Registration is now open for the ASP’s 128th Annual Meeting, a special STEM conference focused on ensuring broad participation in the August 21, 2017, eclipse of the Sun, especially among youth living in diverse and underserved communities located outside the eclipse’s path of totality. Registration is open until November 30 or until available registration spaces fill up.

The vast majority of the population in North America will experience a spectacular partial solar eclipse in their hometowns and could participate in eclipse events at venues such as schools, local parks, libraries, and other sites in their neighborhoods.

The goals of the conference are to (a) convene a mix of outreach-minded scientists, educators, and eclipse enthusiasts together with national STEM Leaders working in underserved communities interested in engaging youth in 2017 eclipse programs, (b) create a dialogue between the astronomy outreach community and STEM Leaders who work with underserved audiences to share best practices for working with underserved youth, (c) provide STEM leaders with access to the resources to plan successful eclipse programs for their communities, and (d) forge lasting partnerships and collaborations between STEM Leaders working in underserved communities and the astronomy education community.

Space is extremely limited for this conference. Invited speakers and panelists for the conference include Derrick Pitts (Franklin Institute, Philadelphia, City Skies), Angela Speck (University of Missouri), Laura Peticolas (UC Berkeley “eclipse megamovie” project), Robyn Higdon (Exploratorium eclipse webcast), and many more. The meeting will also feature presentations and workshops from organizations with expertise in astronomy education and outreach to underserved communities.

For more information, visit astrosociety.org/meeting
Cassini: The Grand Finale
EMILY JOSEPH
One year from now it will be EoM — End of Mission — for Cassini at Saturn.

Eclipse Bulletin: Total Solar Eclipse of 2017 August 21
JOE RAO
I regard this book as essential reading at any time prior to Eclipse 2017.

For Better or Worse: Reflections of an Eclipse-Chasing Family
RICHARD H. DURISEN, ANNAMARIA MECCA, and MICHAEL V. M. DURISEN
Once you experience the rush of totality during a solar eclipse, you are forever trying to recapture it.

Astronomy in the News
A lonely mountain inhabits Ceres, a supernova is ejected from the pages of history, and the observable universe contains 10 times more galaxies than previously thought. These are some of the discoveries that recently made news in the astronomical community.
The Magic of Saturn

It’s sometimes said that the first celestial sight most people see through a telescope is Saturn. I’m not sure that’s true; Saturn isn’t always nicely placed after sunset for viewing at star parties or public (or private) observing sessions, be they planned or impromptu. I suspect that viewing the Moon through a telescope is more likely to be a novice’s first celestial observation.

What is likely true is that a view of Saturn, even through a small telescope, can be dramatic and memorable. I can clearly recall peering at the ringed planet through my little 60-mm refractor, always hoping to see more than it could possibly show me. Even after I graduated to larger scopes, I always longed to see on Saturn the depth of detail visible on Jupiter or Mars at its best — even though I knew that wasn’t possible.

And that’s why I so love the Cassini mission to Saturn. It showed us Saturn, its rings, and retinue of moons as we can never see them from Earth. This issue’s cover image is one such example, and it’s one of my favorite Cassini shots — the giant planet casting its shadow on the rings. It’s also reminiscent of my favorite Voyager 1 view of the ringed world as it departed Saturn in 1980.

Saturn on the cover also marks the beginning of the long goodbye to Cassini. As Planetary Perspectives columnist Emily Joseph explains in her feature “Cassini: The Grand Finale” (page 18), Cassini’s mission will come to an end in September 2017 when it dives into the Saturnian clouds.

The science undertaken during the spacecraft’s final year in orbit will give us many new insights into this giant planet, and that’s great — that’s why Cassini was sent to Saturn in the first place. Nonetheless, after providing us with 13 years of continuous, up-close imagery of the Saturnian system, I will miss Cassini, and I know I won’t be the only one to feel that way.

Paul Deans
Editor, Mercury
During my early career in astronomy some 30 years ago, I was often the only woman in my graduate courses, hired by a university, or attending professional conferences. I experienced my share of gender-based discrimination, and some of it was blatant and demoralizing. On my darkest days, when I seriously considered quitting the field, I thought about the women astronomers from previous generations whose journey had been far more challenging than mine and who had blazed the trail for me.

Katherine Johnson — an African American physicist, space scientist, and mathematician, and undoubtedly one of the key contributors to the success of NASA’s space program — was one of the women I looked up to.

Katherine Johnson had a childhood passion for astronomy and mathematics. She entered high school at age 10, began attending West Virginia State College at 15, and graduated summa cum laude with degrees in math and French at 18.

Born in 1918, Katherine Johnson had a childhood passion for astronomy and mathematics. She entered high school at age 10, began attending West Virginia State College at 15, and graduated summa cum laude with degrees in math and French at 18.

For most young, talented, black women, the story would have ended there. But undeterred by the tremendous racial discrimination, gender bias, and stereotypes of the era, she eventually became a NASA mathematician. She determined the orbital trajectory for Alan Shepard’s first space flight, verified the computer calculations for John Glenn’s first orbit of the Earth, calculated the trajectories for Apollo 11’s historic Moon landing, and used her tremendous mathematical talent to help bring the ill-fated Apollo 13 astronauts safely back to Earth.

For her contributions to the US space program and being a pioneer for African American women in science, Katherine Johnson (at the age of 96) received the Presidential Medal of Freedom from Barack Obama in 2015. In May 2016, the Katherine G. Johnson Computational Research Facility was formally dedicated at NASA’s Langley Research Center, where Johnson had worked from 1953 until her retirement in 1983. On December 25, 2016, the movie Hidden Figures opens in limited release (with wide release in January) and will finally tell her story to the world.

In interviews, when Katherine Johnson is asked how she got interested in astronomy, she gives an inspiring and simple answer: “I just looked up.” She talks about the magnificence of the stars and how they captured her imagination as a young girl growing up in rural West Virginia.

Since retiring from NASA’s Langley Research Center, Katherine Johnson has been a strong advocate for STEM education.
to study the cosmos is available to inspire all of us, regardless of our age, gender, ethnicity, religion, economic status, or physical ability.

Yet while the night sky does not discriminate, the astronomy community is not nearly as diverse as it should be. Compared to Katherine Johnson's time, there are definitely more women and other traditionally underrepresented groups working in astronomy, right? Well, the truth is that the field of astronomy has very far to go.

A 10-year comprehensive analysis of tenured and tenure-track faculty in the nation’s top 100 departments of science and engineering found — unsurprisingly — that minorities and women were significantly underrepresented. But when compared to 15 other science disciplines (including physics, chemistry, biology, engineering, and mathematics), astronomy was near or at the bottom across every dimension of analysis.

Consider one illustrative example. From 1996 to 2005 African American's received only 1% of all the astronomy PhD's awarded; Hispanics fared only slightly better, earning 3%. In fact, since 1955, only 40 African-Americans earned doctorates in astronomy or physics, and out of 594 faculty at top-40 astronomy programs, only six were African-American (1%) and seven were Hispanic (1.2%).

Prof. John Johnson (unrelated to Katherine Johnson) is an exoplanet researcher at the Harvard University and founder of the Banneker Institute that prepares students of color for top graduate programs in astronomy. In a recent Smithsonian.com interview, he said, “black kids are people, and when they learn about planets orbiting other stars, they get just as excited, and their faces light up in the exact same way.” So why do so few of these children grow up to join the ranks of professional astronomers? One factor, according to John Johnson and many others who do research on diversity in science, is the lack of role models. Put simply, when you do not see people of your own gender, ethnicity, or background represented in a profession, you are unlikely to enter it yourself. “Looking up” at night sky is not enough; you also need someone to “look up” to.

To ensure all young people have access to positive role models and programs encouraging their participation in astronomy, the ASP is making equity, diversity, and inclusion a major goal of our new five-year strategic plan. We began work on this critically important initiative several months ago by (1) creating a new ASP Board committee focused on diversity, equity, and inclusion; (2) dedicating the 128th ASP Annual Meeting to ensuring underserved youth all across the nation are fully engaged in 2017 during the North American solar eclipse (page 2); and (3) establishing a new award (the Arthur B.C. Walker II Award; page 45) recognizing an African American (or member of the African Diaspora) who has made significant contributions to astronomy and has promoted diversity and inclusion in astronomy and related fields.

Dr. Arthur B.C. Walker II was Haitian and a renowned solar physicist and astronomer at Stanford University who dedicated much of his life to mentoring others. The Walker Award celebrates the inspirational lives and accomplishments of individuals who will serve as role models for young people who might not be aware of their stories. The inaugural recipient of the Arthur B.C. Walker II Award is Katherine Johnson.

On October 22, 2016, at the ASP’s Annual Awards Gala, her family accepted the award on her behalf. I was deeply honored and moved to recently hand deliver the award to Katherine Johnson in her home just a few days after she celebrated her 98th birthday. It was an experience I will never forget. It is time to tell her amazing story and the story of many more like her. The next generation of astronomers is listening.

LINDA SHORE is the Executive Director of the Astronomical Society of the Pacific.
The late 1600s and early 1700s were a major transition time in astronomy on two fronts. Some philosophers and astronomers still adhered to the works of Aristotle and an Earth-centered universe as proposed by Ptolemy. In the case of Newton, his mathematical explanation of gravity was still hotly debated, and it was not until 1730 that it gained wide acceptance in France. Here I’ll examine how the Copernican revolution fared in a country that rarely gets a mention in the history of astronomy — Portugal.

In the 1690s Manuel Pimentel (1650-1719) was giving lectures about the Sun-centered cosmos, a direct affront to the traditionalists. Manuel was the son of Luis Pimentel (1613-79). Both were cosmographers to the kings of Portugal, a very prestigious post in an age when astronomy and navigation were closely linked. Portugal was a major maritime power with worldwide connections, and this is reflected in Manuel’s 1699 book *Arte Practica de Navegar* (The Art of Practical Navigation) with a second edition in the early 18th century. It covered regions as diverse as Angola, Brazil, and India. In this regard he followed his father Luis, who published a book with a similar title in 1681.

The heavenly crystalline spheres that people believed in for many centuries had already been banished across much of Europe, but Manuel obviously felt the need to make the case in Portugal. Instead of these hard spheres that nothing could cross, Manuel was a proponent of a theory of the fluidity of the heavens.

He wrote: “In regards to the planetary region, this theory is demonstrated by such experiences that the thickness and solidity introduced by Aristotle can no longer be sustained. Comets were observed above the Moon crossing the ethereal spaces, a fact which could not happen were those spaces filled by thick and solid spheres.” He further showed that because Venus appears on both sides of the Sun, it must revolve around the Sun, not Earth.

Moving to the outer solar system, Manuel said “Numerous and systematic observations have revealed that four small planets move around Jupiter, like moons, and two other planets (though presenting various forms) do the same around Saturn. These observations prove that the areas in which these planets move ought to be fluid and free to allow the motion of the small stars that move around them like pages.” His reference to Saturn was made before it was known the planet had rings, which looked like “two other planets.”

Astronomers and philosophers who were adherents of the Aristotelian/Ptolemaic system held to four major reasons why the Copernican system could not be valid. Pimentel had a rejoinder to each of these.

First, it was said Earth was made up of the most impure elements, but Pimentel countered that there was no ontological distinction between Earth and other planets.
Second, the Aristotelians said that because Earth was a heavy body, and heavy elements tended to the center of the planet, it could not move. Pimentel similarly rejected this notion as he did not believe the elements comprising Earth were unusual.

