”

Speaker’s Bureau
NASA SMD has developed the Scientist Speaker’s Bureau online portal to connect interested scientists with those in the general public looking for a speaker for a single event or series. Joining the list is quick and easy — visit the URL (opposite) to include your name and other relevant information, (such as your interest in classroom visits, public talks, libraries, or virtual settings). When organizations need speakers, they input their needs and are connected only with those speakers whose information is a match. You will be contacted through an automated email with a request, which you can accept or decline.

EarthSpace and NASA Wavelength
These are searchable, digital collections of materials, allowing educators of all levels to find peer-reviewed resources for their classrooms and out-of-school programs. EarthSpace contains materials for undergraduate learning, which are reviewed and posted under a Creative Commons Attribution. Wavelength contains resources for all levels, from elementary through college level, and public outreach programs. These resources have passed the NASA SMD product peer-review process to ensure that each product is useful and sound both educationally and scientifically.

Partners and Programs
The Forums partner with professional societies and connect scientists to a variety of programs that offer information and entry points in E/PO. These include the AAS’s Astronomy Ambassador’s MOOSE program — Menu of Outreach Opportunities for Science Education, NASA’s Year of the Solar System, and International Observe the Moon Night.

Feedback from Scientists
Products are constantly in development and revision, and your feedback makes them more useful and effective. Learn more and become involved at the SMD E/PO site. Contact Jennifer Grier or Sanlyn Buxner for more information.

TABLE OF CONTENTS
Building Worlds and Learning Astronomy on Facebook Part III: Testing, Launch, and Evaluation

James Harold (National Center for Interactive Learning at the Space Science Institute), Dean Hines (Space Telescope Science Institute), Evaldas Vidugiris (NCIL/SSI), and Kate Haley-Goldman (SSI/Audience Viewpoints)

With support from NASA and NSF, we are developing an end-to-end stellar and planetary evolution game for the Facebook platform, with external access for middle school students. We’re focusing specifically on the “sporadic play” framework popularized by games such as Farmville, where players may only take actions a few times a day, but may continue playing for months.

This framework is an excellent fit for teaching about the evolution of stars and planets. Players select regions of the galaxy to build in, and then watch as the systems evolve in scaled real time over days to weeks. Massive stars will supernova within minutes, while lower mass stars like our Sun will live for weeks, possibly evolving life before passing through a red giant stage and ending their lives as white dwarfs. Successful systems will advance players, allowing them to create different types of stars and planets, seed life, and customize their worlds. As players progress in the game they will explore concepts including stellar life cycles, habitable zones, and the roles of giant worlds in creating habitable solar systems.

Objectives
- To reach new audiences with NASA science;
- To create new pathways for the public to existing NASA materials;
- To provide an engaging contextual framework to aid the public in understanding NASA Origins science;
- To explore the effectiveness of disseminating NASA’s message through games embedded in social networking environments.

Key Game Elements: Build Stars. Create Life. Profit!

Persistency: The game runs on a server in the background so that systems can evolve while the player is offline.

Time Scales: Events occur on a time scale of one million years per minute. Giant worlds can be built in a few minutes; terrestrial worlds a few minutes after that. Single cell life can arise within an hour, but complex life can require several hours. Star lifetimes can range from seconds (for supergiants) to weeks (for Sun-like stars).
**Energy and Unlocks:** Game flow is controlled through a combination of energy (consumed to create worlds, but replenished over time) and locks, which lock out features until appropriate certain conditions are met.

**Achievements:** The game encourages certain actions through “Feats” — accomplishing each task earns badges and titles and unlocks more features (e.g., moons).

**Learning Goals:** The structure of the game lets us directly address stellar life cycles, their dependence on initial mass, and their relative time scales as well as some conditions relating to life including both galactic and stellar “habitable zones.”

### Where We Are, Evaluation, and Next Steps

It’s currently in closed alpha: game is live and is no longer password protected. “Viral” elements are also turned off for now.

Game is instrumented to collect information on Feat accomplishments, repeat visitorship, duration of play, links followed, and more. Facebook adds to that with basic demographic information (player age bracket and gender). We’re collecting data now, but still tuning.

### Want to Play?

Log in directly via Facebook (and don’t forget to Like Us). Or visit us at our [external site](#) where you can play outside of Facebook as a guest. Feel free to hand this information around. Questions, comments, or ideas for linking to other projects or missions? Let me know: harold@spacescience.org.

Multiple Links to Other NASA Content. There are daily news links to current stories at other sites. Feats include “factlets” that can link to other sites. Star backgrounds can be based on all-sky maps, with links to the mission pages.

Mini Games to Address Other Content. Focus on content is not well addressed by the overall game, so mini games give players something to “grind” on. Can still tie back to the game: this scale game unlocks the ability to “fake” the scale of your solar system.

**“Feats” to Guide Players.** Feats range from simple tutorials (“animate your system”) to complex tasks (“recreate our solar system”). Feats can scaffold, from “create a terrestrial world” to “create a terrestrial world in the habitable zone of an M0 star.” Feats can unlock options or earn currency.
NASA’S SPACE FORENSICS: Solving Cosmic Mysteries with Crime Scene Narratives

Sara Mitchell and Sarah Eyermann; Syneren Technologies & NASA Goddard Space Flight Center; Barb Mattson; and USRA/CRESST and NASA Goddard Space Flight Center

Explosions, collisions, births, and deaths — the universe presents astronomers with an abundance of puzzles to analyze. Scientists are keen to solve the mysteries of these events and explore the origins, evolution, and mechanics of our universe. But these events may have happened millions or billions of years ago, and trillions of kilometers from Earth.

The primary evidence astronomers can collect is electromagnetic radiation — light. The NASA Space Forensics project, funded by NASA’s Physics of the Cosmos (PCOS) and Cosmic Origins (COR) themes, takes audiences through astronomy problem-solving narratives that parallel crime scene forensics. The corpse being examined could be a massive star that ended its life in a brilliant supernova explosion, or a black hole might be the mysterious figure behind a series of cosmic crimes from theft to kidnapping.

The Space Forensics project is an expansion of a successful pilot teacher’s workshop developed in 2007 that took teachers and students through the “crime scene” left after the supernova explosion of Cassiopeia A. With PCOS/COR funding, we have developed a series of Space Forensics cases for classroom use with educational activities and lesson plans to accompany mystery-style narratives. A team that includes NASA astrophysics education and outreach specialists, a professional science writer, a consulting astrophysicist-turned-forensic scientist, NASA scientists, and consulting classroom educators created each of these cases collaboratively.

We have also contracted an external evaluator to guide program development and rigorously assess the curriculum, workshops, and other project elements. Each standards-aligned Space Forensics case fuses STEM and literacy, using mystery narratives and hands-on activities to take students through the process of scientific problem solving. This approach tells the story of “doing science” and meets educators’ needs for resources that encourage reading, writing, and speaking outside of the English Language Arts classroom. We intend Space Forensics to be a model for others seeking to fuse STEM and storytelling.

Beyond these classroom resources, we also brought aboard an outside developer to create an engaging online game to make these cases and activities available to wider audiences, challenging armchair crime-solvers to explore the mysteries of the universe. The Space Forensics project allows teachers, students, and the public...
to engage in the science of PCOS/COR missions and interact with authentic data, imagery, and problem-solving techniques used by NASA scientists. Our goal is to enrich audience understanding of how astrophysics is done in the “real world” — the collaborative, empirical, inquiry-based human endeavor performed by women and men over centuries of recorded history.

This poster highlights one of the Space Forensics cases — “The Case of the Disappearing Star” — and some of the resources and activities contained within it.

**Case Synopsis**
The center of our galaxy — the Milky Way — can be a strange and busy place with lots of stars dancing around, right in the heart of things. In this case, we follow a young star’s blog as he tries to make sense of his fellow stars and their behavior… and realizes that things aren’t always what they seem! Why are a bunch of stars orbiting a spot where there seems to be nothing? What happens when a star suddenly disappears? What is going on?!

Though he doesn’t initially know it, our young star is observing the effects of a mysterious black hole. One of the key challenges with studying black holes is the question of how to detect them against the black background of space. By their nature, no light or signals can escape a black hole to provide us with any information, and therefore we cannot directly “see” them. In a series of hands-on activities, students learn about gravity and orbits, explore means of locating and studying black holes using methods of indirect detection, and bust many of the misconceptions that they may hold about black holes.

**Blog Entry: 1.520 billion years old**
I figured something really cool out. I can make predictions about how that mysterious force works and test them by observing other stars and how they move. For example that system of four stars always moves in the same way. The four stars include two small red stars, two stars like me. They are partnered, each red star has its yellow counterpart. One pair orbits each other very quickly (and they have a large gas planet that whizzes around both). The second pair is very far away from the first pair. They orbit each other a little less quickly. The distant pairs are so far apart that they orbit each other slowly. I’ve mapped it out and I can calculate where the stars will be in their dance even before I look over and check my work. Pretty cool eh?

