SIRIUS ASTRONOMER

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The Newsletter of the Orange County Astronomers

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Venus gleams atop Jupiter and Mars, which were in close conjunction on October 17, 2015. Details: 24mm lens, f/2.8, 15 seconds, ISO 1600. Photo taken 5:30 a.m. CDT. Credit: Bob King

OCA CLUB MEETING

The free and open club meeting will be held December 11 at 7:30 PM in the Irvine Lecture Hall of the Hashinger Science Center at Chapman University in Orange. This month's speaker is Dr. David Crisp of JPL with the topic "Watching The Earth Beneath"

NEXT MEETINGS: Jan. 8, Feb. 12

STAR PARTIES

The Black Star Canyon site will open on December 5. The Anza site will be open on December 12. Members are encouraged to check the website calendar for the latest updates on star parties and other events.

Please check the website calendar for the outreach events this month! Volunteers are always welcome!

You are also reminded to check the web site frequently for updates to the calendar of events and other club news.

COMING UP

The next session of the Beginners Class will be held at the Heritage Museum of Orange County at 3101 West Harvard Street in Santa Ana on December 4. The following class will be held January 1.

GOTO SIG: TBA
Astro-Imagers SIG: Dec. 8
Remote Telescopes: TBA
Astrophysics SIG: Dec. 18, Jan. 15
Dark Sky Group: TBA

How will we finally image the event horizon of a black hole?

By Ethan Siegel

One hundred years ago, Albert Einstein first put forth his theory of General Relativity, which laid out the relationship between spacetime and the matter and energy present within it. While it successfully recovered Newtonian gravity and predicted the additional precession of Mercury's orbit, the only exact solution that Einstein himself discovered was the trivial one: that for completely empty space. Less than two months after releasing his theory, however, the German scientist Karl Schwarzschild provided a true exact solution, that of a massive, infinitely dense object, *a black hole*.

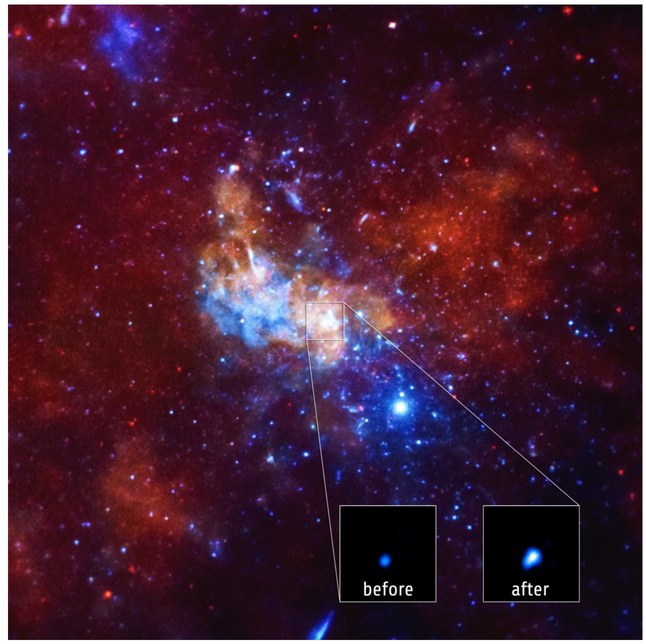

Image credit: NASA/CXC/Amherst College/D.Haggard et al., of the galactic center in X-rays. Sagittarius A is the supermassive black hole at our Milky Way's center, which normally emits X-ray light of a particular brightness. However, 2013 saw a flare increase its luminosity by a factor of many hundreds, as the black hole devoured matter. The event horizon has yet to be revealed.*

One of the curious things that popped out of Schwarzschild's solution was the existence of an event horizon, or a region of space that was so severely curved that nothing, not even light, could escape from it. The size of this event horizon would be directly proportional to the mass of the black hole. A black hole the mass of Earth would have an event horizon less than a centimeter in radius; a black hole the mass of the sun would have an event horizon just a few kilometers in radius; and a supermassive black hole would have an event horizon the size of a planetary orbit.