Their third objection seemed to be more persuasive. If Earth moved, it was claimed, every mountain and city would collapse as the result of the rapidity of the planet’s rotation. Pimentel wrote that “the Earth is provided with a magnetic virtue through which it gets together all its parts, both the internal and the external.”

Those in favor of Aristotle were certainly unmoved (pun intended) by this unsubstantiated notion. In this era, magnetism (whose nature was still unknown) was invoked by other great thinkers of the day to address inexplicable phenomena. John Wilkins, a founder of the Royal Society in 1660, believed planets moved under the influence of magnetic energy radiated from the Sun. In the Jan/Feb 2006 issue of Mercury, I mentioned the magnetic experiments performed by Henry Gellibrand in 1635 that were specifically aimed at overthrowing Aristotle.

The fourth objection was also a powerful argument, namely the lack of parallax for any star. Pimentel rightly countered with an appeal to the immensity of the universe, but this was not a contention he could prove. Parallax would not be measured until 1838.

Full credit for the preceding quotes from Pimentel go to Luis Miguel Carolino, who presented some of this material at the Three Societies “History of Science” conference in June 2016. His translation is from a Portuguese manuscript in the Library of Congress.

CLIFFORD J. CUNNINGHAM recently joined the astronomy staff of the University of Southern Queensland.

Beyond Gravity Waves

Searching for electromagnetic counterparts of the progenitors of LIGO’s gravity waves.

On September 14, 2015, at 5:51 am Eastern Daylight Time, the Laser Interferometer Gravitational-Wave Observatories (LIGO) in Livingston, Louisiana, and Hanford, Washington, made near simultaneous detections of gravitational waves. With this historic detection, every prediction made by Einstein’s theory of relativity has now been confirmed. The event that triggered the gravitational waves was produced by a pair of gravitationally merging black holes some 1.3 billion light-years away. The arrival of gravitational waves at Livingston some seven milliseconds before Hanford gave the LIGO team enough information to establish a probability map: the waves originated from a region of space in the Southern Hemisphere in the proximity of the Magellanic Clouds.

The two black holes that merged and produced the gravity waves were roughly 30 and 36 times the mass of the Sun. About three solar masses of material were converted into gravitational-wave energy. Theoretically, the merger of two black holes in a vacuum is
not expected to produce electromagnetic radiation of any type. Nonetheless, just 0.4 seconds after the gravitational wave (GW) event, the Gamma Ray Burst Monitor on the Fermi satellite detected a one-second gamma-ray burst (GRB) emanating from a region coinciding with the 75% confidence level on the GW event-probability map.

Astrophysicist Abraham Loeb posited that the GRB and GW could have originated from the same source if a single, rapidly rotating massive star broke into two clumps with a dumbbell shaped “bar” of material between the two. The clumps each collapsed to produce a binary black hole (BH) which eventually merged while emitting GWs. An outflow from the merging binary BH could have generated the GRB. Alternatively, the final BH might have produced a jet from the accretion disk formed by the “bar” material. Either way, argues Loeb, the mass contributing to the GRB must have been quite small given the excellent agreement between the observed GW pulse and the theoretical model for binary BH mergers in a vacuum.

Loeb used numerical simulations to determine that the massive progenitor was at least 65 times the mass of the Sun (though it might have nearly double that mass). The progenitor contained an iron core of five solar masses, which split to create two BHs. Each BH then accreted additional mass from the surrounding carbon-oxygen shell, eventually attaining the 30 and 36 solar masses inferred from the observed GW pulses. The GW pulse would be produced first, as the binary BHs spiral toward one another. The GRB would follow, as it is produced after the merger.

As promising as all this sounds, there is reason for caution: the GRB detected by the Fermi instrument was not observed by the INTEGRAL satellite. Nonetheless, Loeb argues that the possibility that a binary BH merger might produce electromagnetic radiation makes it imperative that future GW detection events involve follow-up observations across the electromagnetic spectrum. For example, the radioactive decay of r-process nuclei could produce emissions in the optical and near-infrared.

Shortly after the first GW detection, one group did search for optical counterparts to the event, dubbed GW150914. They used the Dark Energy Camera on a 4-meter telescope at Cerro Tololo Inter-American Observatory. The team surveyed 11% of the probability map during three nights starting two days after the GW event. They looked for fading transient events but made no probable detections. A second GW event (GW 151226) was detected by LIGO on December 26, 2015; this was also a binary BH merger. Searches for optical counterparts to this event were conducted using the Dark Energy Camera and the Pan-STARRS1 telescope with no success. Despite the negative results, each of these searches provides important constraints on optical detection limits for future GW events.

JENNIFER BIRRIEL is Professor of Physics in the Department of Mathematics and Physics at Morehead State University in KY.
Less than a month before the end of the mission, Rosetta’s high-resolution camera has revealed the Philae lander wedged into a dark crack on Comet 67P/Churyumov-Gerasimenko. The images were taken on September 2, 2016, by the OSIRIS narrow-angle camera as the orbiter came within 2.7 kilometers of the surface and clearly show the main body of the lander, along with two of its three legs. The images also provide proof of Philae’s orientation, making it clear why establishing communications was so difficult following its landing on November 12, 2014.

“There is only a month left of the Rosetta mission, we are so happy to have finally imaged Philae, and to see it in such amazing detail,” says Cecilia Tubiana of the OSIRIS camera team, the first person to see the images when they were downlinked from Rosetta.

“A few months of work, with the focus and the evidence pointing more and more to this lander candidate, I’m very excited and thrilled that we finally have this all-important picture of Philae sitting in Abydos,” says ESA’s Laurence O’Rourke, who has been coordinating the search efforts over the last months at ESA, with the OSIRIS and SONC/CNES teams.

Philae was last seen when it first touched down at Agilkia, bounced and then flew for another two hours before ending up at a location later named Abydos, on the comet’s smaller lobe.

After three days, Philae’s primary battery was exhausted and the lander went into hibernation, only to wake up again and communicate briefly with Rosetta in June and July 2015 as the comet came closer to the Sun and more power was available.
However, the precise location was not known. Radio ranging data tied its location down to an area spanning a few tens of meters, but a number of potential candidate objects identified in relatively low-resolution images taken from larger distances could not be analyzed in detail until recently.

While most candidates could be discarded from analysis of the imagery and other techniques, evidence continued to build towards one particular target, which is now confirmed in images taken unprecedentedly close to the surface of the comet.

The discovery came less than a month before Rosetta descended to the comet’s surface. On September 30, the orbiter was sent on a final one-way mission to investigate the comet from close up, including the open pits in the Ma’at region, where it is hoped that critical observations will help to reveal secrets of the body’s interior structure. More details about finding Philae are here.

EMILY JOSEPH, Mercury’s regular Planetary Perspectives columnist, wrote the Cassini feature [page 18], and so for this issue she was released from her regular column-writing duties.

Could Proxima b Really Be Habitable?

Is life possible on this world? The answer is complicated.

The world’s attention is now on Proxima Centauri b, a possibly Earth-like planet orbiting the closest star, 4.22 light-years away. [See press releases here, here, and here.] The planet’s orbit is just right to allow liquid water on its surface, needed for life. But could it in fact be habitable?

If life is possible there, the planet evolved very differently than Earth, say researchers at the University of Washington-based Virtual Planetary Laboratory (VPL), where astronomers, geophysicists, climatologists, evolutionary biologists, and others team to study how distant planets might host life.

Rory Barnes, UW research assistant professor of astronomy, describes research underway through the UW planetary lab — part of the NASA Astrobiology Institute — to answer the question, is life possible on this world? “The short answer is, ‘It’s complicated,’” Barnes writes. “Our observations are few, and what we do know allows for a dizzying array of possibilities.”
Using computer models, the researchers [in the VPL] studied clues from the orbits of the planet, its system, its host star, and apparent companion stars Alpha Centauri A and B — plus what is known of stellar evolution — to begin evaluating Proxima b’s chances.

Relatively little is known about Proxima b:

- It’s at least as massive as Earth and may be several times more massive, and its “year” — the time it takes to orbit its star — is only 11 days.
- Its star is only 12% as massive as our Sun and much dimmer (so its habitable zone, allowing liquid water on the surface, is much closer in), and the planet is 25 times closer in than Earth is to our Sun.
- The star may form a third part of the Alpha Centauri binary star system, separated by a distance of 15,000 astronomical units, which could affect the planet’s orbit and history.
- The data hint at the existence of a second planet in the system with an orbital period near 200 days, but this has not been proven.

Perhaps the biggest obstacle to life on the planet, Barnes writes, is the brightness of its host star. Proxima Centauri, a red dwarf star, is comparatively dim, but wasn’t always so. “Proxima's brightness evolution has been slow and complicated,” Barnes notes. “Stellar evolution models all predict that for the first one billion years Proxima slowly dimmed to its current brightness, which implies that for about the first quarter of a billion years, planet b’s surface would have been too hot for Earth-like conditions.”

Next come a host of questions about the planet’s makeup, location, and history, and the team’s work toward discerning answers.

- Is the planet “rocky” like Earth? Most orbits simulated by the planetary lab suggest it could be — and thus can host water in liquid form, a prerequisite for life.
- Where did it form, and was there water? Whether it formed in place or further from its star, where ice is more likely, planetary lab researchers believe it “entirely possible” Proxima b could be water-rich, though they are not certain.
- Did it start out as a hydrogen-enveloped Neptune-like planet and then lose its hydrogen to become Earth-like? Planetary laboratory research shows this is indeed possible, and could be a viable pathway to habitability.
A Neighboring Galaxy Is Mostly Dark Matter

Astronomers “see” the unseen in a nearby galaxy.

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Our own Sun is expected to burn out in about four billion years, but Proxima Centauri has a much better forecast, perhaps burning for four trillion years longer.

“If Proxima b is habitable, then it might be an ideal place to move. Perhaps we have just discovered a future home for humanity. But in order to know for sure, we must make more observations, run many more computer simulations and, hopefully, send probes to perform the first direct reconnaissance of an exoplanet,” Barnes writes. “The challenges are huge, but Proxima b offers a bounty of possibilities that fills me with wonder.”

[Late-breaking item: “Proxima Centauri Might Be More Sunlike Than We Thought” by the Harvard-Smithsonian Center for Astrophysics.]

PETER KELLY is a writer for the Office of News & Information at the University of Washington in Seattle.

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 qs the glass half empty or half full? Whether an optimist or not, any good physicist will tell you the glass is actually completely full. The top half just happens to be filled with air.

The same might be said for Dragonfly 44. This dim galaxy has 100 times fewer stars than our Milky Way, and it looks rather empty. In fact, astronomers didn’t even know of the galaxy’s existence until last year, despite it being relatively nearby in the well-studied Coma Cluster of galaxies about 300 million light-years away.

But there’s much more than meets the eye in Dragonfly 44…quite literally. Using two powerful telescopes on the Mauna Kea summit in Hawaii — the Keck Observatory and the Gemini North telescope — astronomers have calculated that Dragonfly 44 is 99.99% dark matter.

Dark matter is a mysterious form of matter that doesn’t seem to emit or interact with electromagnetic radiation. Theorists say that about 85% of matter in the universe is dark matter. Only 15% is the “ordinary” stuff we know as protons, electrons, neutrinos and such.

