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Close Encounters of the Jovian Kind
NASA AND THE SOUTHWEST RESEARCH INSTITUTE
Juno has completed its seventh swoop past Jupiter. Here are some encounter results, both visual and scientific, from its earlier passes.

A Cassini Retrospective
NASA/Jet Propulsion Laboratory; edited by PAUL DEANS
The Cassini mission is nearly over, but the wonders it revealed will keep scientists busy for years.

An Eclipse-Watcher’s Guide to a Total Eclipse of the Sun
PAUL DEANS
What to expect, and look for, during the various stages of a total solar eclipse.

Astronomy in the News
Rethinking Earth’s ‘Little Ice Age,’ a new branch in the family tree of exoplanets, and a ringed exoplanet expected to occult its star this September. These are some of the discoveries that recently made news in the astronomical community.
It’s Time

After nearly four decades of waiting, it’s time. A total eclipse of the Sun will cross the United States on August 21st. Totality will be visible along a 70-mile-wide path stretching from Oregon to South Carolina. Elsewhere in the US (and Canada and Mexico), observers will see only a partial solar eclipse.

If at all possible, get thee to totality! Call it what you will — the experience of a lifetime, the most amazing sight in all of nature, a bucket-list item that must be seen to be believed — totality really is an unforgettable experience. I’ve seen 10 totalities, and I’ll be driving 14 hours to see this one. A 99% partial eclipse just isn’t the same as a total eclipse… trust me.

However, I recognize that it will not be possible for everyone to travel to totality. The 21st is a work-day Monday and for many, a school day: Travel Impossible. For various reasons, others may simply be unable to get to the path of totality. Although the eclipse will be heavily promoted in the (news and social) media during the days leading up to the spectacle, let’s face it — many people just won’t care. So be it.

But if you do care, and you’ve procrastinated with your travel planning, don’t despair. If you need to drive, and you can’t find a hotel room inside totality’s path, select one an hour or two away. (Just be sure to depart several hours before the eclipse starts; traffic could be bad.)

The GreatAmericanEclipse.com website has a great selection of maps, including one that shows driving times to the centerline (about half way down this webpage). A little farther down the same webpage are maps of ‘drivesheds’ — the quickest routes to totality in terms of distance, not necessarily driving times — for the eclipse.

Regardless of whether you can make it to totality or will be watching the partial phases from outside the path, I wish you clear skies. And post-eclipse? Start thinking about the next American totality, in April 2024.

Paul Deans
Editor, Mercury
What Did the Dinosaurs Know?

What if dinosaurs did astronomy, but all the evidence of their vast accomplishments is long gone?

Imagine if all the humans on Earth suddenly disappeared. After 65 million years, what evidence would remain to prove we were here, did science, or investigated the great mysteries of the cosmos? According to one of my favorite books, “The World After Us,” future alien archaeologists might find glass bottles and bits of plastic, but everything humanity had ever built would be gone. There would be nothing left suggesting we built computers, launched rockets into space, or observed the sky with massive telescopes.

During an ASP staff party (and after consuming a few glasses of wine), I posed a question I am still teased about. “If dinosaurs dominated the Earth for over 150 million years and became extinct 65 million years ago, how do we know dinosaurs didn’t do astronomy, build rockets, and explore space?” After all, Homo sapiens have been around for only 100,000 years, and in that time we’ve accomplished a lot. T. Rex had lots more time on his tiny hands. What if dinosaurs did astronomy, but all the evidence of their accomplishments is long gone.

Consider the remnants from humanity’s early history. The first civilizations arose only 5,000 years ago, but even within this short time frame most of the achievements of our ancestors have either been destroyed or buried under tons of vegetation and debris. We know some of our early accomplishments from the written descriptions made by subsequent generations. Sometimes we discover a rare artifact in an archaeological dig.

As the Great North American Total Eclipse approaches, consider how our ancient ancestors predicted the timing of solar eclipses with astonishing accuracy. A particularly jaw dropping example comes from the Maya. Archaeologists decoded a 12th-century pre-Columbian Mayan stone calendar and used it to make a fairly accurate prediction of the total solar eclipse that passed through southern Mexico (and over what would have been the Mayan empire) on July 11, 1991, a prediction off by only a couple of days!

By making careful observations of the Moon and Sun over a long period of time, virtually every ancient civilization discovered that for a given solar eclipse, the Sun, Moon, and Earth return to the same relative positions in 6,585.3 days (18 years, 11 days, and 8 hours). This is the Saros cycle, and we can use it to predict when and where the geometry of the August 21, 2017, solar eclipse will repeat. The path and duration of totality for this eclipse will occur again on September 2, 2035. But because a Saros cycle includes an additional eight hours, this eclipse will pass across China, or about a third of the way around the globe to our west.

While we know little about the astronomical knowledge of our ancestors, occasionally a discovery of a scientific artifact (like the Mayan Codex) takes our breath away. In 1901, Greek sponge divers discovered an ancient shipwreck off the Greek Island of Antikythera. Along with large marble sculptures, bronze statues, pottery, coins,
and jewelry, these divers recovered an odd lump of badly corroded metal and wood. The artifact was ignored for decades until CT imaging revealed something amazing. This unremarkable lump of bronze and wood was an ancient, crank-driven analog computer, consisting of 37 metal gears, dials, and pointers. Built very much like the elaborate 14th-century astronomical clocks used centuries later in Europe, this computer constructed around 150 BC had many purposes.

Given the name “Antikythera,” this intricate and complex gear mechanism tracked the date, accurately followed the motion of the Moon and the Sun through the zodiacal constellations, displayed the current phase of the Moon, used the Saros cycle to predicted lunar and solar eclipses, and even told you when the next Greek Olympiad would occur! No one expected the ancient Greeks to possess the knowledge and skills needed to make a device like this — literally 1,200 years before these same calculators would appear in Europe. Some suggest this device was actually an updated version of something the Babylonians might have constructed centuries earlier.

Is the Antikythera an extremely lucky discovery of the only computer of its kind at the time, or are there many more examples of ancient technologies buried under our feet and long forgotten? How much more accomplished were our ancestors than we think they were in areas of the world such as Mesopotamia, Asia, the Americas, Africa, or Polynesia?

Did the dinosaurs do astronomy? Did they create their own version of the Antikythera? Of course they didn’t. They couldn’t, because they never developed the intelligence required. Based on the ratios of their brain volume to physical size, dinosaurs weren’t any smarter than possums. Being around the planet a long time, even for hundreds of millions of years, doesn’t guarantee evolution will bestow a species with intelligence. Bacteria have been around for four billion years, and there is no evidence they solved Fermat’s Last Theorem, or even cared.

It’s Homo sapiens that won the evolutionary jackpot, developing a highly intelligent and curious brain interested in asking and answering questions about the universe. While we search the universe looking for intelligent life elsewhere in the cosmos, we should take a moment and marvel at our rare and unique species and its ability to question, explore, theorize, and conclude — and hope we continue to use our unique brains wisely.

**LINDA SHORE** is the Executive Director of the Astronomical Society of the Pacific.
Meghnad Saha, Light Quanta, and Comet Tails

Why comet tails pointed away from the Sun was a long-standing mystery.

Ask anyone with a passing knowledge of physics or astronomy about comet tails. Specifically, why do they always point away from the Sun? The answer you will likely get is that radiation pressure originating from the Sun causes the atoms to stream way from it. A simple explanation, but not quite correct.

At the core of the problem is the application of the classical theory of light. In the 19th century, the great physicist James Clerk Maxwell laid the foundation for our understanding of magnetism and electricity. He also studied light, and in 1862 discovered that light exerts pressure on particles larger than the wavelength of the incident light. Applying this to comets does not work, as the atoms comprising a cometary tail are smaller than light waves.

Consider our knowledge of comets in 1872, just a decade after Maxwell developed the mathematics of radiation pressure. The English astronomer popularizer Richard Proctor (1837-88) wrote about this for the widely read Eclectic Magazine. Proctor notes that Appian, in the second century CE, was the first European to note a comet tail points away from the Sun.

In 1780, nearly a century before Proctor’s review, the English naturalist Abbé Mann (1735–1809) wrote a book which stated his belief the aurora borealis and the tail of a comet proceed from the same principle and are formed of the same matter that he termed emanations of electrical fluid. This was not far from the truth as tails of comets are composed of charged particles, the charged particles of the plasma surrounding Earth are key to the development of an aurora, and both phenomena are caused by the Sun.

From 1869 came the so-called ‘sea-bird theory’ proposed by University of Edinburgh Professor Peter Tait (1831–1901). He suggested a comet tail consists of a multitude of meteors, travelling in a flight pattern akin to that of sea birds. While neither Mann’s nor Tait’s theories explained the direction of a comet tail, they showed a great divergence of views on what the tail was, which was key to figuring out why it pointed away from the Sun. Tait’s idea reveals that some believed the particles comprising the tail were much larger than the wavelength of light, and thus subject to radiation pressure.

(by Clifford J. Cunningham)
The ‘negative shadow’ theory is one Proctor says, “has been again and again urged, though only to be again and again refuted.” In this theory, the tail of a comet is compared to a beam of light such as a lantern throws amid darkness. “This theory,” writes Proctor, “leads many to forget that the so-called beam of light thrown by a lantern is in reality due to the illumination of material particles; and that in the case of a comet we can neither explain why particles behind the comet (with regard to the sun) should be more brilliantly illuminated than others, nor how the particles come to be there at all.”

The matter remained perplexing until 1919, when the Indian physicist Meghnad Saha (1893-1956) studied it. Fresh from his work in publishing the first English translation (together with S.N. Bose) of Einstein’s papers on relativity, Saha brought the new idea of light quanta to bear on the problem. Einstein had first introduced the concept of light quanta as an indivisible packet of light in 1905. Saha realized that for any particular atom, it can be given a kick only if it is capable of absorbing the incoming radiation.

Consequently, the understanding that radiation pressure forces particles from the comet, creating a tail that points away from the Sun, is correct. But as the work of Saha showed, only certain packets of light will move atoms capable of absorbing them. Thus, the process is selective. So while the ‘dirty snowball’ theory of comets by Fred Whipple in 1950 is usually thought to be the beginning of modern comet studies, it really started with Saha in 1919.