Our galaxy has since been discovered to house a black hole about four million solar masses in size, with an event horizon about 23.6 million kilometers across, or about 40 percent the size of Mercury's orbit around the sun. At a distance of 26,000 light years, it's the largest event horizon in angular size visible from Earth, but at just 19 micro-arc-seconds, it would take a telescope the size of Earth to resolve it – a practical impossibility.

But all hope isn't lost! If instead of a single telescope, we built an *array* of telescopes located all over Earth, we could simultaneously image the galactic center, and use the technique of VLBI (very long-baseline interferometry) to resolve the black hole's event horizon. The array would only have the light-gathering power of the individual telescopes, meaning the black hole (in the radio) will appear very faint, but they can obtain the resolution of a telescope that's the distance between the farthest telescopes in the array! The planned Event Horizon Telescope, spanning four different continents (including Antarctica), should be able to resolve under 10 micro-arc-seconds, imaging a black hole directly for the first time and answering the question of whether or not they truly contain an event horizon. What began as a mere mathematical solution is now just a few years away from being observed and known for certain!

Note: This month's article describes a project that is not related to NASA and does not suggest any relationship or endorsement. Its coverage is for general interest and educational purposes.

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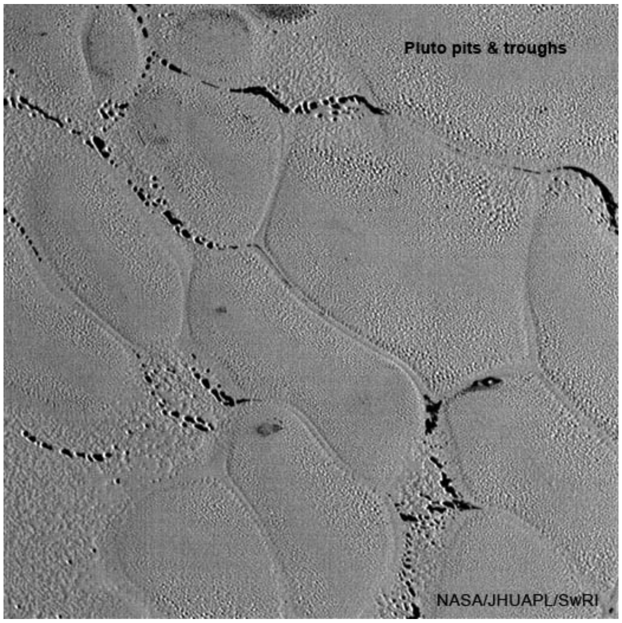
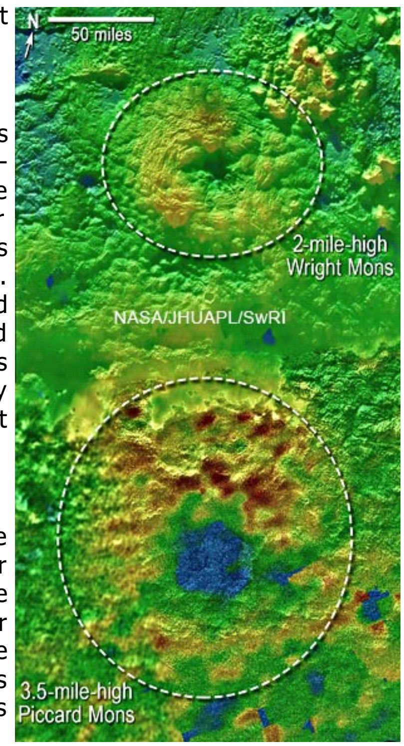
AstroSpace Update