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Christopher Wanjek
So, finding a nearby galaxy that’s almost entirely dark matter is exciting indeed.

How does one go about seeing what, by definition, cannot be seen? Follow the gravity.

Although Dragonfly 44 is dim, with only a fraction of the Milky Way’s starlight, it is nonetheless as massive as our galaxy. And this mass isn’t from ordinary matter. Careful measurements with infrared telescopes, for example, can rule out that the dimness is a result of copious amounts of dust simply blocking the starlight; the cool dust itself would emit infrared radiation.

This leaves dark matter as the probable culprit. A team led by Pieter van Dokkum of Yale University measured the velocity of the visible stars. How fast the stars whip around a galaxy is determined by the mass of the galaxy. The greater mass, the greater the force of gravity, and the faster the movement of stars.

“Motions of the stars tell you how much matter there is,” van Dokkum said. “They don’t care what form the matter is, they just tell you that it’s there.”

In counting the stars and measuring their velocities, it became clear that there wasn’t enough visible mass in the galaxy to explain these speeds, let alone to hold the stars in orbit. The galaxy would fly apart without the gravitational glue of a whole lot of matter… in this case, dark matter. The fact that 99.99% of the galaxy is dark matter is both a surprise and a mystery, the research team noted.

“The Gemini data show that a relatively large fraction of the stars is in the form of very compact clusters, and that is probably an important clue,” said Roberto Abraham of University of Toronto, part of the observation team. “But at the moment, we’re just guessing.”

Van Dokkum said the next step is to study this galaxy even more closely, first with the Hubble Space Telescope and, soon, with the James Webb Space Telescope. This would enable the team to measure velocities more accurately and determine the local distribution of dark matter within Dragonfly 44.

“We’ve recently upgraded the Dragonfly Telephoto Array from eight to 48 lenses, making it six times more powerful,” said van Dokkum, referring to the small telescope in New Mexico that discovered Dragonfly 44 and is dedicated to searching for similar galaxies. “We’re planning to use the upgraded array for a large survey to look for nearby examples of very faint, very large galaxies.”

CHRISTOPHER WANJEK is a Baltimore-based science writer who’s rather sure his retirement fund also seems to be about 99.99% dark matter.
Learning to See

For the upcoming solar eclipse, we need to engage learners with both eyes open, both literally and metaphorically.

Recently I had eye surgery, an event giving me a renewed appreciation for what our brains are capable of, and their elasticity in accommodating and assimilating sensory input as well as ideas. My recovery reminded me of the film shown in many classes during the 1960s, where a researcher wore a set of glasses that caused the world to appear upside down. Within a few days, the researcher’s brain inverted the image, and the world once again appeared right-side up. A couple of days later the glasses came off, and everything again was upside down. Eventually, the researcher again perceived the world as before the experiment.

In my case, a defect in my eye muscles caused them to not work properly, creating a misalignment of my eyes. The misalignment was great enough that my brain couldn’t compensate for the difference, resulting in some double vision. Minor surgery was successful at correcting my muscular imbalance, aligning my eyes so my brain is able to fuse the input from both eyes into a single image. But the fusing of these images following surgery was not instantaneous, and it took several weeks for my brain to relearn how to see and completely restore my singular perception of the world. As with babies, who need several weeks for their brains to learn how to fuse the inputs from each eye into a single image, my ability to track moving objects took longer to redevelop.

The restoration of my sight is somewhat analogous to what educators do when confronted with a learner’s lack of understanding, and perhaps misconception, of scientific principles and/or natural phenomena. An in-depth understanding and ability to thoroughly explain phenomena requires time and multiple opportunities to practice, with sustained contact with the concept for many days if not weeks. Effective teacher professional development related to natural phenomena also requires reinforcement over time.

In the case of solar and lunar eclipses, you could show someone a diagram and explain the phenomena in words, which a learner could, in all likelihood, recite verbatim back to the explainer. However, really owning the concept through cognitive accommodation and assimilation takes time and an awareness of a suite of background concepts and phenomena. These include Earth’s (and the Moon’s) rotation and revolution, and their relationship to how time is measured; shadows and light, particularly the kind of shadow cast by a spherical object illuminated by a single point source; the measurement of angular size; size and distance scale of Earth and Moon; the frequency and pattern of lunar phases; and the frequency and pattern of lunar and solar eclipses, and their relationship to lunar phases.

The learning of any one aspect of eclipse phenomena is akin to keeping one eye closed when looking at a distant object. The depth of understanding is lost, much as binocular vision, necessary for visual depth perception, is lost with one eye shut. Misconceptions — such
as lunar phases are caused by the Moon passing into Earth’s shadow, or the Moon really is larger when it rises — are similar to having both eyes open but with each eye gazing in a slightly different direction. The brain may pay greater attention to one image, while relegating the other as an annoyance to be safely ignored. Unfortunately, many misconceptions offer a stronger and perhaps more intuitive appeal, until the learner is confronted with evidence with which to dispel the misconception. It is in the fusing of all the experiences where in-depth learning and integration of a concept takes place.

As mentioned in previous Education Matters columns, the Next Generation Science Standards have provided a marvelous framework for engaging learners in the sorts of in-depth investigations necessary for fully understanding eclipses. Through the use of a storyline approach, educators can actively engage learners in each of the essential background concepts mentioned above. Using resources developed for ASP programs including the Night Sky Network, Project ASTRO, and Astronomy from the Ground Up, ASP staff have created such a storyline and are using it in workshops to help educators prepare for next year.

The total solar eclipse on August 21, 2017, is a teachable moment without compare. Taking place mid-day, on a day when many schools throughout the country are in session, it is an opportunity for educators, in and out of the classroom, to engage learners of all ages in experiences with both eyes open, both literally and metaphorically. We must take advantage of the eclipse to promote a full understanding of a phenomena that has caused wonder and bafflement for millennia. 

missing out

by Bethany Cobb

I may miss totality in 2017, but experiencing a total eclipse in 2001 was a major moment for me.

In late August, news and social media lit up with post after post proclaiming: “One Year Until the Great American Eclipse!” When I saw these posts, I experienced a mixture of emotions — excitement and disappointment. I’m excited about this fantastic event, but disappointed that in all likelihood I will not be able to see it in person.

I suspect I’m not the only astronomer or individual to feel this way. For many, including myself, planning a year in advance is simply not possible due to personal circumstances. Further, not everyone has the ability to travel the distance of even just a few states for reasons including time, money, and complex physical or family situations.

Fortunately, I have already had the opportunity to see a total solar eclipse in person. While in college, I traveled to Africa as a member of the 2001 Williams College Eclipse Expedition led by veteran eclipse researcher Jay Pasachoff. We travelled to Zambia with crates.
of equipment — including telescopes, cameras, and computers — to record and study the eclipse in an effort to better understand the solar corona.

Seeing a total solar eclipse is an experience I highly recommend! In Zambia, we were fortunate to have been gifted mostly clear weather, and the few minutes of totality were, of course, spectacular. The hours before totality were also full of excitement, and I was surprised at how remarkable the partial phase was — with the “pin holes” between the leaves casting crescents on the ground and the false dusk confusing the birds. We experienced a disappointing malfunction in one of our experiments just before totality, but successfully collected many great images of the corona.

The eclipse was a major moment for me as an undergraduate. Before traveling to Africa, I had never been outside of North America. The beauty of the eclipse was nearly matched by the other amazing experiences associated with the expedition, including a trip to Victoria Falls and driving among wild lions, elephants, and giraffes — we even got to see a rhino with its own personal anti-poacher guard. Certainly, the expedition helped to cement my interest in astronomy as a career. My love of outreach also flourished, as we had the chance to do outreach with the local community around the city of Lusaka, Zambia, particularly demonstrating how to safely observe the partial eclipse phases before and after totality.

Having seen an eclipse — and given that the whole experience was so significant to me — I know exactly what I will be missing next year, which makes me a little sad. Like many things in life, it can be difficult to accept limitations, but I’d like to focus on the positives as much as possible. Foremost, I’m excited that our country will have such a great view of this amazing astronomical event. It will give our community a perfect opportunity for outreach, allowing us to share the wonder and importance of science and astronomy.

I hope to do as much local outreach as possible leading up to the eclipse. While the D.C. area won’t glimpse totality, a significant partial eclipse will still be visible. In fact, it is a partial eclipse that the vast majority of the US will be treated to next year. Outreach to these areas is especially important, because a partial eclipse is not as obvious as totality and requires specialized equipment to observe.

I am also grateful that many astronomers and institutions across the country will be sharing the total eclipse in real time with those of us who can’t be there ourselves. On that day, I will definitely be living vicariously through others thanks to live streaming and social media.

And even if 2017 doesn’t work out, maybe 2024 will be my year.

BETHANY COBB is an Associate Professor of Honors and Physics at The George Washington University, where she studies gamma-ray bursts and teaches physics/astronomy to non-science majors.
Cassini: The Grand Finale

One year from now it will be EoM — End of Mission — for Cassini at Saturn.

By Emily Joseph

In September 2006, while passing through Saturn’s shadow, Cassini shot this 165-image mosaic of the backlit ringed world. Unless otherwise noted, all images are courtesy NASA/JPL/Space Science Institute.
In 1997, Malala Yousafzai was born in Pakistan, Comet Hale-Bopp put on a spectacular show, and a book was published in the UK about an unusual boy named Harry Potter. And on October 15, the Cassini-Huygens mission launched from Cape Canaveral, Florida, aboard a Titan IV rocket.

**In the Beginning**

After a seven-year cruise, the spacecraft reached Saturn and entered orbit on July 1, 2004. On Christmas Day 2004, the Huygens probe detached from the main spacecraft. Three weeks later it descended through the atmosphere of Saturn’s largest moon, Titan, and sent back the first images and data from the surface of a body in the outer solar system.

The original plan called for the mission to spend four years in orbit, flying by several of the planet’s moons and investigating its rings and atmosphere. In those four years, Cassini confirmed the existence of two moons originally spotted (20 years earlier) by the Voyager spacecraft and discovered several more. It found a plume of water vapor and organic material spewing from cracks in the surface of the icy moon Enceladus. Lakes and seas of methane were observed on Titan, new rings were spotted, and as is the case during any good mission of discovery, many questions were raised for every one that was answered.

**Mission Extensions**

In 2008 the team requested and received funding for a two-year mission extension dubbed the Equinox Mission, because it would allow
observations throughout the planet’s northern spring (and southern autumn) equinox. During this extension, many more details of the Enceladus plume were investigated and another tiny moon was spotted among the rings. For a few weeks around the equinox itself, sunlight hit the rings edge-on. This gave us an unprecedented opportunity to examine the vertical structure of the ring system and measure its thickness.