Clark Cunningham was recently seen in Newfoundland chatting with Professor Nicholas Purcell, the 25th Camden Professor of Ancient History at the University of Oxford — a prestigious post that was inaugurated in 1622.

The Milky Way’s Rotational Curve

For nearly 50 years the rotational curve of the Milky Way has been assumed to be flat. The orbital velocities of H II clouds (ionized hydrogen gas) outside the galactic center apparently remain constant with radial distance rather than following the originally expected Keplerian curve. The Keplerian curve describes the velocity of planets and objects in the solar system — these velocities decrease as the inverse of the square root of distance from the Sun. The flat rotational curve of the Milky Way (and other galaxies) is usually explained by assuming the presence of a spherical halo of dark matter surrounding the galaxy. However, recent studies have put a new spin on things.

In 2015, Gazinur Galazutdinov and his colleagues pointed out that the traditional method of using H II clouds as tracers of galactic rotation is problematic, because distances to H II clouds rely on uncertain assumptions about their sizes. Furthermore, the use of OB stars is just as tricky. Distances to OB stars have significant errors,
since so few have accurately measured trigonometric parallaxes, and the use of spectroscopic parallaxes is vexed, because most exhibit photometric variability.

Galazutdinov and his group utilized intensities and Doppler shifts of optical Ca II (singly-ionized calcium) lines from interstellar molecular clouds in the thin disk of the galaxy; these lines are less affected by distance errors and do not require size assumptions. Using the distances and velocities derived from Ca II lines and assuming circular orbits for the interstellar clouds, Galazutdinov’s team found that the galactic rotation curve is Keplerian! This result represents a significant departure from past studies. In particular, a comprehensive study by Yoshiaki Sofue and colleagues found a relatively flat rotation curve. Sofue and his group updated and unified all previously existing data and assumed the usual circular orbit for objects orbiting our galactic center.

In the spring of 2017, P. Gnacinski and T. Mlynik attempted to reconcile these disparate results. They adopted the latest solar velocity around the galactic center and analyzed the rotational velocities of open clusters, older than one billion years of age, located near the outer part of the galaxy. A good number of open clusters are known to have very nearly circular orbits, and those that are not circular have low eccentricity. Since linear velocities depend on distances that have fairly large uncertainties, they also plotted the angular rotational velocities, which have errors that are independent of distance from the galactic center.

Their rotational curve for open clusters were Keplerian for both linear and angular velocities of open clusters. Why? One reason is that the distances to open clusters are more accurately known than those of H II regions. Another reason appears to be the underlying assumption of circular orbits. Gnacinski and Mlynik performed Monte Carlo simulations of 200 stars with elliptical orbits and calculated their radial velocities assuming a circular orbit. The simulation was done to test the effect of deriving velocities for circular orbits from objects that are actually in elliptical orbits. The simulated orbits revealed a large dispersion and a curve that looks generally flat.

Gnacinski and Mlynik conclude the flat curve for H II regions and stars results from the assumption of circular orbits, while the Keplerian curve derives from the actual circular orbits of interstellar molecular clouds. They also ran simulations for objects with highly elliptical orbits and found that radial velocities derived under the assumption of circular orbits for such objects produce a galactic rotation curve that cannot be used to discriminate between a flat or Keplerian curve. All previous determinations of the galactic rotation curve with H II clouds or stars assume circular orbits. Their results have important implications, since the shape of the rotation curve is ultimately used to determine the amount of dark matter in the Milky Way!

JENNIFER BIRRIEL is Professor of Physics in the Department of Mathematics & Physics at Morehead State University in Kentucky.
Flares May Threaten Planet Habitability Near Red Dwarfs

Could flares on cool, red dwarf stars render orbiting planets uninhabitable?

Cool dwarf stars are hot targets for exoplanet hunting right now. The discoveries of planets in the habitable zones of the TRAPPIST-1 and LHS 1140 systems, for example, suggest that Earth-sized worlds might circle billions of red dwarf stars. But, like our own Sun, many of these stars erupt with intense flares. Are red dwarfs really as friendly to life as they appear, or do these flares make the surfaces of any orbiting planets inhospitable?

To address this question, a team of scientists has combed 10 years of ultraviolet observations by NASA’s Galaxy Evolution Explorer (GALEX) spacecraft looking for rapid increases in the brightness of stars due to flares. Flares emit radiation across a wide swath of wavelengths, with a significant fraction of their total energy released in the ultraviolet bands where GALEX observed. At the same time, the red dwarfs from which the flares arise are relatively dim in ultraviolet. This contrast, combined with the GALEX detectors’ sensitivity to fast changes, allowed the team to measure events with less total energy than many previously detected flares. This is important because, though individually less energetic and therefore less hostile to life, smaller flares might be much more frequent and add up over time to create an inhospitable environment.

“What if planets are constantly bathed by these smaller, but still significant, flares?” asked Scott Fleming of the Space Telescope Science Institute (STScI) in Baltimore. “There could be a cumulative effect.” To detect and accurately measure these flares, the team had to analyze data over very short time intervals. From images with exposure times of nearly half an hour, the team was able to reveal stellar variations lasting just seconds. The team then used custom software, developed by Chase Million (Million Concepts) and Clara Brasseur (STScI), to search several hundred red dwarf stars, and they detected dozens of flares.

The flares GALEX detected are similar in strength to flares produced by our own Sun. However, because a planet would have to orbit much closer to a cool, red dwarf star to maintain a temperature friendly to life as we know it, such planets would be subjected to more of a flare’s energy than Earth. Large flares can strip away a planet’s atmosphere. Strong ultraviolet light from flares that penetrates to a planet’s surface could damage organisms or prevent life from arising. A preprint of the paper is available here.
As Cassini approaches the end of its journey, nearly every observation it makes is the first, last, best, or only one of its type. Here are a few highlights of the last 200 days of its 20-year mission:

This animated GIF of Atlas, only 19 miles across, was taken on April 12, 2017, as Cassini passed within 7,000 miles of this tiny moon. The sequence was built using unprocessed raw images. Atlas has a very unusual shape — one team member dubbed it a “space ravioli.”

Cassini took a farewell shot of Earth on April 20th (right).

On April 26th, Cassini “shot the gap” for the first time, passing through the gap between the upper atmosphere of Saturn and its innermost rings (next page, right). This video compresses one hour of imagery into a 21-second movie that shows Saturn’s atmosphere close up as Cassini executes the first of its 22 dives. Related is this interesting side-by-side video, which adds an image of Saturn for reference. The moving red dot on the Saturn image indicates the location of each frame in the movie.

Summer has come to the northern hemisphere of Saturn just as it has to the northern hemisphere of Earth — though on Saturn, it has been about 30 years since its last summer solstice. The pair of images (upper left, page 29) shows one of the seasonal effects Cassini’s extended mission has allowed us to observe — the polar hexagon has changed color with the seasons.

Shortly after Cassini arrived at Saturn in 2004, a few low-resolution ring shots led to the discovery of “propellers,” features in the rings caused by moonlets so small they couldn’t be seen. A May 10th image (next page, far right) shows the largest number and range of sizes yet seen.

Cassini’s fate is now sealed. Ever since its April 22nd flyby of Titan (the 127th of the mission), the spacecraft has been on an inevitable cruise to its own destruction — a ballistic trajectory that concludes with a crash into Saturn in the early morning of September 15.
As I write this, Cassini is executing Sequence 100, and on June 28, the mission operations teams will gather (digitally and otherwise) to give final approval to Sequence 101, which ends with Cassini’s 292nd, and final, orbit of Saturn. It has been quite the journey.

EMILY JOSEPH is a Research Assistant (with an emphasis on Mars studies) at the Planetary Science Institute, and is part-time on the VIMS operations team for the Cassini mission at the University of Arizona Lunar and Planetary Lab.

Right: The region between Saturn and its D ring turns out to be emptier than it appears in this image acquired on May 3, 2017, after Cassini’s second plunge through the gap. Far right: The propellers are the small, bright features that look like double dashes, visible on both sides of the wave pattern that crosses the image diagonally from top to bottom. [NASA/JPL-Caltech/Space Science Institute x2]

Two’s Company, Three’s a New Astronomy Discipline

LIGO’s third detection of gravitational waves moves the field from novelty to reality.

Smash together two black holes and what do you get? Not much light but immense energy nonetheless, in the form of gravitational waves. That’s the prediction from Einstein’s theory of general relativity, that massive objects moving through the universe create a wake in the fabric of spacetime — like a ship cutting across the water. The greater the mass, the larger these ripples in spacetime would be.

After more than a decade of searching, scientists using the twin Laser Interferometer Gravitational-Wave Observatories (LIGO) obtained the first direct detection of these gravitational waves in September 2015, announced with much justified fanfare on February 11, 2016. They detected a second set of waves in December 2015, but kept that quiet until they could confirm it and announced the detection in June 2016.

Both sets of waves were set in motion by merging black holes many times the mass of our Sun. The waves are subtle, distorting the
LIGO detectors (like the rising and falling of a buoy) by only about one-thousandth the width of a proton. Passing trucks rattle the detectors with far greater intensity. But LIGO has matching facilities in Louisiana and Washington state; the same waves sweep through one facility and then the next, traveling at light speed, about three milliseconds later, helping scientists distinguish signal from noise.

The first detection was groundbreaking; the second detection assured us this wasn’t a fluke. Now with a third detection — made in January 2017 but announced on June 1 in the journal Physical Review Letters — scientists are moving away from this being merely a novelty occurrence, said David Shoemaker, a physicist at MIT and spokesman for the LIGO Scientific Collaboration. Science has tipping points, Shoemaker explained. We saw this with the detection of pulsars, gamma-ray bursts, and then exoplanets. First one, then two, then three, then a whole lot. Once we know how to find something, we learn how to refine the search to find many more. In this regard, Shoemaker said, we may be on the verge of conducting real astronomy via this window to gravitational waves, energy that is different from electromagnetic radiation, the mainstay of astronomy.