December 2015

Gathered by Don Lynn from NASA and other sources



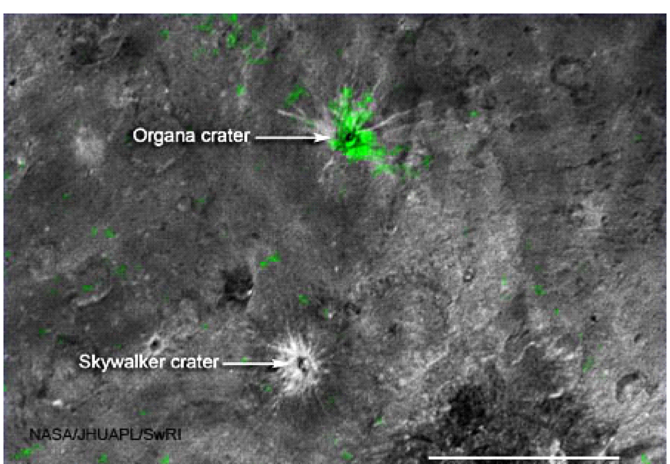
New Horizons (Pluto mission) continues to return data taken during the recent flyby of Pluto. The smooth nitrogen ice plain known as Sputnik Planum was found to have thousands of small pits. Scientists theorize that the pits, as well as troughs there, are possibly formed by sublimation or evaporation of ice into Pluto's thin atmosphere. The details of formation of pits and troughs remain mysteries though. No impact craters are found in this area, so it has been resurfaced in the last 10 million years or less. Areas in Pluto's northern and mid latitudes and the dark area called Cthulhu have the most craters, so must be the oldest surfaces, perhaps unchanged for 4 billion years. There are also areas of less cratering, indicating that Pluto has been partially resurfaced at various times. Crater counts by size show most impactors were no more than a few miles (km) across. The little data we had previously had implied that objects of this size in the Kuiper Belt would be less numerous. The new crater counts imply the percentages of objects in this small size range in the Kuiper Belt is more like the percentages in the asteroid belt. This new data will require theories of planet formation to be tweaked.



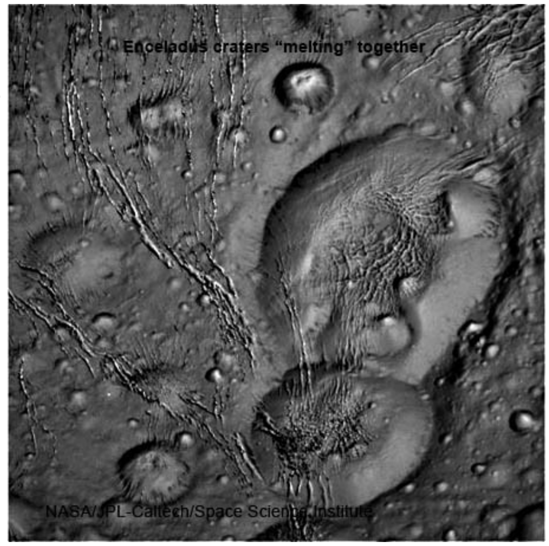
Scientists have found in New Horizons images of Pluto 2 mountains with craters at the top that appear to be volcanoes. The temperatures there would require these to be **ice volcanoes**. That is, materials that we consider ices, such as water ice, dry ice, or nitrogen ice, would form the mountain, and this material melted to liquid would spew out. This is surprising, because theory says there should not be enough heat in Pluto to do this melting. However new studies of ammonia-water mixtures show that volcanism with this material could occur at lower temperatures and allows more tectonic movement in the mantle, and so is a good possibility for activity on Pluto. The mountains are tens of miles (km) across and a few miles (km) high. They are located south of Sputnik Planum. They appear to have formed very recently geologically, perhaps within the past 10 million years. More analysis will be done to confirm that they are indeed volcanoes.

Most outer planet small moons end up tidally locked to their planet, always showing the same face to the planet. **Pluto's 4 small moons** were found to be completely different. Their spin periods range from 10-130 hours, much faster than their orbital periods. Hydra, being the extreme, spins 89 times during each orbit. Nix rotates retrograde, and the spin axes of the other 3 are tipped on their side relative to their orbits. Probably Charon's gravity has mixed up the spins of the small moons, and continues to do so. Observations seem to show that spins rates and directions are changing for these 4 moons. Nix is rotating 10% faster than it did 3 years ago.

A relatively young crater preliminarily named Organa on Pluto's moon **Charon** was found to be rich in frozen ammonia. A neighboring crater of similar size, as well as any other Charon craters, are not. Scientists are trying to figure out what made Organa different. Leading theories are that the area was rich in ammonia just below the surface before the impact, or that the impactor was rich in ammonia. Either one leaves the previous source of the ammonia not accounted for.