A second extension began in 2010 and is currently underway as Saturn’s northern hemisphere approaches summer. This Solstice Mission lengthened the mission to nearly half a Saturnian year, so we will have seen all four seasons up close before Cassini’s end — spring and summer in the north, and fall and winter in the south. We were rewarded for staying with a massive northern hemisphere storm, which encircled the entire planet and was 9,000 miles across — the largest we’ve ever been able to observe up close. The extension has also allowed for dozens more moon flybys. We’ve gathered good evidence that Enceladus’ water isn’t restricted to its plume, and we now believe there is a saltwater ocean beneath its icy surface. In

Left: At the edge of Saturn’s B ring, vertical structures tower as high as 2.5 kilometers (1.6 miles) above the ring plane, casting long shadows on the rings in this image taken two weeks before the planet’s 2009 equinox. Part of the Cassini Division, between the B and A rings, appears at the top of the image, showing ringlets in the inner division. Right: In this true-color view, a huge storm churning through the atmosphere in Saturn’s northern hemisphere overtakes itself as it encircles the planet. This picture was taken about 12 weeks after the storm began, and by this time the clouds had formed a tail that wrapped around the planet.
2014, the spacecraft completed its 100th flyby of Titan. During the course of Cassini’s mission, it has observed storms, studied aurorae, and examined atmospheric features across the planet. Both poles have unique patterns — there is a cyclone in the south, and, in the north, the winds have formed a six-sided hexagon in the clouds. Being able to observe a full half-cycle of seasons will hopefully shed some light on the unusual “weather” on this gas giant.

The last part of Cassini’s mission is known as the Grand Finale. In late November of 2016, the spacecraft will enter a high-inclination orbit that sweeps high above Saturn’s north pole and passes just outside the F ring, the thin border of the main ring system. After 20 of these orbits, the trajectory will change again, and Cassini’s final 22 circuits of Saturn will pass through the 2,000-mile gap between the inner rings and the planet’s atmosphere. On September 15, 2017, Cassini’s mission will come to an end with a swan dive into the Saturnian clouds.

Why crash a still-functioning spacecraft into a gas giant? Aliens.

How to End a Mission
A principle known as “planetary protection” was established at the dawn of the Space Age to prevent the contamination of Earth by extraterrestrial life, and, conversely, to keep Earth’s life forms from being unintentionally introduced to other worlds. Planetary protection is why the Apollo 11 astronauts, upon their return to Earth, greeted President Nixon from inside a sealed cabin — they were quarantined just in case they had brought back a lunar virus.

With Cassini’s discoveries of potentially habitable environments on several of Saturn’s moons, the NASA Office of Planetary Protection required the team to find a way to end the mission without contaminating those moons with any extremely hardy Earth microbes that could potentially still be hanging on to the spacecraft.

With this in mind, a number of alternatives were considered for the end of Cassini. The spacecraft could escape from Saturn’s orbit and travel to a new target — possibly Neptune, Uranus, Jupiter, or an asteroid. Several stable orbits within the Saturn system were also options, either around the planet itself or circling Titan. There was also the possibility of crashing, on purpose, into either a moon or the rings. These were all analyzed for their scientific value, their costs, how long they would take, and their feasibility.

While sending Cassini elsewhere sounds tempting, the travel time to a new target ranged from about three years to reach an asteroid to 40 years to get to Neptune. Even the most optimistic engineers were unsure about the spacecraft’s ability to function for several more years, let alone decades. Reaching one of the proposed stable orbits in the Saturnian system involved setting up very specific trajectories, which would require large quantities of fuel to achieve.
Eventually a plan was selected that promised the best combination of science and efficiency. It involves altering Cassini’s trajectory so it executes a series of short orbits that bring it progressively closer to the planet, and ends with the craft plunging into the atmosphere of Saturn and burning up like a meteor.

End-of-Mission Science
The science Cassini will do during its last year is literally once-in-a-lifetime, and the mission team is treating it accordingly. Each orbit is crammed full of observations by as many instruments as possible. We hope to learn a lot!

Currently, our measurement of the mass contained in Saturn’s rings has a very high uncertainty due to the difficulty in collecting accurate data on such a fragmented system. Cassini’s proximity to the rings during the Grand Finale will greatly decrease this uncertainty. In addition, new particles enter the rings as meteoroids every day, and we hope to determine the rate at which this happens. These measurements will provide a better idea of the age of the rings — and thus how they formed.

Cassini’s magnetic field and particle-studying instruments are devoting their final year to untangling the complicated magnetic, gravitational, and radiation fields around Saturn. The planet’s magnetosphere interacts with the rings, the Sun, and several of its moons in ways we do not yet fully understand. These observations will provide further clues to the internal structure and motion of Saturn.

*Upper:* Saturn’s icy rings shine in scattered sunlight in this view, which looks toward the unilluminated northern side of the rings. The Sun lights the rings from beneath (the south). Some of the sunlight not reflected from the rings’ southern face is scattered through the countless particles, setting the rings aglow. *Lower:* A moonlet, located in the outer portion of Saturn’s B ring, was found by detection of its shadow which stretches along the rings. The shadow length implies it’s protruding about 660 feet above the ring plane. If the moonlet is orbiting in the same plane as the surrounding ring material, it must be about 1,300 feet across.
Saturn and its satellites.

The remote sensing instruments — our spectrometers and cameras — will be taking the highest-resolution data we’ve ever acquired of Saturn and its rings. Some tiny “moonlets” within the rings have never been spectrally analyzed because they have always been smaller than a pixel in our instruments — no longer! While there aren’t any official “flybys” of the large moons other than Titan, there will be many opportunities to observe the icy satellites that orbit near the rings.

There are some challenges and risks in these final orbits. A particle that is a mere inch in diameter has the potential to disable Cassini either partially or completely, though nothing that large is expected to be common outside the main ring system. The planned trajectory avoids this hazard by moving from orbits outside the F ring to orbits between the D ring (the innermost ring) and the planet itself. As an added precaution, during the times when Cassini crosses the ring plane very close to the main ring system, it will be oriented with its high-gain antenna facing the craft’s direction of the motion, thereby using the large “satellite dish” as a shield for the rest of the spacecraft.

The spacecraft itself is going to be pushed to its limits. Flying closer to Saturn than we’ve ever been means Cassini is moving very quickly, making it tricky to track certain targets without violating our own rules about how fast the spacecraft is allowed to turn. Saturn itself puts out a decent amount of heat, which causes problems for the two cryogenic spectrometers on board. Usually, these instruments keep cool by pointing their radiators towards deep space, but with the planet taking up a huge chunk of the sky, that becomes harder than ever to do. The desire to pack as much as possible into the remaining orbits also means doing certain observations at less-than-ideal times, such as imaging the planet while the Sun is lurking just out of view — menacingly close to blinding our cameras.

All these observations are causing a “good” problem to have: too much data. Since Cassini has finite hard-drive space, and we downlink to Earth only every day or two, the spacecraft is often scheduled to collect more bits than can be stored and sent. This means complicated negotiations between the various instrument and science teams to determine who gets to use what hard drive space and when.
various complications offer interesting problem-solving opportunities for the mission team.

The Grand Finale
As of April 18, 2017, Cassini’s fate will be sealed. That’s the day of the final Orbital Trim Maneuver (OTM), the last time the spacecraft will fire its engines and adjust its orbit. That maneuver will set up the 126th (and final) close flyby of Titan, which will put Cassini on what is called a “ballistic trajectory” — subject only to gravity, the spacecraft will inevitably enter Saturn’s atmosphere five months later. After the OTM, even if something were to disable the spacecraft and deprive us of some science, Cassini will dive into the planet on schedule.

Usually, Cassini’s instruments record information to the on-board hard drive, and then the data is downloaded a day or two later. But during the last few hours of the mission, data will be sent back to Earth in real time. These last data will focus on the structure and composition of the upper atmosphere. The Ion and Neutral Mass Spectrometer is being given top priority in the final moments while it directly samples the atoms and ions around the spacecraft. The magnetic instruments on board will be measuring the field lines connecting the atmosphere to the rings, and the other plasma and dust analyzers will be sending back whatever they can.

Once Cassini enters Saturn’s atmosphere, drag from the thickening gas will pull on the spacecraft, and as it turns away from Earth, we will cease to be in radio contact. This is called “LOS” — loss of signal — and will mark the end of one of the most successful missions ever, just a few weeks shy of its 20th birthday.

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Saturn’s northern hemisphere in 2016, as that part of the planet nears its summer solstice in May 2017. The images used to make this mosaic were obtained just prior to the beginning of a 44-hour movie sequence. Cassini will complete its mission just after northern summer solstice.
Eclipse Bulletin:
Total Solar Eclipse of 2017 August 21

I regard this book as essential reading at any time prior to Eclipse 2017.

Review by Joe Rao
Editor’s Note: Book reviews don’t normally run in Mercury, but this is the exception to the rule. With the 2017 solar eclipse less than a year away, this Eclipse Bulletin is one book every potential totality chaser should be aware of. The review first appeared on GreatAmericanEclipse.com and is reprinted with permission.

There can be no denying the value of this book. Fred Espenak — better known to eclipse chasers around the globe as “Mr. Eclipse” — is the established authority on eclipse calculations. Before he retired from NASA/Goddard, he published 13 similar eclipse bulletins (with coauthor Jay Anderson) between 1993 and 2008. This latest bulletin was published sans NASA funding and is by far the biggest and most extensive eclipse circular that he has ever produced. Amateur astronomers even vaguely interested in the subject of eclipses should have come across his work by now. If not, now is the time to start.

The title accurately describes the aims and objectives. Anybody who intends to witness firsthand the long-awaited 2017 “All American Eclipse” may have already given some thought as to where they intend to be on eclipse day, but I would regard this book as essential reading at any time. If, for example, on eclipse day I’m driving along an unfamiliar road within the path of totality, I would want this book within arm’s reach.

Weather Considerations
As a broadcast meteorologist and eclipse chaser with 11 totalities under my belt, I always consider the first problem (apart from money) as being how to deal with the weather prospects. Few have the necessary expertise to make a balanced judgment, and that is where this book is particularly valuable. Jay Anderson, formerly with Environment Canada (Canada’s national meteorological service) has written extensively on the climatology of places along eclipse tracks for nearly four decades and is eminently suited to be your guide. As such, much space is devoted to the merits of each practical region along the totality path.

Each region is treated to a detailed critique, finishing with some specific recommendations. Anderson, however, goes further than that, to list statistics on the climate and then summarize them in the form of diagrams, maps, graphs and tables. I especially found the tables containing cloud-cover statistics most valuable.

Over the years, I’ve used a simple formula which provides a representative percentage value for the chance of seeing the Sun in a blue sky. For this I use the average percentage of total cloudiness, as well as the percentages of a clear and partly cloudy sky. Usually, I’ve had to dredge these statistics up on my own, but Anderson’s tables have saved me the work. Of the 38 locations within the totality path, my own subjective percentages ranged from a high of 85.1 for Ontario, Oregon, to a low of 43.8 for Charleston, South Carolina.

Of course one must also remember that any statistical climate
analysis is not absolute, as is evidenced by the oft-quoted axiom by the late Robert Heinlein: “Climate is what you expect; weather is what you get.” — as so many who headed to the Big Island of Hawaii in 1991 painfully learned!

I particularly enjoyed the travelogue section dealing with the trip along the umbral path undertaken by Anderson and fellow Canadian Stan Runge. I got a chuckle out of the anecdote concerning the owner of the farm closest to the point of greatest eclipse in Kentucky. According to the unnamed owner, he already is getting dozens of people who visit his property each week “looking for the eclipse track.” When Anderson told him that he’ll have “quite a crowd” on eclipse day, the owner replied: “Maybe I’ll let my grandkids set up a lemonade stand. Except the bureaucrats will want them to get a license.”