For example, the new detection revealed hints about the orientation of the spins of the two smaller black holes shortly before they merged. “This is the first time that we have evidence that the black holes may not be aligned, giving us just a tiny hint that binary black holes may form in dense stellar clusters,” said S.B. Sathyaprakash, a professor of physics at Penn State University, who was part of the discovery team.

The masses of the detected black holes also are significant. Before the first LIGO detection, scientists thought that stellar-size black holes topped out at about 10 solar masses. That first detection was a pair 36 and 29 times as massive as the Sun. The latest detection, named GW170104, was a pair 19 and 31 solar masses, confirming that stellar black holes can be much more massive than theory had predicted.

“In my view, the third confirmed detection, also of large-mass stellar black holes, begins to sketch out a population of these systems, a population that we had no knowledge of before LIGO began these observations,” said John Baker, a theoretical physicist in the Gravitational Astrophysics Laboratory at the NASA Goddard. And the distance of GW170104, three billion light-years away, far more distant than the first two, demonstrates that gravitational waves can be detected from events across the universe.

With the NSF-funded LIGO a clear success, NASA and ESA hope to build a similar observatory in space. A planned observatory, called Laser Interferometer Space Antenna (LISA), is in an advanced design stage.

“[LIGO] is certainly stimulating new enthusiasm for LISA,” Baker said. “It has shown that gravitational waves can indeed reveal astrophysical surprises, opening up previously unknown aspects of the universe to study.”

Baltimore-based writer CHRISTOPHER WANJEK is riding a wave of excitement generated by ESA green-lighting LISA for funding in June 2017.
Astronomical Phenomena as a Provocation for Learner Engagement

Might this year’s solar eclipse set the stage for a resurgence in the teaching of space science in the classroom?

The total solar eclipse taking place on August 21, 2017, is a natural phenomenon on a grand scale. Although only those within the narrow swath cutting across the country from Oregon to South Carolina will see totality, everyone throughout the rest of the North America will have the potential to see a partial eclipse.

One of the more remarkable aspects of this eclipse is that it is taking place during normal school hours, on a day when many schools across the country are in session. For most, it is the first day of school for the year. For educators, this creates a teachable moment without compare, providing an opportunity to engage learners in investigating and explaining this spectacular phenomenon in the sky.

But what to do when the excitement fades, and there isn’t an easily accessible phenomenon for students to experience directly? How do educators keep the momentum going? For most of the sciences, it is relatively easy to demonstrate phenomena in the classroom, or to point to something learners experience in their daily lives, thus actively engaging them in a scientific investigation. Other than an eclipse, what astronomical phenomena are learners able to experience first-hand or relate to in their own lives?

The phases of the Moon and the seasons are perhaps the easiest to experience and investigate, and maybe tracking the bright planets as they change position from night to night. Noticing that not all stars are the same color or the same brightness is another good one.

The trouble is, most astronomical phenomena are not accessible to learners or useful for engaging them in an active, inquiry-based classroom investigation. It isn’t that learners lack interest in celestial phenomena, it’s just that celestial events don’t rise to the level of a teacher posing a problem such as: “It rained two nights ago, and you noticed there were puddles of water on the playground when you got to school yesterday. When you left at the end of the day, the puddles were gone. Where did the water go?” This lack of relationship to a teacher or learner’s normal, everyday life may help explain why astronomy and space science are traditionally underrepresented in curricula and classroom instruction.

In the presence of a robust program of space exploration, space science instruction is able to utilize various missions as an engagement into an investigation. For example, Mars exploration is a popular subject leading to a variety of classroom experiences, possibly due to the similarity of Mars to Earth, the long history of speculation about life on Mars, and the potential for an eventual human on what is arguably
the most fascinating object in the solar system beyond Earth. This use of what we might call analogous phenomena is worthwhile in that they create an indirect experience and relevance for learners.

Moving to phenomena beyond the solar system presents a unique difficulty to the science educator due to their remote nature and lack of easily identifiable analogous phenomena. For example, one of the performance expectations for middle school learners in the Next Generation Science Standards (NGSS) says “Students who demonstrate understanding can: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.” Investigating gravity within the classroom is easily accomplished. However, it can prove problematic when extended to the solar system and further to galaxies. It requires greater abstractions than many learners are able to handle. They are not able to directly observe and experience planetary motions and have to infer them based on changes in position of the planets. Motion within galaxies is even less obvious, requiring more direct instruction from educator to learner, which takes the investigation away from the learner-directed or educator-guided inquiry.

This is an important challenge to astronomy and space science educators — to develop a rationale and identify a suite of astronomical phenomena educators can incorporate into their instruction. Imagery of distant galaxies and nebulae are stunning in their ability to show us what the universe looks like. Identifying the phenomena they display and we want learners to investigate is much more difficult.

Perhaps this year’s solar eclipse will set the stage for a resurgence in the teaching of space science in the classroom. It is our task to make sure the learners have something to pique their interest, a suitable provocation to engage them in the wonders of the universe.

BRIAN KRUSE manages the formal education programs at the ASP and is the Director for Region F of the National Science Education Leadership Association.

You Can’t Convince Everyone

Convincing someone who has never seen totality that they ‘must’ see it…is sometimes just not possible.

There is some frustration among the eclipse community regarding a lack of interest in the eclipse, even among family and friends. The response to enthusiastic comments about totality is often “that sounds neat,” but that’s usually as far as it goes.

Just prior to my first totality in 1979, I was running the telescope at Griffith Observatory for the public. As eclipse day approached, I was asked a lot of questions about what the eclipse would be like. Being the ‘expert’ (or so I thought, based on reading and seeing photos), I described what to expect. Only when I witnessed it for myself did I realize just how far I was from understanding what the experience was really like. It isn’t something to see but something that happens to you; not just a spectacular sight, but an amazing experience.

I’ve never seen someone who thinks “that sounds neat but not worth much trouble” be turned around to the point of traveling to...
an eclipse, even a nearby one. In 1979, a close friend was in the path of totality in Idaho where they had clear weather, but she wouldn’t get out of bed to see it (she worked late). She knew we were driving up from southern California to Washington in a rented motor home for it, and her boyfriend tried (and failed) to get her up. We all know of people who are driving during totality and merely turn on their headlights rather than stop and look up.

I think that most people who are already in the path of totality will go outside and watch. Having to travel even a short distance (drive an hour, say) will lose a lot of them. The ones who seem to be receptive to traveling to totality are those who say “I’ve always wanted to see a total eclipse,” or are otherwise very receptive to the idea of new experiences. They may not really understand it, but they’re able (and willing) to hear why it’s even better than they realized. I have convinced people like that to make the effort.

But many people are just not open to new experiences. Their lives are satisfying as they are, and adventure is just not of interest. And, yes, even driving to an eclipse is an adventure for some people — such as those who have never traveled outside their own cities, because they just have no interest. You can’t convince them that they really should see some other sights.

Do you remember what you thought about a total eclipse before you saw your first? I was willing to do anything to see one, but I still thought it was something to see, not the overwhelming experience I found it to be. As has been pointed out many times, conveying just what that experience is like is well-nigh impossible.

We can describe our and others’ responses to totality, but the result depends on listeners believing that their response will be the same. It requires someone really empathetic and/or a leap of faith. Folks on the receiving end need to be able to identify with the people encouraging them to see the eclipse. Those of us heading to totality are going to sound like extreme cases, because we’re unusual. “Ordinary” people won’t identify with us in this, because they won’t encounter enough other people (friends, relatives, neighbors, people they work with) who have seen one. And we’re bombarded with enough other extraordinary claims, often on a daily basis, that it’s easy to pass off totality as hype.

My hope is that after 2017 there will be so many ordinary people — not just us “eclipse nuts” — describing the experience that other ordinary people get the idea that they could also have that experience. That would mean a much bigger involvement in the eclipse of 2024. It’s rare you get a do-over like this. In my opinion, the big effort for 2024 should be to have those ordinary people who were unexpectedly transformed by totality in 2017 — people who didn’t expect anything but realized they were wrong once they experienced it — out front telling others to get into the path…instead of us.

Not that we shouldn’t keep trying to convince people to see totality in 2017. Even a small success rate means a lot of people in the world’s third largest country will make the effort. I’m just not going to try and convince the unconvincible. I’ll focus on those I think I can persuade.

MIKE SIMMONS is the president of Astronomers Without Borders.
Close Encounters of the Jovian Kind

Juno has completed its seventh swoop past Jupiter. Here are some encounter results, both visual and scientific, from its earlier passes.

By NASA and the Southwest Research Institute

Jupiter’s Great Red Spot is the largest swirling storm in the solar system. It is a hurricane larger than Earth and has been raging at least as long as telescopes could see it. This enhanced-color image of the Great Red Spot was created by citizen scientist Jason Major using data from the JunoCam imager on NASAs Juno spacecraft. Courtesy NASA/JPL-Caltech/SwRI/MSSS/Jason Major.
For a very short time, there are spacecraft orbiting two giant planets in our solar system: Cassini at Saturn (see page 22) and Juno at Jupiter.

“Juno flies over the poles of Jupiter and it goes very close; within 2,000 miles of the cloud tops,” said Scott Bolton, Juno Principal Investigator from the Southwest Research Institute (SwRI), at a recent press conference. “Every 53 days we scream by Jupiter from north to south in about two hours [called perijove]. Most of our science is collected during these very close passes. That’s what is unique about Juno. We get so close to Jupiter and we cross over both poles. That allows us to see new and unique things about the interior and learn how the magnetosphere works.

“We knew, going in, that Jupiter would throw us some curves,” he added. “But there is so much going on here that we didn’t expect, that we have had to take a step back and begin to think of this as a whole new Jupiter.”

The South Pole
Each time Juno sweeps past either Jovian pole, only half of it is sunlight. To create the image that appears on the next page, two amateur image processors stitched together images from three separate orbits so the entire south pole appears sunlit.

“What you see is complex features: cyclones and anti-cyclones all over the poles, this wasn’t expected,” said Bolton.
“The bluish hue is probably real. The biggest feature is that Jupiter from the poles doesn’t look like anything it does from the equator. There it has zones and belts and the Great Red Spot [GRS].

