We seek submissions from talented, scientifically minded students addressing two of the Big Questions we face today in astronomy and cosmology.

High School Essay:
Are we alone in the universe? Or, are there other life and intelligence beyond the solar system?

College Essay:
What is the origin of the complexity in the universe?

Monetary prizes of $5,000–$50,000 will be awarded to about 16 winners.

The competition aims to inspire students to consider careers in science and to nurture their enthusiasm for the subject. Educators are encouraged to inform talented students of this extraordinary opportunity.

This program is being organized as part of the New Frontiers in Astronomy and Cosmology: An International Grant Competition for Scientists. Winners will be notified September 2012.

Essay deadline: June 15, 2012 15:00 UTC
Lighting the Fire
DON MCCARTHY

Astronomy Camps at The University of Arizona have had a life-changing impact on students, and after 25 years, we'll soon enroll children of former Campers.

Creative Teaching with Astronomically Inspired Music
MATTHEW WHITEHOUSE

Since 2006, I have helped students explore the connections between music and astronomy for The University of Arizona's Astronomy Camp.

Societal Impact: A Harbinger for Astrobiology
TREVOR QUIRK

Astrobiology, long perceived as a disparate collection of different sciences, is coming into its own thanks to the Kepler spacecraft.

Astronomy in the News

New looks at Mercury and Vesta, a Martian dust devil, and when dark energy turned on — these are some of the discoveries that recently made news in the astronomical community.

NAVIGATION TIPS

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Where are All the Good UFO Photos?

Thanks to the Kepler mission, we can now say with some confidence that there are planets aplenty out there in the Milky Way. And as Trevor Quirk points out on page 14, Kepler’s discoveries have incited increased interest in astrobiology, a field of study long plagued by a lack of very much to study.

Admittedly, we’re not there yet in terms of describing distant planets at the level of detail visualized by the creators of Avatar or Star Wars. Still, a multiplicity of planets bodes well for the concept that we are not alone in the Milky Way. And when it comes to extra-terrestrial life, it seems likely that some of it will be farther along the evolutionary tract than we are, while others will be less advanced.

Even before we knew for certain that other solar systems existed, many Earthlings believed in advanced alien civilizations, and some were adamant that aliens were already visiting us in the guise of Unidentified Flying Objects — UFOs. Back in the 1950s and 60s, UFO sightings complete with poor-quality photographs seemed commonplace. Now? Not so much.

Oh, sightings still flow into organizations that track and investigate UFOs. But the descriptions are usually vague and the photos, if any, remain mediocre. The images are often dark and/or out of focus, or the UFO itself is a mere spot of light, or the UFO is large in the frame but fuzzy and with no point of reference for a size estimate. Some of those stills from the 50s and 60s look way better.

How can this be? After all, in today’s digital age, image-capturing devices are ubiquitous. It seems that everybody owns either a DSLR or a decent point-and-shoot, or both. Cameras capable of acquiring quality images are now so small they can fit into the pocket of a pair of form-fitting jeans and barely leave a bulge. There are cameras in cell phones and smart phones and laptops and tablets. More people are carrying cameras than ever before.

So with this worldwide proliferation of cameras, you’d think we’d be flooded with high-quality UFO photos that could be easily analyzed by NASA, ESA, or, for that matter, anyone with image-processing software, a little time, and a little skill. But it’s not happening. Decent photos of UFOs still don’t exist.

Why not? Perhaps the UFOnauts are smart enough to stay farther out as our image-capture technology advances. Perhaps they have cloaking devices that fool our cameras. Or, perhaps, all those objects in the sky are just that — sights (real or fake) that have a terrestrial explanation. They’re Unidentified Flying Objects to be sure, but alien spacecraft? Color me skeptical, at least until a crisp and verifiable photo of their warp drive is published.

Paul Deans
Editor, Mercury

Amateur photo of an alleged UFO, Passoria, New Jersey, July 31, 1952.

ON THE COVER
Front: This New Horizons montage shows a color composite of Jupiter in infrared. The Great Red Spot is visible as the prominent blush-white oval. The Io image is an approximate true-color composite and shows a major eruption in progress on Io’s night side. Courtesy NASA / JHUAPL / SWI / GSFC.

Back: The distorted appearance of the two galaxies classified as Arp 273 is due to gravitational tides raised as they interact. The galaxies are some 300 million light-years away; their cores are a mere 100,000 light-years apart. Courtesy NASA / ESA / Hubble Heritage Team (STScI / AURA).
Real Things

Sometimes the planets align.

At the very beginning of spring, I attended a conference in Washington D.C. in the midst of an unusually warm March following an unusually mild winter. These meteorological factors resulted in the early budding of the famed cherry blossom trees, and as luck would have it, for the very first time, I was in town for their unusually early bloom.

Everything converged on March 20: the vernal equinox, the beginning of the short window of peak bloom, and a bit of free time in my schedule. An early morning thunderstorm had left everything fresh and wet, and the sky cleared enough for the Sun to peep through in what was predicted to be a mostly soggy week. So I headed down to the National Mall, and took a stroll.

It was like walking through a cloud.

In scattered groves around the Washington Monument, and all around the Tidal Basin, the trees were laden and bursting with pinkish-white blossoms in incredible profusion. Pendulous branches of white swept low over the water, formed a canopy over my head, and arrayed themselves into elegant horizontal poses, every tree a graceful bonsai form.

This also happened to be the 100th anniversary of the first planting of these gifts from Japan in 1912, and about 100 of the original trees still survive among the several thousand currently flourishing here, their gnarled black trunks a counterpoint against the flurry of soft white.

Oh, I'd seen pictures. And heard the accounts. But to stand there and be able to reach up and touch those delicate, flower-laden branches made them real — real in a way that only direct experience can.

The thought stayed with me as my wanderings took me later that day into the Air and Space Museum. Here I could look upon the real Spirit of St. Louis that took Lucky Lindy across the Atlantic Ocean. The real Apollo 11 capsule that ferried astronauts, headed for the first landing, to and from the Moon. A real chunk of dark maria basalt returned by a later crew. And I was reminded why people still come to museums. It's the place where you can see real things — not imitations, not copies of things, but the real relics of human endeavor and the natural world.

If I walked over to the Natural History Museum, I could see real bones of dinosaurs and titanotheres and saber-toothed cats, behold the real Hope Diamond, and gaze upon the real Allan Hills meteorite that ignited a wonderful controversy about evidence for past life on Mars. And I could know that if I could just reach beyond the warning signs and ropes and plexiglass, I could touch them for myself.

This is also the reason I think it's so important to put down the pictures of planets and nebulae and galaxies, turn off the Discovery Channel, close the lid of the laptop, pocket the iPhone, and actually go outside on occasion to peek through a telescope at the glories of the universe. Granted, most objects so viewed look small and ghostly and indistinct. They're not color-enhanced, super-magnified,
animated, time-lapsed, or flown through. But you know that if your arm were long enough, you could reach up and touch them for real.

Just knowing that creates a direct experience that makes them present in way that an image or third-person account cannot. And that means something.

In our insulated, heated, air-conditioned, electronically conve
nienced, comfortable existences, one of our great challenges is making the universe and the world around us real for the people we engage. Ultimately that calls for direct experience, with manipulata
bles to demonstrate concepts and processes and natural laws, and with activities under the real sky, using instruments to show real things. It's what the ASP is about, and we've been doing it since long before Washington's cherry blossom trees were planted. And with the help of our friends and supporters, we shall continue to make a difference long into the future, and help our constituencies to do the same.

Next time a thunderstorm makes everything wet and fresh, and the sky clears and blossoms with stars, go outside and look up. Take someone with you. Find a telescope. Have a look. Make the universe real for someone, and they will keep coming back.

For there's simply no substitute for the real thing!
In early 1932, Dutch astronomer Willem de Sitter gave a popular lecture in San Francisco, which was published in the April 1932 Publications of the ASP under the title “The Size of the Universe.” In this lecture de Sitter described several theories for the nature of the universe, whether it might be expanding or static, and whether it is infinite or finite. Eighty years later we are still working on some of those questions.

He began by discussing the meaning of the term “universe,” since until fairly recently there had been much talk of “island universes” (which we now call galaxies). For de Sitter, “there is only one universe, which contains all these systems, and everything that can be observed and that we can think of as being observable, either now or in the future. The universe is the whole of all things that exist in the physical or outer world.” Today we would also include unobservable (for now) things like dark matter and dark energy.

He then continued with a discussion of our Milky Way galaxy, made of vast numbers of stars and star clouds; there were also dark patches between them, which had recently been shown to be areas “where there is something to prevent us from seeing the stars, clouds of dark matter, either in gaseous form or, more probably, in the form of finely divided dust.” In addition, there are “many bright nebulous patches…which used to be distinguished as the white and the green nebulae.” The green nebulae, like that in Orion, radiate only light of certain colors; these colors serve to identify the emitting gases as hydrogen, oxygen, and other elements. The white ones generate light of all colors, and are made up of stars and gas clouds; these are what we now call galaxies.

De Sitter pointed out that most of the white nebulae were spiral in shape, and that millions of them existed in the sky. “They all have the same general shape consisting of a bright nucleus, from which two arms run out, coiling around it in widening spirals. In the arms there are conglomerations of stars, star-clouds, intermingled with bright and dark nebulosity.” The Andromeda spiral is the nearest and brightest, believed in 1932 to be about one million light-years away (we would now say about 2.2 million light-years).

He further believed that our Milky Way “…probably has the structure of a spiral nebula. The nucleus coincides with the centre of the system of globular clusters. The whole system has a motion of rotation around this centre, and it is very flat.” The mass could be estimated at about one hundred billion times the mass of the Sun. All this is in general accord with our current picture though we know much more now, particularly about the nucleus, which seems to contain a large black hole perhaps four million times the mass of the Sun.

De Sitter then discussed the motions of the spirals, which all seemed to be running away from us and from each other. “The velocities increase as the distances increase, and roughly the velocities are proportional to the distances. Consequently…the whole system is expanding.” He accepted Lemaître’s theory of an evolving universe, which “started as a static universe in the past, and has since been expanding, and it will go on expanding” for an infinite time. Its size is then finite but changing: a few billion years ago its radius was about a billion light-years, whereas now it is “somewhere between two and twenty times this.”

De Sitter’s talk concluded with a warning: “The theory of today is not the theory of tomorrow…The whole of physical science, including astronomy, is in a state of transition and rapid evolution…We are, however, on the right track. The theory of the expanding universe…will remain true in its essential parts, although the final form which it will take…cannot be predicted now.”

This warning is still valid today. We have discovered that the expansion of the universe seems to be speeding up, not slowing down as had been thought, and the reasons for this are still unclear. We hypothesize that the expansion began in a Big Bang some 14 billion years ago, and some 90% of the mass of the universe seems to be invisible. So we still have a long way to go before we can say for sure what the size of the universe is, or whether that is even a meaningful question.

Katherine Bracher taught astronomy at Whitman College in Walla Walla, WA, for 31 years. Retired in 1998, she currently lives in Brunswick, Maine. Her research focuses on eclipses and the astronomy of the ancient world; her other principal interest is early music.
William Gascoigne's life and reputation literally hangs by a thread. Born in England 400 years ago, his fame rests on a thread that led to the invention of the micrometer, used ever since by astronomers to measure celestial objects. But it was only by the slenderest of threads that he got any recognition for it.

Descended from Sir William Gascoigne, chief justice of England during the reign of Henry IV, our William was born in 1612. He acquired, entirely on his own, a practical knowledge of astronomy and optics. He wrote to a friend in 1640 that he did this during his part time “which other gentlemen, our neighbors, spend in hunting.”

Of his great invention, the micrometer, his self-effacing nature is most evident in this letter he wrote to the Oxford University mathematician William Oughtred: “That I lose no credit is the sole gain I expect; and that the lovers of art may know the advantage that this will afford, is the only end wherefore I would divulge it. If I add only a hair breadth to the knowledge of others, so it be useful, it will content me.”