I can map other systems also. I found a beautiful pattern in a binary system. The inner star is four times bigger than the outer star. So the inner star goes around in a small circle. The outer star circles that circle...
but moves much faster because it travels a farther distance around than the inner star. Between them, a planet orbits. If the inner star was the only star, that planet would have a simple elliptical orbit, but since a second star also tugs on the planet, the little planet’s orbit looks like a series of loops. Beautiful!

Why Teach Space Forensics?

• Tells the story of doing science — science as a cycle of questions and answers.
• Shows the links between topics in science and technology instead of standalone concepts.
• Overlap of science, technology, engineering, and mathematics — plus history and language arts.
• Presents real science in the context of compelling human stories.

Space Forensics Interactive Online Game

Space Forensics will also be adapted into a series of humorous web-based point-and-click adventure games set at NASA Goddard. They star an inept detective, Eagle “Strange” Quark, who was accidentally assigned to the facility and is keeping himself busy by investigating non-existent “crimes” he “uncovers” by misunderstanding things he reads or overhears.

In “The Case of the Missing Star,” Eagle hears that a star has disappeared, but soon finds out that it’s not one of the ones in Hollywood! But even once he realizes we’re talking about stars in the sky, he considers that our Sun is a star, and wonders if we could be the next ones to disappear.

The case takes Eagle on a quest around NASA Goddard, interrogating scientists and other personnel about black holes and learning about orbits, gravity, stars, and cosmic distances through his investigations. Using real NASA data from missions such as Suzaku and NuSTAR, as well as cutting-edge visualizations, Eagle discovers that the disappearance of a star may not be a crime, but black holes remain a scientific mystery.

How Can You Get Involved?

• Help us find pilot-testing sites for our first three cases! We’ll be rolling these cases out throughout the fall and winter of this year.
• Share the science and technology of your mission, and help us accurately portray the real scientific process behind astronomical research.
• Do you have a mystery that would be a great fit for Space Forensics? We’re always interested in hearing about prospective cases that could be a part of the next batch!
• Intrigued? Contact us: Sara Mitchell or Sarah Eyermann.
astroEDU
An Open-access Platform for Peer-reviewed Astronomy Education Activities

Linda Strubbe (Editor-in-Chief), Canadian Institute for Theoretical Astrophysics (Toronto)

What is astroEDU?
- astroEDU makes the best astronomy activities accessible to educators around the world.
- astroEDU is an open-access platform for peer-reviewed astronomy education activities.
- astroEDU is a platform for educators to discover, review, distribute, improve, and remix educational astronomy activities.

Why peer reviewed educational activities?
astroEDU assigns two reviewers (an astronomer and an educator) to review the activity. This process increases the quality of the scientific content, educational implementation, and credibility of the activities.

What does astroEDU expect to achieve?
astroEDU tries to solve some past issues with educational activities in astronomy. Many of the educational activities are difficult to find; difficult to use. The number of existing activities is large, but their quality is often difficult to judge. Through peer-review, astroEDU is improving standards of quality and visibility, and providing credibility to astronomy educational activities.

What incentive is there for the activity creators?
The same way that peer-reviewed scholarly articles are the base for performance evaluation of scholars, astroEDU will provide a new metric to assess the quality of the work developed by educators. The activities will also be given higher visibility with much wider distribution through the partner networks and the official seal of the IAU.

Which license does astroEDU use?
One of the main goals of the astroEDU is to promote the use of excellent activities worldwide. That is the reason why all the astroEDU activities will be licensed through the Creative Commons Attribution 3.0 Unported license.

What about other languages?
At the moment astroEDU is a prototype to test the infrastructure and procedures. We already accept activity submission in different languages, although the astroEDU on-line platform is only available in English for now. However, language support will follow as soon as astroEDU leaves the prototype phase.
Could you be a reviewer?
If you are an educator or research astronomer who would be willing to review submitted activities, please get in touch with us at www.iau.org/astroedu.

Who is behind astroEDU?
astroEDU is a project of the International Astronomical Union under the framework of the IAU Office of Astronomy for Development.
- Editor-in-chief: Linda Strubbe (CITA, Canada)
- Managing Editors: Edward Gomez (LCOGT, UK) and Pedro Russo (UNAWE/Leiden University, the Netherlands)
- Assistant Editor: Thilina Heenatigala (UNAWE, Sri Lanka)
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For more information about astroEDU — peer-reviewed astronomy education activities — see our website at www.iau.org/astroedu. ▶
Finding Habitable Worlds Around Other Stars

Astronomers are getting a first glimpse of the possibilities of life elsewhere in the universe.

By Geoff Marcy

This artist’s concept depicts Kepler-62f, a super-Earth-size planet (40% larger than Earth) in the habitable zone of a star smaller and cooler than the Sun. It’s a lovely illustration, but we really have no clue if the planet contains an atmosphere, clouds, oceans, or continents. [NASA Ames/JPL-Caltech]
O ccasionally, during the course of human history, we can sense that a great discovery is imminent. Scientific discoveries often happen with some preamble, some preparatory work, or some prior experiments, and give us a chance to sense that we’re in a great moment of history.

A fine example is the Apollo era. Those of us alive in the 1960s can remember that each successive mission gave us a sense that we might well make it to the Moon. That was a moment when you could anticipate this great achievement by humanity. Another one that comes to mind is cracking the code of DNA for humans — the human genome. For years in advance you could almost smell the DNA that was being cracked by the biologists. And now we know the composition of the DNA that makes us human. I think we’re at another such moment, and it involves the search not just for planets around other stars, but planets that might be suitable for life.

**How to Detect an Extrasolar Planet**

I’ll start by reminding you of something that is, frankly, a little embarrassing. As of 2014, we still don’t know how common Earth-like planets are in the universe or even within our Milky Way galaxy. And that question of the uniqueness of Earth is made more poignant by realizing that the *only* place in the entire universe where we find any life at all is right here on planet Earth. We still have not found one shred of actual evidence of life anywhere else.

One first step is to try to detect the planets around other stars that might be the size, temperature, and chemical composition of Earth. And the question is — how do you search for Earth-like planets? Well, there’s a technique that really came into prominence during the past five or six years. If you want to detect an Earth-like planet, you simply watch a star and measure its brightness. When a planet transits (crosses in front of) a star, it blocks a little of the starlight, and causes the star to dim. You can’t see the planet itself; you can’t even see the disk of the star. But you can measure the brightness of the star, minute after minute, hoping to detect a dimming. And not just one. The star will dim over and over as the planet goes around the star again and again. So you should see a repeated dimming of the star if there really is a planet orbiting it.

Luckily NASA picked up on this and in 2009 launched the *Kepler Space Telescope*. It did something so boring and so spectacular at the same time that it was amazing. All Kepler did was take snapshots with a camera of a patch of the sky near the constellation Cygnus, capturing images of 160,000 stars every minute, for four years. The goal was to see if any of those stars dimmed not just once, but repeatedly as a planet crossed in front. And some did.

**A Case Study: Kepler-10**

Here’s an example: the star Kepler-10. Looking at the repeated dimmings in its light curve (*next page*), dimmings of about a few hours...
out of 300 days, what we see is the telltale sign of a planet orbiting a star, crossing in front of the star, and blocking a small fraction of the star’s disk of light during that transit (upper right). Seeing this, we immediately know the orbital period of the planet — 45 days — because every 45.29 days the star dims. And the time it takes the planet to orbit the star is related to the distance of the planet from the star. So we can immediately link the two and determine how far this planet is from its sun. But there’s more. The fraction of starlight blocked by the planet is small, because it blocked only a tiny fraction of the star’s surface. We know how large the star is, and knowing that the planet blocked a tiny but definitive fraction of the star’s surface, we can then easily calculate the diameter of the planet.

So think about that. We haven’t seen a picture of this planet (now called Kepler-10c) — not even a dot of light from the planet — but we know its orbital period, the distance of the planet from the star, and how big the planet is. But there’s more. Knowing how far the planet is from the star tells us how warm the planet is.

And there’s still more. If we zoom in on the light-curve data from Kepler-10 (next page), we can see a second set of dimmings. It’s very slight, almost buried in the noise, but this tells us immediately that there is a second, even smaller planet with an orbital period of less than a day — about 20 hours. We know the planet, Kepler-10b, is small, because we can see that just a tiny fraction of the light from the star is blocked. We can do some quick math (knowing how big
the star is) and calculate how big the planet is. The answer: it’s 40% bigger than the Earth.

That’s great, but what does Kepler-10b actually look like? Frankly, we have very little clue. We don’t even have a dot of light from the planet, but we can guess, knowing its size, temperature, and proximity to the star. Probably it’s a smallish, rocky planet (right), so close to its star that one side is bright and scorched, while the backside of the planet is dark and cold. What kind of geology might there be? Plate tectonics, volcanism, canyons, mountains? We have no idea. The dayside temperature is likely more than 2,000°; iron and lead might melt. But it’s an exciting prospect to realize that we are seeing the first Earth-size planets ever found around other stars — albeit in this case a hot one.