“But when you look from the pole, it looks totally different. The number of cyclones that we see at the poles is something new that we didn’t expect, and the fact that the north and south poles don’t look like each other is also a puzzle. We’re also wondering whether this is a stable configuration. We’ve only gone over a couple of times. Are these storms stable and will they stay the same way for years like the GRS, or are they dynamic. Only time will tell.”

**Juno’s Microwave Radiometer**

The MWR is a new instrument, invented to allow Juno to look into the planet’s upper atmosphere. The ‘familiar face’ of Jupiter in the illustration below is from Cassini. The cutout shows some of the microwave data. The cutout’s right edge is the cloud top; the red arc at its left edge is about 350 km down. In between, the orange, yellow, white, and blue hues indicate the amount of ammonia presence, from orange (abundant) to blue (very little).

*Above: Jupiter’s south polar region, created by stitching together views from three different perijoves. [NASA/JPL-Caltech/SwRI/MSSS/Betsy Asher Hall/Gervasio Robles] Left: Illustration showing some of the results from the MWR instrument. [NASA/JPL-Caltech/SwRI]*
The most unexpected feature is the central column of orange — a deep band of ammonia that appears to rise and emerge in Jupiter’s equatorial zone. But at the cloud tops, the belts and zones at other latitudes don’t seem to correspond to the presence or absence of ammonia. The data suggest the ammonia is quite variable and continues to increase as far down as can be seen (about 200 miles), contrary to expectations that ammonia in the upper clouds would be uniformly mixed.

**Planet Beautiful**

The images at right and below showing a slice of Jupiter’s northern hemisphere were acquired by Juno’s JunoCam during perijove6. “When we’re close to Jupiter, we do not see horizon to horizon,” explained Candice Hansen (PSI), a Juno Co-Investigator. “So we see only a limited range in latitude.

“Here we see it’s a really stormy day on Jupiter, with [numerous]
little white storm systems. They’re about 30 miles across, and they’re above the cloud deck. We know that because we can see them casting tiny shadows. We’ve seen this before in some of our earlier images, but in this particular perijove, the lighting is really good to see these features, and we had the camera settings dialed in.

“I want to mention that these close-up images were processed by two of our citizen scientists, Gerald Eichstädt and Seán Doran,” added Hansen. “They have processed quite a number of our images, but the whole endeavor of JunoCam was to find ways for the public to participate in a meaningful way on a mission. We have a tiny ops team, and the contributions of the amateurs are essential. I cannot understate how important the contributions are.

“What I find the most phenomenal of all is that this takes real work. When you download a JunoCam image and process it, it’s not something you do in five minutes. The pictures that we get — that people upload to our site — are from people who have invested hours and hours of their own time and then generously return the image to us, so it has really been remarkable.”

THE SOUTHWEST RESEARCH INSTITUTE, headquartered in San Antonio, Texas, is an independent, nonprofit, applied research and development organization. NASA’s Juno mission to Jupiter is led by SwRI’s Dr. Scott Bolton.
A Cassini Retrospective

The Cassini mission is nearly over, but the wonders it revealed will keep scientists busy for years.

NASA/Jet Propulsion Laboratory; assembly, introduction, and epilogue by Paul Deans

NASA’s Cassini spacecraft captured this stunning view of Saturn while the craft was in the planet’s shadow. The cameras were turned toward Saturn and the Sun so that the planet and rings are backlit. This view looks toward the non-illuminated side of the rings from about 19° below the ring plane. Unless otherwise indicated, all images are courtesy NASA/JPL-Caltech/Space Science Institute.
On September 15, 2017, on Cassini’s 293rd orbit of Saturn, the spacecraft will plunge into the Saturnian atmosphere and be destroyed. Yes, this was planned.

By 2016, spacecraft was running low on the rocket fuel used to adjust its course. If it actually ran out of fuel, mission operators would no longer be able to control the path of the spacecraft. Cassini data revealed that Titan and Enceladus have the potential to contain habitable environments. So to avoid the chance of Cassini someday colliding with one of these moons, and the (admittedly remote) possibility of contaminating them with hardy microbial hitchhikers from Earth, NASA decided to dispose of the spacecraft in the atmosphere of Saturn. Thus was Cassini’s end of mission set in motion.

Introduction: Cassini’s Grand Finale

Cassini’s finale actually began November 30, 2016, when a close flyby of Titan nudged it into a series of 20 ring-grazing orbits that saw it cross Saturn’s ring plane within 4,850 miles of the center of the narrow F ring. Five months later (April 2017), another Titan encounter altered Cassini’s orbit once again, sending it through the gap between Saturn’s upper atmosphere and the inner edge of its D ring. This is Cassini’s Grand Finale mission. The spacecraft will make 22 plunges through this gap, ending with its final dive into Saturn on September 15.

According to Cassini project scientist Linda Spilker, “It’s like getting a whole new mission. The scientific value of the F ring and Grand Finale orbits is so compelling that you could imagine a whole mission to Saturn designed around what we’re about to do.”

During its final orbits, Cassini will make the closest-ever observations of Saturn, map the planet’s magnetic and gravity fields and return ultra-close views of the atmosphere. Scientists also hope to gain new insights into Saturn’s interior structure, the precise length of a Saturnian day, and the total mass of the rings — which may finally help settle the question of their age. The spacecraft will directly analyze dust-sized particles in the main rings and, during its final five orbits, dip down to sample Saturn’s upper atmosphere.

It will take time to analyze all the data from Cassini’s Grand Finale, though its first passage between the inner edge of the D ring and Saturn’s atmosphere has already revealed that the region appears...
to be surprisingly dust-free. That data will add to the treasure trove of discoveries already made about this giant planet, its rings, and its system of moons. So as we await Cassini's final plunge, here's a brief look at some of those amazing finds. This compilation is subjective and is based largely on what caught the eye of *Mercury*'s editor.

**Titan**

The 2005 landing on Titan by ESA's Huygens probe was an historic first in the outer solar system. The probe's 2-hour and 27-minute descent revealed Titan to be remarkably like Earth before life evolved, with methane rain, erosion and drainage channels, and dry lake beds. A soup of complex hydrocarbons, including benzene, was found in Titan's atmosphere. Huygens also provided the first on-site measurements of the atmospheric temperature.

Titan is the only other place in the solar system that we know has stable liquid on its surface, though its lakes are made of hydrocarbons — liquid ethane and methane — rather than liquid water. While there is one large lake and a few smaller ones near Titan's south pole, almost all of Titan's lakes appear near the moon's north pole. Cassini found deep, steep-sided canyons on Titan that are flooded with liquid hydrocarbons. Although long suspected, it was the first direct evidence of the presence of liquid-filled channels on Titan, as well as the first observation of canyons hundreds of meters deep.

Titan's atmosphere is a zoo teeming with a variety of molecules — the most chemically complex in the solar system. Beginning with sunlight and methane, ever more complex molecules form until they become large enough to generate the smog that covers the giant moon. Nearer the surface, methane, ethane, and other organics condense and fall to the surface where other prebiotic chemistry may take place.
Enceladus
The discovery of Enceladus’ massive plumes from its south polar region was such a surprise that mission designers completely reshaped the mission to get a better look. The discovery became even more important when Cassini found evidence of water-based ice in the jets. The spacecraft detected hydrogen in the plume of gas and icy material spraying from Enceladus during its last, and deepest, dive through the moon’s jets on October 28, 2015. Scientists determined that nearly 98% of the gas in the plume is water, about 1% is hydrogen, and the rest is a mixture of other molecules including carbon dioxide, methane, and ammonia.

The spray is coming from a global ocean that lies beneath the icy crust of this geologically active moon. Researchers found the magnitude of the moon’s very slight wobble as it orbits Saturn can be accounted for only if its outer ice shell is not frozen solid to its core, meaning a global ocean must be present. If the surface and core were rigidly connected, the core would provide so much dead weight the wobble would be far smaller than we observe it to be. This proves that there must be a global layer of liquid separating the surface from the core.

Strange Moons
The origin of Iapetus’ two-faced surface has been a mystery for more than 300 years. Cassini solved the puzzle. Thermal segregation is probably most responsible for Iapetus’ dark hemisphere and its yin-yang appearance. Dark, reddish dust in Iapetus’ orbital path is swept up and lands on the leading face of the moon. Iapetus rotates slowly (once every 79.3 days), so the daily temperature cycle is very long. Consequently, the dark material can absorb heat from the Sun and warm up. This heating will cause any volatile, or icy species within the dark material, to sublime out and retreat to colder regions on Iapetus. This sublimation of volatiles results in the dark material becoming even

This image of Enceladus' jets was acquired as the spacecraft looked across the moon's south pole. The shadow of the body of Enceladus on the lower portions of the jets is clearly visible.

Dark material splatters the walls and floors of craters in the frozen wastelands of Iapetus. This image shows terrain in the transition region between the moon's dark leading hemisphere and its bright trailing hemisphere.
These two global images of Iapetus show the extreme brightness dichotomy on the surface of this peculiar Saturnian moon. The left-hand image shows the moon's leading hemisphere, while the image on the right reveals its trailing side. The dark terrain covers about 40% of the moon's surface.

Saturn. The most noticeable close-up feature of Hyperion is its oddly cratered surface. Hyperion's craters are particularly deep and do not have significant rays of ejecta (though there appears to have been slumping or landslides inside many of the bigger craters). The result is a curiously punched-in look, somewhat like the surface of a sponge or a wasp nest. Many of the crater walls on Hyperion are bright, which suggests an abundance of water ice.

Ring Moons
There are five small moons circling Saturn in or beside the rings. Pan orbits inside the Encke gap, which is located within Saturn's A ring. The distinctive, thin ridge around Pan's equator is thought to have come after the moon formed and had cleared the gap in the rings in which it resides today. Infalling material formed a tall, narrow ridge of material. Pan's gravity is so feeble that the ring material simply settles onto Pan and builds up, but other dynamical forces keep the ridge from growing indefinitely.

Daphnis is nicknamed "the wave maker" (see page 28). The little moon's gravity raises waves of nearby ring particles as it orbits within the Keeler Gap, a...
25-mile-wide opening some 150 miles from the A ring’s outer edge. Atlas orbits just outside the edge of the A ring. Like Pan, Atlas has a distinctive flying-saucer shape created by a prominent equatorial ridge not seen on the other small moons of Saturn.