There are 21 detailed maps of the umbral path in the book; this one shows western Oregon. The duration of totality is marked in 30-second intervals. [Espenak and Anderson]

Here is something which should be looked upon not as a criticism but a suggestion. The possibility of a tropical cyclone when speaking of weather prospects for South Carolina and its adjacent coastal waters was not considered. While the odds for a full-blown tropical storm or hurricane situated near the South Carolina coast exactly on August 21 is rather small, the prospects for any sort of tropical system does increase rapidly after August 1 and “E-day” comes only 20 days before the traditional peak of hurricane season in the Atlantic basin.

Recent systems that have passed relatively close to South Carolina in late August/early September include “Irene” (8/27/11), “Hanna” (9/6/2008), “Ernesto” (8/31/2006), and “Gaston” (8/29/2004). Of course, nobody in Charleston will ever forget Hurricane “Hugo” (a Category 3) which scored a direct hit there, albeit in late September (9/22/89). However, even a tropical system that makes landfall hundreds of miles away (say, along the Gulf Coast) might adversely
impact the totality zone by spreading clouds and remnant rains to the north and east into the eclipse path.

**Plenty of Information**

The remainder of the book is crammed with tons of information on the 2017 eclipse and how to predict the shadow path, how the saros (#145) has changed over time and how it compares with other cycles, and much, much more. About three dozen maps depicting the totality path as well as the visibility zone of the entire eclipse are included. I *love* the stereographic projection map on page 13. Now if only concentric contours for the semi duration of the partial phases — a personal preference — could also be added. The United States Naval Observatory (USNO) has always used stereographic projection for their eclipse maps, but discontinued the practice of depicting semi durations in 1983.

Local circumstances for more than 1,000 cities across North America as well as northern South America, northwest Africa, and Western Europe are provided, with times for each phase of the eclipse along with the eclipse magnitude, obscuration value, and Sun’s altitude. For any specific location that has not been listed, a good compromise can be obtained by means of simple interpolation. For those places inside the eclipse track, the duration of totality is provided as well as the umbral depth.

It is good that on page 32, Espenak explains the reason why the *Eclipse Bulletin* departs from the International Astronomical Union (IAU) convention, adopted in August 1982, of using a slightly larger value for the mean lunar radius, noting that to employ it “…guarantees that some annular or annular-total eclipses will be misidentified as total.” (A good case in point would be the eclipse of November 3, 2013.) As such, the 2017 *Eclipse Bulletin* adopts a smaller value, which produces a shorter central duration and a narrower path of totality. This explanation is important for those who decide to utilize the eclipse predictions by the USNO, which bases its computations on the IAU’s larger value.

There is a section providing valuable tips on eclipse photography and perhaps most important of all for eclipse neophytes, a section concerning eye safety, written by Dr. Ralph Chou, Professor Emeritus, School of Optometry and Vision Science at the University of Waterloo in Ontario, Canada. It was Dr. Chou’s pioneering research into the effects of solar radiation on the eye that confirmed that aluminized Mylar was safe and effective for use in observing solar eclipses, and which helped lead to its widespread adoption by the astronomical community, and therefore, by the public at large. Notes Espenak: “Dr. Chou’s contribution should help dispel much of the fear and misinformation about safe eclipse viewing.”

Oregon’s topography along the eclipse track. Seven such maps are included the book. [Espenak and Anderson]
Concluding Comments

The *Eclipse Bulletin* finishes with a thorough bibliography as well as a chapter titled “Eclipse Marketplace,” which provides a listing of products for safely viewing the Sun and solar eclipses as well as companies who will be running eclipse tours for the August 2017 event.

In any book of this detailed statistical nature, it is to be expected that there will be typographical errors. While there may be some who delight in finding such things, that effort should not be allowed to detract from the true value of this book.

I ran across a couple of very minor typos, but as Espenak recently commented: “One of the great things about the print-on-demand process I’m using for the 2017 *Eclipse Bulletin* is that I can make corrections and updates to the manuscript whenever necessary.” So the typos I found in my copy are likely to be gone for anyone who now purchases their own copy.

In fact, to augment the plethora of data already provided, Espenak has created an extras webpage, which contains links to additional tables, information and yes…errata.

Lastly, I was happy that in the Acknowledgements, Espenak gave a “shout out” to the great Belgian celestial mechanic, Jean Meeus, who stimulated many of us into the world of eclipse calculations with his 1966 classic *Canon of Solar Eclipses*. Indeed, without Meeus’ incentive, the 2017 *Eclipse Bulletin* might not exist.

What more can I say? If you plan to “bask in the shadow of the Moon” in 2017, this book is for you!

About the Book Authors

Fred Espenak is a retired NASA astrophysicist and was the agency’s expert on solar and lunar eclipse predictions. Known as “Mr. Eclipse,” he is the author of numerous books including *Totality – Eclipses of the Sun* and *Thousand Year Canon of Solar Eclipses*.

Espenak’s [www.MrEclipse.com](http://www.MrEclipse.com) website focuses on eclipse photography, while his new [www.EclipseWise.com](http://www.EclipseWise.com) website contains more than 5,000 years of eclipse predictions. An avid eclipse chaser, he has participated in dozens of eclipse expeditions around the world to remote locations such as the Sahara, the Bolivian altiplano, and Antarctica. Now living in rural Arizona, he spends most clear nights losing sleep and photographing the stars from Bifrost Observatory.

Jay Anderson is a meteorologist, formerly with the Meteorological Service of Environment Canada. Astronomy has been a large part of his life since his mid-teens, and it was only after graduating with a degree in Physics and Astronomy from the University of British Columbia that he adopted meteorology as a second pastime.

He has written on the climatology of places along eclipse tracks since 1978, when a solar eclipse was predicted to pass over his home town. He still lives in that home town (Winnipeg) with his wife Judy and an assortment of past and present cats. Anderson’s eclipse-weather website is [http://eclipsophile.com](http://eclipsophile.com).

Joe Rao is one of the best-known broadcast meteorologists in the northeastern United States; his career in weather casting spans nearly four decades. He’s also an associate astronomer at the American Museum of Natural History’s Hayden Planetarium and has witnessed 11 totalities.

The beach at Lincoln City, Oregon, on eclipse day in 2013. [Jay Anderson]
For Better or Worse: Reflections of an Eclipse-Chasing Family

Once you experience the rush of totality during a solar eclipse, you are forever trying to recapture it.

By Richard H. Durisen, Annamaria Mecca, and Michael V. M. Durisen

On March 7, 1970, Zolt Levay saw totality from beautifully clear Virginia Beach, Va. This image was taken on Kodak Tri-X film with his first SLR camera, a Minolta SRT-101, attached to his homemade 6-inch reflecting telescope. [Courtesy Zolt Levay.]
Haiku by M.V.M Durisen

High noon becomes night,
Shadows taunt frightened creatures,
The Sun held captive.

Among the natural events that human beings can witness, the total phase of an eclipse of the Sun is one of the most spectacular and deeply moving. In any solar eclipse, there is only a narrow ribbon, if any, where the umbra of the Moon’s shadow touches Earth’s surface. There and only there, for a few precious minutes, does the Moon completely block the solar photosphere, the surface layer of gases from which most of the Sun’s light escapes. Although this “path of totality” can be many thousands of kilometers long, it is never more than 270 kilometers wide. Outside the path, over a much larger area of Earth, the Moon only blocks the view of part of the photosphere. As a result, many people can see a partial solar eclipse without effort. There is a universe of difference, however, between the experiences of seeing a partial eclipse and seeing totality. At every eclipse for which totality occurs, there are people who will go out of their way to place themselves somewhere along the umbral path. As a family, we have become such “eclipse-chasers.” The following personal reflections may help you to understand some of the rewards and frustrations of this avocation.

March 7, 1970
RICHARD: On March 7, 1970, while I was an astrophysics graduate student at Princeton, a solar eclipse occurred for which the path of totality grazed land along the US East Coast. With thermoses of coffee, ruffled road maps, and an issue of Sky & Telescope containing eclipse path details, I drove south from New York City on the day of the eclipse with two astronomy postdocs from Columbia University. About a half hour before totality, we stopped on a country road in North Carolina where a few dozen amateurs had set up cameras and telescopes alongside a tobacco field. Intellectually, I knew what I would see, but when the photosphere disappeared and the Sun became a pearly corona surrounding a pitch black disk, something deep inside me responded with a profound awe. It was about the closest thing I have ever had to a “religious” experience. The fabric of my everyday reality was ripped asunder momentarily to reveal an unsuspected underlying majesty. I have before and since seen various lunar eclipses, several partial solar eclipses, and even one annular solar eclipse; but nothing compares to the haunting beauty of a total eclipse of the Sun.

Anna and I met shortly after I joined the faculty at Indiana University in 1976. During the course of those wonderful exploratory conversations that begin a relationship, I found out that she had lived in Hawai‘i. I shared my eclipse experiences and mentioned that there would be an exceptional solar eclipse in July 1991, where the path of totality would pass across the Big Island. We promised, in all seriousness, that, regardless of the status of our relationship 15 years later, we would meet in Hawai‘i to see the eclipse together.

Of course, our romantic notions at the time did not include having our seven-year-old son (Michael) with us, but as 1991 approached, we made plans. A cosmic event in paradise! How could we miss it? Well, we almost did, despite positioning ourselves on the Saddle Road below Mauna Kea Observatory, within sight of the (then) new Keck telescope dome. According to cloud cover records, this should have given us the best possible chance of good weather.

July 11, 1991
ANNA: I loved the idea of meeting in Hawai‘i for a solar eclipse. I knew I would do it, no matter where I was in the world, or whatever I
was doing. I never imagined we would actually still be together and have a young son in tow. Having never seen a total solar eclipse, I didn’t know what to expect. I was surprised at how anxious Richard became as the day approached. We made our preparations and drove at night from our hotel in Kona to the other side of the island to wait in the car for the Sun to rise partially eclipsed. I was pretty relaxed, but Richard was pacing and watching the sky most of the night.

MICHAEL: We had been in Hawai‘i for a week already, indulging in the luxuries of a sun-warmed paradise and almost forgetting our reason for being there. Every day we bathed in the radiant heat of the sun. The day before the eclipse, my family drove up the side of the volcano to a place that was supposed to be the best for viewing this spectacular show. Being a young child, I was as excited about the idea of sleeping in the car for the night as I was about the eclipse. I couldn’t wait to tell my friends when we got home.

The next morning my Dad woke me up with as much enthusiasm as a 10-year-old at Christmas.

ANNA: Clouds formed and grew thicker throughout the night and early morning. We saw some of the partial phases, but as totality approached the Sun became obscured. Here we were in Hawai‘i, where the Sun always shines. We’d waited and planned this event for 15 years. Were we going to miss totality because of cloud cover? I couldn’t believe this would happen to us. Meanwhile, I noticed local people were in their cars, just driving to work as if nothing was happening. The only indication that they knew the eclipse was in progress was that they had their headlights on. How could they ignore such a monumental event?

MICHAEL: Because my Dad is an astronomer, he was ecstatic about this event. His energy was overwhelming. It was a cloudy day, and that just made matters worse. Ironically, we went to a place renowned for good morning Sun, just to find it covered up. Every time a cloud covered the Sun my Dad would say, “Guess we might not see it,” in a very solemn tone, and then he perked up the second the Sun showed its shining face again.

It was almost time for the Moon to cover the Sun completely, and it had clouded over again. My Dad, bordering on hysteria, was very disappointed and tried to get us to hop in the car and find a better spot. Finally, he piled us in, and we drove around the mountain. With our situation not improving, he gave up.