We have found other Earth-size planets with the Kepler telescope that are less scorched by their host star — for example, Kepler-62e and 62f. These planets are roughly the size of Earth, but what’s nice is their orbital periods are longer than the planets of Kepler-10: the former is 122 days; the latter 267 days. These periods are beginning to remind us of the 365-day orbital period of Earth. That means the planet is a significant fraction of the distance the Earth is from the Sun — far enough out so that the temperature would be something like lukewarm.

In fact these two planets lie in the habitable zone, the area around a star where planets would have a temperature conducive to water being in liquid form. That habitable zone is where water, if any, would not be ice or steam but a liquid. And we think liquid water is a pre-requisite for life.

By zooming in on 10 days of Kepler-10 data, another periodic dimming emerges (the dashed red lines), revealing the planet Kepler-10b. [NASA]

Kepler-10b is a scorched world, orbiting more than 20 times closer to its star than Mercury is to our Sun. Intense radiation from the star probably keeps the planet from holding onto an atmosphere. [NASA/Kepler Mission/Dana Berry]
Prevalence of Earth-like Planets

Having looked at some examples of Kepler-discovered Earth-like planets, I’d now like to take a wider view and examine the possible prevalence of Earth-like planets in the galaxy. The histogram (above) shows how common certain types of planets are on the vertical axis, and planet size on the horizontal axis. On the far left is Earth, with the planets getting bigger toward the right.

What’s dramatic is this. The two blue regions show planets between one and two times the size of Earth, and they show something quite profound. Twenty-six percent of all Sun-like stars have a planet between the size of Earth and twice the size of Earth with an orbital period of less than 100 days — that is to say, inward of Venus’s orbit in our solar system. So one-quarter of all the Sun-like stars we see in the night sky have an Earth-size planet orbiting inward of Earth’s orbit. That’s amazing.

To generalize, one out of four or five stars that you see in the night sky has an Earth-size planet in its habitable zone. We didn’t know, until the end of 2013, that planets the size of Earth are dirt-common in the galaxy.

Here’s a fun question. How far away from us is the nearest star that has a habitable Earth-size planet? We live in our galaxy’s suburbs, about two-thirds of the way out from the center. If we shrink the Milky Way down to the size of the United States, how far away is the nearest habitable Earth-size planet? Since we’re in the Bay area, let’s ask how far away from San Francisco we have to go to find the nearest star that has an Earth-size planet in its habitable zone? The answer: across the Golden Gate bridge. The Milky Way is so full of Earth-size, lukewarm planets that they are literally a stone’s throw away in a galactic sense.

Kepler-11 is a Sun-like star around which six planets orbit. This artist’s concept shows the simultaneous transit of three planets observed by NASA’s Kepler spacecraft on August 26, 2010. [NASA/Tim Pyle]
We also found many families of planets — stars that have two, three, four, and even seven planets. Kepler-11 is the poster child with its six planets, and what’s interesting is that all six planets were discovered because they transit the star. They all orbit in a thin plane just as our solar system has all its major planets orbiting within a thin plane called the ecliptic.

Indeed, the Kepler telescope has found more than 400 stars with multiple planets. So think of it. We have found hundreds of planetary systems, we know the sizes of all these planets, we know the orbits they’re in, and we know the exact time they pass in front of their star, which means we also know where the planet is in its orbit around each star at any particular time. All this is a treasure trove of information as well as a treasure map, because now we can go back with ground-based telescopes and study each one of these planetary systems.

Are There Aliens Out There?

In the true tradition of storytelling, I’m going to tell a tale about the prospects of finding life in the universe, and the story I’m going to tell is, I think, rather daunting. We know almost nothing about life beyond Earth, so I’m going to speculate with some humility and concern for my own credibility.

There are some ways to speculate that are fairly secure. One of them is to ask the simple question: Is our Milky Way galaxy filled with intelligent life? We know that our galaxy has 200 billion stars. And we’ve learned that one out of five has an Earth-size planet at lukewarm temperatures in its habitable zone. So there are possibly some 40 billion habitable planets just within our galaxy.

But now we need to ask: How many of these 40 billion planets in our galaxy somehow spawned intelligent life? I don’t know the answer. One out of 10? One in 100? One in 1,000? The most pessimistic answer I’ve ever heard came from Frank Drake, the famous searcher for intelligent life and creator of the Drake Equation. He said maybe intelligent life, like we humans, is a one in a million throw of the biological dice.

But even that’s not too bad. Because one in a million out of 40 billion habitable planets means thousands of intelligent species occupying the Milky Way galaxy. Some of them would have sprung up a thousand years ago…a million years ago…maybe even 100 million years ago. Some would be far advanced compared to us. They would have technology we couldn’t imagine — maybe their iPhones actually work as phones! It’s really unfathomable what their
technology might be like, but what’s interesting is that this prediction — that the galaxy is teaming with advanced civilizations — has been the staple of science fiction writers for decades.

This is the theoretical model that we all carry in our heads. How could it not be that the galaxy is filled with these advanced civilizations? There are just too many stars, too many planets, and too many prospects for advanced technology. But if that’s the case, why don’t we have any signs of these many thousands of advanced civilizations with their powerful technologies? They should have wandered into our solar system just by luck — even ants eventually find their way into your kitchen!

I’d like to offer the pessimistic view. Maybe the science fiction writers didn’t get it right. We don’t know whether advanced intelligent life is common or not. Maybe intelligent life is rare in the galaxy. Let’s explore how this might happen.

Are We Rare?
Maybe Earth is a little more unusual than we think it is. It does have water, but very little. The water on our planet comprises only 0.06% of the Earth’s mass. If an Earth-size world has a lot more water, the surface would be covered with oceans. If an Earth-size planet has half the amount of water Earth has, it would be a dry, desert world.

So what are the odds that a planet somewhere in or near the habitable zone would have no water at all on its surface? Well, look at the two planets on either side of us. Venus and Mars are kindred planetary spirits in our solar system, but neither has water on its surface — certainly not liquid water — for different reasons. Maybe there are multiple reasons why a planet could be either devoid of water or just have too little water for much of it to puddle onto the surface.

The other alternative is that some planets might have twice or three times as much water as Earth does. Such a planet, covered by water, would have no continents on which a civilization could build modern technology. It would be a bad Kevin Costner film! So it’s possible that planet Earth, with just the right amount of water, could be very uncommon, and we don’t know it.

There’s another reason we humans might be rare in the galaxy. We like to think of ourselves as residing at the pinnacle of Darwinian evolution, the end product, the top of the food chain. Well, it’s not clear that we really are the end product of Darwinian evolution. You can look at the development of brains among other species and ask: Do those species enjoy a brain size and intellectual capability that increased as they evolved over the millennia? The answer is — brain sizes typically do not grow.

There’s no better example than the dinosaurs. They roamed and ruled Earth for 200 million years. We humans have been around for only a million years or so. They had 200 million years for their brains to get bigger. How? Well, the smart dinosaurs would outcompete the not-so-smart dinosaurs. Didn’t happen. The paleontological record shows that their brains were no bigger than the size of walnuts. They had chicken brains, and indeed, chickens are the descendants of dinosaurs. So it’s interesting to think that maybe we big-brain humans are some lucky fluke of evolution.

Finally, maybe intelligent life does pop up occasionally in the Milky Way. Maybe it’s rare, maybe not. But when it does, it might develop the technology and the capability to threaten its own existence — either with weapons or via damage to the ecosystem, the atmosphere, the oceans, and so on. And we are certainly aware that humans, for the first time in our history, have the ability to threaten our own existence in one of these ways. So it is, perhaps, a daunting message, from the civilizations we don’t see, that we should take care of ourselves.
A Question As Yet Unanswerable

We don’t have an answer to the question of life elsewhere in the universe. We ought to be looking, because it is the most profound scientific question that we know of. You might even say it’s the most profound question of all.

But I really do think we are in a special moment in the history of humanity. We have witnessed the first discovery of Earth-size planets. Some of them are definitely rocky. We now know that one in five Sun-like stars have an Earth-size planet that’s roughly habitable. And we are very close to learning the true nature of these rocky planets, how many of them are rocky, and if they have water on their surface or in their atmosphere. This is a golden moment in human history when we’re getting a first glimpse of the possibilities of life elsewhere in the universe.

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Science fiction writers and artists like to think life, and intelligent life, is common throughout the galaxy. But perhaps the circumstances that led to the rise of humanity on Earth really are special, and alien civilizations such as this one exist only in the minds of dreamers. (Copyright 2014 Dan Durda)
Flying the Infrared Skies: An Authentic SOFIA Educator Experience

I've long been associated with SOFIA, so it was great to finally partake in a flight.