There are two so-called “shepherd satellites” on either side of the F ring, a thin ring located about 1,800 miles beyond the outer edge of the A ring. Prometheus constrains the extent of the inner edge of the F ring; Pandora orbits on the outer edge of the F ring. While the traditional view has been that the F ring is held in place by these two shepherd moons, recent studies indicate only Prometheus contributes to the confinement.

Rings, Propellers, and Vertical Structures
Equinox is a time when the Sun is directly above a planet’s equator. Equinox at Saturn (which occurs once every 15 years) means the rings are edge-on to incoming sunlight. The illumination geometry that accompanies an equinox lowers the Sun’s angle to the ring plane and causes any structures jutting out of the plane to throw shadows across the rings. Thanks to the low Sun angle, vertical structures were seen rising abruptly from the edge of Saturn’s B ring and casting long shadows on the ring. Cassini scientists believe that this is one prominent region at the outer edge of the B ring where large moonlets, up to a mile across, are located. These bodies may significantly affect the ring material streaming past them and force the particles upward, in a “splashing” manner.

*Left:* Prometheus, some 85-miles long, acts as a shepherd satellite for Saturn’s F ring. *Right:* Pandora, about 52 miles across, orbits Saturn just outside the narrow F ring. The two images are not to scale.

Vertical structures rise from Saturn’s B ring edge to cast shadows on the ring. Part of the Cassini Division, between the B and the A rings, appears at the top of the image. Some of these towers of ring material reach as high as 1.6 miles above the ring plane — a significant deviation from the average 30-foot vertical thickness of the A, B, and C rings.

A propeller-shaped structure created by a moonlet is brightly illuminated on the sunlit side of Saturn’s rings. The moon, too small to be seen, is at the center of the disturbed ring material, which is visible left of center near the Encke Gap of the A ring. The propeller’s dimensions are about 35 miles by three miles.
Another sight made visible during equinox were “propellers,” disturbances in a segment of a ring caused by a central moonlet. The moonlet — perhaps a half-mile across — is too small to be seen. Disturbed ring material around the moonlet reflects sunlight, causing the material to appear like a white airplane propeller. Numerous propellers have been spotted (and tracked) by Cassini. Scientists have seen changes in the orbits of these moonlets, though they don’t yet know exactly what causes these changes.

Do more opaque areas of the rings contain a greater concentration of material than places where the rings seem more transparent? Apparently not. Some parts of Saturn’s B ring are up to 10 times more opaque than the neighboring A ring, but the B ring may weigh in at only two to three times the A ring’s mass. While the opacity of the B ring varies greatly across its width, the mass doesn’t vary much from place to place. At present, it’s not clear how regions with the same amount of material can have such different opacities. It could be something associated with the size or density of individual particles, or it could have something to do with the ring structure.

A Giant Planet
Saturn is big, and everything involving Saturn is big, too. And so it was with Saturn’s great northern storm, the biggest, most intense storm since 1990. Cassini’s radio and plasma wave science instrument detected the first signs of lightning on December 5, 2010, with data showing the lightning flash rate as more than 10 times per second. The storm grew rapidly, and by late January 2011, it had wrapped completely around the planet. The storm’s active convecting phase ended in late June 2011, but the turbulent clouds it created lingered in the atmosphere until 2012.
Saturn's polar regions have displayed extreme seasonal changes during Cassini’s decade-long watch, providing the most comprehensive view ever obtained of seasonal change on a giant planet. Saturn’s polar stratosphere features large warm vortices (a polar hood) during the summer that changed substantially during the last decade. The north pole warmed by about 36°F during its spring; the south pole cooled by about 63°F during its autumn. Shifting polar temperatures depend not only on sunlight but also on enormous global circulation patterns.

In the middle of Saturn’s north pole hexagon, a behemoth hurricane swirls. The hurricane’s eye is more than 3,000 miles in diameter; the winds in the eye wall travel at 340 mph. Unlike Earth’s hurricanes, which tend to move, Saturn’s hurricane is locked onto the planet’s north pole.

Epilogue: End of Mission
On September 15, Cassini’s observations will end. Images will no longer stream back from Saturn. We will miss those. But the data returned during the past 13 years will continue to be mined, and discoveries will continue to be made. And yet, without the flow of beautiful new images, it won’t be quite the same.

Farewell, Cassini.

The NASA/JPL top 10 lists for each year of the Cassini mission (plus two extra lists) can be found here.

PAUL DEANS is the editor of Mercury and was at NASA Ames in September 1979, when Pioneer 11 became the first spacecraft to encounter Saturn.
An Eclipse-Watcher’s Guide to a Total Eclipse of the Sun

What to expect, and look for, during the various stages of a total solar eclipse.

By Paul Deans

One of the most beautiful sights associated with a total solar eclipse is the “diamond ring.” It appears just before the beginning of totality, and again as totality is ending. Courtesy Rick Fienberg/TravelQuest International/Wilderness Travel.
Totality, no matter what its duration, seems to last no longer than eight seconds. This remark, by former Sky & Telescope editor Norm Sperling, accurately describes the eclipse experience for anyone encountering totality for the first time. Even for eclipse veterans, totality always seems far too short.

Of course, the eclipse itself lasts more than two hours, with totality comprising only a small segment of the experience. And there are times, particularly immediately prior to and during totality, when you’ll be conflicted as to what to look at, because so much is happening simultaneously.

So here are some suggestions as to what to look for (and what to expect) during the hour prior to totality, the hour after totality, and during those fleeting moments in between when the Sun is completely covered by the Moon. If you’ve never experienced totality, I hope you find this description useful.

In the Beginning
When the Moon takes its first tiny nibble out of the solar disk, it’s called first contact. First contact is initially visible only through a telescope, then in binoculars, and finally with the unaided eye. Regardless of how you view it, you must use a safe solar filter.

During the next hour, the lunar disk gradually hides more and more of the solar face. It’s a leisurely affair, so there’s no need to stare continuously at the Sun. Using your solar filter or eclipse shades/glasses, look at the Sun every five minutes or so, and mentally mark the progress of the Moon across the solar disk.

Also, take the time to look around. As the eclipse progresses, can you detect any change in the color and quality of the sky, the clouds,
nearby objects, and distant landscapes? How about any changes in the demeanor of your eclipse-watching companions?

As the partial phase progresses and the disk of the Sun becomes more of a crescent, look for a multitude of tiny images of the crescent Sun on the ground under any trees. The spaces between overlapping leaves act like the lenses of pinhole cameras to create this effect. If your site lacks trees, you can get the same effect using a straw hat, pinholes punched into a sheet of paper, or even your crossed fingers. Or bring a perforated spoon to create these tiny crescents!

Once more than half the Sun is covered, the light begins to fade, albeit imperceptibly at first. About 15 minutes prior to totality, the light becomes noticeably dimmer and starts to take on an odd or eerie “tint.” Shadows become sharper and more detailed. Look away from the shrinking crescent — has there been a change in the color of the sky and clouds since the eclipse began?

As the sunlight dims, you may notice animals and birds acting in a peculiar manner. Many start to settle in as if night is falling. Notice the people around you — they may be more animated than the local wildlife! As totality approaches, you may notice a perceptible drop in temperature, and the wind might pick up or change direction.

It’s Coming

In addition to a thinning solar crescent and fading light, another sign that totality is approaching is the appearance of Venus. In 2017, Venus is magnitude -4 (that means it’s bright), and it may appear 10 to 15 minutes prior to totality (depending on the clarity of the sky at your observing site). Venus is some 40° west of the Sun, so keep that in mind when you’re looking for it.

Shadow bands are dim, undulating ripples of dark and light that may flow across the ground just prior to second contact (and/or immediately after third contact). They can be hard to see, and if this is your first totality, I suggest you ignore this aspect of the eclipse.

Just before totality begins, the only parts of the Sun’s bright face not yet covered by the Moon are those that peek through deep valleys on the advancing lunar limb. Seen through safe solar filters, they look like a short curve of bright points. These are Baily’s beads. This image was shot without a solar filter to also show the red arc of the Sun’s chromosphere and two red loops of hot gas called prominences — visible immediately above the bright beads in this scene. [Courtesy Robert B. Slobins]

Look west a couple of minutes before totality. Can you see the approaching umbral shadow? If there are clouds on the horizon, they’ll go dark as the Moon’s shadow sweeps over them, thereby making the approaching umbra more noticeable.

Just prior to totality, all that remains of the Sun are a few shafts of light shining through deep valleys on the lunar limb. The effect is a few brilliant beads popping on, then off — these are called Baily’s beads. If you’re observing with eyes or optics, keep your solar filters on everything. If you’re not using your optics, take the filters off…but I suggest keeping your eyes protected by wearing your eclipse shades/glasses. I recommend this, because then you’ll be
better able to better appreciate the full extent of the Sun’s corona during totality, which is coming up fast.

**Totality Time**
The Moon’s shadow envelopes your observing site. Only a single bead remains — it shines like a brilliant diamond set into a pale ring of the pearly white corona (see the image on page 30). As you might guess, this is called the diamond ring, and as it fades, remove the filters covering your optics (if you haven’t already done so) and your eyes (if you still have your eclipse shades on).

The fading of the diamond ring also marks second contact and the official start of totality. As you are plunged into the lunar shadow, and the Sun’s ghostly, gossamer corona glows around the Moon’s black silhouette, feel free to scream and yell in delight, or just stare in silent awe. (Some observers have felt so overwhelmed at the sight that they start to cry. That’s fine, too.)

For a brief time after the start of totality, the Sun’s chromosphere (lower atmosphere) remains visible along the solar limb still being covered by the Moon. This vivid arc of red vanishes quickly, so don’t miss it. Depending on how active the Sun is, you may spot streamers of red stretching up from the chromosphere into the corona. These are solar prominences, and they, too, will rapidly disappear behind the intruding lunar limb.

Now’s the time to explore the solar corona. Using just your eyes, take a few moments to carefully examine the appearance of the corona near the Sun. Can you detect any color? Does the corona look smooth or mottled? Use averted vision (stare at the eclipsed Sun but concentrate your attention on either side) to determine how far east and west the faint, outer corona extends. Is it rounded or elongated?