So what is the micrometer, and how did he invent it? Like the falling apple in Newton's discovery of gravity, this one comes with a legend. A thread from a spider's web got caught at exactly the combined optical focal points of two lenses he was studying. When he peered through the lenses, Gascoigne saw the web bright and sharp. Using the concept of placing crossed wires at the focal point to define the center of the field of view, he added this to a sextant of five-foot radius, allowing him to measure the distance between objects in the sky much more accurately than anyone before him.

Not content with that, he made the crucial next step of realizing that he could measure the size of an image by viewing two points whose separation could be adjusted using a screw. Thus the micrometer was born. And that spider thread? Some astronomers used them (instead of metal wires) right up to the nineteenth century.

Tragically, Gascoigne’s life was cut short in 1644 when, at the age of 32, he died while fighting for his king, Charles I, at the Battle of Marston Moor during the English Civil War. Most of his papers and correspondence were also lost during the war.

If it were not for his friendship with the Towneley family, William Gascoigne would never have received credit for his work. Christopher Towneley was a friend of his, and it was Christopher’s nephew Richard who rescued Gascoigne from oblivion.

In the 1660s a Frenchman, Adrien Auzout, claimed to have invented the micrometer. In 1667, Richard — a noted astronomer himself — wrote a letter to the Royal Society in London setting the record straight. “Mr. Gascoigne found out that, before our late Civil Wars, he had not only devised an instrument of as great a power as M. Auzout’s, but had also for some years made use of it, not only for taking the diameters of the planets…but had further endeavoured out of its preciseness to gather many certainties in the heavens.”

Robert Hooke, the “curator of experiments” for the Royal Society, immediately took up the baton. Towneley sent Hooke a micrometer, and by late 1667 he published a detailed description of the device in the Philosophical Transactions. Hooke used the device to calculate the size of comets and other objects in the sky, and it quickly became an essential tool of every astronomer. On behalf of the Royal Society, Robert Hooke provided a description, complete with plates, of Gascoigne’s instruments (Philosophical Transactions of the Royal Society, Vol. II, No. 29, p. 541-544).

All this derived from someone with literally no education, as Gascoigne himself wrote. “I entered upon these studies accidentally after I betook myself to the country, having never had so much aid as to be taught addition.” As an inspiration to any young person interested in astronomy, it is all the more fitting that we should remember such a noble and gallant gentleman on his 400th birthday.
Green Pea (GP) galaxies are an intriguing new class of young galaxies discovered by the volunteers of the “Galaxy Zoo” project. In Sloan Digital Sky Survey (SDSS) images, these galaxies appear small and green, inspiring their name. GP galaxies reside in the local universe and their color results from green emissions of doubly ionized oxygen atoms. These rare galaxies are compact, low mass, and exhibit high optical and ultraviolet luminosities.

GP galaxies appear spherical in SDSS images because they are unresolved. In Hubble Space Telescope (HST) images, however, these objects exhibit bright, clumpy star-forming regions. The strong, extremely broad green emission at 5007Å (Angstroms) indicates that Green Peas contain a large population of young stars. In fact, these galaxies have some of the highest specific star-formation rates (rate of star formation per unit stellar mass) in the local universe. In addition, GPs exhibit low metallicity (a low abundance of elements heavier than hydrogen) and are found in low-density environments.

The physical properties and residential environments of GP galaxies are similar to high-redshift, ultraviolet luminosity galaxies such as Lyman-break Galaxies (LBG). LBGs are responsible for the majority of star formation in the early universe. It follows that studies of GP galaxies should provide insights into the extreme star-formation processes in LBG galaxies.

The high star-formation rates in GPs should result in a large number of resident supernovae. Electrons accelerated by supernovae should emit synchrotron radiation, which would be detectable at radio wavelengths. Astrophysicists Sayan Chakraborti, Naveen Yadav, Carolin Cardamone, and Alak Ray calculated the expected radio fluxes of the 80 identified GPs using a well-known formula for typical star-forming galaxies.

Chakraborti and colleagues found that the brightest GP galaxies should emit radio waves below the one-mJy (milliJansky) threshold of The Very Large Array Faint Images of the Radio Sky at Twenty Centimeters (VLA FIRST) survey. However, they calculated that stacking 32 VLA FIRST images should be sufficient to detect the brightest GPs. These GPs were detected in the stacked images, but the observed fluxes were only about half of what was expected. The group argues that these systematically lower-than-expected radio fluxes are best explained if each these young galaxies possess a magnetic field larger than that of the Milky Way.

Our current understanding is that galactic magnetic fields result from the amplification of seed fields, as turbulent kinetic energy is transferred to the magnetic field (known as dynamo action). Thus, galactic magnetic fields should increase over timescales of hundreds of millions to billions of years. How can young galaxies such as GPs have magnetic field strengths larger than the much older Milky Way? It has been suggested that a dynamo might amplify small-scale magnetic fields, but the lifetimes of such fields are small, on the order of tens of millions of years.

The large field strengths of GP galaxies imply that galaxies in the early universe (i.e. LBGs) had very strong magnetic fields. Some star-formation scenarios suggest that magnetic fields play a pivotal role in star formation by aiding the in-fall of ionized gas. If GP galaxy magnetic fields are indeed as strong as Chakraborti’s team suggests, this may force a revision of theoretical and computational models of early star formation, which typically assume weak magnetic fields.

Earlier this year Steven Hawley examined spectroscopic data for 71 of the original GP galaxies. He reported the first detection of the He II 4686Å line in nine of the original GP galaxies. The ratios of the He II 4686/He I 4861 lines in these nine objects fall in the range of one to two percent, consistent with photoionization by Wolf-Rayet (W-R) stars. Hawley also identified a slight enhancement in nitrogen abundances compared to other low-metallicity galaxies, which can be explained by the presence of W-R stars or intermediate stars from a previous quiescent epoch. Hawley’s analysis suggests that GP galaxies more closely resemble planetary nebulae, whereas most star-forming galaxies resemble H II regions. Hawley’s new calibrations for GP galaxy diagnostics should prove to be very useful if future studies find star-forming galaxies that resemble GP galaxies.

Jennifer Birriel is an Associate Professor of Physics in the Department of Mathematics, Computer Science, & Physics at Morehead State University in KY. She recalls having a childhood aversion to green peas as well as zucchini.
I'm probably going to get into trouble with this one, so I'll just jump right in. From a planetary perspective, the NASA FY2013 budget as proposed by the President and the OMB is a disaster. Although NASA's funding as a whole remains more or less flat, it's only because the agency's budgetary deck chairs are being rearranged. In the process, the only program that loses more money in FY2013 than planetary science is the now deceased Space Shuttle. For all the amazing and inspiring science return from planetary exploration and research across the solar system, a 21% cut is a hard blow.

I know a natural first response might be to want to campaign for a reduction in the overall cuts for the agency. I think most of us would like to see an overall increase in funding for NASA. But that's clearly not in the cards. Not until we really come to grips with the rampant runaway mandatory spending that is consuming our nation's financial foundation. Until then, we're in a worse than zero-sum game when it comes to little discretionary programs like NASA.

If we're not going to get more money for science any time soon, we have to look more closely at what we're doing with the funding we have. Here's where we can identify some problems right now and where I'm going to get into trouble. So, I'll just say it — the James Webb Space Telescope should be canceled. Now. Before the further overruns that are still coming do even more damage.

To demonstrate that I have nothing against my astrophysics colleagues, and to try to head off any artificial ‘us versus them’ arguments, I'll put forward my opinion that the Mars Science Laboratory mission (Curiosity) currently on its way to Mars should have likewise been canceled years ago. For the same reason. Years ago both missions were known to be on a path to severe budget overruns, to the combined tune of many billions of dollars. It is unconscionable that these kinds of massive overruns in just a few programs are allowed to eat the lunch of many other innocent flight and basic research programs that have been properly managed.

Big and complex missions like JWST and MSL are prone to overruns for several reasons. The first is the game that everyone knows is played as a result of the tight budget the agency is forced to work with — lying to hide the sticker-shock factor. If you tell OMB and Congress up front that science mission X is going to cost, let's say, $10B, it kinda makes the hairs on the back of their neck stand up. But if you tell them $3B maybe they'll go for it, and then you can sneak in the extra costs later once there's too much committed (primarily politically, because of the financial implications) to cancel it.

Then there's the very real factor that it really is hard to estimate the total costs of a challenging new mission that is on the edge of what is technologically doable. The aerospace industry has costing models that attempt to project these sorts of uncertainties, but in the end, you simply can't know what you don't know. That's reality.

But neither reason is an acceptable excuse to press forward once the trajectory to a huge overrun is identified. Not in a zero-sum budget environment when an overrun is larger in magnitude than the entire budget lines of smaller missions or the research and analysis programs that are the heart of a healthy basic research community. We can no longer afford this old way of doing things. We could sometimes get away with it in years past, but those days are gone. We must break the cycle and establish a harsh new policy of not allowing the guilty few to "slaughter the innocent", as former NASA Science Mission Directorate Associate Administrator Alan Stern has put it.

But here we are, faced with severe cuts to planetary (and other) science at NASA. Cuts severe enough to be ending stellar, decades-long careers of good scientists. And, yes, parallel problems exist in the halls of the human exploration program, so hard times are upon us all. As the coming budget battle is waged in the negotiations between the 'proposed' Presidential budget and the final ‘disposed’ Congressional one, I think it'd be a good idea for us to be sending a message of reform in addition to our pleas for help.

Daniel D. Durda is a planetary scientist; the opinions expressed here are his alone and do not in any way reflect those of his employer.
A Brief, Bold Look at Antimatter

Scientists hold antimatter long enough to get their first look at its properties

So, why are we here? I don't mean to get too metaphysical. It's just that, according to the Standard Model of physics, there should be no matter in the universe, let alone people in this universe brainy enough to develop something called the Standard Model.

The Standard Model is the blueprint of particle physics and attempts to explain electromagnetic and nuclear forces. According to this model, the Big Bang should have produced equal amounts of matter and antimatter. And if you ever read a science fiction comic book, you know that matter and antimatter annihilate when they meet, leaving no ash, just a pure release of energy.

Which brings us back to the central question, why is anything here...or there...or anywhere? All matter and antimatter should have annihilated a long time ago, leaving nothing except energy. It's a question that has bugged physicists for decades, essentially since the concept of antimatter was developed by Paul Dirac in the 1920s.

The fact that we are here to contemplate our existence means that either the Standard Model is very wrong or that there is an asymmetry between antimatter and matter that allowed the latter to prevail. Concerning the asymmetry, could it be that matter and antimatter aren't the mirrored twins that we have envisioned them to be? Maybe there are slight differences.

To study this question, an international team of scientists using instruments at CERN in Switzerland has set upon a quest to trap antimatter long enough to study it. After years of incremental successes, the team — called the ALPHA collaboration, comprising 14 institutes in seven countries — has reached a milestone: As relayed in the March 8, 2012, issue of Nature, the collaboration has captured the first ever spectrum of an antihydrogen atom. And, well, it looked just like ordinary hydrogen...but we'll get back to that in a moment.

Neutral hydrogen, comprising a positively charged proton and a negatively charged electron, is the simplest and most abundant atom in the universe. Hydrogen's charm is in its simplicity and in the accuracy with which its spectrum can be measured and compared to theory. Study of its spectrum gave rise to quantum mechanics, and it remains a tool for studying fundamental constants.

The ALPHA collaboration believes that a thorough analysis of antihydrogen in comparison to the well-studied hydrogen could yield insights into the nature of matter–antimatter asymmetry. The only problem, as you might imagine, is working with antimatter, given its tendency to annihilate upon contact with regular matter.

The first step in the ALPHA experiment is to make "fresh" antimatter. There are natural sources in today's universe. Cosmic explosions create antiprotons and antielectrons (called positrons), and certain radioactive decay can produce positrons and antineutrinos. However, there is no known way to capture and store naturally produced antimatter.

The ALPHA collaboration uses positrons and antiprotons produced by CERN accelerators. As early as 1995, prior to the ALPHA project, CERN scientists had developed a technique to combine positrons and antiprotons into antihydrogen. But this antimatter was gone in a flash, figuratively and literally. Slowly the scientists learned how to stabilize antimatter. In 2010, the ALPHA collaboration trapped 38 antihydrogen atoms for a sixth of a second, a scientific first.