By James Manning

Over a blanket of snow covering California's southern Sierra Nevada Mountains, NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) — a highly modified Boeing 747SP aircraft — flies with the sliding door over its telescope cavity fully open. [NASA/Jim Ross]
The Stratospheric Observatory for Infrared Astronomy (SOFIA) is a unique NASA facility: it’s a telescope that takes off and lands. Sporting a primary mirror 2.5 meters (100 inches) in diameter tucked into the rear of a short-bodied Boeing 747, the flying observatory does its work at altitudes that can exceed 40,000 feet. Up there, it’s above enough of Earth’s atmosphere to fill in the infrared gap that Earth-bound observatories encounter because those longer-wavelength photons are blocked from reaching the ground by Earth’s atmosphere. Operated in partnership with the German Aerospace Center, this telescope/aircraft combination provides opportunities not only for learning more about the universe, but also for bringing numerous people along for the flight — including teachers.

The flagship education and public outreach (E/PO) effort for the SOFIA mission — the one that gets teachers flying the infrared skies along with the scientists — is the Airborne Astronomy Ambassadors (AAA) program. The effort is an outgrowth of a similar program aboard the Kuiper Airborne Observatory (a modified C-141 jet transport with a 0.9-meter telescope) that flew for many years prior to SOFIA.

The current AAA project is a teacher professional development program designed to *improve teaching* by providing teachers with first-person experiences in the conduct of science; *inspire students* through the exploits of their teachers, the flight-informed lessons they create, and the “I was there” vibe they can bring to the classroom; *inform the community* through public presentations and the platform their new-found notoriety can bring; and *contribute to STEM literacy* through all of the above. The program competitively selects two-person teacher teams who take a graduate-level Astronomy for Teachers on-line course. The teams then fly twice on SOFIA missions to experience the workings of an airborne observatory, to interact with the scientists they encounter, to observe research in progress, and to learn how scientists use technology.

When they’re finished, they implement classroom lessons based on their experience, complete an outreach plan, give presentations, initiate professional development for their peers, and do much else to bring the work of the high-flying observatory down to Earth for the benefit of science and technology education.
Preparing to Fly

In May 2014, I had the privilege of taking part in one of these flights as an E/PO escort. SOFIA and I go back a long way, and I’ve been variously associated with it for much of its development history. I was part of the original E/PO advisory committee starting in 1997 that strongly supported the AAA program, and during my time with the Astronomical Society of the Pacific (ASP), we were partners with the SETI Institute in managing the E/PO program (a partnership that continues). So it was gratifying to finally witness this program in action.

Of course, one doesn’t just show up and hop aboard as if it were a commuter flight. There are preliminaries.

Arriving the day before my flight in Palmdale, California, I had much to attend to. The other educators and I were given an extensive tour of the NASA Armstrong Flight Research Center’s Palmdale facilities where the space agency houses many of its scientific research aircraft. There were scientists to talk with, a variety of SOFIA instruments and technologies to learn about, and not least, an extensive mini-course on flight safety to attend. One must remember that the SOFIA 747 is not a commercial airliner. It’s an experimental aircraft, as befits a jet airplane that opens a big door in its side in mid-flight — on purpose. That means there’s a very comprehensive safety protocol and thus a very detailed briefing that everyone has to go through to understand the various safety procedures and equipment. In fact, once on the aircraft, we have to wear our own little oxygen systems, in a carry bag with the strap slung over our shoulders, at all times — just in case something happens.

Once we finished with the classroom part of the briefing, including videos and manipulation of devices, the second half was conducted on board the aircraft to be sure we could find and recognize safety equipment and remember how to use it if the need should arise. And you know those safety cards in your seat pocket that you see on every flight you ever take? Well, SOFIA has its own custom-made version (right) — a laminated cheat sheet containing diagrams and covering all of the safety procedures we’d been drilled on.

After a good night’s sleep and a leisurely morning, it was back to the Palmdale facility the next afternoon, laden with provisions for the night ahead plus warm clothing for what was to be a chilly mission. There we attended the pre-flight briefing, where mission controllers took attendance, in effect, to account for all of the staff, scientists, and educators who would be flying that night; to report on the status of the airplane (good to go); the status of the telescope (A-OK); weather conditions (nothing to worry about beyond some possible areas of turbulence we would likely fly above); and the flight path we would be traveling.

The flight path was something to behold. It was hardly one of the gentle arcs from one city to another that cover maps of the US in the backs of airline flight magazines. This had the look of an odd, segmented, lopsided analemma: straight lines connecting a path extending up to Montana and down across the Midwest into the deep South, doing a little pirouette on the Georgia/Florida border before heading back to California. Each straight-line segment
represented a precise heading for the observation of a particular celestial object by the telescope, strung together on a dance card that would keep us aloft for 10 hours during the deep of the night.

**A GREAT Instrument**

The instrument attached to the telescope for our flight was the German Receiver for Astronomy at Terahertz Frequencies — GREAT for short. Mounted on the pier running through the bulkhead from the telescope cavity into the pressurized cabin, this instrument doesn’t collect photons per se. Rather, it works like a high-frequency radio receiver in that it detects light waves rather than light particles. In the series of flights that included mine, the German scientists minding the instrument were debuting a new channel on GREAT designed primarily to study the transitions of neutral atomic oxygen and ionized carbon — that is, when oxygen and carbon atoms’ electrons change their energy state, and the atoms emit a particular wavelength of energy, thus betraying their presence.

GREAT’s oxygen and carbon detection capabilities will be useful in answering pesky astronomical questions — for example, it will help to determine the “energy balance” of the interstellar medium, the gas and dust between the stars. When this gas and dust gravitationally contracts into denser clouds — the first step in producing stars — the contraction causes infalling particles to collide and jostle, moving faster and creating a thermal energy that works against further contraction.

But neutral oxygen and ionized carbon can emit infrared radiation (heat) of wavelengths that can escape even a dense contracting cloud, theoretically providing an avenue for this thermal energy to “leak” out, allowing the cloud to contract further to the point of...
forming stars. Knowing the abundance, distribution, and dynamics of interstellar oxygen and carbon via their emissions can thus help astronomers to better characterize the process by which stars form.

The instrument requires cool conditions to aid its super-cooled innards in ferreting out answers to such cosmic questions — hence the need for warm clothing. On this flight, the cabin temperature would be kept a little above refrigeration level.

The Airborne Experience

With the briefing complete, it was time to make our way out to the plane. Once we mounted the tall metal stairway to reach the door of the 747 from the tarmac, the flight’s education contingent stowed their gear in the “first class section” in the nose of the plane, which retained passenger seats on one side with equipment racks on the other. We reviewed the safety cards, were attentive for the obligatory safety talk, slung on our emergency oxygen carry bags, buckled up, and settled in for the taxi as the Sun headed for the horizon. We took off at 7:30 in the evening, into the west toward the setting Sun, then banked to turn northward over the arid Antelope Valley.

Our heading aimed us toward the California/Nevada border. As SOFIA gained altitude, we unbuckled when the signal was given and wandered the cabin, waiting for the Sun to go down so the night’s observing could begin. We rose through thin clouds, and the view outside was of an airy taffeta landscape suffused with orange sunset glow. The view inside was all equipment and business.

The Clipper Lindbergh (retaining its original name from its days with Pan American World Airways) is no longer a passenger plane; it is completely reconfigured and outfitted for scientific research. And the setting is a far cry from rows of seats serviced by beverage carts. Behind the former first class cabin, past the tiny galley, rest rooms, and the stairs to the upper deck, is the main cabin, converted for science. The far end toward the tail is blocked by a blue bulkhead, beyond which the telescope lies in its isolated cavity, waiting for the Sun to go down so that the door in the side of the plane can open to prepare the telescope for the night’s work. On our side of the bulkhead, the GREAT instrument clings firmly to its end of the Nasmyth tube, the hollow tube connecting telescope and instrument and through which the light from the telescope is directed. In moments of slight turbulence, I could see the tube with the instrument bob and sway in subtle movements. But it is not the telescope assembly itself that moves about on the plane; rather, it’s the plane that moves about the telescope, utilizing an impressive stabilization system that keeps the instrument stock-still to accurately track its targets.

Forward of the bulkhead are all of the worker bees at their stations, facing the telescope cavity bulkhead at the back of the plane. In the middle of the main cabin sits the flight control station, where the mission controllers orchestrate the night’s activity from takeoff to landing. Aft and to their left are the telescope operators busy at their console. Nearby along the port side of the aircraft and directly aft of
the mission controllers are the stations for the scientists and technicians (mostly a German crew on my flight) who monitor the receipt of data from the instrument on their laptops. One deck up, the flight crew completes the night’s contingent, keeping to the precise flight plan to ensure that the telescope is in the right place at the right time. Constant communication between the mission controllers, the telescope operators, and the cockpit ensures that everything goes smoothly as the aircraft proceeds along its trajectory.

The Observing Run

Just before 8:30 pm — at 38,000 feet and an hour into the flight, with the Sun on the verge of setting — the action began. The door in the fuselage opened, and the telescope roused to life. As dusk gathered, the first target was acquired: Alpha Geminorum (Castor) in the constellation of Gemini, a bright star glimmering out of the gathering darkness that allowed calibration and setup tasks to proceed. By 9:00, all was in readiness, and the jet turned onto the proper northeasterly heading for its first research object: IC 342, a “starburst” galaxy (a galaxy in the throes of forming stars at a higher rate than is considered seemly) that was being mapped during several flights in “C+,” shorthand for ionized carbon.