Use binoculars or a telescope to check out detail within the corona. Look for loops and arcs that reveal solar magnetic fields, and compare the structure of the corona at the Sun’s poles and equator. (And if you see a bright star embedded in the corona next to the Sun, that’s Regulus.)

Now…take a moment to look around. Sky darkness during totality varies from eclipse to eclipse, and how dark it gets depends on a number of variables. Outside the path of totality, the Sun is still shining, albeit dimly. This feeble light creates a beautiful 360° sunset glow around the horizon. Don’t miss it.

If you’ve never experienced totality before, don’t squander it by looking for planets and stars. Trust me on this. If you must look, Venus should be obvious (even before totality), and for observers east of Casper, Wyoming, Jupiter is the bright object visible low in the southeast during totality.

The total phase of the November 3, 2013, solar eclipse as seen from Gabon, Africa. Totality was quite short; the red chromosphere remained visible for some time after second contact. This view of the Sun’s corona is about what you might expect to see looking through binoculars or a small telescope at low power. [Courtesy Jay Pasachoff/Allen Davis/Vojtech Rusin/Miloslav Druckmüller.]
The End is at Hand

All too soon, the sky and the edge of the corona roughly opposite where the Sun vanished become a little brighter. Fingers of red (prominences) may rise from behind the Moon’s retreating limb, followed by an emerging arc of red light — the chromosphere. The end of totality is imminent.

A blazingly bright bead of sunlight erupts into view. It’s the diamond ring — third contact. Totality is over. The stages of the eclipse now repeat themselves in reverse order.

More rays of sunlight burst through lunar valleys (Baily’s beads) and quickly combine to form a very thin crescent. It’s time to put the solar filters back on your optics and use your eclipse shades/glasses to view the Sun. The solar crescent rapidly expands, and the sky quickly brightens.

If you’re not busy watching Baily’s beads, quickly turn 180° away from the emerging Sun. Can you see the retreating shadow of totality as it rapidly speeds away to the east? The temperature may continue to cool slightly immediately after totality but will begin to rise shortly thereafter. However, the change may be subtle and could be masked by changes in wind speed and direction.

As the Sun emerges, so too will any wildlife that decided something odd was happening and went to bed. Meanwhile, your travel companions will likely be happily chatting among themselves, comparing totality images, and probably ignoring the returning solar disk. And the one recurring topic of conversation will be: When and where is the next total solar eclipse?

Just as it took a while for the Moon to cover the Sun, it will take an equally long time for the Moon to move off the solar disk, though the time between third and fourth contact will seem much, much longer than between first and second contact! But don’t lose track of time if you want to witness the official end of the eclipse.

At fourth contact the last tiny lunar indentation on the solar disk disappears, and the Moon no longer covers any part of the Sun’s surface. That’s it: The eclipse is officially over.

Final Comments

The key to not becoming overwhelmed by the sight of totality is to create a short list of what you really want to see and do, memorize it, and stick to it. Otherwise, you’ll spend your time gaping at the hole in the sky and totality will fly by — in what will seem like eight seconds.

To answer the obvious question: The next total eclipse of the Sun occurs July 2, 2019. The path of totality crosses the southern Pacific Ocean and touches land only in Chile (north of Santiago) and central Argentina. The next totality to touch North America? April 8, 2024.

Mercury editor Paul Deans has seen totality 10 times. Each one is different, and the experience never grows old. He’ll be in Idaho for Eclipse 2017.
Paintings, Sunspots, and Frost Fairs: Rethinking the Little Ice Age

Royal Astronomical Society

The whole concept of the ‘Little Ice Age’ is misleading, as the changes were small-scale, seasonal, and insignificant compared with present-day global warming argue a group of solar and climate scientists. Explanations for the cooling to Earth’s climate, thought to have occurred between the 16th and 19th centuries, include low solar activity, volcanic eruptions, human changes to land use, and natural climatological change.

But in a new paper in *Astronomy & Geophysics*, Professor Mike Lockwood (University of Reading) and his collaborators note that the temperature shift was smaller than that seen in recent decades resulting from the emission of greenhouse gases, and that although low solar activity may have been one driving factor, it certainly was not the only one.

Professor Lockwood said: “Commentators frequently refer to the Little Ice Age in discussions on climate change. We wanted to carry out a comprehensive study to see just how reliable the evidence is for a cooler climate, how big an impact it really had, and how strong the evidence for a solar cause really was.

“On the whole the Little Ice Age was a manageable downturn in climate concentrated in particular regions, even though places like the UK had a larger fraction of cold winters. Our research suggests that there is no single explanation for this, that warm summers continued much as they do today, and that not all winters were cold.”

Researchers scrutinized historical records, such as the accounts of ‘frost fairs’ when the River Thames froze solid, and looked at the paintings from the era, such as the landscapes of Pieter Bruegel the Elder, with *The Hunters in the Snow* depicting a cold winter scene.
Curiosity Peels Back Layers on Ancient Martian Lake

NASA/ Jet Propulsion Laboratory

A long-lasting lake on ancient Mars provided stable environmental conditions that differed significantly from one part of the lake to another, according to a comprehensive look at findings from the first three-and-a-half years of NASA's Curiosity rover mission. Different conditions favorable for different types of microbes existed simultaneously in the same lake.

Previous work had revealed the presence of a lake more than three billion years ago in Mars' Gale Crater. This study defines the chemical conditions that existed in the lake and uses Curiosity's powerful payload to determine that the lake was stratified. Stratified bodies of water exhibit sharp chemical or physical differences between deep water and shallow water. In Gale's lake, the shallow water was richer in oxidants than deeper water was.

"These were very different, co-existing environments in the same lake," said Joel Hurowitz of Stony Brook University, lead author of a report in the journal Science. "This type of oxidant stratification is a common feature of lakes on Earth, and now we've found it on Mars. The diversity of environments in this Martian lake would have provided multiple opportunities for different types of microbes to survive, including those that thrive in oxidant-rich conditions, those that thrive in oxidant-poor conditions, and those that inhabit the interface between those settings."

Whether Mars has ever hosted any life is still unknown, but

seeking signs of life on any planet — whether Earth, Mars, or more distant icy worlds — begins with reconstruction of the environment to determine if it was capable of supporting life. Curiosity's primary goal when it landed inside Gale Crater in 2012 was to determine whether Mars has ever offered environmental conditions favorable for microbial life.

MORE INFORMATION

This evenly layered rock (center) photographed by Curiosity shows a pattern typical of a lake-floor sedimentary deposit not far from where flowing water entered a lake. The view spans about five feet across in the foreground. These rocks are interpreted to record sedimentation in a lake, as part of or in front of a delta, where plumes of river sediment settled out of the water column and onto the lake floor. [NASA/JPL-Caltech/MSSS2]
Star’s Birth May Have Triggered Another Star Birth
National Radio Astronomy Observatory

Astronomers using the National Science Foundation’s Karl G. Jansky Very Large Array (VLA) have found new evidence suggesting that a jet of fast-moving material ejected from one young star may have triggered the formation of another, younger protostar. “The orientation of the jet, the speed of its material, and the distance all are right for this scenario,” said Mayra Osorio, of the Astrophysical Institute (IAA-CSIC) of Andalucia in Spain.

The scientists studied a giant cloud of gas some 1,400 light-years from Earth in the constellation Orion, where numerous new stars are being formed. The region has been studied before, but Osorio and her colleagues carried out a series of VLA observations at different radio frequencies that revealed new details.

Images of the pair show that the younger protostar, called HOPS (Herschel Orion Protostar Survey) 108, lies in the path of the outflow from the older, called HOPS 370. This alignment led Yoshito Shimajiri and collaborators to suggest in 2008 that the shock of the fast-moving material hitting a clump of gas had triggered the clump’s collapse into a protostar. “We found knots of material within this outflow and were able to measure their speeds,” said Ana K. Diaz-Rodriguez also of IAA-CSIC.

The new measurements gave important support to the idea that the older star’s outflow had triggered the younger star’s formation process. The scientists suggest that the jet from HOPS 370 (also known as FIR 3) began to hit the clump of gas about 100,000 years ago, starting the process of collapse that eventually led to the formation of HOPS 108 (also known as FIR 4). Four other young stars in the region also could be the result of similar interactions, but the researchers found evidence for shocks only in the case of HOPS 108.

While the evidence for this triggering scenario is strong, one fact appears to contradict it.

MORE INFORMATION

Protostar FIR 3 (HOPS 370) with outflow that may have triggered the formation of younger protostar FIR 4 (HOPS 108). Pullouts are VLA images of each protostar. [Osorio et al., NRAO/AUI/NSF]
New Branch in Family Tree of Exoplanets Discovered
California Institute of Technology

Since the mid-1990s, when the first planet around another Sun-like star was discovered, astronomers have been amassing what is now a large collection of exoplanets — nearly 3,500 have been confirmed so far. In a new Caltech-led study, researchers have classified these planets in much the same way that biologists identify new animal species and have learned that the majority of exoplanets found to date fall into two distinct size groups: rocky Earth-like planets and larger mini-Neptunes. The team used data from NASA’s Kepler mission and the W.M. Keck Observatory.

“This is a major new division in the family tree of planets, analogous to discovering that mammals and lizards are distinct branches on the tree of life," says Andrew Howard, professor of astronomy at Caltech and a principal investigator of the new research. In essence, the research shows that our galaxy has a strong preference for two types of planets: rocky planets up to 1.75 times the size of Earth, and gas-enshrouded mini-Neptune worlds, which are from 2 to 3.5 times the size of Earth (or somewhat smaller than Neptune). Our galaxy rarely makes planets with sizes in between these two groups.

“Astronomers like to put things in buckets," says Fulton. "In this case, we have found two very distinct buckets for the majority of the Kepler planets.”

The Caltech team took a closer look at the Kepler planets’ sizes with the help of the Keck Observatory. They spent years obtaining spectral data on the stars hosting 2,000 Kepler planets. The spectral data allowed them to obtain precise measurements of the sizes of the Kepler stars; these measurements, in turn, allowed the researchers to determine more precise sizes for the planets orbiting those stars.
Giant Ringed Planet Likely Cause of Mysterious Eclipses

University of Warwick, UK

A giant gas planet — up to 50 times the mass of Jupiter, encircled by a ring of dust — is likely hurtling around a star more than a thousand light-years away from Earth, according to new research by an international team of astronomers, led by the University of Warwick.