The next accomplishment came in 2011, when the collaboration trapped hundreds of antihydrogen atoms, some for as long as 1,000 seconds. To do so, the scientists used a magnetic device in a vacuum chilled to a half degree above absolute zero to first combine a positron and antiproton and then keep the newly made antihydrogen hovering in the magnetic field, preventing it from touching the ordinary matter of the walls of the tank.

One thousand seconds (nearly 17 minutes) is long enough for the antimatter to relax to its ground-state energy level, identical to hydrogen's ground state. Now it is ready to be probed. As reported in Nature, the scientists bombarded the relaxed antihydrogen with pulses of microwave energy to see if it would behave exactly like hydrogen at ground state.

In tests so far, the antihydrogen has behaved exactly like hydrogen: Waves of one frequency did nothing to the antihydrogen, as would be expected for hydrogen. Waves at another frequency flipped the spin of the antihydrogen (as it would for hydrogen) and sent the antihydrogen flying into the wall of the magnetic trap, where it annihilated.

The results were far from anti-climatic. This was a crude experiment, the team said, but a solid a proof of concept and the first time anyone has ever measured a property of antimatter prior to annihilation. The team now hopes to build more sophisticated tools to measure antihydrogen's properties in greater detail. This is crucial because any difference between the characteristics of hydrogen and antihydrogen would have to be slight.

If the ALPHA collaboration continues to find no discernible differences between the properties of matter and antimatter, this leaves open the possibility of entire domains of antimatter created in the Big Bang that escaped annihilation and that have since expanded with space beyond the visible universe. Intelligent beings of this anti-world might very well contemplate their existence, too.

As charming as they might be, we definitely don't want to meet them.
Imagine you get up from your desk and go to the storeroom for a red pen. The walk from your office to the storeroom is uneventful but, upon arrival, you have forgotten why you went there. Frustrated, you walk back to your office and, as you cross the threshold, you suddenly remember: Red pen!

This is not absentmindedness. Recent research by Gabriel Radvansky and two colleagues indicates that doorways cause forgetting. No, I did not read the Journal of Irreproducible Results to prepare this column. Radvansky argues that doorways help the brain compartmentalize memory. The “doorway” does not have to be physical: Virtual boundaries can also induce context-dependent forgetting (with obvious applications to multimedia-based learning). Learning is not the issue, retrieval is.

As we all know, you do not have to physically return to your office to remember the pen. But you have to at least mentally retrace your steps in order to re-cross the boundary noted by the brain to access the cue that retrieves the memory.

Students who don’t “get it” may actually have the needed knowledge — they most likely have not learned how to cue retrieval. And because learning is context-dependent, students need our help to learn how to utilize their brains in the novel environment of the astronomy classroom.

Learning is contextual in many different ways. Students tend to not only compartmentalize ideas by discipline but also by section within the course (or even within one class period). For example, using Kepler’s Laws for stellar mass determination often remains unlinked to Kepler’s Laws for planetary motion. In fact, the memory about stars might be so deeply filed away that during the planet discussion, many students may claim Kepler’s Laws were never discussed before.

Helping students use ideas simultaneously in different contexts assists in building context-independent memory. Discuss planets, stars, and galaxies when you introduce Kepler’s Laws, using examples from each. Then, when you return to Kepler’s Laws in each topical discussion, students should be better prepared to retrieve the memory. Having context-independent memory is one thing that separates experts from novices, and it is less fragile under stress (such as an exam) than context-dependent memory.

Word cuing and use of jargon can be dangerous; expecting to see Kepler’s Laws to trigger the memory of binary star mass will fail if the question does not contain the “right” words (which students then perceive as a trick). Might “balance between gravitational contraction and gas pressure” be more retrieval-ready than “hydrostatic equilibrium”?

Environment also establishes memory “boundaries.” The idea of spectral types might be tagged to the music a student was listening to while stellar temperature might be related to where the student sat that day. Trying to remember what music was playing so you can retrieve an idea during an exam is not a pathway to success. Research by Harry Grant et al shows that studying with music, but taking an exam in silence, is not as successful as studying and taking the exam in the same environment. If the exam is in silence, then students are better off studying in silence. Another environmental factor can be role in a group. A student acting as leader may not be able to retrieve memories during an exam when acting as “student.”

The advice to have students study for the exam in the same environment as the exam is not always practicable. (Which environment: Sound? Location? Role?) Instead, we need to have students pay attention to the cues in the learning environment that will help them retrieve memory. Or better yet, we need to teach them to insert their own cues that will enable them to retrieve memory. Concentrating on relationships, emphasizing bigger conceptual structures during the introduction of the topic, and not focusing on factual knowledge can help students build context-independent memory. Using multiple representations of a concept can also build stronger retrieval capability.

Given the odd and manifold ways novices may store memories, I believe it is imperative that instructors help students learn how their brain works. It may seem like one more task for which we do not have class time, but if done early in the term, it can pay big dividends, especially in the context of the tasks you need students to perform.

**DAVID BRUNING** teaches astronomy at a Midwestern state university. He is still trying to remember why he needed the red pen.
NASA and the Arts

A program that began in 1962 with the visual arts has branched out dramatically since then.

In 1962, as NASA was embarking on its ambitious manned space program, its administrator, James Webb, started the NASA Arts program. He said, “Important events can be interpreted by artists to give a unique insight into aspects of our history-making advances into space.”

This emerged from NASA’s founding legislation of the Space Act of 1958, which instructed NASA to disseminate its results to as wide an audience as possible. Initially the program concentrated on the visual arts, and provided a small commission to the artists. An exhibition of the initial works was held at the National Gallery of Art in Washington, DC, in 1965 and was one of its most popular exhibits at the time. Since 1990, the program has branched out into video, photography, prose, music, poetry, and dance. It has produced a number of collaborations between NASA and artists, even when NASA funding was not available.

These collaborations take many forms, as NASA continues to recognize that the arts provide a unique way to tell its story and to reach audiences who might not otherwise be engaged by science. As part of these collaborations, NASA provides access to people, its facilities, imagery through its public domain holdings, and its expert visualization scientists.

Earlier this year I gave a presentation at the Association of Performing Arts Presenters about the intersection of NASA and the arts. This conference was an interesting mix of agents looking to publicize their performers, and venue operators looking to book performing artists. I spoke on a panel session attended by artists interested in connecting with science. As part of my preparation for this, I had the opportunity to talk with some of the artists who have engaged in collaborations with NASA.

Maestro Emil De Cou specializes in synthesizing imagery with music. As an associate conductor for the National Symphony Orchestra, he has produced a number of NSO concerts at Wolf Trap, the National Park for the Performing Arts. Programs featuring NASA imagery have included Fantastic Planet and Holst’s The Planets, and anniversary concerts celebrating events such as the Apollo 11 Moon landing. Starting with the program’s premise, De Cou chooses musical selections ranging from classical to pops to movie music and popular music. He then approaches NASA with a list of suggested imagery. He finds that music, which might be intimidating, becomes approachable with the visuals.

As a film producer, Duncan Copp has told numerous NASA stories, including In the Shadow of the Moon, the Apollo story. After he obtains funding from other sources, he pitches his idea to NASA. If agreeable, NASA provides access to NASA facilities, scientists, engineers, and imagery. A science story always has a narrative, but Copp mediates that narrative between the scientists and the general public, allowing the passion of the scientists to carry the story.

NASA commissioned storyteller Jay O’Callahan to write and tell a story celebrating its first 50 years. His story, Forged in the Stars, focuses on the stories of Neil Armstrong, Christa McAuliffe, and J.C. High Eagle (an Oklahoma Cherokee who was an engineer during the Apollo era). Jay visited NASA centers, talked with people involved with these stories, and did many hours of his own research. This is a powerful story, which he’s told at all the NASA centers, as well as at the National Storytelling Festival.

But you don’t have to be a “rock star” to get a gig. Other scientists and educators have followed their ideas and made connections.

Don Lubowich (Hofstra University) brings star parties to thousands of concertgoers at outdoor venues, engaging individuals who have little previous interest in science with displays, conversation, and the night sky. Matthew Fillingim (UC Berkeley) is embarking on a program that instills science into a visual arts afterschool program. Valerie Casasanto (University of Maryland Baltimore County) joined forces with Kenji Williams to provide science programming and teacher workshops for Williams’ “Bella Gaia” performances, marrying together music, imagery, and education about the Earth. In all these instances, art is used as a means toward STEM education and public awareness.

In all my conversations, Lewis Peach, who worked with Jay O’Callahan, summed it up best, “Both science and art are about the search for and expression of truth. The approach we take and the way we express it is different. But we’re trying to connect to something larger and something that gives us meaning.”

JAMES LOCHNER is the Program Manager for the Science Mission Directorate’s Education and Public Outreach programs at NASA Headquarters.
In March 2009, the Kepler spacecraft blasted into the Cape Canaveral night — struck like a match, blazing white and orange across the sky. It was NASA’s first mission entirely dedicated to astrobiology, a science that draws on knowledge from many disciplines to search for alien life. Since reaching its Earth-trailing orbit, Kepler has been sending home data that is inciting dramatic growth in the field. Astrobiology is more active and has more resources than ever, and it has finally begun to take a place on the mantle of legitimate science.

Kepler’s primary goal is simple: Determine the prevalence of Earth-like planets in our galaxy. World-class telescopes traditionally facilitate several astronomical projects at a time, but Kepler is one of the simplest in NASA’s history — a point-and-shoot operation, aimed along a thin but deep cone of space.

“We didn’t know what we were going to find,” says Alan Gould, Director of the Lawrence Hall of Science in Berkeley and a Kepler Co-Investigator. “We knew we had a good technique. But we really did not know.” Gould says that failing to find any Earth-like planets would have been more significant than finding just some, since the region of the sky that Kepler observes is representative of our entire galaxy. “Then we could have said: ‘We are alone!’” he laughed.

Astrobiology and Kepler

Astrobiology has long struggled to establish itself as a credible scientific field. It emerged in the 1960s and has since been derided by some notable scientists. The evolutionary biologist George Simpson famously decried it “a field without a subject.”

Joe Nuth, Senior Scientist for Primitive Bodies at Goddard Space Flight Center, admits that initially, astrobiology “was a conglomerate of a bunch of other fields.” He believes that the main obstacles for a multidisciplinary field like astrobiology are social. “The language barriers are enormous,” he says. “We’re still learning to talk to one another.”

The Kepler mission also struggled to gain momentum. NASA rejected Kepler five times during a 10-year period before being convinced it would succeed at determining the frequency of Earth-like planets in our galaxy. Obtaining a federal green light for the mission represented a major victory for astrobiology, but it also raised a lot of expectations for its results.

The telescope itself resembles a pipe sheered at an angle, its triangular solar panels arrayed like pinioned wings. It’s currently examining roughly 150,000 stars, looking for tiny fluctuations in brightness that occur when a planet across the face of a star — a transit. The stellar dimming effect is almost imperceptible. Almost.

Gould once compared the technique to “trying to spot a gnat flying across a searchlight from a mile away.” The $600 million mission may be simple, but the equipment isn’t lacking sophistication.

Planets Galore

The stellar dimming can be used to deduce the size of the planet and the distance of separation from its star, which are both essential in determining whether the planet is Earth-like. This is a notoriously precarious balancing act that caused many scientists to designate these Earth-like candidates as “Goldilocks Planets.” Planets that are just the right size, just the right temperature, just the right distance from their star, and so on.

The data released in February 2011 detailed Kepler’s latest findings, which raised the number of planet candidates to 1,235. A series of releases later in the year marked discoveries that tripled the number of stars known to have more than one planet, and trumpeted the discovery of planets orbiting double stars. (As of April 2012, the number of planet candidates is 2,321.)

Dimitar Sasselov, Director of the Harvard Origins of Life Initiative, found the results inspiring. “Kepler was always one of the crucial missions for the field,” he says, adding that if the telescope had found very few planets, progress in the field could have been delayed by up to 20 years. Why? Few planets would severely limit the options of all the missions to follow, making it increasingly difficult to justify funding.