And ours was a ringside seat, for there was one other console at the very front of the main cabin — the education console, around which the education group clustered during the flight. It offered very extensive displays that included a status board monitoring the state of the flight (longitude, latitude, altitude, airspeed, outside temperature) and the status of the telescope — where it was pointing, what it was pointing at, its configuration within its cavity behind the bulkhead, tracking status, various operational telemetries, and so on.

We also had displays that showed the telescope's field of view, indicating what field stars were locked onto for tracking and often showing a visible-light manifestation of the target object. The console was further equipped with a number of headphones, allowing us to switch through channels and listen to the cross-talk between mission control, telescope operation, and the flight deck. In these ways, the educators had access to what was going on and an opportunity to experience scientific research in action.

For nearly 45 minutes as we crossed Montana airspace near the Canadian border, the telescope remained fixed on IC 342, gathering data across its span. It’s one of the two brightest galaxies in the so-called Maffei 1 Group, the nearest clutch of galaxies to our own Local Group. But this face-on spiral is rather difficult to observe, because the dusty plane of our own Milky Way galaxy lies in the way, and the dust much obscures it. Infrared wavelengths, however, can pass though the dust, and thus does SOFIA find its niche above most of the air, gathering in wavelengths that most other instruments and telescopes cannot, providing essential new views of the celestial menagerie.
The observation was successful, and the 747 turned southeastward over North Dakota just before 10:00 and locked onto its next target: the Iris Nebula (a combination star cluster and reflection nebula lying within our own galaxy), mapping it in neutral atomic oxygen at which the new GREAT channel is especially adept. We could observe the field of view from our education console, with several stars encased in green boxes. These were the tracking stars for this observation — the stars the telescope locks onto to keep it steadfastly aimed at the temporary object of its desire. This is one of the important reasons why the observatory flies at night. The tracking system needs visible-light stars near the target objects that can be latched onto in order to make its observations. These are usually faint stars that require a dark sky to see.

By 10:30, the telescope turned to its next target, a hydrogen emission nebula — a star-forming region where infrared probing can reveal contents that visible light cannot. Thirty minutes later, SOFIA was flying southeast across the Midwest, taking oxygen readings of the young, compact planetary nebula NGC 7027. A minor technical issue lost the scientists 10 minutes of observing time on this object, and they elected to forego the next target on the observing list and continue taking data on the planetary nebula to obtain their map; such are the fortunes of science-on-the-fly. By now, our altitude had risen to 40,000 feet, the expenditure of fuel allowing for additional height and hence less air (including water vapor) between the telescope and the cosmos.

Around midnight, with the scientific game plan unfolding in good order, I took advantage of an opportunity to steal upstairs to the flight deck to see operations from the vantage point of the flight crew. I slid into a jump seat behind Matt Pitsch, the affable flight engineer, who kindly answered my questions (during breathers from his duties) about details of the flight and the professional life of a NASA flight crew. Ahead of him sat the pilot, Frank Batteas, and the co-pilot, Ace Beall, who flew another jet for NASA — the one that carried the space shuttle on its back on the returns from the Edwards Air Force Base landing site to the Kennedy Space Center. These were definitely guys with the “right stuff,” and interacting with them was as much a part of the experience as interacting with the scientists.

I observed operations from the flight deck as we flew over Georgia and made the turn at the Florida border, beginning the return leg about 1:00 am. I peeked out of the cockpit window to my left and spied Mars and Spica, Saturn and Scorpius — strung across the sky with a low-hanging, just-waning gibbous Moon above the teapot of Sagittarius. We were heading northwest at 43,000 feet, on the way back across the southern US. The telescope was aimed generally south now, searching for the final, most challenging objects of the night’s observing.
Heading back down to the main cabin, I found the teacher teams and escorts still fully immersed in the flight, and this extended beyond monitoring the displays and audio channels and looking over the shoulders of the scientists. The teachers engaged the scientists personally, and when the scientists weren't busy with some aspect of the mission, they were happy to talk about the technologies, the science they were doing, and the results they were getting.

My own conversation with GREAT’s program manager Stefan Heyminck offered some fascinating insights into the instrument’s systems and technology, while US SOFIA engineer Bill Waller showed me how his software provides a means for GREAT and the telescope to communicate with each other and how he could monitor that conversation to make sure they were getting along. And German scientist Robert Simon regaled me with insights into how their research was helping them learn about the chemistry and dynamics of the objects they were observing and what it said about the cosmos.

And the enthusiasm was rubbing off on the rest of us. Several of the teachers recorded in-flight interviews with various members of the science team in both video and audio formats, to use in their lesson plans for classes and for their community outreach to come. And New York teacher Elizabeth Rosenberger remarked to me how her experience had enhanced her understanding of the passion these scientists have for their work, and how important SOFIA was to them in advancing astronomy.

As the wee hours passed, our trajectory headed westward and the telescope continued to snare subjects for study. An observation of a solar-mass binary protostar embedded in a molecular cloud proved to be tricky, thanks to the challenge of finding suitable tracking stars, and a few small glitches lost a bit of observing time, but data were obtained. The telescope then aimed at a supernova remnant in Sagittarius within three degrees of the 95% illuminated Moon and successfully locked onto tracking stars, despite the brilliant background, to obtain readings. And the final object of the night, an ionized hydrogen nebula in another star-forming region, had the telescope pointing just about as high out of its door as it could go throughout the run, but it harvested light like a champ.

By 4:00 am, the first light of dawn began to materialize along the southeastern horizon. Around 4:40, the last observation was completed. Ten minutes later the telescope door closed, and the instrument was configured for landing as we turned south toward southern California. One of the teachers and I headed back up to the cockpit’s jump seats for the descent to Palmdale and a feather-light touchdown a little after 5:30 am. We were on the ground again, under all that air that veils a sizeable stretch of the infrared spectrum from our view. But through the auspices of a remarkable technology...
that can take off and land, and the scientists and technologists that created and use it, we had parted that veil for a night, returning with a treasure of data that, accumulating over time, continues to improve and extend our understanding of the larger cosmos.

**Inspirational Education**

It was time to disembark. The plane was wheeled alongside its cavernous hangar in the early morning sunlight, and the stairs pushed up to the jetliner door. We collected our gear and descended, from the night’s height of 43,000 feet, the last 20 or so to the ground.

Tired but exhilarated, we piled into more conventional vehicles for the drive back to our Palmdale hotel. Despite having just pulled an “all-nighter,” one of the first things new Airborne Astronomy Ambassador Rosenberger did upon arriving was set up her laptop in the hotel lobby and conduct a video debrief of her experience with her class, just beginning their school day on the East Coast. It was inspirational education in action, by both teacher and students, and illustrated the impact a program like this can have.

Later in the day, after a few hours sleep, we wound our way through the San Gabriel Mountains back to the LA Basin and the airport for our journeys home. On the way, we passed by the Vasquez Rocks, where the original Star Trek TV series shot some of its episodes. You often hear how that series, along with NASA’s Mercury, Gemini, and Apollo programs, inspired many a lad and lass in the late 1960s to aspire to careers in science, technology, and STEM education. (I know because I am among them.) Excepting popular culture, who can serve today?

In the van that ferried us back to LAX were four newly minted Airborne Astronomy Ambassadors, ready to go forth and do the good work their experience with science research, 43,000 feet closer to the universe, has inspired them to do. How far might their influence ripple, like the infrared waves SOFIA collects?

The nice thing about SOFIA is that it’s one of those missions that creates two kinds of products. It produces science, of course — new discoveries and new insights on the universe of which we are part and parcel. But the other product is education — the kind represented by the Airborne Astronomy Ambassadors, teachers who have had an authentic science experience, and then go back to their classrooms and their communities and demonstrate in tangible ways how NASA provides unique assets and resources for the improvement of STEM education in the US. These teachers — these four and all of the others who have gone through this program and who may in the future — are on the front lines of that effort. It’s an effort that can help to bridge the distance between the scientists in the air and the people on the ground.

Long may they fly!

**James Manning** is a science education and public outreach consultant, the former Executive Director of the Astronomical Society of the Pacific, a past Head of the Office of Public Outreach for STScI, and a long-time formal and informal astronomy educator with three decades of planetarium education, administration, and college introductory astronomy teaching under his belt. This article is adapted and expanded from his presentation at the 126th annual meeting of the ASP in August 2014.
"J" Marks the Spot for Rosetta's Lander
European Space Agency

Rosetta’s lander Philae will target Site J, an intriguing region on Comet 67P/Churyumov–Gerasimenko that offers unique scientific potential, with hints of activity nearby, and minimum risk to the lander compared to the other candidate sites.

Site J is on the ‘head’ of the comet, an irregular shaped world that is just over 4 km across at its widest point. The decision to select Site J as the primary site was unanimous. The backup, Site C, is located on the ‘body’ of the comet. The 100 kg lander is planned to reach the surface on November 11, where it will perform in-depth measurements to characterize the nucleus in situ, in a totally unprecedented way. [Update: The lander will be deployed on November 12.]