Hugh Osborn, a researcher from Warwick’s Astrophysics Group, has identified that the light from this rare young star is regularly blocked by a large object, and predicts that these eclipses are caused by the orbit of this as-yet undiscovered planet.

Using data from the Wide Angle Search for Planets (WASP) and Kilodegree Extremely Little Telescope (KELT), Osborn and fellow researchers analyzed fifteen years of the star’s activity. “We found a hint that this was an interesting object in data from the WASP survey,” said Osborn, “but it wasn’t until we found a second, almost identical eclipse in the KELT survey data that we knew we had something special.”

They discovered that every two and a half years, the light from this distant star — PDS 110 in the Orion constellation, which is same temperature and slightly larger than our Sun — is reduced to 30% for about two to three weeks. Two notable eclipses observed were in November 2008 and January 2011.

“What’s exciting is that during both eclipses we see the light from the star change rapidly, and that suggests that there are rings in the eclipsing object, but these rings are many times larger than the rings around Saturn,” says Leiden astronomer Matthew Kenworthy.

Assuming the dips in starlight are coming from an orbiting planet, the next eclipse is predicted to take place in September this year — and the star is bright enough that amateur astronomers all over the world will be able to witness it and gather new data. Only then will we be certain what is causing the mysterious eclipses. If confirmed in September, PDS 110 will be the first giant ring system that has a known orbital period.
GBT Captures Orion Blazing Bright in Radio Light

Green Bank Observatory

A team of astronomers has unveiled a striking new image of the Orion Molecular Cloud (OMC) — a bustling stellar nursery teeming with bright, young stars and dazzling regions of hot, glowing gas. The researchers used the NSF’s Green Bank Telescope (GBT) in West Virginia to study a 50 light-year-long filament of star-forming gas that is wending its way through the northern portion of the OMC known as Orion A. The GBT rendered this image by detecting the faint radio signals naturally emitted by molecules of ammonia that suffuse interstellar clouds.

These observations are part of the first data release from a large campaign known as the Green Bank Ammonia Survey. Its purpose is to map all the star-forming ammonia and other key tracer molecules in a massive structure known as the Gould Belt. The Gould Belt is an extended ribbon of bright, massive stars stretching about 3,000 light-years in an arc across the sky. This first release covers four distinct Gould Belt clouds, one located in Taurus, one in Perseus, one in Ophiuchus, and Orion A North in Orion.

“We hope to use these data to understand better how large clouds of gas in our galaxy collapse to form new stars,” said Rachel Friesen, one of the collaboration’s co-principal investigators and, until recently, a Dunlap Fellow at the Dunlap Institute for Astronomy and Astrophysics at the University of Toronto (Canada). “The new data are critical to assessing whether certain gas clouds and filaments are stable and enduring features or if they are undergoing collapse and forming new stars.”

The new GBT image is combined with an infrared one taken with NASA’s Wide-field Infrared Survey Explorer (WISE) telescope. The composite image illustrates how star-forming gas in this region relates to the bright stars and dark, dusty regions of the nebula.

The 100-meter GBT, which is located in the National Radio Quiet Zone, is exquisitely sensitive and uniquely able to study the molecular composition of star-forming clouds and other objects in the cosmos.
**Producing Runaway Stars**

*AAS Nova/Susanna Kohler*

How are the hypervelocity stars we’ve observed in our galaxy produced? A recent study suggests that these escapees could be accelerated by a massive black hole in the center of the Large Magellanic Cloud. Since their discovery in 2005, we’ve observed dozens of candidate “hypervelocity stars” — stars whose velocity in the rest frame of our galaxy exceeds the local escape velocity of the Milky Way. These stars present a huge puzzle: how did they attain these enormous velocities?

One potential explanation is known as the Hills mechanism. In this process, a stellar binary is disrupted by a close encounter with a massive black hole (like those thought to reside at the center of every galaxy). One member of the binary is flung out of the system as a result of the close encounter, potentially reaching very large velocities. Usually, discussions of the Hills mechanism assume that Sagittarius A*, the supermassive black hole at the center of the Milky Way, is the object guilty of accelerating the hypervelocity stars we’ve observed. But what if the culprit isn’t Sgr A*, but a massive black hole at the center of the Large Magellanic Cloud (LMC), one of the Milky Way’s satellite galaxies?

Though we don’t yet have evidence of a massive black hole at the center of the LMC, the dwarf galaxy is large enough to potentially host one as large as 100,000 solar masses. Assuming that it does, two scientists at the University of Cambridge, Douglas Boubert and Wyn Evans, have now modeled how this black hole might tear apart binary star systems and fling hypervelocity stars around the Milky Way.

Boubert and Evans determined that the LMC’s hypothetical black hole could easily eject stars at ~100 km/s, which is the escape velocity of the LMC. When this speed is combined with the orbital velocity of the LMC itself (another ~380 km/s relative to the Milky Way), this could result in hypervelocity stars moving faster than the escape speed of the Milky Way, as observed.

If the LMC is indeed ejecting hypervelocity stars along its orbit, this could explain an observed anisotropy in the hypervelocity stars we’ve detected, with many of these stars clustering in the constellations of Leo and Sextans. This clustering is consistent with stars ejected ahead of the LMC’s orbit.
Extreme Fine Measurements of Motion in Orbiting Supermassive Black Holes
Stanford University

Approximately 750 million light-years from Earth lies a gigantic, bulging galaxy with two supermassive black holes at its center. These are among the largest black holes ever found, with a combined mass 15 billion times that of the Sun. New research from Stanford University has used long-term observation to show that one of the black holes seems to be orbiting around the other. If confirmed, this is the first duo of black holes ever shown to be moving in relation to each other. It is also, potentially, the smallest ever-recorded movement of an object across the sky, also known as angular motion.

“If you imagine a snail on the recently discovered Earth-like planet orbiting Proxima Centauri — a bit over four light-years away — moving at one centimeter a second, that’s the angular motion we’re resolving here,” said Roger W. Romani, professor of physics at Stanford.

Over the past 12 years, scientists led by Greg Taylor (University of New Mexico) have taken snapshots of the galaxy containing these black holes — called radio galaxy 0402+379 — with a system of 10 radio telescopes that stretch from the US Virgin Islands to Hawaii, and New Mexico to Alaska. The galaxy was officially discovered back in 1995. In 2006, scientists confirmed it as a supermassive black-hole binary system with an unusual configuration.

“The black holes are at a separation of about seven parsecs, which is the closest together that two supermassive black holes have ever been seen before,” said Karishma Bansal, a graduate student in Taylor’s lab. With this most recent paper, the team reports that one of the black holes moved at a rate of just over one micro-arcsecond per year, an angle about one billion times smaller than the smallest thing visible with the naked eye. Based on this movement, the researchers hypothesize that one black hole may be orbiting around the other with a period of 30,000 years.
Catherine Wolfe Bruce Gold Medal

The Astronomical Society of the Pacific (ASP) is proud to award the 2017 Catherine Wolfe Bruce Gold Medal to Dr. Nick Scoville, the Francis L. Moseley Professor of Astronomy (Emeritus) at the California Institute of Technology and former director of Caltech’s Owens Valley Radio Observatory. He is a pioneer in millimeter-wave astronomy and a leading expert in studies of galaxy evolution, the nature of the dense interstellar molecular gas in galaxies, and star formation.

Prof. Scoville spearheaded and led the Cosmic Evolution Survey (COSMOS), a landmark project using data from virtually every large space- and ground-based telescope to study the large-scale structure of the universe and the evolution of galaxies over a vast range of cosmic distance. COSMOS engages in excess of 100 astronomers in more than a dozen countries, investigating a single patch of sky about 16 times the size of the full Moon. Since 2004, with a large allocation of observing time on the Hubble Space Telescope, COSMOS has detected more than a million galaxies spanning cosmic time back to the first billion years of the universe. Prof. Scoville has recently used the Atacama Large Millimeter Array (ALMA) to investigate the evolution of star formation in the early universe, going back to two-thirds of the age of the universe using a sample of 700 galaxies in the COSMOS field. He has also led the highest-resolution ALMA imaging of the nearby colliding starburst galaxy Arp 220.

Scoville’s awards and recognitions include presenting the 50th Jansky Lecture, receiving the prestigious Guggenheim Fellowship, and receiving the Aaronson Award from the University of Arizona. In addition, he is the author of more than 600 publications in observational and theoretical astrophysics.

The Catherine Wolfe Bruce Gold Medal was established by Catherine Wolfe Bruce, an American philanthropist and patroness of astronomy. It is given annually by the ASP to a professional astronomer in recognition of a lifetime of outstanding achievement and contributions to astrophysics research. It was first awarded in 1898 to Simon Newcomb. Previous recipients of the Bruce Medal include Giovanni V. Schiaparelli (1902), Edwin Hubble (1938), Fred Hoyle (1970), and Vera Rubin (2003). (Here is a complete list of the Catherine Wolfe Bruce Gold Medal recipients, and more details about Prof. Scoville can also be found here.)
Single Eclipse Activity Kit
Organizing a family and/or friends trip to see the eclipse this August? You might want to plan with this affordably priced Eclipse Demo to demonstrate how a solar (or lunar) eclipse happens. Free enclosures include: Solar glasses and a pinhole postcard to view safely, and UV beads to demonstrate colorful effects of UV rays. Shipping included. The kit is available in the ASP’s AstroShop.

Position Available: Mercury Editor
The Astronomical Society of the Pacific is looking to replace the current editor of Mercury magazine, who is retiring from the position at the end of the year. Currently, Mercury is a 40- to 50-page digital magazine published quarterly, featuring articles showcasing the latest developments in astronomy as well as Society news and monthly sky events.

The editor of Mercury works with the Director of Membership and reports directly to the ASP’s Executive Director. This position has responsibility for the content, style, and quality of the magazine, ensuring Mercury serves the ASP’s mission to increase science literacy through astronomy.