Jim Kasting, a Distinguished Professor of Geosciences at Penn State, agrees, and says that Kepler’s results have made him more optimistic than before and that they “helped us for sure.” However Kasting stresses that the data are preliminary, and they will mean
little without new missions. The ultimate goal of astrobiology is, after all, to discover new life. Both Sasselov and Kasting are already involved in subsequent projects that were contingent on Kepler’s success and findings. The mission had to work, and the telescope had to find something, in order for the field to progress and for astrobiology to grow — which it has, in many ways.

Following Kepler
New projects that offer the most tangible rewards are set in our planetary neighborhood. Unfortunately the 2013 budget for NASA, if implemented as proposed, is likely to force significant cutbacks that will affect astrobiology — particularly when it comes to Mars exploration. Currently, there is still funding for future missions to explore Jupiter’s oceanic moon, Europa, and to retrieve samples from asteroids and even icy itinerant comets, both of which could contain fossil records.

All the while, our conception of life is radically expanding, as is our awareness of how poorly we understand it. According to Nuth, our understanding of life on Earth determines how we search for life elsewhere. So scientists look to the utmost extreme conditions on our planet to better understand where else life can emerge. For example, they find life, seemingly impossible life — such as microbes that never see the Sun — thriving in thermal vents on the ocean floor.

Major telescope projects useful to astrobiology are also in development. Both Gould and Kasting note that the James Webb Space Telescope — Hubble’s eagerly anticipated replacement — will be able to actually image some of the planets Kepler has found. Right now, these worlds can be visualized only through an artist’s imagination. Sasselov is excited about NASA’s approval of the Transiting Exoplanet All-Sky Survey (TESS), which will follow up on Kepler by identifying planetary candidates closest to Earth.

Much of the momentum in astrobiology relies on the success of major projects. TESS will follow Kepler, and if its mission is a success and yields meaningful results, then other missions may follow. Each major scientific discovery helps justify more funding, garners scientific and public interest, and creates new incentives to improve the links between the many disciplines that comprise the field.

Each discovery also usually reveals new and more difficult problems. Each mission is more expensive and more intricate than its predecessor, making failure increasingly plausible. Not coincidentally, the riskier missions bring us closer to answering the ultimate question that is the very crux of astrobiology: Are we alone in the cosmos?

News Release: Potentially Habitable Planet Found Orbiting Nearby Star

A team of scientists led by Nader Haghighipour from the University of Hawaii at Manoa has discovered a potentially habitable super-Earth planet orbiting a nearby star. This discovery demonstrates that habitable planets could form in a greater variety of environments than previously believed.

“This planet is the new best candidate to support liquid water and, perhaps, life as we know it,” team leader Guillem Anglada-Escudé said. Super-Earth planets are two to ten times more massive than Earth.

The team used the planet-finding technique of measuring the small wobbles in a star’s orbit in response to a planet’s gravity. An M-class dwarf star called GJ 667C, which is 22 light-years away from Earth, had previously been observed to have a super-Earth (called GJ 667Cb) that orbited the star in only 7.2 days, making it too close to the star, and thus too hot to support life.

The study started with the aim of learning more about the orbit of GJ 667Cb. But the research team found a clear signal of a new planet (GJ 667Cc) with an orbital period of 28.15 days and a minimum mass of 4.5 times that of Earth.

The new planet receives 90% of the light that Earth receives. However, because most of the incoming light is heat (infrared), a higher percentage of this incoming energy should be absorbed by the planet. When both these effects are taken into account, GJ 667Cc should absorb about the same amount of energy from its star that Earth absorbs from the Sun. This would allow surface temperatures similar to Earth and perhaps liquid water, but this cannot be confirmed without further information on the planet’s atmosphere.

“The detection of this planet is strong evidence that our strategy in choosing M-stars as potential hosts for habitable planet is correct and has been successful,” said Haghighipour, who is a member of the UH NASA Astrobiology Institute. M-stars are smaller than our Sun.

The team used public data from the European Southern Observatory and analyzed it with a novel data analysis method. They also incorporated new measurements from the Keck Observatory’s High Resolution Echelle Spectrograph in Hawaii and the new Carnegie Planet Finder Spectrograph at the Magellan II Telescope in Chile.

GJ 667C is a member of a triple-star system and has less metallic elements (those heavier than hydrogen and helium) than our Sun. The other two stars in the triple system (GJ 667AB) also have a small concentration of heavy elements. Since such elements are the building blocks of terrestrial planets like Earth, the team thought it was unusual for a metal-depleted star system to have an abundance of low-mass planets.

The work on this project will be published in The Astrophysical Journal Letters. The current version of the manuscript is posted at arXiv.org.
Astronomy Camps at The University of Arizona have had a life-changing impact on students.

by Don McCarthy

Students using the 10-meter submillimeter radio telescope for a Camp project. Image courtesy Jeff Regester.
Growing up in the 1950s and 60s, I was captivated by the adventure, both physical and mental, of the era of space exploration. I longed to be part of that process and somehow to contribute personally. So I became a scientist with the goal of working in space. However, I missed the final cut of the original Shuttle astronaut selection in 1977, as 10,000 applicants were whittled down to 100 and finally to only a few.

From that exciting experience I learned something surprising: NASA had not understood the ‘deep impact’ that Mercury, Gemini, and Apollo had on a new generation. The combination of forefront research and education is a powerful force to inspire and empower people of all ages. Yet, the benefits of inspiration and education are long-term. They do not lend themselves easily to quantitative assessment and may only be realized decades later.

For nearly three decades I have led a group of dedicated students and educators in an inspiring educational program called “Astronomy Camp.” Sponsored by The University of Arizona (UA) Alumni Association, the “Camps” have engaged students from around the world and impacted my university and the nation in surprising ways. After five years of operation we described our approach and its impact in Mercury (Nov./Dec. 1993). Now, on our 25th anniversary, we will soon enroll children of former Campers! Our experience illustrates the benefits of teaching science authentically, merged holistically with its partners of math, engineering, and technology. It also contains lessons to benefit parents, educators, and administrators who

Guiding Principles

Our efforts are guided by three basic principles. The first one resonated with me while listening to a post-flight press conference conducted by the Apollo 15 crew. Commander David Scott quoted Plutarch: “The mind is not a vessel to be filled but a fire to be lighted.” A single moment can influence an entire life. So every day at Camp includes inspirational moments with guest speakers, unusual activities, watching satellites, looking for the green flash, and listening to President Kennedy’s famous “Why go to the Moon?” speech. Also, every night we dark adapt under the stars to a variety of musical selections.

I learned a second principle from veteran high school science teacher Jeff Lockwood who shared the article “Never Playing the Game” by Robert Yager. Yager stated: “In typical science teaching, we ignore the lessons we might learn from sports.” In sports we put people on the field quickly instead of confining them to a classroom watching videos of other people hitting home runs. Typical science teaching forces students to memorize laws discovered by others. At Camp, we quickly put students in charge of our telescopes, instruments, and activities, coaching them as needed to succeed in their observations and experiments. As a result, participants experience realistic science. As one of our Girl Scout leaders commented: “I always thought that science was just memorizing facts, but you guys are encouraging us to think and explore.”

The third principle is adapted from a corporate slogan: We measure success one ‘student’ at a time (Dean Witter Reynolds, Inc.). Typically, our student-faculty ratio is about two or three to one. We emphasize personal interaction and mentoring. Seeing Campers as capable, responsible, contributing scientists permeates every activity — including cooking and cleaning together as faculty/staff/students. Such teamwork overcomes generational barriers and builds long-lasting bonds.
seek to solve the growing problem of a changed society that seems not to value basic research and numeracy.

**A New Direction**

Joan Morrill and astronomer Ray White conceived Astronomy Camp as an outreach for children of UA alumni. Ray quickly realized that he really didn’t have much patience for teenagers, and I soon found myself leading the program. When it began in 1988, “science” was entirely the realm of professionals, and astronomical observatories were off-limits to the public at night. Although scientists were dissuaded from spending time in science education, we pioneered the idea of enabling the public to “become scientists.”

Using the “Sky Island” environment of our observatories in the Catalina mountains (9,200 feet) north of Tucson, we began bringing teenagers, adults, educators, college students, Girl Scout leaders, and school groups to live and work at these observatories, primarily during weekends, holidays, and vacation months. Our guests learned to operate research-class telescopes and technology, interact with leading scientists, interpret their own observations, investigate their own questions and curiosities, and most importantly have fun exploring together. Today our Camps also utilize most of the facilities at Kitt Peak National Observatory, and the potential exists to extend the model.

The Advanced Teen Camp attracts some of the nation’s best students, in part because they can engage in publishable research projects using major astronomical facilities under dark skies in southwest Arizona. Such facilities include the Arizona Radio Observatory, the Large Binocular Telescope, the University Mirror Lab, the McMath-Pierce Solar Telescope, and the WIYN and RCT telescopes on Kitt Peak. In 2001, under the direction of former Camper John Moustakas, 29 advanced teen Campers contributed to professional research by being the first group to classify the spectra of three new supernovae using the 2.3-meter Bok telescope. All their names were listed on the three international discovery telegrams. Our students often continue their projects and place highly in local, regional, and national science fairs.

**The Astronomy Camp Model**

Astronomy Camps promote an authentic understanding of science, research, and engineering among young students and adults by providing unique, hands-on, “immersion” adventures in scientific exploration via astronomy and related subjects at high-altitude observatories. We model the entire scientific process — from the inception of an idea, hypothesizing, and proposing to a Telescope Allocation Committee, to observing, interpreting, presenting, and publishing results. Students work in teams, just like real scientists.

Besides focusing on astronomy, we show how science, math, and technology impact daily life, and how experience in these subjects can empower students in any career they choose. We begin each day with a problem in critical thinking. Throughout the day we incorporate a holistic approach to STEM education via our language and by a diversity of activities such as eTextiles, a liquid-nitrogen cannon, electrocution of pickles, dissection of cow’s eyes, music (see the Whitehouse article on page 22), space art, hiking the solar system and nearby stars (to scale), and observing natural phenomena. Every aspect, including cooking and cleaning, is designed to reinforce scientific principles and quantitative literacy. We want students to value these subjects and to experience their interrelationships as imagined by an Honor’s middle school student who said:

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

In so doing we hope to alleviate the problems faced in college where even our Honor’s students see “…no value in taking math except to pass a test in math class.” Is it any wonder they do not
understand simple fractions, ratios, percentages, or how to read a graph? Kate Follette and I discussed this situation more thoroughly in another *Mercury* article (Winter 2012, page 20).

The Camps do not fit today's standard mold for education programs. We have never received external funding, we work with small numbers (about 30 per Camp), we do not have a large marketing budget, we welcome risk and change, we immerse participants in the process of science, we live and work around the clock at high-altitude observatories, we adopt a personal approach, we create most of our own activities, and we pay modest salaries.

The Camps are financially self-sufficient. We once sought NSF funding but were told “You can't teach students anything in one week.” This shortsighted attitude fails to recognize our first principle—the value of inspiration. Our operation depends entirely on student tuition, donations, volunteer work, and cleverness. Thus, we can focus our energy on the Campers. We enjoy the freedom to design our own activities, determine our own schedule, react spontaneously to students’ interests and to unexpected phenomena in the sky, and to recruit and follow-up with students without the burden of paperwork and proposals.

**A Life-changing Experience**

The impact of Astronomy Camp has surprised parents who wonder why their child had a “life-changing experience.” For example, it is not unusual for Camp students to improve their attitudes to school, change schools to have a stronger math-science emphasis, form Facebook groups, and arrange reunions.

Campers have also entered and won major science fair competitions, published articles about Camp, donated funds, returned as staff members, enrolled in the UA, and even met their eventual life-partner at Camp. Seven have become research astronomers and 22 PhDs (10 in astronomy) are in progress. Many others earned advanced degrees in a wide variety of scientific and technical fields as well as in business, creative writing, dance, economics, education, engineering, library science, organ and composition, and more.

In hindsight, we might have predicted the life-changing aspects of Astronomy Camp. A weeklong summer camp is a large fraction of a teenager’s life and can be tremendously influential. The underlying reasons for our success were revealed by a Master’s level research study (Deborah A. Fields, 2002) of the Advanced Teen Camp:

- A youth-centered, personal approach by the entire Astronomy Camp staff, treating youth as colleagues rather than children;
- Authentic scientific inquiry with realistic projects involving modern research telescopes, technology, and equipment;
- Real scientists as mentors;
- Student peers with common interests in science and engineering;
- A fun attitude toward learning, exploring ideas, and searching for answers;
- The aesthetic qualities of the dark skies of Sky Islands in southern Arizona.