But choosing a suitable landing site has not been an easy task. “As we have seen from recent close-up images, the comet is a beautiful but dramatic world — it is scientifically exciting, but its shape makes it operationally challenging,” says Stephan Ulamec, Philae Lander Manager at the DLR German Aerospace Center. “None of the candidate landing sites met all of the operational criteria at the 100% level, but Site J is clearly the best solution.”

MORE INFORMATION
Cassini Tracks Clouds Developing Over a Titan Sea

NASA/JPL

NASA’s Cassini spacecraft recently captured images of clouds moving across the northern hydrocarbon seas of Saturn’s moon Titan. (A movie is available here.) This renewed weather activity, considered overdue by researchers, could finally signal the onset of summer storms that atmospheric models have long predicted.

The Cassini spacecraft obtained the new views in late July [2014], as it receded from Titan after a close flyby. Cassini tracked the system of clouds developing and dissipating over the large methane sea known as Ligeia Mare for more than two days. Measurements of cloud motions indicate wind speeds of around 7 to 10 mph (3 to 4.5 meters per second).

For several years after Cassini’s 2004 arrival in the Saturn system, scientists frequently observed cloud activity near Titan’s south pole, which was experiencing late summer at the time. Clouds continued to be observed as spring came to Titan’s northern hemisphere.

But since a huge storm swept across the icy moon’s low latitudes in late 2010, only a few small clouds have been observed anywhere on the icy moon. The lack of cloud activity has surprised researchers, as computer simulations of Titan’s atmospheric circulation predicted that clouds would increase in the north as summer approached, bringing increasingly warm temperatures to the atmosphere there.

“We’re eager to find out if the clouds’ appearance signals the beginning of summer weather patterns, or if it is an isolated occurrence,” said Elizabeth Turtle, a Cassini imaging team associate at the Johns Hopkins University Applied Physics Lab in Laurel, Maryland. “Also, how are the clouds related to the seas? Did Cassini just happen catch them over the seas, or do they form there preferentially?”

Observing seasonal changes on Titan will continue to be a major goal for the Cassini mission as summer comes to Titan’s north and the southern latitudes fall into winter darkness.
Half of all Exoplanet Host Stars are Binaries

National Optical Astronomy Observatory

Imagine living on an exoplanet with two suns. One, you orbit and the other is a very bright, nearby neighbor looming large in your sky. With this “second sun” in the sky, nightfall might be a rare event, perhaps only coming seasonally to your planet. A new study suggests that this could be far more common than we realized.

The NASA Kepler Space Telescope has confirmed about 1,000 exoplanets, as well as thousands more stars considered “Kepler objects of interest”, dubbed KOIs — stars that could possibly host planets. Until now, there has been an unanswered question about exoplanet host stars; how many host stars are binaries? Binary stars have long been known to be commonplace — about half the stars in the sky are believed to consist of two stars orbiting each other. So, are stars with planets equally likely to have a companion star, or do companion stars affect the formation of planets? A team of astronomers, led by Dr. Elliott Horch, Southern Connecticut State University, have shown that stars with exoplanets are just as likely to have a binary companion: that is, 40% to 50% of the host stars are actually binary stars. As Dr. Horch said, “It’s interesting and exciting that exoplanet systems with stellar companions turn out to be much more common than was believed even just a few years ago.”

Their study makes use of very high spatial resolution observations that were carried out on the WIYN telescope located on Kitt Peak in southern Arizona and the Gemini North telescope located on Mauna Kea in Hawaii. The technique used by the team is called speckle imaging and consists of obtaining digital images of a small portion of the sky surrounding a star of interest, 15 to 25 times a second. The images are then combined in software using a complex set of algorithms, yielding a final picture of the star with a resolution better than that of the Hubble Space Telescope.

By using this technique, the team can detect companion stars that are up to 125 times fainter than the target, but only 0.05 arcseconds away. For the majority of the Kepler stars, this means companion stars with a true separation of a few to about 100 times the Sun-Earth distance. By noting the occurrence rate of these true binary companion stars, the discoveries can be extended to show that half of the stars that host exoplanets are probably binaries.

MORE INFORMATION

This artist’s concept illustrates Kepler-16b, the first planet known to definitively orbit two stars — what’s called a circumbinary planet. [NASA/JPL-Caltech/T. Pyle]
Clear Skies on Exo-Neptune

European Space Agency

Astronomers using data from the NASA/ESA Hubble Space Telescope, the Spitzer Space Telescope, and the Kepler Space Telescope have discovered clear skies and steamy water vapor on a planet outside our solar system. The planet, known as HAT-P-11b, is about the size of Neptune, making it the smallest exoplanet ever on which water vapor has been detected.

The discovery is a milestone on the road to eventually finding molecules in the atmospheres of smaller, rocky planets more akin to Earth. Clouds in the atmospheres of planets can block the view of what lies beneath them. The molecular makeup of these lower regions can reveal important information about the composition and history of a planet. Finding clear skies on a Neptune-size planet is a good sign that some smaller planets might also have similarly good visibility.

“When astronomers go observing at night with telescopes, they say ‘clear skies’ to mean good luck,” said Jonathan Fraine of the University of Maryland, USA, lead author of the study. “In this case, we found clear skies on a distant planet. That’s lucky for us because it means clouds didn’t block our view of water molecules.”

HAT-P-11b is a so-called exo-Neptune — a Neptune-sized planet that orbits another star. It is located 120 light-years away in the constellation of Cygnus. Unlike Neptune, this planet orbits closer to its star, making one lap roughly every five days. It is a warm world thought to have a rocky core, a mantle of fluid and ice, and a thick gaseous atmosphere. Not much else was known about the composition of the planet, or other exo-Neptunes like it, until now.
NASA’s Spitzer Telescope Witnesses Asteroid Smashup

NASA’s Spitzer Space Telescope has spotted an eruption of dust around a young star, possibly the result of a smashup between large asteroids. This type of collision can eventually lead to the formation of planets.

Scientists had been regularly tracking the star, called NGC 2547-ID8, when it surged with a huge amount of fresh dust between August 2012 and January 2013. "We think two big asteroids crashed into each other, creating a huge cloud of grains the size of very fine sand, which are now smashing themselves into smithereens and slowly leaking away from the star," said lead author and graduate student Huan Meng of the University of Arizona, Tucson.

While dusty aftermaths of suspected asteroid collisions have been observed by Spitzer before, this is the first time scientists have collected data before and after a planetary system smashup. The viewing offers a glimpse into the violent process of making rocky planets like ours.

In the new study, Spitzer set its heat-seeking infrared eyes on the dusty star NGC 2547-ID8, which is about 35 million years old and lies 1,200 light-years away. Previous observations had already recorded variations in the amount of dust around the star, hinting at possible ongoing asteroid collisions. In hope of witnessing an even larger impact, which is a key step in the birth of a terrestrial planet, the astronomers turned to Spitzer to observe the star regularly.

Beginning in May 2012, the telescope began watching the star, sometimes daily.

A dramatic change in the star came during a time when Spitzer had to point away from NGC 2547-ID8 because our Sun was in the way. When Spitzer started observing the star again five months later, the team was shocked by the data they received.

MORE INFORMATION
Radio Telescopes Settle Controversy Over Distance to the Pleiades

National Radio Astronomy Observatory

Astronomers have used a worldwide network of radio telescopes to resolve a controversy over the distance to a famous star cluster — a controversy that posed a potential challenge to scientists’ basic understanding of how stars form and evolve. The new work shows that the measurement made by a cosmic-mapping research satellite was wrong.

The astronomers studied the Pleiades, the famous “Seven Sisters” star cluster in the constellation Taurus. The cluster includes hundreds of young, hot stars formed about 100 million years ago. As a nearby example of such young clusters, the Pleiades have served as a key “cosmic laboratory” for refining scientists’ understanding of how similar clusters form. In addition, astronomers have used the measured physical characteristics of Pleiades stars as a tool for estimating the distance to other, more distant, clusters.

Until the 1990s, the consensus was that the Pleiades are about 430 light-years from Earth. However, the European satellite Hipparcos, launched in 1989 to precisely measure the positions and distances of thousands of stars, produced a distance measurement of only about 390 light-years.

“That may not seem like a huge difference, but, in order to fit the physical characteristics of the Pleiades stars, it challenged our general understanding of how stars form and evolve,” said Carl Melis, of the University of California, San Diego. To solve the problem, Melis and his colleagues used a global network of radio telescopes to make the most accurate possible distance measurement. The result of their work is a distance to the Pleiades of 443 light-years, accurate, the astronomers said, to within one percent. This is the most accurate and precise measurement yet made of the Pleiades distance.