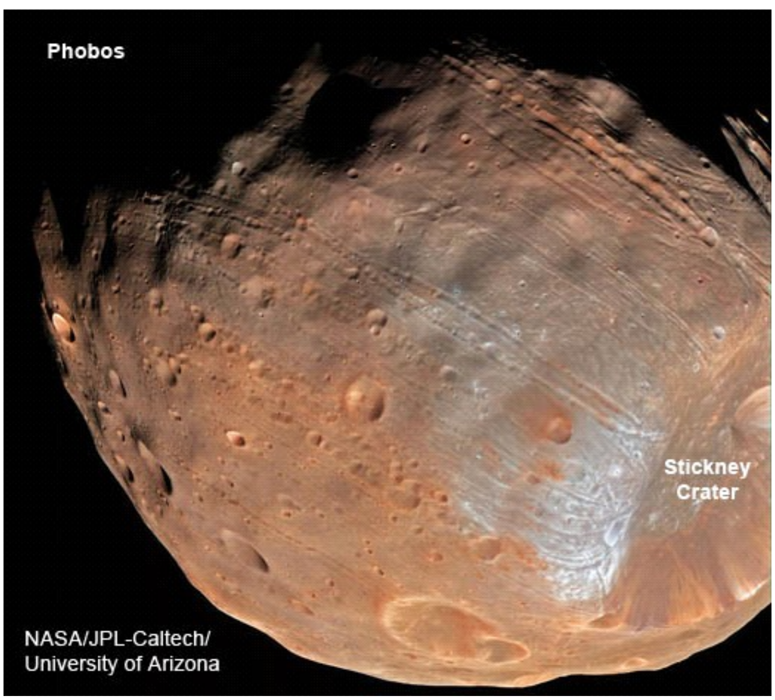


Since the discovery of **Pluto's thin atmosphere** decades ago, scientists have wondered how it survives. It should either freeze out on the surface or leak away from the top into interplanetary space. New Horizons data show the atmosphere is much colder and more compact (about 3 times more compact) than anyone expected. Both of these factors reduce the loss to space drastically, about 1000 times more slowly than previously calculated. This would allow the atmosphere to remain for billions of years. It probably does partially freeze onto the surface, but later sublimes/evaporates from either the Sun's heat or Pluto's internal heat.



Cassini (Saturn mission) made 2 close flybys of Saturn's moon Enceladus in October, one over the north pole and one over the south pole. This is the 1st encounter over the north pole since the seasons changed and the pole is in sunlight. Scientists expected the northern region to be heavily cratered, but found also a network of thin cracks that slice through the craters, and therefore formed after the crater impacts occurred. Craters near the north pole appear to be melting into each other. The southern flyby went right through the jets from the geysers. Since it has now been established that the material spewed by the geysers came from a global ocean under the icy surface, Cassini was able to directly measure particles from the ocean as it flew through the jets. Only one more flyby of Enceladus is scheduled during the mission, and that occurs this month (December). Cassini just achieved 18 years in space, nearly 7 of those to fly to Saturn, the rest orbiting the planet.

MAVEN (Mars orbiter) has determined that Mars a few billion years ago lost its thick atmosphere and surface liquid water because it lost tremendous quantities of gas to space via stripping by the solar wind. This had long been theorized, but MAVEN's measurements confirmed it. The process started about 4.2 billion years ago when Mars lost its global magnetic field. Before that, the magnetic field deflected the solar wind. The surface water mostly disappeared by 3.7 billion years ago. MAVEN has been orbiting the red planet and measuring its atmospheric properties since September last year. The solar wind was found to be stripping about ¼ pound (100 g) per second. But that increases by 10-20 times during periods when coronal mass ejections (CMEs) are thrown off by the Sun and strike the planet. But the Sun was much more active in its early history, so CMEs would have played a bigger part during the time Mars lost most its atmosphere. Also the atmosphere was then a larger target for the solar wind to hit. So the rate of loss would have been 100 to 1000 times as high then as now. Further work is being done to better estimate this loss rate during Mars' major atmospheric loss. Study is also being done on the effects of Mars' current magnetic bubbles on atmospheric loss. The current atmospheric loss was found to occur in 3 directions: a polar plume driven by electric fields (25% of loss occurs this way), drift down the tail behind the planet from the Sun (75%), and drift up into a halo which then is blown away by solar wind (trace percentage). MAVEN completed its primary mission in November, but has been approved for an extended mission.