**Girl Scouts and NIRCam**

In 2002, Astronomy Camp had a major opportunity to benefit astronomical research. We proposed an educational partnership with the Girl Scouts of the USA as part of Steward Observatory’s NASA proposal to build the Near-Infrared Camera (NIRCam) for the future James Webb Space Telescope (JWST). Our proposal was accepted and helped secure more than $300 million to build NIRCam, with roughly $1.5 million used to host biannual workshops with Girl Scout leaders to “Train the Trainers.” As an aside, our efforts have also led to the phrase “Go Girl Scouts” being engraved onto the optical bench of the NIRCam instrument. So the GSUSA will be literally going into space!

From the outset we began hosting biannual training workshops for leaders from around the world, not only to train them on specific astronomical topics but also to focus on encouraging young girls in the basic fields of science, technology, and numerical literacy. To date more than 200 GSUSA leaders from 41 US states, Japan, and Guam have attended these workshops, impacting the lives of thousands of Girl Scouts. Our efforts also helped to correct fundamental errors in the official Girl Scout badge materials relating to astronomy. With a JWST launch date of 2018 and a lifetime of approximately 10 years, NIRCam’s education efforts will impact an entire generation of young women.

**Unexpected Benefits**

Although Astronomy Camp receives no UA funding, it has contributed financially to the university’s mission in both education and research. Several former Campers and their families have donated more than $1 million toward operating costs and improvements of the Catalina Observatories, and also for major projects such as the entire SkyCenter on Mt. Lemmon and the expansion of the Catalina Sky Survey’s research into the discovery and characterization of Near-Earth Objects. Besides the improved publicity and community
relations, the university also derives some overhead money associated with these projects.

During more than 100 Camps we have engaged thousands of people from 49 US states and 22 foreign countries, and we remain in contact with many of our alumni. Their motivation continues long afterwards. Surprisingly, more than 60 Camp students enrolled at the UA as undergraduate and graduate students, pursuing subjects both technical and nontechnical. Some of these students are now employed in technical capacities such as telescope operators, computer technicians, programmers, research assistants, etc.

Although the Camps seek only to encourage students to continue their education in science, mathematics, and engineering, they have also motivated students to receive PhD and Masters degrees in astronomy. Each year several former Campers return to serve as Camp counselors and give of themselves to motivate yet another generation. Alumni also contribute funds for scholarships and general operation.

The Camp's model of engaging the public in research has also fostered research-based educational initiatives in the National Optical Astronomy Observatory, the Arizona Radio Observatory, young scientist CAREER grants, graduate and postdoctoral fellowship proposals, and a collaborative education program (CAMPARE) with Cal State-Pomona. It also helped develop a model for local and national classes in astronomical research through Jeff Lockwood and the Research Corporation. Our model also helped pave the way for future public involvement in major research projects such as the Large Synoptic Survey Telescope and the JWST.

Astronomy Camp has also benefited our local community in Tucson. We have provided scholarships to the Tohono O'odham Nation and Tucson's Boys and Girls Clubs. In addition, our outreach programs with JWST/NIRCam have supported Southern Arizona's Council of the GSUSA through new STEM activities, graduate student involvement, and the hiring of a STEM advisor (Larry Lebofsky). NIRCam also funds scholarships to Girl Scouts at the Beginning Teen Camp.

Graduate Student Involvement

Astronomy Camp owes its existence to the creativity and dedication of graduate students, starting with Todd Henry, J. Davy Kirkpatrick, Eric Hooper, and Jeff Regester. These students, along with 28 others from Steward Observatory, have invested enormous energy in designing new activities and demonstrations, mentoring students personally and in research, and in the logistics of planning and conducting each Camp. Despite the exhausting effort of each Camp, these students also experience renewed energy and enthusiasm for their research.

Compared to the graduate students of 25 years ago, today's grads are a different breed. They view education as part of their development and expect to have experiences like Astronomy Camp during their graduate careers. They seek out such opportunities during their visits to prospective schools.

So what started simply as a fun sideline of sharing astronomy with the public helped begin a new paradigm of science education worldwide — involving the public directly in science instead of relegating them to a classroom. Even more importantly, Astronomy Camp shows the value of "lighting the fire" in both students and staff — allowing them to be creative, and then supporting their efforts.

DON MCCARTHY is a research astronomer and lecturer with Steward Observatory at The University of Arizona. He specializes in infrared astronomy and engineering and has been passionately doing science education at all age levels throughout his life. More information about Astronomy Camp can be obtained by e-mailing the author or by visiting the Camp's website.
An advantage of informal education is the ability to maintain relationships as the years pass. With the perspective of 25 years, we see how events such as Astronomy Camp can affect lives. Here are three examples.

As a high school sophomore, Cyndi Carr attended our first Advanced Teen Camp in 1990. Inspired by the experience, she built a photodiode photometer and coupled it to both her father’s 5-inch telescope and the UA’s 21-inch telescope for observations of variable stars. She won the regional competition and qualified for the International Science and Engineering Fair. The following year she used the same photometer to study water pollution and again won the regional contest. Cyndi enrolled at The University of Arizona, graduated as the Most Outstanding Senior in Molecular and Cellular Biology, and received her PhD in Neuroscience. Along the way she fulfilled a childhood passion and became Miss Tucson Valley with a community service platform about the importance of science education.

Elizabeth Waterhouse attended her first Camp in 1995. She was such a gifted and driven dancer that she had never thought of graduating from high school. At Camp she observed the Centaur object Chiron with the 61-inch telescope. The following year we replicated NASA’s ongoing Roadmap study about searching for extrasolar planets. Elizabeth drafted her team’s recommendations and submitted the report to NASA’s Director, Dan Goldin. She later enrolled at Harvard majoring in physics and astronomy, researched galaxies with Lars Hernquist, and also researched high-mass stars with Philip Massey during a summer Research Experience for Undergrads program at Northern Arizona University. Elizabeth now dances professionally.

Rick St. Clair attended the Beginning Teen Camp in 1994 as a very young teenager with an (over)abundance of energy. He was a discipline problem during Camp. The following year he wrote a near-perfect essay for admission to the Advanced Camp, and after consulting with his teacher, I admitted him. He was a model student! Years later, he e-mailed saying that he was in the Navy’s nuclear propulsion program, had been encouraged to become an officer and receive an undergraduate degree in engineering physics, and could I recommend an advisor at the UA? Rick is now seeking his double major in physics and astronomy at The University of Arizona and even became a student “preceptor” in my Cosmology course to non-science undergraduates.

— D. M.
CREATIVE TEACHING WITH ASTRONOMICALLY INSPIRED MUSIC

Using music to expand students' astronomical horizons.

by Matthew Whitehouse
Imagine that you are sitting on the floor in the dome of a large scope — perhaps the 2.3-meter Bok telescope at Kitt Peak National Observatory. You’re at The University of Arizona’s Astronomy Camp, and sunset’s glow is fading — time for the nightly dark-adaptation music presentation.

Following a few logistical announcements, the dome lights dim to red and a brief explanation of the night’s dark-adaptation music selection commences. The dome lights are then turned out completely, and the music begins to play. This piece is more unusual than the selections from the preceding nights of Camp, and you find the music almost perplexing.

After the music finishes, you join in a discussion regarding the ways in which you think the music connects with astronomical concepts. The whole experience leaves you ready to “let your mind start a journey through a strange new world,” to quote from Andrew Lloyd Webber’s “Music of the Night.”

A Musical Approach
Since 2006, I have helped students explore the connections between music and astronomy for the UA’s Astronomy Camp. This exploration takes the form of a series of 15- to 20-minute presentations at the beginning of each night of Camp. These presentations take place in the telescope dome, in the dark, and allow campers time to become dark adapted before beginning the night’s observing activities.

My background is musical; I am an organist and composer completing my doctorate in music at The University of Arizona. Astronomy, particularly astronomy education, is my second passion. As a composer, my work is frequently inspired by astronomical concepts and phenomena. I’m a former student in the Astronomy Camp program and returned to the program as a counselor when I came to Tucson for graduate school. Additionally, I volunteer for Project ASTRO-Tucson.

Astromony Camp emphasizes a broad, interdisciplinary approach to science engagement. Campers participate in hands-on, interactive activities that explore not just astronomy but also related areas such as physics, engineering, and mathematics. Campers often have arts backgrounds — many sing, play a musical instrument, or are involved in other areas of the performing and visual arts. Given campers’ backgrounds and the program’s broad approach to science education, the program is an ideal setting for exploring connections between music and astronomy.

Expanding Students’ Horizons
One of the first decisions I made while designing Camp music programming is that it should be both a scientific and artistic exploration. In other words, musical selections should not just reinforce science concepts; they should also expand students’ awareness of the creative aspects of music. Presentations are designed to stretch students and introduce them to music that may be new to them. Most of the selections are 20th- or 21st-century “classical” music, including my own compositions.

In the spirit of stretching students and expanding their artistic awareness, I typically present pieces in their entirety. Large-scale or multi-movement works are an exception, and in such cases I present a single movement or section. These decisions are made so that the musical integrity of the composition is preserved as much as possible. Pieces that are easier to grasp are presented near the beginning of the week, with musical offerings becoming increasingly challenging as the Camp progresses.

Each evening’s music presentation is similarly structured. It begins with a brief introduction to the composition, the composer, and the science concept that serves as an inspiration for the piece. Following this preliminary explanation, I play a recording of the composition. After students listen to the piece, I facilitate a discussion about the ways in which science and music connect and encourage the students to ask questions about the music.

One technique I frequently use in my introductory talk is avoiding a discussion of specific ways in which music and science intersect. Instead, I help students establish a basic understanding of the scientific concept behind the composition, but I don’t say much about the ways in which that concept serves as inspiration for the piece. My goal is to have campers form their own connections while listening to the music, and for them to share the connections they’ve made.

This approach encourages students to think critically about the selection, and transforms the post-listening discussion into a creative experience. I have found that students often establish cogent science/music connections themselves and frequently share insights about the piece that I had not previously considered. If needed, I facilitate the discussion, assisting campers in finding music/science connections by asking leading questions. However, this often proves to not be necessary.

A Few Specific Examples
Andrew Fraknoi’s excellent article “The Music of the Spheres in Education: Using Astronomically Inspired Music” in Astronomy Education Review includes a large compilation of music based on astronomical phenomena. In the spirit of Fraknoi’s list, I’ll describe several compositions I’ve found effective in demonstrating intersections between music and astronomy.

On the Camp’s opening night, the traditional music selection is “Music of the Night” from Andrew Lloyd Webber’s Phantom of the Opera. The piece contains dramatic lyrics, making it an ideal first-
night selection. The text, “Let your mind start a journey through a strange new world,” which occurs at the song’s central climax, is particularly fitting for the beginning of Camp. This text sets the stage for the adventure that is Astronomy Camp, an adventure in which students will be encouraged to shift their perspectives about the world around them. I often begin “Music of the Night” with the telescope dome closed, and start opening the dome at the onset of the central climax — a particularly dramatic and inspiring effect. “Music of the Night” is an Astronomy Camp theme song of sorts, and the “Let your mind start a journey through a strange new world” text was featured on the 2001 Camp T-shirt.

On the second night I frequently present the finale of Transit, a work for electric guitar and computer-synthesized orchestra by University of South Carolina composer John Fitz Rogers. Transit is a large-scale work that combines rock and classical elements and causes students to think broadly about relationships between music, science, and technology. The solo electric guitar line pushes both instrument and player to their limits. In the computer-synthesized part, there are rhythms so mathematically complex, and speeds so extreme, as to be completely out of the grasp of a human player. Thus, while the work’s title suggests the astronomical event characterized by one celestial object passing in front of another, in actuality the work can be seen as an example of creative interaction between humans and computers.