MORE INFORMATION

Using the parallax technique, astronomers observe a celestial object at opposite ends of Earth’s orbit around the Sun to precisely measure its distance. [Alexandra Angelich, NRAO/AUI/NSF]
This Star Cluster Is Not What It Seems

European Southern Observatory

The Milky Way galaxy is orbited by more than 150 globular star clusters, which are balls of hundreds of thousands of old stars dating back to the formation of the galaxy. One of these, along with several others in the constellation of Sagittarius, was found in the late 18th century by the French comet hunter Charles Messier and given the designation Messier 54.

For more than two hundred years after its discovery Messier 54 was thought to be similar to the other Milky Way globulars. But in 1994 it was discovered that it was actually associated with a separate galaxy — the Sagittarius Dwarf Galaxy. It was found to be at a distance of around 90,000 light-years — more than three times as far from Earth as the galactic centre.

Astronomers have now observed Messier 54 using the VLT as a test case to try to solve one of the mysteries of modern astronomy — the lithium problem.

Most of the light chemical element lithium now present in the universe was produced during the Big Bang, along with hydrogen and helium, but in much smaller quantities. Astronomers can calculate quite accurately how much lithium they expect to find in the early universe, and from this work out how much they should see in old stars. But the numbers don't match — there is about three times less lithium in stars than expected. This mystery remains, despite several decades of work.

Up to now it has only been possible to measure lithium in stars in the Milky Way. But now a team of astronomers led by Alessio Mucciarelli (University of Bologna, Italy) has used the VLT to measure how much lithium there is in a selection of stars in Messier 54.

MORE INFORMATION
The election for the Board of Directors of the Astronomical Society of the Pacific has concluded, and the following three individuals have been elected by the ASP membership.

Gibor Basri received his PhD in Astrophysics from the University of Colorado, Boulder, in 1979. An award of a Chancellor’s Postdoctoral Fellowship brought him to UC Berkeley that year, where he joined the faculty of the Astronomy Department in 1982.

He has worked on stellar magnetic activity and low mass stars (including the Sun) throughout his career. He was an active user of the Lick and Keck Observatories as well as a number of space telescopes. He was a pioneer in the discovery and study of magnetospheric accretion onto newly forming stars. He was a co-discoverer of brown dwarfs, and found and helped characterize the death of stellar chromospheres at the bottom of the main sequence.

Basri has pioneered several means of directly measuring stellar magnetic fields, and studied their role in the angular momentum history of stars and brown dwarfs. Recently he has been utilizing stellar data from the Kepler mission to learn more about starspots.

Back on Earth, he will soon step down from several years as the founding Vice Chancellor for Equity and Inclusion at UC Berkeley.

Pamela L. Gay is an assistant research professor in the Center for STEM Research, Education and Outreach at Southern Illinois University Edwardsville. She received her PhD in astronomy from the University of Texas Austin and has worked as an astronomer, writer, and podcaster. Her most recent work has focused on using new media to engage people in learning and doing astronomy. She is the director of CosmoQuest.org, a virtual research facility that provides the public access to opportunities normally only available to professional researchers, including the chance to work on citizen science projects that support MESSENGER, Dawn, Lunar Reconnaissance Orbiter, and other NASA missions.

Her most well known project may be Astronomy Cast, a podcast she co-hosts with Fraser Cain (Publisher of Universe Today). Each week, Astronomy Cast takes their listeners on a facts-based journey through the cosmos that explores not only what we know about the universe but how we know it. In addition to podcasting, she also works to communicate astronomy to the public through her blog StarStryder.com, through frequent public talks, and through popular articles. Her writing has appeared in Astronomy, Sky and Telescope, and Lightspeed magazines, and she has made appearances on the History Channel’s The Universe and National Geographic’s Top Secrets.
Philip Sadler first earned a BSc in Physics from MIT in 1973 while co-authoring a textbook on introductory calculus. He then taught middle school science, engineering, and mathematics for several years. During this time, he developed the Starlab portable planetarium, which has since brought the night sky to tens of millions of school children, worldwide. He returned to academia earning a doctorate in education from Harvard in 1992. Sadler has taught Harvard’s courses for hundreds of students preparing to be science teachers and for the next generation of science professors. As F.W. Wright Senior Lecturer in Astronomy, he carries on Harvard’s oldest undergraduate course in science — Celestial Navigation. He currently directs the Science Education Department at the Harvard Smithsonian Center for Astrophysics.

Sadler’s research program has included the assessment of students’ astronomical misconceptions and how they change with instruction, the development of the MicroObservatory network of automated telescopes that allow K–12 students to engage in research, and curriculum development in astronomy and the physical sciences. He won the Journal of Research in Science Teaching Award for work on assessing student understanding in science, given yearly for “the most significant contribution to science education research.” He won both the ASP’s Brennan Prize for contributions to astronomy teaching and Project ASTRO’s Astronomy Education Recognition Award. He was awarded the 2010 American Astronomical Society Education Prize and in 2012, he won the Millikan Medal of the American Association of Physics Teachers for his “notable and intellectually creative contributions to the teaching of physics.”
NEW MEMBERS — The ASP welcomes new members who joined between June 24 and September 28, 2014.

**Individual**

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<tr>
<th>Name</th>
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<tr>
<td>Bruce Agee</td>
<td>Dixon, CA</td>
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<td>Bernhard Beck-Winchatz</td>
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<td>Christine Bertko</td>
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<td>Ted Blank</td>
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<td>Paul Buck</td>
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<td>Roger Cecchi</td>
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<td>Nicoline Chambers</td>
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<td>Demian Cho</td>
<td>Winona, MN</td>
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<td>Whitney H. Cobb</td>
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<td>Edward M. Coppola</td>
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<td>Sandra M. Dawson</td>
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<td>Eric L. DeBlackmere</td>
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<td>Steve Dupaix</td>
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<td>Sarah E. Eyermann</td>
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<td>Donald Gardner</td>
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<td>Ralph C. Gregg</td>
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<td>Vincent Guthrie</td>
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<td>Heidi B. Hammel</td>
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<td>Madeline Hill</td>
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<td>Douglas Ingram</td>
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<td>Alexander Jay</td>
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<td>Yuko Kakazu</td>
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<td>Catherine Kaleida</td>
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<td>Edwin Ladd</td>
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<td>Argy Leyton</td>
<td>Rancho Cucamonga, CA</td>
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<td>Catherine Lorenz</td>
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<td>Jazmin Maravilla</td>
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<td>Jaeel Owens</td>
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<td>Tanya L. Phillips</td>
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<td>Nancy Price</td>
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<td>Marc Stowbridge</td>
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<td>Thomas Target</td>
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<td>B. Ray Thompson</td>
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**Technical**

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<tr>
<td>Gibor S. Basri</td>
<td>Berkeley, CA</td>
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<td>Daniel B. Caton</td>
<td>Boone, NC</td>
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<td>William Fenech</td>
<td>San Ramon, CA</td>
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<td>David A. Hurdis</td>
<td>Narragansett, RI</td>
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<td>Glenn Kelly</td>
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<td>Rasha Moussa</td>
<td>Giza, Egypt</td>
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<td>James G. Peters</td>
<td>Berkeley, CA</td>
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<td>Nicole Ponce</td>
<td>Castro Valley, CA</td>
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**Supporter’s Circle**

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<td>Durruty Jesus de Alba Martinez</td>
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<td>Katy D. Garmany</td>
<td>Tucson, AZ</td>
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<td>Lynne A. Hillenbrand</td>
<td>Pasadena, CA</td>
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<td>Laurel E. Ladwig</td>
<td>Albuquerque, NM</td>
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<tr>
<td>Benjamin Schramm</td>
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**Legacy Giving**

Astronomy compels the soul to look upwards and leads us from this world to another — Plato

Leave a universal legacy...

Astronomy shows us that we are part of something much greater than ourselves, and that our actions on Earth have a lasting impact. A legacy gift to the ASP as part of your estate plan reflects this understanding, and will support future generations as they reach for the stars.

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**Support the ASP through the Combined Federal Campaign**

ASP is a member of the Combined Federal Campaign (CFC) for federal employees (CFC#:10651). Individual members’ and supporters’ CFC gifts 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 ASP.
The Skies of November

There is a dearth of bright planets at sunset this month. Mars is low in the southwest at dusk, setting more than three hours after the Sun. On the 2nd, the red planet sideswipes the globular cluster M28 in Sagittarius, and between the 5th and 7th it passes near M22, another globular cluster, but you’ll need binoculars (at least) to see these events. The crescent Moon visits Mars on the 25th.

Jupiter rises in the east around 11:30 pm at the start of the month and before 10:00 pm by month’s end. On the night of the 13th/14th, the giant planet climbs into the sky with the last-quarter Moon immediately to its right.

Mercury is nicely placed for viewing in the dawn skies during the first week of November. It rises about 90 minutes prior to the Sun, and 30 minutes before sunrise, it sits about 10° above the east-southeast horizon. It’s a shame there’s no Moon nearby to guide your gaze. By the time the thin crescent Moon hovers over this little planet on the morning of the 21st, both are very close to the horizon 30 minutes before sunrise.

Both Venus and Saturn are lost in the solar glare this month.