Phobos (Martian moon) – New computer simulations show that tidal forces are slowly cracking up Phobos. The grooves seen on the surface are signs of this. Those grooves had previously been attributed to cracking that occurred at the time of the impact that formed the moon's largest crater, named Stickney. But the grooves are not quite the right direction to have been made by that cause. Tidal forces are not strong enough to crack a solid moon, but it is now believed that Phobos is more of a rubble pile inside, not solid, and is surrounded by a powdery layer roughly 100 yards (100 m) thick. The simulations showed such a composition would crack like what is observed. Some of the grooves appear to be younger than others, meaning the cracking process is ongoing. Phobos is closer to its planet than any other moon in the Solar System, and is slowly dropping lower, by about 2 yards (2 m) per century. It should break up entirely in 30-50 million years.

Mercury meteors – A study of MESSENGER (spacecraft that orbited Mercury until April this year) data shows that the amount of calcium in Mercury's very thin atmosphere peaked at an unexpected time. Orbiting through zodiacal dust was expected to add calcium, but at a different time. A computer simulation of comet dust showed that material thrown off by Comet Encke about 10-20 thousand years ago would have drifted due to drag forces such that it hit Mercury at just the time the calcium peak was seen. Comet Encke is the source of the Taurid meteors seen on Earth. Apparently it causes meteor showers on Mercury too.

Moon formation – Scientists combined dynamical, thermal and chemical Moon formation computer simulations to explain key differences between the compositions of lunar and Earth rocks. The Moon's lack of easily vaporized elements (like potassium, sodium and zinc) provides evidence about how the Earth-Moon system formed 4.5 billion years ago. Scientists think the Moon formed from an Earth-orbiting disk of matter produced by a giant impact between Earth and another Mars-sized body soon after the planets formed.

The best previous theory was that the volatiles vaporized by the impact escaped before the Moon solidified. The new result is that as the Moon grew, volatile-rich material was preferentially deposited onto Earth. The new simulations showed that the Moon began accumulating from the disk along the inner edge of the disk and later moved to the outer edge. The outer edge had less volatiles. The volatiles that remained ungathered in the inner edge eventually fell to Earth. Hence more volatiles on Earth's surface than the Moon's surface.

Asteroid origins – An infrared study of near-Earth asteroids (NEAs) shows that they originated all across the asteroid belt, though most came from the inner edge. Perturbations by planets move them to the Earth's vicinity. About 5% that resemble comets or have carbon-rich surfaces came from the outer edge of the asteroid belt. The origins were determined on the basis of surface composition, measured by infrared spectra. 2 different orbital computer simulations were run to verify that the infrared-based origins were likely. A surprise found by the study was that objects with composition of common stony meteorites come from the outer region of the asteroid belt. The NEAs from this region are much less common than the meteorites.

Planet formation – A couple of months ago I reported that using the Pebble theory of planet formation, computer simulations were for the 1st time able to grow cores for the gas giant planets Jupiter and Saturn to the right size in the right time frame. The Pebble theory says that the major growth of planets occurred by accumulating pebbles, defined as material a foot (0.3 m) or a little less in size. The same theory has now allowed simulations to grow the inner planets correctly, with Mars much smaller than Earth, and asteroids much smaller than Mars. The accumulation of pebbles was found to proceed much more efficiently at the distances from the Sun where Venus and Earth are, but so inefficiently at Mars and the asteroid belt that the size to which a planet could grow was very limited.