As the week progresses, I introduce the campers to music for the organ. The pipe organ is a superb instrument for “astronomical” music because of its wide dynamic range. The pipe organ can be alternatively very soft or very loud, is capable of producing a huge array of sounds, and can sustain notes indefinitely — excellent characteristics for music with an astronomical inspiration.

One organ work that makes a frequent appearance is Nova by American composer, organist, and amateur astronomer Myron Roberts. Nova is a musical evocation of a Type II supernova. The beginning of Nova brings to mind the increasing instability of a star that is about to go supernova. Then, a lengthy crescendo builds to a series of massive chords (played on the full power of the organ) depicting the supernova itself. Nova concludes with a mysterious passage in which the organ’s highest and lowest notes are superimposed, evoking the supernova remnant’s dispersal into space.

Live Performances at Camp
At the 2011 Camps, we extended the music component to include a live session at the organ. This event featured my performance of my own composition Nebulae, a musical journey through the process of star formation. Nebulae opens with a mysterious, ethereal section depicting the beginning stage of star formation: a dark, cold molecular cloud. A violent passage suddenly ensues, evoking the arrival of a supernova shock front — one possible mechanism for triggering the collapse of the cloud and the start of star formation. A central dance section that grows in both intensity and rhythmic complexity marks the protostar stage. This dance builds to a series of large chords played on the full power of the organ, signaling the start of nuclear fusion and the birth of a star. Nebulae concludes with a fast-moving passage evoking the brilliance of the newly formed star.

For this live performance, I used the technique described earlier, in which I do not highlight specific astronomy/music connections. Before my performance, I conducted an introductory activity summarizing the stages of star formation. This activity involved students sequencing a set of images representing various stages of the star-formation process. I then performed Nebulae; during my

Some Other Musical Selections

In addition to Nova, two other examples of organ pieces with astronomy connections are Coalescence and Time Machine by University of Houston organist/composer Robert Bates. These two works combine a live organ part with a pre-recorded segment in which the organ’s sound has been manipulated via computer. Coalescence is an evocation of the origin of life on Earth and can serve as a departure point for discussions of early Earth history, the early solar system, and even astrobiology. Time Machine is a musical depiction of a journey through a wormhole.

Other works include (University of South Carolina) Reginald Bain’s degrees of accuracy for trombone and computer-generated sounds — a piece based on the number pi. The main theme is constructed by mapping digits of pi onto musical notes, and many of the rhythmic relationships are based on pi as well — a fascinating example of creative relationships between mathematics and music.

Movements from George Crumb’s Makrokosmos series have made appearances, as has “Jupiter” from British composer Gustav Holst’s The Planets. From an educational standpoint, “Jupiter” provides a springboard for introducing students to important British astronomers such as William Herschel. Herschel is often referred to as the father of modern astronomy, but he was a musician — organist, conductor, and composer — for much of his career.

Another work with a historical-cultural basis is Australian composer Ross Edwards’ Symphony No. 4: Star Chant, a large-scale piece for chorus and symphony orchestra. Star Chant features a choral text which pairs Western star and constellation names with their Australian aboriginal counterparts. I use Star Chant to introduce students to the fields of cultural astronomy and ethnoastronomy.

— M.W.
performance the output of a laptop-based sound spectrum analysis program was projected onto a large screen.

After listening to Nebulae, the students discussed the ways in which the music they just heard connected with the astronomical concepts introduced in the opening activity. As expected, the students were able to make and express cogent connections between music and astronomy — no doubt assisted by the “wow factor” of a live performance on a large pipe organ. Student reactions to Nebulae tended to be particularly insightful. For instance, I had students make connections between the superimposition of very high and very low organ sounds and hydrostatic equilibrium in a star.

Our event at the organ also included a hands-on discussion on the physics of sound. I had a set of small organ pipes available, so students were able to get a close-up look at the sound source of a pipe organ. We used our laptop-based analysis program to display the sound spectrum of various notes from the organ. The myriad sounds and tone colors produced by the organ differ both in the actual overtones present and in the amplitudes (volume levels) of those overtones. Also, when the organ is played at full volume, the overtone structure produced is extraordinarily complex because many pipes are sounding at the same time — even when only one key is pressed. The organ is thus a wonderful vehicle for exploring how overtone structure determines the nature of the sound produced.

Let Your Mind Start a Journey

Astronomy Camp is not just about developing students’ knowledge of STEM fields. It is also about inspiring students, encouraging them to use their imaginations, and broadening their perspectives about the universe around them. The Camps take place in the aesthetically impressive environment of a mountaintop observatory, and the inspiring experience of observing with large telescopes under dark skies is a central feature of the program. Astronomy Camp is thus an ideal setting for creative educational activities that combine science and the arts.

Just imagine, once again, that you are in an observatory dome, with a large telescope looming over you in the dark. As you listen to the evening’s music selection, you are inspired to “let your mind start a journey through a strange new world.”

MATTHEW WHITEHOUSE is an organist, composer, and astronomy educator. He is on the public outreach staff of Kitt Peak National Observatory and serves as music director at Christ the King Episcopal Church in Tucson. Sound files of his compositions can be found on his website.
**Excerpts from recent press releases that describe an assortment of astronomical discoveries.**

**MESSENGER Provides New Look at Mercury**  
*Johns Hopkins University Applied Physics Laboratory*

MESSENGER completed its one-year primary mission on March 17. Since moving into orbit about Mercury a little over one year ago, the spacecraft has captured nearly 100,000 images and returned data that have revealed new information about the planet, including its topography, the structure of its core, and areas of permanent shadow at the poles that host the mysterious polar deposits.

“The first year of MESSENGER orbital observations has revealed many surprises,” says MESSENGER Principal Investigator Sean C. Solomon, of the Carnegie Institution of Washington. “From Mercury’s extraordinarily dynamic magnetosphere and exosphere to the unexpectedly volatile-rich composition of its surface and interior, our inner planetary neighbor is now seen to be very different from what we imagined just a few years ago.”

Observations from MESSENGER’s Mercury Laser Altimeter have provided the first-ever precise topographic model of the planet’s northern hemisphere. The spread in elevations is considerably smaller than those of Mars or the Moon…the most prominent feature is an extensive area of lowlands at high northern latitudes that hosts the volcanic northern plains.

Scientists have also come up with the first precise model of Mercury’s gravity field that, when combined with the topographic data and earlier information on the planet’s spin state, sheds light on the planet’s internal structure, the thickness of its crust, the size and state of its core, and its tectonic and thermal history. Mercury’s core is huge for the planet’s size, about 85% of the planetary radius.

**NPP’s New Blue Marble**  
*NASA Goddard*

Responding to public demand, NASA scientists created (and released on January 25, 2012) a companion image to the wildly popular ‘Blue Marble’.

The Suomi NPP satellite is in a polar orbit around Earth at an altitude of 512 miles (about 824 kilometers), but the perspective of the new Eastern hemisphere ‘Blue Marble’ is from 7,918 miles (about 12,743 kilometers). NASA Goddard scientist Norman Kuring managed to ‘step back’ from Earth to get the big picture by combining data from six different orbits of the Suomi NPP satellite. Or putting it a different way, the satellite flew above this area of Earth six times over an eight hour time period. Norman took those six sets of data and combined them into one image.

The new image is a composite of six separate orbits taken on Jan. 23, 2012 by the Suomi National Polar-orbiting Partnership satellite. Both of these new ‘Blue Marble’ images are images taken by a new instrument flying aboard Suomi NPP, the Visible Infrared Imaging Radiometer Suite (VIIRS).

Compiled by Kuring, this image has the perspective of a viewer looking down from 7,918 miles (about 12,742 kilometers) above the Earth’s surface from a viewpoint of 10 degrees South by 45 degrees East. The four vertical lines of ‘haze’ visible in this image shows the reflection of sunlight off the ocean, or ‘glint,’ that VIIRS captured as it orbited the globe.

Images of the Western and Eastern hemispheres plus an Australia view are available [here](#).
Dawn Reveals Secrets of Giant Asteroid Vesta

Findings from NASA’s Dawn spacecraft reveal new details about the giant asteroid Vesta, including its varied surface composition, sharp temperature changes and clues to its internal structure.

Spacecraft images, taken 420 miles (680 kilometers) and 130 miles (210 kilometers) above the surface of the asteroid, show a variety of surface mineral and rock patterns. Coded false-color images help scientists better understand Vesta’s composition and enable them to identify material that was once molten below the asteroid’s surface.

Researchers also see breccias, which are rocks fused during impacts from space debris. Many of the materials seen by Dawn are composed of iron- and magnesium-rich minerals, which often are found in Earth’s volcanic rocks. Images also reveal smooth pond-like deposits, which might have formed as fine dust created during impacts settled into low regions.

“Dawn now enables us to study the variety of rock mixtures making up Vesta’s surface in great detail,” said Harald Hiesinger, a Dawn participating scientist at Muenster University in Germany. “The images suggest an amazing variety of processes that paint Vesta’s surface.”

At the Tarpeia crater near the south pole of the asteroid, Dawn revealed bands of minerals that appear as brilliant layers on the crater’s steep slopes. The exposed layering allows scientists to see farther back into the geological history of the giant asteroid. Layers closer to the surface bear evidence of contamination from space rocks bombarding Vesta’s surface. Layers below preserve more of their original characteristics.

Mars Orbiter Catches Twister in Action

An afternoon whirlwind on Mars lofts a twisting column of dust more than a half mile (800 meters) high in an image from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA’s Mars Reconnaissance Orbiter.

HiRISE captured the image on Feb. 16, 2012, while the orbiter passed over the Amazonis Planitia region of northern Mars. In the area observed, paths of many previous whirlwinds, or dust devils, are visible as streaks on the dusty surface. The active dust devil displays a delicate arc produced by a westerly breeze partway up its height.

The image was taken during the time of Martian year when that planet is farthest from the Sun. Just as on Earth, winds on Mars are powered by solar heating. Exposure to the Sun’s rays declines during this season, yet even now, dust devils act relentlessly to clean the surface of freshly deposited dust, a little at a time.

Dust devils occur on Earth as well as on Mars. They are spinning columns of air, made visible by the dust they pull off the ground. Unlike a tornado, a dust devil typically forms on a clear day when the ground is heated by the Sun, warming the air just above the ground. As heated air near the surface rises quickly through a small pocket of cooler air above it, the air may begin to rotate, if conditions are just right.
**Hubble Reveals a New Type of Planet**
*Harvard-Smithsonian Center for Astrophysics*

Our solar system contains three types of planets: rocky, terrestrial worlds, gas giants, and ice giants. Planets orbiting distant stars come in an even wider variety, including lava worlds and “hot Jupiters.”

Observations by NASA’s Hubble Space Telescope have added a new type of planet to the mix. By analyzing the previously discovered world GJ1214b, astronomer Zachory Berta (Harvard-Smithsonian CfA) and colleagues proved that it is a water world enshrouded by a thick, steamy atmosphere. “GJ1214b is like no planet we know of,” said Berta. “A huge fraction of its mass is made up of water.”

GJ1214b was discovered in 2009 by the ground-based MEarth (pronounced “mirth”) Project. This super-Earth is about 2.7 times Earth’s diameter and weighs almost 7 times as much. It orbits a red-dwarf star every 38 hours at a distance of 1.3 million miles, giving it an estimated temperature of 450°F.

In 2010, CfA scientist Jacob Bean and colleagues reported that they had measured the atmosphere of GJ1214b, finding it likely that the atmosphere was composed mainly of water. However, their observations could also be explained by the presence of a worldwide haze in GJ1214b’s atmosphere.

Berta and his co-authors used Hubble’s WFC3 instrument to study GJ1214b when it crossed in front of its host star. During such a transit, the star’s light is filtered through the planet’s atmosphere, giving clues to the mix of gases. The atmospheric model most consistent with HST data is a dense atmosphere of water vapor.

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**Herschel Spots Comet Massacre Around Nearby Star**
*European Space Agency*

ESA’s Herschel Space Observatory has studied the dusty belt around the nearby star Fomalhaut. The dust appears to be coming from collisions that destroy up to thousands of icy comets every day.

Fomalhaut is a young star, just a few hundred million years old, and twice as massive as the Sun. Its dust belt was discovered in the 1980s by the IRAS satellite, but Herschel’s new images of the belt show it in much more detail at far-infrared wavelengths than ever before.