ANNA: In the end, we returned to the same place we were originally, A post-totality family portrait in Hawai‘i taken July 11, 1991, in the light of the partially eclipsed Sun. [Courtesy the authors.]
convinced we would miss totality. Just moments before second contact, however, the clouds near the Sun parted. We experienced the entire four minutes. Now I understood what a spectacular event this is. I was touched to my core. This felt important, primal. I was seeing light as I'd never seen it before, a stillness, beauty. My senses, all on high alert, knew everything coming in was unique. I stood in awe, experiencing a power in our universe like no other.

**RICHARD:** During totality, I remember scanning the horizon — a complete ring of peculiar twilight. I spent a lot of the total phase viewing pink-purple prominences around the Sun’s limb with binoculars. Toward the end of the eclipse, I saw a thin sliver of chromosphere emerge from behind the Moon’s limb. I was sure of this, because it was about the same color and light intensity as the prominences. I recall thinking excitedly, “Wow, that’s the chromosphere.”

Then, a split second later, I realized that this meant the photosphere would not be far behind. I lowered my binoculars immediately and told my family to do the same just in time to see a spectacularly beautiful “diamond ring” when the first bit of photosphere appeared. Almost simultaneously, I glimpsed the Moon’s umbra in the cloud cover racing away to the east.

**MICHAEL:** Near totality, an eerie light began to cover the mountain. The light was darker than twilight but lighter than night. It was the most unearthly light I have ever seen in my life. The energetic chirping of the birds ceased the minute the light began to change. Earth around me fell silent, and it was like a blanket had been laid over the Sun. Then the clouds opened up, and I was awestruck. What I saw was without a doubt the most beautiful thing I had ever seen. It was like someone had shot a hole through the Sun. Brilliant streaks of fire could be seen sticking out from the black hole the Moon created in the center of the Sun. Most of the people around us were staring silently at the celestial wonder.

When the light returned and the Moon retreated from its position, people were a buzz of commotion. Everyone had big smiles on their faces and seemed filled with a sense of satisfaction I had never seen in people before. This was one of the most amazing sights I believe I will ever witness in my life, and the emotion I experienced was like no other emotion I had felt before.

**August 11, 1999**

**RICHARD:** The successful total eclipse in Hawai’i created an appetite in us for more, but we were not (yet) fanatics. We were not willing to brave difficult travel, wilderness, or civil wars. Our eclipse planning was guided in part by considerations of cost, comfort, and convenience. After Hawai’i, our next likely target proved to be 1999’s eclipse where totality swept across Europe.

During the 1990s, I happened to establish some strong research collaborations and friendships with scientists in Munich, Germany, right along the path of totality. We knew the weather would be iffy, but that is always the case with eclipse chasing, hence the title of...
this piece. Just as our luck was “better” for the Hawai‘i eclipse, it was “worse” for the Munich one. In the weeks preceding the eclipse, the weather was terrible. I found myself looking up at the sky often, every day, and thinking, “If totality were now, would I see it?” All too often, the answer was “no” (overcast) or “probably not” (mostly cloudy).

ANNA: I wasn’t calm this time. Now I knew what missing the eclipse meant. Having lived in Munich before, I felt a sense of doom. The weather in Munich is terrible. I kept asking myself why I was setting myself up for disappointment, but deep inside I held hope. I really wanted to experience another total solar eclipse. We watched the weather for days. Each day had both rain and Sun.

We decided on eclipse day to go with only our binoculars to the English Garden, a huge park just a few blocks from our Munich apartment. We again saw portions of the early partial phases, with thousands of people cheering around us. Then the clouds came. We moved to a different place in the park, chasing a hole in the clouds. It started to pour. We sought shelter under a tree and exchanged eclipse stories with two other Americans. When the rain subsided, we emerged and plotted a final strategy. It didn’t look good.

MICHAEL: Even though I really wanted to see totality again, I didn’t worry as the clouds moved in and out. Things were happening pretty much the same way they did in Hawai‘i, and we had been successful then. I couldn’t help feeling that, because I had taken the trouble to be in the path of totality, I would see it. I was so calm that, when it wasn’t raining and we weren’t running to chase holes in the clouds, I just sat and read a book of Dilbert comics.

RICHARD: There were many layers of clouds. We had the Sun positioned in a hole through the high clouds, but minutes before totality, a small, low, dark cloud raced toward us from the horizon like an angel of darkness — and covered the Sun. To add insult to injury, it rained again. Later we were told that just a kilometer or two away people had been able to see the total phase. It was hard to feel happy for them. We were so upset that, even though we already knew we were going to write this article, we forgot to have someone take a family picture at the event.

ANNA: All we could do at this point was look at our watches and imagine what we were missing. It got very dark and very still. Many around us were excited to experience these aspects of totality, but it
was hard for me to appreciate them. I felt too much disappointment. I had to know when the next total solar eclipse would be. I was a believer. I had to have more. Could we see another one? Where? When? I could even wait another 15 years, if I had to. Seeing totality is worth it.

MICHAEL: I was not very happy with the universe after missing totality in Munich, and now I am even more hungry to see it again. I'd go out of my way to see a total solar eclipse, even though I would again be crushed if I didn't see totality.

RICHARD: Unfortunately, the eclipses of the next decade tend to be in somewhat less hospitable and more distant places, such as the Arctic, the Antarctic, Central or Southern Africa and Asia, and, of course, various oceans. We may have to opt for a cruise or an exotic vacation to catch one of these, because the next total solar eclipse in the US is not until August 21, 2017.

**August 21, 2017**

**Update:** After the 1999 Munich eclipse, our family stopped actively chasing solar eclipses. However, because we all live in Bloomington, Indiana, and since the 2017 path of totality passes nearby, we plan to track the weather carefully in the week leading up to the eclipse. Early on the day of the eclipse, we'll hop in a van and head for the most promising location within about a three-hour driving radius.

For the August 11, 1999, eclipse, Philippe Duhoux chose a hill located about 10 kilometers northwest of Garching (just north of Munich). While the partial phase was mostly cloudy, the sky went clear three minutes before the totality and remained so for about 15 minutes. (Philippe Duhoux, ESO)

This article first appeared in the March-April 2000 issue of *Mercury*. At that time, RICHARD H. DURISEN was a Professor of Astronomy at Indiana University (IU) in Bloomington, ANNAMARIA MECCA supervised the clinical training of graduate students in Speech Pathology as a faculty member in the Department of Speech and Hearing Sciences at IU, and their son MICHAEL V. M. DURISEN was a sophomore at Bloomington High School South.

Richard retired in 2010 and is now a Professor Emeritus of Astronomy at IU. Annamaria, though mostly retired, works part time at IU’s Early Childhood Center. Michael teaches Yoga and Martial Arts at IU and trains protection dogs.
**Ceres’ Geological Activity Revealed in New Research**  
*NASA/JPL-Caltech*

A lonely 3-mile-high (5-kilometer-high) mountain on Ceres is likely volcanic in origin, and the dwarf planet may have a weak, temporary atmosphere. These are just two of many new insights about Ceres from NASA’s Dawn mission published in six papers in *Science*.

Ahuna Mons is a volcanic dome unlike any seen elsewhere in the solar system, according to a new analysis led by Ottaviano Ruesch of NASA’s Goddard Space Flight Center and the Universities Space Research Association. Ruesch and colleagues studied formation models of volcanic domes, 3-D terrain maps and images from Dawn, as well as analogous geological features elsewhere in our solar system. This led to the conclusion that the lonely mountain is likely volcanic in nature. Specifically, it would be a cryovolcano — a volcano that erupts a liquid made of volatiles such as water, instead of silicates.

While Ahuna Mons may have erupted liquid water in the past, Dawn has detected water in the present, as described in a study led by Jean-Philippe Combe of the Bear Fight Institute. Combe and colleagues used Dawn’s visible and infrared mapping spectrometer to detect probable water ice at Oxo Crater, a small, bright, sloped depression at mid-latitudes on Ceres.

A surprising finding emerged in the paper led by Chris Russell, principal investigator of the Dawn mission: Dawn may have detected a weak, temporary atmosphere. Dawn’s gamma ray and neutron (GRaND) detector observed evidence that Ceres had accelerated electrons from the solar wind to very high energies over a period of about six days. In theory, the interaction between the solar wind’s energetic particles and atmospheric molecules could explain the GRaND observations.

The dwarf planet’s various crater forms are consistent with an outer shell for Ceres that is not purely ice or rock, but rather a mixture of both — a conclusion reflected in other analyses.
Methane-Filled Canyons Line Titan’s Surface

American Geophysical Union

Liquid methane-filled canyons hundreds of meters deep with walls as steep as ski slopes etch the surface of Titan, researchers report in a new study. The new findings provide the first direct evidence of these features on Saturn’s largest moon, and could give scientists insights into Titan’s origins and similar geologic processes on Earth.

New Cassini radar observations of Titan’s north pole depict cavernous gorges a little less than a kilometer (less than a half-mile) wide with walls up to 570 meters (1870 feet) tall — about 30 meters (98 feet) higher than New York’s Freedom Tower. The eight canyons branch off from Vid Flumina, a more than 400-kilometer (250-mile) long river flowing into Titan’s second-largest sea, Ligeia Mare. The new data confirm the canyons are filled with flowing methane — a feature researchers had suspected but not directly observed, according to the study’s authors.

The new findings suggest the canyons were likely carved by liquid methane draining into Vid Flumina, a process similar to the carving of river gorges on Earth, according to the study’s authors. The new research could help scientists better understand these geological processes, they said.

“These are processes we need to totally understand because they can shed deeper light on our own planet,” said Valerio Poggiali, a planetary scientist at the La Sapienza University of Rome, Italy, and lead author of the study.
Pluto ‘Paints’ its Largest Moon Red

In June 2015, when the cameras on NASA’s approaching New Horizons spacecraft first spotted the large reddish polar region on Pluto’s largest moon, Charon, mission scientists knew two things: they’d never seen anything like it elsewhere in our solar system, and they couldn’t wait to get the story behind it.

Over the past year, after analyzing the images and other data that New Horizons has sent back from its historic July 2015 flight through the Pluto system, the scientists think they’ve solved the mystery. Charon’s polar coloring comes from Pluto itself — as methane gas escapes from Pluto’s atmosphere and becomes “trapped” by the moon’s gravity and freezes to the cold, icy surface at Charon’s pole. This is followed by chemical processing by ultraviolet light from the Sun that transforms the methane into heavier hydrocarbons and eventually into reddish organic materials called tholins.

The New Horizons team dug into the data to determine whether conditions on the Texas-sized moon (with a diameter of 753 miles or 1,212 kilometers) could allow the capture and processing of methane gas. The models using Pluto and Charon’s 248-year orbit around the Sun show some extreme weather at Charon’s poles, where 100 years of continuous sunlight alternate with another century of continuous darkness. Surface temperatures during these long winters dip to -430 Fahrenheit (-257 Celsius), cold enough to freeze methane gas into a solid.
Supernova Ejected From the Pages of History

_Chandra X-ray Observatory_

A new look at the debris from an exploded star in our galaxy has astronomers re-examining when the supernova actually happened. Recent observations of the supernova remnant called G11.2-0.3 with NASA’s Chandra X-ray Observatory have stripped away its connection to an event recorded by the Chinese in 386 CE.