Mercury’s editor solicits articles, finds and selects images and art elements, writes stories and other items as required, edits all copy, and works closely with the ASP’s designer during all stages of the magazine’s production.

The editor of Mercury must possess a broad knowledge of astronomy and/or space science in addition to having strong editing and proofreading skills. The ASP is also seeking a better way to reach a wider, younger, and more diverse audience, so the successful candidate for the position will have knowledge of, and experience with, innovative approaches to creating and disseminating digital content.

This is a freelance, contract position — the position does not include benefits. Compensation to be determined based on the qualifications of the applicant. More details, including how to apply, are available here.

NASA Virtual Reality for Informal Education
This is a collection of media, which includes spherical images/videos using equi-rectangular warping, which should be usable by most digital planetarium systems, goggle VR, and smartphone VR setups with minimum extra work. Files, including videos, are downloadable.

Possible uses include use inside your existing planetarium shows, live “space update” or “sky tonight” shows, use on your museum floor with a simple smartphone and goggle setup with a facilitator up to a full, professional VR rig, and use in the classroom or at a science festival with a smartphone or computer (download for offline use to save wireless data charges).

The NASA VR website is: https://informal.jpl.nasa.gov/museum/VR.
**Save the Date**

Join us December 5 and 6, 2017, at the Moonrise Hotel in St. Louis, Missouri, for the ASP’s 129th Annual Meeting. This year’s conference theme is *Beyond the Eclipse: Engaging Diverse and Underserved Communities in Astronomy and STEM*, with a special emphasis on working with and engaging diverse and underserved communities.

This ASP 2017 conference will help us all look “beyond the 2017 eclipse” as a follow-up to last year’s conference, which focused on how best to engage all underserved communities in the 2017 solar eclipse. Join us four months after the August eclipse to share outreach efforts that worked best and discuss what could be improved, not just for future eclipses but to inform other astronomy education and outreach activities striving to reach diverse audiences.

You can learn more at our [conference webpage](#), where you can also sign up to be notified when registration opens.

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**NEW MEMBERS** — The ASP thanks all those who recently renewed their membership, and welcomes new members who joined between April 1 and June 30, 2017.

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<thead>
<tr>
<th>Individual</th>
<th>New Members</th>
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<tr>
<td>José Almeida, Sanger, CA</td>
<td>Carrie Given, Clovis, CA</td>
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<td>Michelle Anctil, Grand Terrace, CA</td>
<td>Nick Gray, Lodi, CA</td>
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<td>Angela Arends, Clackamas, OR</td>
<td>Janet Hubner, Fresno, CA</td>
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<td>James Artero, Santa Rosa Valley, CA</td>
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<td>Jessie Breton, Edmonton, AB, Canada</td>
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<td>Marianne Chang, Ione, CA</td>
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<td>Millie Chavez, Sanger, CA</td>
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<td>Chris Courtney, Oakdale, CA</td>
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<td>Karina Engstrom, Rancho Cordova, CA</td>
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<td>Alan Ewy, Parlier, CA</td>
<td>James Lowenthal, Northampton, MA</td>
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<td>John Folkerts, Snøhomish, WA</td>
<td>Melissa Marcucci, Turlock, CA</td>
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<td>Cindy Friday Beeman, Fresno, CA</td>
<td>Christie McCaa, Stockton, CA</td>
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<td>Elizabeth García, Dinuba, CA</td>
<td>Samantha McCoy, Stockton, CA</td>
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<td>Cristal Meza, Sanger, CA</td>
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<td>Mark Croom, Yorktown, VA</td>
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<td>Paul Hemphill, Nashville TN</td>
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<td>Robert Hoyle, Moose, WY</td>
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<td>Michihiro Shimada, Nara, Nara, Japan</td>
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<td>Alice Enevoldsen, Seattle, WA</td>
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The Moonrise Hotel, St. Louis, MO. [ASP/Paul Deans]
The Skies of August

The highlight of the month is, obviously, the total eclipse of the Sun on the 21st. If you’ve just returned after years of slaving in the Mines of Moria and know nothing about it, you can check out the ASP’s 2017 Solar Eclipse Resources, read more than 15 recent Mercury articles and columns about the eclipse, and learn more than you thought you ever needed to know about the eclipse at the American Astronomical Society’s Eclipse Across America webpage. Just remember, the path of totality is the place to be. As the saying goes: Be there, or be square! — a 99% eclipse, visible just outside the path, simply won’t do.

The Perseid meteor shower peaks on the 12th, but during daylight hours for North America. You might have good observing luck by watching on two nights: Friday night/Saturday morning (August 11/12) and Saturday night/Sunday morning (August 12/13). This annual display is likely one of the most regularly watched celestial events, precisely because it’s regular. Unfortunately, moonlight from the waning gibbous Moon will tend to wash out the fainter Perseids.

Another highlight is not visible from North America. On the 7th there is a partial eclipse of the Moon, but the best views are from eastern Africa, India, China, and most of Australia.

Elsewhere in the sky, the planets continue to roll through the heavens, though both Mars and Mercury are hidden in the solar glare this month. Jupiter is reasonably well placed for viewing after sunset, particularly during the first half of the month as it sets more than two hours after the Sun. But it sinks lower each evening, so pull out your telescope and start observing as soon as possible as twilight fades. The giant planet sits to the left of the crescent Moon on the 24th and to the Moon’s lower right on the 25th.

On the other hand, Saturn is nicely positioned for observing this
month. It’s a popular target for summer star parties, and it appears well up in the south after sunset. After Jupiter sinks too low for reasonable views, swing your scope over to this lovely ringed planet. On the 2nd, Saturn sits just below the 10-day-old Moon; on the 29th and 30th, the just-past-first quarter Moon is to Saturn’s upper right and upper left respectively. Perhaps avoid observing Saturn on these three dates, because moonlight will interfere with your viewing pleasure.

Finally, **Venus** continues to shine at dawn. It’s more than 25° above the eastern horizon some 30 minutes before sunrise and is a lovely bright celestial beacon in the dawn sky. On the morning of the 18th, the crescent Moon is to the planet’s upper right; the next dawn finds a very slender crescent almost directly below Venus.

**The Skies of September**

**Jupiter** remains visible low in the west after sunset, but its evenings as a sunset sight are numbered. At the beginning of the month, it sets roughly 90 minutes after the Sun, but by month’s end the giant planet sets a mere 50 minutes after sunset. On the 22nd Jupiter will be some 7° to the lower right of the 2.5-day-old crescent Moon.

At least **Saturn** continues to be nicely placed for viewing as twilight fades. It’s still in the south at sunset, setting several hours later — making it a prime target for Astronomy Day observing at month’s end. On the 26th, this ringed planet sits only 2° below the nearly first quarter Moon as both emerge from dusk’s glow.

In the east at dawn, **Venus** remains bright. It’s still fairly high and obvious 30 minutes before sunrise on the 1st, but it appears lower and lower in the sky at the same time each subsequent morning. On the 17th the waning lunar crescent sits to the planet’s upper right. **Mercury** puts on a decent dawn show during mid-month. It’s more than 10° below and slightly left of Venus during this time. On the 16th, look east about 45 minutes before sunrise. If you can find Mercury in binoculars, you’ll find **Mars** a mere 0.3° below it. Two mornings later, with Venus some 20° high and a very thin crescent Moon just below it, look half again as far below the Moon as Venus is above the Moon to find faint reddish Mars and below it, somewhat brighter Mercury. (Neither Mercury nor Mars are particularly bright, though Mercury is the brighter of the two.) Look for Venus and Mars to get together early next month, while Mercury falls back sunward.

On the 12th, most of North America (plus Hawaii, but only the very southern tip of Alaska) will be able to see the last quarter Moon **occur the 1st-magnitude star Aldebaran** (in Taurus, the Bull). But there’s a catch. If you live east of the Rockies, the occultation occurs post-sunrise. Only if you’re west of the Rockies will you see the disappearance (and possibly the reappearance) of the star in a darkish sky. Those two sentences are a very general statement, so check this list to find the **Universal Times** of the events for your location.

The **Autumal Equinox**, the moment autumn officially begins in the Northern Hemisphere, occurs on September 22nd at 20:02 Universal Time, which translates into 16:02 Eastern time or 13:02 Pacific time. **Autumn Astronomy Day** occurs Saturday, September 30th; check the **Clubs & Events page** on the NASA/ASP Night Sky Network for events in your area.
The Skies of October

Only one planet remains in the sunset sky, and that’s Saturn. It sits moderately high in the southwest as twilight fades. On the 23rd the planet is to the left of the crescent Moon; the next evening it’s to Luna’s lower right.

Within a few days of the start of the month, Jupiter has slid down into the solar glare and is invisible until mid-November, while Mercury doesn’t move out of the Sun’s glow until early next month.

In the dawn sky, Mars rises past Venus, as Venus falls sunward. On the 5th, Venus sits a mere ¼° from Mars; they’re about 10° high in the east some 45 minutes before sunrise. You will definitely need binoculars or a small telescope to separate the two. Because Mars is so dim, you might lose track of it after its conjunction with Venus. So on the 17th, look for Mars a mere 2° to the upper right of the thin crescent Moon — with Venus some 5° directly below the crescent. The next morning, Venus sits above the crescent.

Across much of the central US and Mexico, the waning crescent Moon will occult bright Regulus (in Leo, the Lion) during the morning hours of the 15th. As with the occultation of Aldebaran last month, you’ll need to check a list of the star’s disappearance and reappearance times (in Universal Time) to determine if you’ll be able to see this occultation from your observing site.

International Observe the Moon night takes place on Saturday, October 28. You can learn more about this event here and here.

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 5 ($2.99 for the basic version; available for iPhone, iPad, and iPod touch; also 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.

— P.D.
On July 4, 1997, NASA’s Pathfinder mission bounced to a successful landing on Mars. It later released its little Pathfinder rover. In the 20 years since, eight other NASA landers and orbiters have arrived successfully, and not a day has passed without the US having at least one active robot on, or in orbit around, Mars. This view of Pathfinder, next to the rock known as Yogi, is part of a large panorama acquired shortly after Pathfinder landed. [Courtesy NASA/JPL]