Closest Earth-sized exoplanet, dubbed GJ 1132b, was discovered orbiting a small star just 39 light-years away. The discovery was made using MEarth-South, an array of 8 telescopes of 16 inch (40 cm) size in Chile. The array monitors nearby red dwarf stars (M type). The planet is about 1.2 times the Earth's diameter and its mass is 1.6 times Earth's. This makes it a rocky planet. It is quite close to its star, so is very hot (over 400°F = 200°C) and likely tidally locked so that one side always faces its star. Though it is too hot for liquid water, it is cool enough to retain a substantial atmosphere. Because it is so close, many types of observations are possible that may reveal the composition of its atmosphere, pattern of winds, or colors of sunset. The James Webb space telescope, scheduled for launch in 2018, should be able to observe this planet well.

Exoplanet weather – PSO J318.5-22 is an object about the size of Jupiter, but roughly 8 times as massive. This makes it probably a planet rather than a brown dwarf. It is estimated to be around 20 million years old. It is 75 light-years away. However it is by itself, not orbiting a star. But without the starlight in the way, it is easier than ordinary planets to image. A telescope in Chile was used to look at it in infrared. The observers discovered that it is covered in multiple layers of thick and thin clouds, made up of hot dust and droplets of molten iron.

Kepler (planet-finding space telescope) – Something is making KIC 8462852, one of the 160,000 stars monitored by Kepler during its primary mission, fluctuate wildly and unpredictably in brightness. The best guess is that a crumbling comet is orbiting there and passing in front of (transiting) the star. At least that is the theory that has the least problems explaining the observations. Many other theories, such as dust arcs or colliding planets should show up in infrared, but aiming infrared telescopes there has found nothing that might be intermittently blocking the star light. It has been pointed out that a solar-system-sized structure built by an advanced civilization of aliens might also explain the observations. Though there are a number of reasons to doubt this, astronomers pointed radiotelescopes at the star to check for radio signals, but found none.

K2 (Kepler follow-on mission) has uncovered strong evidence of an asteroid-sized object being torn apart by tidal forces as it orbits a white dwarf star. It has long been theorized that a white dwarf might do this to any planets that might have survived the red giant star phase that precedes becoming a white dwarf, but it had never been observed before. This is, in fact, the 1st time any planetary object has been found orbiting a white dwarf. But its transit did not look like an asteroid or comet, since it has a large tail and changes shape over time. Such a tail would be formed of debris as the asteroid was torn apart. The object orbits every 4.5 hours, so is extremely close to its star, where strong tidal forces would be expected. Due to intense gravity, material other than hydrogen and helium near the surface of a white dwarf are expected to sink. Indeed most white dwarfs show only hydrogen and helium in their spectra. However a few show heavier elements such as calcium, silicon, magnesium and iron. Scientists have long suspected that the source of this pollution was an asteroid or small planet being torn apart by tidal forces.

Star destroyed – Astronomers have observed material being blown away from a black hole after it tore apart a star. The mass of the black hole is estimated at a few million times that of the Sun. Gas often falls toward black holes by spiraling inward in a disk. In this study, astronomers witnessed the formation of such a disk by looking in X-ray light, using 3 different orbiting X-ray telescopes, observing the spectrum as it changed over time. Spectral lines seen showed that material was blowing away from the black hole. The black hole is located in a galaxy about 290 million light-years away.

Stellar magnetic fields – Astronomers have for the 1st time measured the magnetic fields inside stars, finding they are strongly magnetized. The technique used was to measure the pulsations at the surface and match them to simulations of sound waves passing through the interior. So far this works only with red giant stars, because they have denser cores so waves pass through the cores rather than bouncing off them. Magnetic fields partially disrupt the propagation of waves, and this can be measured in the pulsations at the surface. The magnetic field measured in several red giants showed they were as much as 10 million times the strength of Earth's magnetic field. The measurements were taken from Kepler data; Kepler was designed to detect planets passing in front of stars, but it picks up surface vibrations of stars also.

Star formation – Astronomers using ALMA (radiotelescope array in Chile) have imaged episodic outflow from a young protostar. Its twin jets show distinct gaps, revealing that the star grew by fits and starts. The researchers found 22 episodes. As protostars ingest raw material, they throw out material they don't need in jets. It is the 1st time astronomers have seen such a growth pattern within a star cluster. The star is in Serpens South, a star cluster 1400 light-years away. In the past only cumulative outflows of clusters have been seen; this time the outflow of a single star within the cluster was seen.