Bram Acke, at the University of Leuven in Belgium, and colleagues analyzed the Herschel observations and found the dust temperatures in the belt to be between -230° C and -170° C. Both the narrowness and asymmetry of the belt are thought to be due to the gravity of a possible planet in orbit around the star, as suggested by earlier Hubble Space Telescope images.

The Herschel data show that the dust in the belt has the thermal properties of small solid particles, with sizes of only a few millionths of a meter across. But this created a paradox because the HST observations suggested solid grains more than ten times larger.

Those observations collected starlight scattering off the grains in the belt and showed it to be very faint at Hubble’s visible wavelengths, suggesting that the dust particles are relatively large.

To resolve the paradox, Dr Acke and colleagues suggest that the dust grains must be large fluffy aggregates, similar to dust particles released from comets in our own solar system. These would have both the correct thermal and scattering properties. However, this leads to another problem.

The bright starlight from Fomalhaut should blow small dust particles out of the belt very rapidly, yet such grains appear to remain abundant there.
Archaeology of Galaxies: The Dragon Clash
l’Observatoire de Paris

Numerous collisions have probably affected the shape of galaxies, and perhaps, half of spiral galaxies have been formed this way during the last 9 billions years. Possibly this is the case for NGC 5907, a spiral galaxy in the Dragon constellation. However this galaxy is almost bulgeless, while prominent and classical bulges are generally considered to be a signature of major mergers.

In fact NGC 5907 has been observed with the deepest ever-made imagery, revealing a system of stellar currents forming gigantic loops in its surrounding halo. These phenomena have been intensively studied by a team of six scientists of the l’Observatoire de Paris, CNRS, Chinese Academy of Sciences, National Astronomical Observatories of China (NAOC) and Marseille Observatory. To reproduce them they have used several state of the art, hydrodynamical, and numerical simulations with particle numbers ranging from 200,000 to 6 million. They succeeded in doing so after assuming that these gigantic loops were the relic of a gigantic collision between galaxies of similar sizes, which would have occurred 8 to 9 billion years ago.

Previously the 150,000 light-years loops surrounding NGC 5907 were believed to be associated to the capture of a very small satellite that would have lost its matter relatively recently. New simulations are excluding satellite masses that would be below one-twelfth of the main galaxy. It also implies that the progenitors of NGC 5907 and its loops were very gas rich, with a gas fraction of at least 60%.

Dark Matter Core Defies Explanation
Canada-France-Hawaii Telescope

It was the result no one wanted to believe. Astronomers have observed what appeared to be a clump of dark matter left behind during a bizarre wreck following a collision between massive clusters of galaxies.

The dark matter appears to have collected into a “dark core” while most of the galaxies seemed to have moved on, sailing past the collision site. This result could present a challenge to basic theories of dark matter, which predict that galaxies should be anchored to the invisible substance, even during the shock of a collision.

The initial detection, made in 2007, was so unusual that astronomers shrugged them off as unreal because of the signal’s moderate significance. However, new results from NASA’s Hubble Space Telescope confirm that dark matter and galaxies parted ways in the gigantic merging galaxy cluster called Abell 520, located 2.4 billion light-years away.

“This result is a puzzle,” said astronomer James Jee of the University of California, Davis, leader of the Hubble study. “Dark matter is not behaving as predicted, and it’s not obviously clear what is going on. Theories of galaxy formation and dark matter must explain what we are seeing.”

One way to study dark matter is by analyzing smashups between galaxy clusters, the largest structures in the universe. When galaxy clusters collide, astronomers expect galaxies to tag along with the dark matter, like a dog on a leash. Clouds of intergalactic gas, however, plow into one another, slow down, and lag behind the impact.

But studies of Abell 520 showed that dark matter’s behavior may not be so simple. The original observations found that the system’s core was rich in dark matter and hot gas but contained no luminous galaxies, which normally would be seen in the same location as the dark matter.
When Dark Energy Turned On
Harvard-Smithsonian Center for Astrophysics

Astronomers announced that they have made the most accurate measurement yet of galaxy distances in the faraway universe, giving an unprecedented look at the time when dark energy turned on. Some five to seven billion years ago, the expansion of the universe stopped slowing due to gravity and started to accelerate due to dark energy. Yet the nature of dark energy remains a puzzle.

“We see the influence of dark energy on cosmic structure, but we have no idea what it is. The data gathered by this survey will help answer that question,” said Daniel Eisenstein (Harvard-Smithsonian Center for Astrophysics), the director of the third Sloan Digital Sky Survey.

“There’s been a lot of talk about using galaxy maps to find out what’s causing accelerating expansion,” said David Schlegel of the Lawrence Berkeley National Laboratory, principal investigator of the Baryon Oscillation Spectroscopic Survey. “We’ve been making a map and now we’re using it — starting to push our knowledge out to the distances when dark energy turned on.”

Planck All-Sky Images Show Cold Gas and Strange Haze
NASA / JPL

New images from the Planck mission show previously undiscovered islands of star formation and a mysterious haze of microwave emissions in our Milky Way galaxy. The views give scientists new treasures to mine and take them closer to understanding the secrets of our galaxy.

“The images reveal two exciting aspects of the galaxy in which we live,” said Planck scientist Krzysztof M. Gorski from NASA’s Jet Propulsion Laboratory in Pasadena, Calif., and Warsaw University Observatory in Poland. “They show a haze around the center of the galaxy, and cold gas where we never saw it before.”

The new images show the entire sky, dominated by the murky band of our Milky Way galaxy. One of them shows the unexplained haze of microwave light previously hinted at in measurements by NASA’s Wilkinson Microwave Anisotropy Probe (WMAP).

“The haze comes from the region surrounding the center of our galaxy and looks like a form of light energy produced when electrons accelerate through magnetic fields,” said Davide Pietrobon, another JPL Planck scientist.
News and information for Society members

**New ASP Director of Development and Communication Announced**

The ASP is pleased to announce that Kathryn Harper has joined the organization staff as Director of Development and Communication.

Holding a Bachelor of Arts degree from Antioch University and a Master’s degree from Seattle University, Kathryn brings to the ASP more than 15 years in development, marketing, and public relations experience in the nonprofit, public, and private sectors. Prior to joining the ASP, she directed development and communications for an Easter Seals affiliate with an $18 million budget, where she introduced successful new initiatives in online giving, grant writing and social media marketing, and outreach. Her experience also includes working with boards of two museums, a non-partisan think tank, and an international medical relief organization.

Born and brought up in Hawaii, Kathryn has traveled and worked extensively overseas. She most recently lived in Seattle and Honolulu, and now resides in San Francisco. Kathryn brings a particular passion for cross-sector and cross-culture communications, which helps her advocate effectively for needed funds and resources on behalf of very worthy causes.

An avid writer, cyclist, and self-professed Star Trek and Star Wars “geek,” she is already hard at work on the very worthy cause of fostering scientific curiosity and advancing science literacy through astronomy, while working with the ASP staff and board to build a development and communications plan in keeping with the ASP’s strategic initiatives.

The ASP is very pleased to have Kathryn on board, and we welcome her to the team!

**Galileo Goes To Mars**

This hands-on workshop on astronomy is for teachers in grades 3 to 12 and those who work with them. It’s part of the 124th Annual Meeting of the Astronomical Society of the Pacific being held in Tucson, Arizona. The workshop takes place on Saturday and Sunday, August 4th and 5th, from 8:30 am to 5:00 pm at the DoubleTree Hotel Reid Park, 445 S. Alvernon Way, Tucson, AZ. Workshop participants will explore:

- Classroom-tested, standards-based, hands-on astronomy activities (with a focus on the solar system)
- The development of students’ understanding of science and science reasoning skills
- How astronomy and space science fit into the new science framework and standards
- Historical and multi-cultural perspectives on astronomy
- Why the world won’t end in 2012 (despite what you hear on tabloid TV and the Internet), and why your students will still be taking tests in 2013!
- How to keep up with (and teach about) recent developments in our exploration of the universe
- The wealth of astronomy teaching resources now available (each person will receive *The Universe at Your Fingertips* 2.0, a collection of 133 classroom-ready activities and many other teaching resources on DVD-ROM).

No background in astronomy is required. This workshop is part of the ASP’s national “Galileo Teacher Training Workshop” series, begun in 2009 during the 400th anniversary celebration of Galileo’s telescope.

We welcome both novice and veteran science teachers, and will have a track especially for teachers who may be just a bit nervous about having to include astronomical ideas in their curriculum.

Registration is $75 for both days (includes the new *Universe at Your Fingertips* DVD, a $30 value.) Registration is limited and will be accepted in the order received. The deadline for priority registration is June 10, 2012, but register soon to be assured of a place. Registration details are available online.

**2012 Spring Fund Drive**

As the northern hemisphere begins to tip toward the Sun, and the nurturing sunlight and rain bring renewal and new growth, it is the time of year when the Astronomical Society of the Pacific likewise turns to you, our nurturing friends, and asks you to renew your support for the Society in our spring appeal.

For you make the difference as we open minds and lives to the wonders of science through astronomy.

Allow me to introduce you to just two of the many thousands whose efforts you help to nurture.

Christina Malm is a naturalist/instructor at Ellanor C. Lawrence Park near Chantilly, Virginia. Christina uses the materials and training she received in the ASP’s Astronomy from the Ground Up (AFGU) program to teach youth classes, including merit badge activities for scouts. “I love all the materials AFGU has given me. It helps make the programs so much more interesting and more memorable for the kids,” Christina writes. “I would never have been comfortable teaching this program without AFGU.”

Mike Broughton is an interpretive naturalist at Kensington Metropark Nature Center in Milford, Michigan, serving youth, scouts and people of all ages. He uses tried-and-true AFGU materials in his popular presentations, and writes, “The AFGU workshops have been some of the best educational opportunities that I’ve ever had….Teachers and scout leaders rave about our astronomy programs, thanks to AFGU.”

Through the thousands of Christinas and Mikes in the ASP programs your gifts help to support, you are making a difference — in classrooms, museums, nature centers and other venues across the country and around the world.

You are touching and inspiring the lives of tomorrow’s scientists, science educators, and science-informed citizens who are so critical
to the future of us all — using the sky we all love.

It's important work. And in this season of renewal, we ask you to be as generous as you can with a nurturing gift: an investment in a science-literate future that can make all the difference in the lives of today's kids and tomorrow's leaders.

Please consider making an online donation by going to: www.astrosociety.org/forms/donation.html.

Thank you for your consideration, and happy spring!

Best Wishes.

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

P.S. In this nurturing season, please help us to nurture the good work of the Christinas and Mikes of the world through your important gift!

www.astrosociety.org/donate

The ASP Spring Appeal is now underway. At the start of our new fiscal year, we are grateful for your support and very excited to redouble efforts to engage new generations in astronomy — nurturing especially those with limited access to programs and services that can inspire a lifetime of science understanding and achievement.

Together we are making an impact, and making a difference! Please consider making a gift today.

www.astrosociety.org/donate

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All proceeds from product sales support the mission and education programs of the ASP
The Astronomical Society of the Pacific wishes to thank the following organizations and individuals for their generous philanthropic support. This list reflects gifts and grants received between March 1, 2011, and February 29, 2012. Funds raised support the ASP’s mission to foster scientific curiosity, advance science literacy, and share the joy of exploration and discovery — to encourage tomorrow’s science, technology, and academic leaders. Although each star shines alone, they add up to a glittering night sky. Likewise, each donation adds to the next to make a great impact. Thank you for making it possible!