Historical supernovas and their remnants can be tied to both current astronomical observations as well as historical records of the event. Since it can be difficult to determine from present observations of a remnant exactly when a supernova occurred, historical supernovas provide important information on stellar timelines. Stellar debris can tell us a great deal about the nature of the exploded star, but the interpretation is much more straightforward given a known age.

New Chandra data on G11.2-0.3 show that dense clouds of gas lie along the line of sight from the supernova remnant to Earth. Infrared observations with the Palomar 5-meter Hale Telescope had previously indicated that parts of the remnant were heavily obscured by dust. This means that the supernova responsible for this object would simply have appeared too faint to be seen with the naked eye in 386 CE. This leaves the nature of the observed 386 CE event a mystery.

Taking advantage of Chandra’s successful operations since its launch into space in 1999, astronomers were able to compare observations of G11.2-0.3 from 2000 to those taken in 2003 and more recently in 2013. This long baseline allowed scientists to measure how fast the remnant is expanding. Using this data to extrapolate backwards, they determined that the star that created G11.2-0.3 exploded between 1,400 and 2,400 years ago as seen from Earth.

Previous data from other observatories had shown this remnant is the product of a “core-collapse” supernova, one that is created from the collapse and explosion of a massive star.

MORE INFORMATION

Although this Chandra image appears to show the supernova remnant G11.2-0.3 has a very circular, symmetrical shape, the details of the data indicate that the gas that the remnant is expanding into is uneven. [X-ray: NASA/CXC/NCSU/K.Borkowski et al; Optical: DSS.]
Spiral Arms Embrace Young Star
_National Radio Astronomy Observatory_

Swirling around the young star Elias 2-27 is a stunning spiral-shape pinwheel of dust. This striking feature, seen with the Atacama Large Millimeter/submillimeter Array (ALMA), is the product of density waves — gravitational perturbations in the star’s protoplanetary disk that produce sweeping arms reminiscent of a spiral galaxy, but on a much smaller scale.

“These observations are the first direct evidence for density waves in a protoplanetary disk,” said Laura Pérez, an astronomer and Alexander von Humboldt Research Fellow with the Max Planck Institute for Radio Astronomy in Bonn, Germany.

Previously, astronomers noted compelling spiral features on the surfaces of protoplanetary disks, but it was unknown if these same spiral patterns also emerged deep within the disk where planet formation takes place. ALMA, for the first time, was able to peer deep into the mid-plane of a disk and discover the clear signature of spiral density waves.

Nearest to the star, ALMA found a familiar flattened disk of dust, which extends past what would be the orbit of Neptune in our own solar system. Beyond that point, ALMA detected a narrow band with significantly less dust, which may be indicative of a planet in formation. Springing from the outer edge of this gap are two sweeping spiral arms that extend more than 10 billion kilometers away from their host star.

Elias 2-27 is located approximately 450 light-years from Earth in the Ophiuchus star-forming complex. Even though it contains only about half the mass of our Sun, this star has an unusually massive protoplanetary disk. The star is estimated to be at least one million years old and still encased in its parent molecular cloud, obscuring it from optical telescopes.

**MORE INFORMATION**
Rare Fossil Relic of Early Milky Way Discovered
Keck Observatory

A fossilized remnant of the early Milky Way harboring stars of hugely different ages has been discovered by an international team of astronomers. This stellar system, located in the galactic bulge, has the appearance of a globular cluster, but it is like no other cluster known. It contains stars remarkably similar to the most ancient stars in the Milky Way but also a significant population of young stars, thus bridging the gap in understanding between our galaxy’s past and its present. The research presents a possible route for astronomers to unravel the mysteries of galaxy formation, and offers an unrivaled view into the complicated history of the Milky Way.

The system, called Terzan 5, has been classified as a globular cluster since its discovery 40 years ago. Now, an Italian-led team of astronomers has discovered that Terzan 5, which is 19,000 light-years from Earth, is like no other globular cluster known. The team found compelling evidence there are two distinct kinds of stars in Terzan 5, which not only vary in the elements they contain, but have an age-gap of roughly 7 billion years.

“The finding was so surprising, we decided to double check it by using the 10-meter telescope at Keck Observatory and ESO’s Very Large Telescope,” said Francesco Ferraro from the University of Bologna, Italy, and lead author of the study. “Thus in August 2010, thanks to the long-standing collaboration with Prof. Rich from UCLA, we secured ultra-deep K-band images of another portion of the cluster. These data have been crucial to solidly determine the age of the two stellar populations.

“Back in 2009 we discovered that Terzan 5 harbored two sub-populations of stars with different chemical abundances: after seven years of research we finally succeeded in dating these populations,” he said. The ages of the two populations indicate that the star formation process in Terzan 5 was not continuous, but dominated by two distinct bursts of star formation.
ALMA Explores the Hubble Ultra Deep Field

European Southern Observatory

In 2004 the Hubble Ultra Deep Field (HUDF) images — pioneering deep-field observations with the NASA/ESA Hubble Space Telescope — were published. These spectacular pictures probed more deeply than ever before and revealed a menagerie of galaxies stretching back to less than a billion years after the Big Bang. The area was observed several times by Hubble and many other telescopes, resulting in the deepest view of the universe to date.

Astronomers using ALMA have now surveyed this seemingly unremarkable, but heavily studied, window into the distant universe for the first time both deeply and sharply in the millimeter range of wavelengths. This allows them to see the faint glow from gas clouds and also the emission from warm dust in galaxies in the early universe.

One team led by Jim Dunlop (University of Edinburgh, UK) used ALMA to obtain the first deep, homogeneous ALMA image of a region as large as the HUDF. This data allowed them to clearly match up the galaxies that they detected with objects already seen with Hubble and other facilities.

This study showed clearly for the first time that the stellar mass of a galaxy is the best predictor of star formation rate in the high redshift universe. They detected essentially all of the high-mass galaxies and virtually nothing else.

Jim Dunlop, lead author on the deep imaging paper, sums up its importance: “This is a breakthrough result. For the first time we are properly connecting the visible and ultraviolet light view of the distant universe from Hubble and far-infrared/millimeter views of the universe from ALMA.”

“We conducted the first fully blind, three-dimensional search for cool gas in the early universe,” said Chris Carilli, an astronomer with the National Radio Astronomy Observatory in Socorro, New Mexico, and member of the research team. “Through this, we discovered a population of galaxies that is not clearly evident in any other deep surveys of the sky.”

MORE INFORMATION
Hubble Reveals Observable Universe Contains 10 Times More Galaxies Than Previously Thought

*Space Telescope Science Institute*

The universe suddenly looks a lot more crowded, thanks to a deep-sky census assembled from surveys taken by NASA’s Hubble Space Telescope and other observatories. Astronomers came to the surprising conclusion that there are at least 10 times more galaxies in the observable universe than previously thought. This places the universe’s estimated population at, minimally, 2 trillion galaxies.

In analyzing the data, a team led by Christopher Conselice (University of Nottingham, UK), found that 10 times as many galaxies were packed into a given volume of space in the early universe than found today. Most of these galaxies were relatively small and faint, with masses similar to those of the satellite galaxies surrounding the Milky Way. As they merged to form larger galaxies the population density of galaxies in space dwindled. This means that galaxies are not evenly distributed throughout the universe’s history.

“These results are powerful evidence that a significant galaxy evolution has taken place throughout the universe’s history, which dramatically reduced the number of galaxies through mergers between them — thus reducing their total number. This gives us a verification of the so-called top-down formation of structure in the universe,” explained Conselice.

One of the most fundamental questions in astronomy is that of just how many galaxies the universe contains. The landmark Hubble Deep Field, taken in the mid-1990s, gave the first real insight into the universe’s galaxy population. Subsequent sensitive observations such as Hubble’s Ultra Deep Field revealed a myriad of faint galaxies. This led to an estimate that the observable universe contained about 100 billion galaxies. The new research shows that this estimate is at least 10 times too low.

MORE INFORMATION

This HST view reveals thousands of galaxies stretching back into time across billions of light-years of space. The image covers a portion of a large galaxy census called the Great Observatories Origins Deep Survey (GOODS). [NASA/ESA/the GOODS Team, and M. Giavalisco (U of Massachusetts, Amherst)]

Deep Field, taken in the mid-1990s, gave the first real insight into the universe’s galaxy population. Subsequent sensitive observations such as Hubble’s Ultra Deep Field revealed a myriad of faint galaxies. This led to an estimate that the observable universe contained about 100 billion galaxies. The new research shows that this estimate is at least 10 times too low.
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Dr. Katherine Johnson Receives ASP’s New Arthur B.C. Walker II Award

Dr. Katherine Johnson, the NASA mathematician who calculated and verified the trajectories that took the first Americans into space and to the Moon, is the inaugural recipient of the Astronomical Society of the Pacific’s Arthur B.C. Walker II Award. The Arthur B.C. Walker II Award recognizes outstanding achievement by an African American in astronomy as well as for actively promoting diversity in science. Dr. Johnson’s family accepted the award on her behalf on October 22, 2017, during the ASP’s Annual Award Gala in Burlingame, California.

Katherine Coleman Goble Johnson (born August 26, 1918) is a space scientist and mathematician who made major contributions to aeronautics for NASA’s space programs from 1953 to 1986. Known for the accuracy of her orbital calculations, she determined the trajectories for Project Mercury and the 1969 Apollo 11 flight to the Moon. When NASA used electronic computers for the first time to calculate John Glenn’s orbit around Earth, Glenn insisted that she verify the computer’s numbers.

NASA dedicated the Katherine G. Johnson Computational Research Facility at the Langley Research Center in Hampton, Virginia, on May 5, 2016. This occurred on the 55th anniversary of Alan Shepard’s historic rocket launch and splashdown, which Katherine Johnson helped make possible through her orbital calculations. After retiring from NASA, Dr. Johnson dedicated herself to inspiring young people to pursue careers in science, mathematics, and engineering.

About Arthur B.C. Walker II. Arthur B.C. Walker II (1936 – 2001), Professor of Physics and Applied Physics at Stanford University, was a renowned and highly respected aerospace engineer and solar physicist. While at Stanford, Arthur was an active member of the Center for Space Science and Astrophysics and chaired the Astronomy Program from 1977 until 1980. His most significant contribution to academic life at Stanford was mentoring under-represented graduate students in science, namely women and African Americans.
Among these students was Sally Ride, the first female US astronaut. He was also a leader of the African American community at Stanford and the longest serving member of the advisory committee for the Afro-American studies program. He served as a role model for many of the young African American assistant professors including Condoleezza Rice.

NASA recognized his lifetime of service during a combined meeting of the National Conference for Black Students and the National Society of Black Physicists in 2001. Art’s devotion to science and service encouraged and promoted African Americans to enter physics as a profession at all levels.

**About the Arthur B.C. Walker II Award.** The ASP’s Arthur B.C. Walker II Award has been established to honor an outstanding scientist whose research and educational efforts substantially contribute to astronomy and who has (1) demonstrated a substantial commitment to mentoring students from underrepresented groups pursuing degrees in astronomy and/or (2) been instrumental in creating or supporting innovative and successful STEM programs designed to support underrepresented students or their teachers.

The Arthur B.C. Walker II Award also includes an “Arthur B.C. Walker II Scholarship,” which the recipient gives to a student of their choice. In addition, and perhaps even more important than the financial benefit, the prestigious scholarship from the ASP will help support the student’s academic and career goals.