The Leonid meteor shower peaks during the evening of the 17th/18th. This shower’s activity is usually weak; there’s often only a trickle of meteors radiating from a region near the Sickle of Leo, the Lion. While it’s always worthwhile stepping outside to scan for meteors, a better shower is next month’s Geminids.

The Skies of December

This month’s highlight is the Geminid meteor shower, which peaks on the night of the 13th/14th. Although the last-quarter Moon rises around midnight, the shower’s radiant (the point in the sky from
which the meteors seem to fly) in Gemini, near the bright star Castor, is well up during the early evening. If the sky is clear and you can avoid light pollution, you should see an average of a meteor every minute during much of the evening.

**Venus** is starting to peek above the western horizon after sunset — but just barely. Even on the 23rd, when the 2-day-old crescent Moon hangs high above Venus in the southwest, this brilliant planet sets a mere 60 minutes after the Sun. A clear, low western horizon is needed if you want to glimpse it. The situation improves significantly next month.

Faint **Mercury** is also slowly emerging from the solar glare. If you can spot Venus shortly after sunset at month’s end, look for much-dimmer Mercury about 4° to Venus’ lower right. Binoculars will likely be required.

**Mars** continues to hang around low in the southwest, setting more than three hours after the Sun. If you’re having trouble finding it, look for a little reddish dot about 5° to the left of the 3-day-old Moon after sunset on the 24th.

The giant planet **Jupiter** is nicely placed for viewing this month. It rises in mid-evening, is high in the south during the early morning hours, and is visible until dawn. On the 11th the Moon passes below this giant world and its retinue of four large satellites. **Saturn** is a morning object, and by mid-month it rises some two hours before the Sun. On the morning of the 19th, this ringed world hangs just below the waning crescent Moon.

The **solstice** occurs on December 21st at 6:03 pm Eastern time; 3:03 pm Pacific. This marks the astronomical start of winter in the Northern Hemisphere and summer in the Southern.

**The Skies of January**
The year begins with bright **Venus** very low in the west after sunset; dim **Mercury** is 3° to Venus’ lower right. Both are slowly climbing into the dusk sky, but Mercury is closing in on Venus (at least for a little while). Between the 7th and 13th, the two planets are less than 1° apart: find Venus (perhaps in binoculars) and that dim point of light to its right is Mercury. If you’ve never seen Mercury, this is a great opportunity to spot it. But you’ll need a low and clear southwestern horizon to observe them both, because 30 minutes after sunset they’re a mere 10° above the horizon.

On the 21st, as Mercury is sinking back toward the Sun, the 40-hour-old crescent Moon appears 5° (half the width of your fist held at arms’ length) to the right of Venus; faint Mercury is an equal distance below the thin crescent.

After sunset the next evening, with Venus hanging well below the lunar crescent, look about 4° to the left of the Moon. There you’ll see a faint reddish dot: **Mars**. The red planet continues to keep ahead of the Sun, setting some three hours after sunset.

**Jupiter** rises in the mid- to early evening and is nicely placed for viewing all night. A gibbous Moon rises with Jupiter on the 7th. Meanwhile, **Saturn** is a morning object, rising some three hours before the Sun. The ringed planet sits just to the right of a thin crescent Moon on the morning of the 16th.
Looking Ahead to 2015
There will be four eclipses during the year — two solar and two lunar. On March 20th, a total eclipse of the Sun will be visible along a narrow path that intercepts only two land masses: the Faroe Islands and Svalbard. However, the partial phases will be visible throughout Europe, northern and western Africa, and northwestern Asia. This is followed on April 4th by a total eclipse of the Moon, visible from the western half of North America, the Pacific, Australia, and much of eastern Asia. A partial eclipse of the Sun on September 13th will be seen only from southern Africa, southern Madagascar, and the eastern part of Antarctica. Finally, on September 28th a total eclipse of the Moon will be visible in western Asia, Africa, Europe, and all of South and North America (except Alaska).

It will be a visually interesting year for the two brightest planets, Venus and Jupiter. On February 21st and 22nd, Venus and Mars are less than ½° apart in the sunset sky; while the evening prior (the 20th), a crescent Moon sits near both. On June 30th and July 1st, Venus and Jupiter are less than ½° apart, also post-sunset. In fact, these two bright planets will hang together throughout June and July, with a thin crescent Moon sitting 1° away from Venus on July 18th.

Then, they do it again, only this time at dawn. October 17th and 18th: Mars and Jupiter are less than ½° apart. October 23rd: Jupiter is mid-way between Venus and Mars; the latter two planets are less than 3° apart. October 25th and 26th: Jupiter and Venus are 1° apart. November 2nd: Venus and Mars sit 1° apart.

Star Charts
If you'd like a star chart to help you explore the naked-eye night sky, you have several options: purchase a star wheel (planisphere) or planetarium software, download a PDF showing the sky this month, find an online star chart, or locate an app for your tablet or smart phone.

PDF Star Charts. Skymaps produces a well-done chart that goes beyond a mere monthly star chart. It includes a list of monthly highlights and observable celestial objects. The downside: each month is available only at the very end of the previous month. Another nice star chart is available from Orion Telescopes and Binoculars; you can download it one month in advance. If you'd like simple star charts that don't show the planets, a set of 12 is available from the Canada Science and Technology Museum.

Online Star Charts. Sky View Café gives you control over the chart’s date, time, and location, plus a few other options. But the chart names only a few bright stars, doesn't identify the constellations, and the printout of the resulting chart is poor. The star chart created on the Tau Astronomy Club website offers fewer options but a better printout. But it lists no star names and the stars are color coded based on their spectral type.

Apps For Tablets and Smart Phones. SkySafari 4 ($2.99 for the basic version; available for iPhone, iPad, and iPod touch; now available for Android) is a very well done star chart app and is the one I use consistently. The Sky for iOS by Software Bisque is one of the most popular planetarium programs out there, and is now available for the iPad. If ASP stargazers have a favorite night sky app, regardless of the device, I'd like to hear about it.

— P.D.
The Gift that Keeps on Giving

A very brief primer on things you should know before buying a first telescope.

Do you know someone who might like the gift of a telescope? But do you know nothing about scopes. Does the potential recipient know something about them? If so, go talk to him or her. The gift won’t be a surprise, but the recipient will end up with an instrument that he/she will use.

And that’s the key. The best telescope is to buy is the one that will be used — whether the scope is for a friend, a youngster, or yourself. There’s no point in having a telescope (expensive or otherwise) if it sits, unloved and unused, in a closet or basement or garage.

I don’t have the space to go into detail about the varieties of telescopes, mounts, and accessories that are available, and what all the tech-terms mean. Instead, go to our ASP FAQ webpage where you’ll find links to a number of different articles on these topics (the ones from Astronomy and Sky & Telescope are particularly good). There you’ll discover the difference between a reflector, refractor, and a compound telescope; learn about alt-az and equatorial mounts; and find out what words such as aperture, focal length, eyepiece, go-to, finderscope, and Dobsonian mean.

Once you know the basics, find a nearby astronomy club, science center, or planetarium, attend one of their public observing nights, check out the various telescopes being used, and ask questions. If you know the terms, then you’ll understand the responses, and you’ll also know better than to ask: “How far can you see with that thing?”

Here are a few points to ponder before buying that first telescope. The size and type of scope you give (or acquire) should depend on where it will be used. A large telescope, good in a backyard or a country setting, is a poor choice for someone in an apartment with a small balcony (or no balcony at all). A small scope that’s quick to set up often sees more use than a large one that takes time to get ready.

Ideally, you’ll find a local shop, perhaps in a nearby science center, that has knowledgeable staff and sells mostly telescopes — buy from them if they have what you want. But if you purchase a scope online, make sure the vendor has a money-back guarantee.

Regardless of the type of telescope acquired, the tripod it sits on must be rock-solid sturdy or the whole scope is pretty much use- less. And if you live in a light-polluted environment, spend the extra money it’ll cost to buy a computer-driven scope (they’re called go-to telescopes) that will find celestial sights for you. Otherwise you’ll spend far more time looking for those sights than looking at them.

Finally, take your time — the sky isn’t going anywhere. Seek advice, shop around, and peek through different telescopes if at all possible. With a good scope in your possession, you’ll find that the night sky is the gift that keeps on giving.

Paul Deans is the editor of Mercury, was an editor at Sky & Telescope for several years, and while working in planetariums, answered the question “Which telescope should I buy?” too often to count.
Indian Space Research Organization

**MOM’s Mars**

India’s Mars Orbiter Mission (MOM) captured this global view of Mars on September 28, 2014, from a distance of 74,500 kilometers. North is to the upper left, and the south polar cap is clearly visible to the lower right. The huge, lighter-red area just above center is Arabia Terra, a densely cratered and heavily eroded uplands region. The whitish clouds to the upper left are part of a regional dust storm. Because of its very elliptical orbit, MOM will take images such as this on a regular basis.

Image courtesy Indian Space Research Organization; the link goes to their image gallery.