**Society Benefactor** ($25,000 and above)
- Estate of Kenneth L. Cashdollar
- Estate of Leopold Tedesco
- Windy Ridge Foundation in support of Galileo Teacher Training Program

**President’s Circle** ($5,000 – $24,999)
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- Estate of Mark A. Stolle
- Lockheed Martin Space Systems Co. in support of Bay Area Project ASTRO
- Gordon & Diane Myers
- Hagopian-Herschel Science Center (HNSC)
- NASA Lunar Science Institute
- NASA’s Chandra X-Ray Observatory
- NASA’s Exoplanet Exploration Program – JPL

**Atmospheric and Geographic Observatories for Infrared Astronomy (SOFIA) Spitzer Science Center (SSC)**

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**Estate of Kenneth L. Cashdollar**

**Estate of Mark A. Stolle**

**Lockheed Martin Space Systems Co. in support of Bay Area Project ASTRO**

**Gordon & Diane Myers**

**Hagopian-Herschel Science Center (HNSC)**

**NASA Lunar Science Institute**

**NASA’s Chandra X-Ray Observatory**

**NASA’s Exoplanet Exploration Program – JPL**

**Atmospheric and Geographic Observatories for Infrared Astronomy (SOFIA)**

**Spitzer Science Center (SSC)**

**Edward S. Holden Society** ($2,000 – $4,999)

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We apologize in advance for any errors or omissions. If you have a correction, please contact the Development Department at 415-337-1100 ext. 106 or by email: development@astrosociety.org so that we may correct our records.
The Skies of May

During May and June, sunset occurs and darkness falls later and later each evening. The farther north you live (or travel), the more pronounced this is. And the combination of late sunsets and long twilight exaggerates the seasonal change in the constellations. The springtime star groups seem to hurry through the evening sky, as if anxious to make way for their summer cousins.

But during May and into June, some of the brightest springtime constellations are nicely placed for viewing in the south and west after sunset. Of course, very high in the west are the bright seven stars of the familiar Big Dipper. The Dipper is usually used to identify Polaris, the Pole Star. But in spring, the Dipper’s Handle is a handy way to find two of the brightest stars of spring. Skywatchers, scout/guide leaders, and amateur astronomers running springtime star parties have long used the phrase “Arc to Arcturus, then speed to Spica” to help beginners find these two stellar gems.

What does that mean? Simply extend the curve/arc of the Handle of the Big Dipper southward until your eye intercepts a bright, pale, yellow-orange star. That’s Arcturus, the brightest star in the constellation Boötes, the Herdsman. Then, if you keep going with the arc, you’ll end up at blue-white Spica in Virgo, the Maiden.

At the moment Spica has a companion — Saturn. The ringed planet sits above Spica, and since the two are close (and roughly the same brightness), it’s a perfect opportunity to test out an astronomical truism: Stars twinkle; planets don’t. Is it true? (It should be, though once this star/planet pair approaches the horizon, both will likely twinkle madly.)

While the fainter stars of Virgo and Ursa Major (the Big Dipper’s home constellation) are often difficult to discern in city skies, the seven brightest stars of Boötes are not. Six of them take the shape of a large kite, with Arcturus at its base, and a star near Arcturus marks the kite’s short, stubby tail.

Directly underneath the Big Dipper is another set of spring stars — Leo, the Lion, and its bright star Regulus. The front half of Leo is easy to find; the stars of his head take the shape of a huge backwards question mark known as the Sickle. His hind quarters are represented by a triangle of stars sitting well to the Sickle’s east.

Leo also has a planetary visitor — Mars. The approximate positions of the red planet for mid-May and mid-June are indicated on the star chart. Mars is slightly brighter than Regulus, and its red hue will give it away.

Regulus and Leo will vanish into the sunset glow by early July, but Mars pushes ahead of the Sun for a while yet. Indeed, by late August the red planet catches up to the ringed planet and forms a nice little triangle with Spica. They’re joined by a crescent Moon on August 21st, which will make for a very pretty sight.

Meanwhile, back in May, both Mercury and Jupiter are lost to the glare of the Sun. Venus continues to shine high in the west at dusk, but it drops lower and lower after sunset as the month progresses. A thin crescent Moon shines to the lower left of this still-brilliant planet on the 22nd.

Mars is gradually heading east, away from Regulus. It’s also fading, though it remains reasonably bright. On the 28th the first quarter Moon sits below the red planet.

Throughout the month, Saturn is well up in the southeast and south as the sunset sky turns dark. On the 3rd the nearly full Moon is to the right of the Saturn/Spica pair; on the 4th it sits below the two of them. Almost a month later — on the 31st — the Moon is directly below Spica, with Saturn perched on top of both.

And on May 20th an annular eclipse of the Sun is visible along a narrow band stretching from southern Japan into the western US. Accompanying the annular is a partial solar eclipse, observable across much of northwestern North America and eastern Asia. Excellent charts showing the narrow path of annularity can be found on meteorologist Jay Anderson’s eclipse weather site.

The Skies of June

The transit of Venus. That is the highlight of the month, the year, and quite possibly the century. Eclipses, conjunctions, occultations,
alignments — they come and go, and if you miss one, you don’t have to wait long to see another. Miss the June 5/6 transit of Venus, and you, personally, will never see another. The transit is discussed in this issue’s Reflections column, where you’ll find hotlinks to a number of informative sources.

Keep in mind one very important fact. If you live in North America, northwestern South America, Hawaii and some of the eastern Pacific islands such as Tahiti, you’ll see the transit during the afternoon/evening of June 5th — the spectacle will be in progress as the Sun sets. If you live anywhere else in the world (except for the eastern two-thirds of South America and the western third of Africa), you’ll see the transit on June 6th. In Europe, the Middle East, and eastern Asia, the Sun rises with Venus on its face. Those two exceptions mentioned in the earlier sentence? Folks living there don’t see the transit at all.

Since most ASP members live in North America, here are the approximate June 5th times when Venus begins its journey across the solar face: 18:04 EDT; 17:04 CDT; 16:05 MDT; 15:06 PDT; 14:06 AKDT; and 12:10 HAST. Make sure you’re set up and ready to roll well before the start time.

A secondary highlight is a more regular celestial event. In the early morning hours of June 4th, a partial eclipse of the Moon is visible across much of North and South America. Mid-eclipse occurs at 6:03 am CDT; 5:03 am MDT; 4:03 am PDT, and 1:03 am in Hawaii. The Moon sets before entering the dark umbral shadow for observers in northeastern US and Canada. The complete partial is visible across the Pacific Ocean and into Australia. You can download a NASA PDF that will show where the eclipse is visible and the Moon’s path through the northern edge of Earth’s shadow.

Mercury peeks through the glow of sunset starting just before midmonth. Look for it low in the west-northwest about 30 minutes after sunset. On the 21st this dim planet will stand to the upper right of the two-day-old crescent Moon — both with the challenging to spot in the sunset glow.

Mars is high in the southwest after sunset and continues its slow fade in brightness. The red planet will sit high above the Moon on the 25th. Two days later, it’s Saturn’s turn to hover over the Moon.

During the first half of the month, Venus is lost in the solar glare — except, of course, when it transits the Sun. But toward month’s end, it pops up in the east-northeast some 60 to 90 minutes before the Sun. And it’s not alone. Rising about 30 minutes prior to Venus is Jupiter. The two make a brilliant pair in the dawn sky, reprising their roles in the sunset skies of March. On the 15th about 30 minutes before sunrise (right), see if you can spot a very thin crescent Moon to Jupiter’s lower left. The slightly orangish star upper right of Venus is Aldebaran, the brightest star in Taurus, the Bull.

The sky at dawn on July 15th with Venus, Jupiter, the crescent Moon, and Aldebaran.
Thanks to *Sky & Telescope* magazine, *Mercury* readers have direct access to *S&T*’s online Interactive Sky Chart. While anyone can go to it on Sky’s website, registration is required to load and use the charts. Registration is free and has some advantages, but it’s not necessary for ASP members who just want to retrieve the monthly star chart.

**Please note that the *S&T* Interactive Sky Chart does not work on the iPad.**

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

### Using the Chart: The Basics

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

For instance, when you click on the link for the *May Sky Chart*, you should see, in a new window, a screen that looks like the image above. Each of the monthly links in Sky Sights will take you to a chart set for 40° north latitude and 100° west longitude (so it’s useful throughout the continental US) at 10:00 pm local time at mid-month in May, June, and July. The chart can be used one hour later at the start of each month and one hour earlier at month-end.

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

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

### Changing the Chart

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

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

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

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

### Tech Talk

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

If you have trouble getting the Sky Chart to open on your computer, please review Sky’s detailed system requirements to check whether you’re using a supported operating system. And don’t forget to also review the *Help* page.  ■ [RETURN]
June 5/6, 2012: The Transit of Venus

By the time it's over you'll be tired of hearing about it, but you'll be unhappy if you miss it.

If you head over to the ASP's website, you'll find a page of resources for viewing the June 5/6 transit of Venus, including a Mercury article about the transit (from the 2011 Summer issue), instructions for building a Sun Funnel to attach to a telescope for safe transit viewing, a downloadable 2012 almanac, and more.

Now I can't believe you don't know it's coming, but on the off chance that you've just emerged from a 520-day simulated Mars mission, here is the Coles Notes version of the transit of Venus.

Every 584 days Earth, Venus, and the Sun are roughly aligned. This is called an inferior conjunction. A transit of Venus occurs when Earth, Venus, and the Sun are exactly aligned, and Venus passes across the solar face as seen from Earth.

Venus transits are rare. They occur in pairs, separated by eight years. One transit pair is separated from the next by more than a century. Since the invention of the telescope, only three transit pairs have occurred: 1631 and 1639; 1761 and 1769; and 1874 and 1882. The fourth and current pair (2004 and 2012) concludes this June: June 5th throughout North America and Hawaii, and June 6th in Europe, Asia, east Africa, and the Pacific. Miss it and you'll have to wait until December 11, 2117, for the start of the next transit pair.

A Transit of Venus is a leisurely affair — about 6.5 hours from start to finish. The bits of particular interest occur as Venus moves on to (ingress), and off of (egress), the solar face. Each lasts about 18 minutes. The rest of the time you're simply following the progress of a tiny black dot across the Sun's disk.

During previous centuries, astronomers were desperately interested in timing those 18-minute segments. They hoped to use the transit to calculate the size of the solar system. For a nice summary of transit observing and the science behind it, see A Brief History of the Transit of Venus by Dr. Sten Odenwald (NASA/ADNET).

Danger, Will Robinson, Danger

Think of the transit of Venus as an annular solar eclipse in miniature. So the safety rules for observing an annular or partial eclipse of the Sun also apply to observing a Venus transit. And the number one rule is: Never look at the Sun without using a safe solar filter.

According to Ralph Chou, an Associate Professor of Optometry at the University of Waterloo (Canada), unsafe filters include all color film, black-and-white film that contains no silver, film negatives with images on them (x-rays and snapshots), smoked glass, sunglasses (single or multiple pairs), photographic neutral density filters, and polarizing filters. Looking at the Sun through a telescope, binoculars, or a camera with a telephoto lens without proper eye protection can result in "eclipse blindness," a serious injury in which the eye's retina is damaged by solar radiation. (This NASA article explains what can happen.)

So, what to do? Use a safe solar filter of course. You can make one using Baader AstroSolar Solar Filter material; Google it to find local suppliers. It comes in a sheet, so you'll need to build a filter cell to place over the front of your telescope, binoculars, or camera.

You can find information about safe viewing (and where to find solar filter suppliers) in this Mercury article, learn how to build a Sun Funnel, observe with an astronomy club that's holding a transit event, and read about the science behind safe solar viewing. And an article here describes six different ways to safely view the transit.

Where and When...and Why

Of course you'll want to know the circumstances of the transit (when it starts and ends) for your observing site. Fortunately, there is a transit calculator that is ridiculously simple to use. You can enter your address, or simply drag the location marker on the map to your site. Once the data is inserted, the four contact times plus the midpoint of the transit are calculated. (If the clock face is black, it means the Sun has set.) Be aware that any predictions are apt to be slightly off, so start watching early for all the contact points.

A Venus transit isn't the most exciting astronomical sight you'll ever witness. But that's not really the point. The transit of Venus is one of those singular "once in a lifetime" events (though it's actually a twice-in-a-lifetime-and-then-never-again-for-several-generations event). It's a reprise of a rare, historical occurrence that scientists in previous centuries were anxious to observe. So get out, see it, and appreciate it for what it is — a rare spectacle.

Mercury editor PAUL DEANS still isn't sure where he'll watch the transit, but he will definitely put in a full effort to see it.

The June 8, 2004, transit of Venus at sunrise from an overlook above the Catawba River near Connelly's Springs, NC.