**Addendum:** The movie *Hidden Figures* tells the story of mathematician Katherine Johnson and her two African-American colleagues who helped NASA catch up in the space race. The movie opens in limited release on Dec. 25, with a full release on Jan. 6, 2017.

**Free My Sky Tonight Workshop**

Museum and planetarium educators, please join us for a free *My Sky Tonight* workshop to bring the excitement of astronomy to pre-K children and their families.

Each participant will receive a free toolkit of hands-on astronomy activities designed for 3- to 5-year-old children, and tested at multiple museums. The goal of this workshop is to provide educators with the opportunity to learn methods of engaging young children and their families in activities related to astronomy including some of the stepping stones to astronomy, such as exploring near versus far and observing changing shadows. Participants will gain the following through participation in the workshop:

- Detailed descriptions of astronomy activities for preschool-aged children.
- An education toolkit with the materials needed for implementing the activities at your venue.
- Content knowledge in astronomy.
- Strategies we have found to be successful in engaging preschool-age children and their families.
- Membership in the *Astronomy from the Ground Up* online community, a support network of peers from all over the country who have participated in similar astronomy workshops for informal educators.
We are offering the six-week online workshop two more times:
January 17–February 24, 2017, and February 27–April 7, 2017. For
more information, and to apply to participate in this free workshop:
goo.gl/L1SMaJ.

My Sky Tonight: Early Childhood Pathways to Astronomy is a
project of the Astronomical Society of the Pacific, in partnership
with a team of early childhood researchers and museum educa-
tors, funded by a National Science Foundation grant. Here is a little
more information about the project.

ASP’s 2017 Solar Eclipse Information & Resources
The ASP has prepared a webpage containing a variety of download-
able information and resources about the upcoming 2017 total
solar eclipse — and the contents are free to all. Included are links to
the upcoming ASP eclipse conference, an eclipse resource guide, a
link to eclipse products in the ASP’s Astroshop, and a link to a page
containing all of the feature articles and columns touching on solar
eclipses in general, and the upcoming August 2017 total eclipse of
the Sun in particular, that have appeared in Mercury. 

NEW MEMBERS — The ASP thanks all those who recently renewed their membership, and welcomes new members who joined between July 1 and September 14, 2016.

Individual
Marc Adolph, Long Beach, CA
Steven Bal, San Diego, CA
Jacqueline Barge, Chicago, IL
Rachael Beaton, Charlottesville, VA
Fernando Bianchi, Santiago, Chile
Sheri Breaux, Alhambra, CA
Rita Brinkmann, Petaluma, CA
Brennan Brockbank, San Carlos, CA
Sarah Burstein, Grants Pass, OR
Janet Carter, Dana Point, CA
Kristi Coale, San Francisco, CA
John S. Cooper, Davis, CA
Genevieve Crook, Huntsville, AL
Samantha Davis, San Diego, CA

Shashank Dholakia, Santa Clara, CA
Shishir Dholakia, Santa Clara, CA
Esmeralda Español, San Jose, CA
Bryan Flaig, Berkeley, CA
David & Catie Garcia, San Diego, CA
Jennifer Godfrey, Detroit, OR
Eugene Heisel, Del Mar, CA
Katharina Hessen, San Diego, CA
Joylette Hylick, Hampton, VA
Tamara Juarez, Mountain View, CA
John Kerns, Diamond Bar, CA
Donald Kirkpatrick, Conway, SC
Vijayakumar Krishnamurthy, San Marcos, CA
Nicholas Kuhn, San Diego, CA
Elan Lavie, San Francisco, CA
Lori Lester, Palo Alto, CA
Rick Linden, Oninda, CA
Remberto Lopez, Jr., Riverbank, CA
Jack Massie, Harbor City, CA
Ian McLean, Los Angeles, CA
Heather Mellows, Sunnyvale, CA
Frank Mendoza, Cypress, CA
Katherine Moore, Hampton, VA
Susan Murphy, Marietta, GA
William Munson, Tehachapi, CA
Cameron Smith, San Diego, CA
Oliver Staton, San Francisco, CA
Charles Steidel, Pasadena, CA
Wolf Witt, Mountain View, CA
Cynthia Wolley, Union City, CA
James Wright, Modesto, CA
Robert Victor, Palm Springs, CA
Camille V. York, Richmond, VA
Annie Yount, Cupertino, CA

Senior
Gary Alguire, Encinitas, CA
Michael Farquhar, Altadena, CA
Mark Hebert, Dallas, TX, Senior
Katherine Johnson, Hampton, VA
John Roberts, Richmond, VA
Joe Robinson, Glendale, AZ
Joseph Sonderleiter, Portland OR
The Skies of November
Get ready. Here it comes again. The hype…oh, the hype! Yes…it’s the return of the **SuperMoon**! On the 14th the Moon is full less than three hours after its closest approach to Earth (an event known as *lunar perigee*). It is the closest full Moon — a ‘mere’ 356,509 kilometers away — until 2034. (The average Earth-Moon distance at lunar perigee is 363,400 km.) The only real effect of this so-called superMoon will be higher-than-normal tides, so if you live on the coast, take care. Otherwise, it’s a super non-event.

There are three planets in the west at dusk, but **Venus** is the only one easy to spot. It’s a little more than 10° (the width of your fist held at arm’s length) above the southwest horizon some 30 minutes after sunset at the start of the month…and a more obvious 20° high at the same time by month’s end. On the 2nd, Venus sits well to the lower left of the 3-day-old crescent Moon. But look carefully about 3° beneath the Moon. That dim “star” you see is **Saturn**. This is probably your last chance to easily spot the ringed world before it slips into the solar glare later this month (emerging at dawn in late December).

Meanwhile, if you follow the Moon, you’ll see it pass above **Mars**. After sunset on the 5th the red planet is to the Moon’s lower left; on the 6th it’s to the far lower right of the nearly first quarter Moon. Mars has faded dramatically (in size and brightness) since its excellent opposition nights this past spring.

In the east, **Jupiter** rises two hours before the Sun on the 1st; more than four hours before sunrise on the 30th. On the morning of the 24th, the waning lunar crescent is well above Jupiter. The next morning it’s below the giant planet, and the bright star nearly 10° below Jupiter (and half that distance to the lower right of the Moon) is **Spica**.

And where’s **Mercury**? Lost in the solar glare. But December is a different story.

The **Leonid meteor shower** peaks during the morning hours of the 17th. This shower’s activity is usually weak; there’s often only a trickle of meteors radiating from a region near the Sickle of Leo, the Lion. While it’s always worthwhile stepping outside to scan for meteors, the shower peak falls just three days after the full Moon. A better shower (in terms of numbers of meteors) is next month’s Geminids.

As a minor timekeeping note, **Daylight Saving Time** ends for most of North America on the 6th.
The Skies of December

This month’s highlight would normally be the Geminid meteor shower, which peaks on the night of the 13th/14th. It’s usually the year’s best, with upward of 100 meteors per hour pouring out of the constellation Gemini. (The shower’s radiant, the point in the sky from which the meteors seem to emanate, is near the bright star Castor.) Unfortunately, the Moon is full the same night, which means only the brighter Geminids will punch through the moonlight. Next year will be better; in 2017 the Moon will be two days past last quarter on Geminid peak night.

Another challenging celestial event is the occultation of Aldebaran (the brightest star in the Hyades star cluster in Taurus, the Bull) during the night of the 12th, visible across much of North America (and far Western Europe). Why is it challenging? Because the Moon is only one day short of full.

On the East Coast, Aldebaran vanishes around 11:00 pm or so (Eastern time); on the West Coast disappearance happens around 7:00 pm (Pacific time). The occultation can last more than an hour, depending on your viewing location. This PDF map shows where the occultation will be visible. The International Occultation Timing Association has published a list of ingress and egress times for hundreds of locations. However, do note that those times are Universal Time and need to be converted to your local time.

In the west, brilliant Venus continues to dominate. By month’s end it’s nearly 30° high in the south-southwest at sunset and sets more than three hours later. On the 2nd and 3rd the crescent Moon visits — the pair make a lovely sight in the sunset sky. On the 4th, the red planet Mars sits some 5° to the left of the 5-day-old Moon.

During the first two weeks of the month, Mercury puts in an appearance after sunset. It doesn’t get very high, but between the 4th and the 20th, see if you can spot this elusive planet low in the southwest (you’ll need a low, flat horizon) starting 30 minutes after sunset.

Jupiter rises one to two hours after midnight all month and is well up in the south as dawn breaks. The post-last quarter Moon hangs above Jupiter as both rise on the 22nd.

Meanwhile, by month’s end, Saturn is emerging from the solar glare. Can you glimpse it below the 28-day-old Moon as both rise at dawn on the 27th?

The solstice occurs on December 21st at 5:44 am Eastern time, 2:44 am Pacific. This marks the astronomical start of winter in the Northern Hemisphere and summer in the Southern.

The Skies of January

If you don’t have a go-to telescope and have never seen Neptune, now is your chance. In fact, you have a couple of opportunities.

After sunset on the 2nd, reddish Mars hangs about 7° to the upper left of the 5-day-old Moon. Take your binoculars and look exactly in between Mars and the dark limb of the Moon. Can you see a dim, pale-blue “star”? That’s Neptune.

If you can’t find it, try again on the 11th to 13th, using Venus as your guide. On the 12th, about an hour after sunset, grab your telescope or binoculars, go outside, and find brilliant Venus high in the
southwest. Look carefully less than 1° below Venus for that dim, blue “star” — Neptune. On the 11th, Neptune will be about 1° to Venus’ upper left, while on the 13th it’ll be a little more than 1° below Venus.

Backing up a bit, note that Venus continues to blaze in the southwest, not setting until nearly four hours after the Sun. On New Year’s Day evening, the crescent Moon is about 5° to Venus’ lower right. And on the 12th, Venus is at greatest eastern elongation — the maximum angular separation of Venus from the Sun as viewed from Earth at dusk. (Greatest brilliance occurs in February.)

Jupiter rises between 11:00 pm and midnight. Just after midnight on the 19th, look for Jupiter and the last quarter Moon rising side by side.

At dawn during January, Saturn and Mercury rise up from the solar glare, but only Saturn hangs in. By mid-month Mercury is a good 10° above the southeast horizon some 30 minutes before sunrise, while Saturn is some 10° to Mercury’s upper right. But neither planet is particularly bright. On the 24th the ringed planet is to the lower right of the thin crescent Moon, while the next morning the even thinner crescent is almost directly above Mercury.

The Quadrantid meteor shower is actually a nice one, with up to 40 meteors per hour radiating from a point in northern Boötes (which rises in the northeast about 1:00 am). The shower peaks during the early morning hours of the 4th. The 5-day-old Moon will set before midnight on the 3rd, leaving a dark sky for what could be a decent show. This shower is not well observed, likely because it’s usually rather cold in the Northern Hemisphere at this time of year!

### Star Charts

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

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

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

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

— P.D.
reflections
NASA/SwRI/MSSS/Roman Tkachenko

Pinwheels on Jupiter
Numerous cyclones are visible near Jupiter’s south pole; three are highlighted in this Juno image processed by Roman Tkachenko. See more image-processing contributions by amateurs in Juno’s Image Processing Gallery. [NASA/SwRI/MSSS/Roman Tkachenko]