Hubble Space Telescope has made observations that have taken advantage of gravitational lensing to reveal the largest sample of the faintest and earliest known galaxies in the Universe. Some of these galaxies are fainter than any other galaxy yet uncovered by Hubble. Over 250 tiny galaxies were found that existed only 600-900 million years after the Big Bang. The accumulated light of such galaxies was found to have played a major role in the epoch of reionization. This started when the neutral hydrogen gas, which is opaque to ultraviolet light (UV), began to be ionized from the light of growing early galaxies, making it transparent to UV. The reionization came to a close about 700 million years after the Big Bang. By this time the light from bright and massive galaxies was insufficient to entirely reionize, so the contribution of the small galaxies in this Hubble study had to be substantial.

Black hole flare – Observations by 2 X-ray space telescopes have helped astronomers determine the mechanism involved when black holes flare. The black hole is located in a galaxy 324 million light-years away known as Markarian (Mrk) 335. Black holes have a corona surrounding them made up highly energetic particles that generate X-ray light. They also generally have a disk of hot material from which matter is pulled into the black hole. When material falls in, flares occur. There are 2 theories of where the light of the flares is generated: the lamppost, where the flare comes from a small region above and/or below the black hole; and the sandwich, where the flare comes from the slices (like sandwich bread) above and below. The new observations support the lamppost theory. The corona was seen to gather inward, then launch upward into a jet. It moved at about 20% the speed of light. The flare occurred from the jetting corona.

Galaxy halos – A team of astronomers used the Jansky Very Large Array (VLA) radiotelescope to study 35 edge-on spiral galaxies at distances from 11-137 million light-years away. The VLA has been upgraded and can now detect much fainter radio emission than before. The study found that radio halos about spiral galaxies are much more common than thought. Studying these halos can give us information about the rate of star formation within the disk, the winds from exploding stars, and the nature and origin of the galaxies' magnetic fields. The images of 30 galaxy halos were scaled to the same diameter and combined into a single image to see what the average halo is.

Bulge star formation – Observations in infrared using the VISTA telescope in Chile looking for Cepheid variable stars found that there is a thin plane of very young stars within the Milky Way's central bulge. The search examined 100 million light sources, found 30,000 of them variable in brightness, of which 655 fit the Cepheid pattern. Then they sorted out which ones were Type I Cepheids (massive and young) or Type II (lighter and old). It was a surprise to find that stars in this plane had been forming recently. Except for the central star cluster, no star formation was known in the galaxy bulge.

Interstellar magnetic field – Analysis of magnetic field data from Voyager 1 found that the direction of the magnetic field is slowly changing with spacecraft location. If this continues, Voyager 1 should reach in about 10 years a point where the magnetic field will be in the direction that has been measured remotely by the IBEX spacecraft. The discrepancy between IBEX and Voyager 1 magnetic direction data had been bothering astronomers.

Rosetta (comet mission) – Spacecraft controllers had originally planned to leave Rosetta hibernating in orbit with its comet after its mission completes next year, hoping that it would wake up when the comet and spacecraft returned 4 years later. But the team changed that, deciding instead to crash Rosetta into the comet at very slow speed at the end of the mission, next September. The spacecraft could possibly survive a slow crash, but once on the surface it would not be able to point its solar panels or radio antenna, so would be useless. But on the way down to the crash, Rosetta would be able to take incredibly detailed pictures and other data.

Mars Reconnaissance Orbiter has outlived its software. It was launched more than 10 years ago with about 11 years of tables specifying the location of the Earth and the Sun. These are used to recover from glitches, which have occurred 16 times so far; in such cases the spacecraft points its solar panels at the Sun and its antenna at Earth to await recovery instructions. The software is being updated in 2 phases for each of the 2 onboard computers to include more years of Sun and Earth data. The software has been updated once before (in 2009), for a different reason, so controllers are sure they know how to do it safely. Science operations and communication relays from the Mars rovers are being interrupted for a week during the process. Odyssey Mars orbiter is filling in with the communication relays during that week.

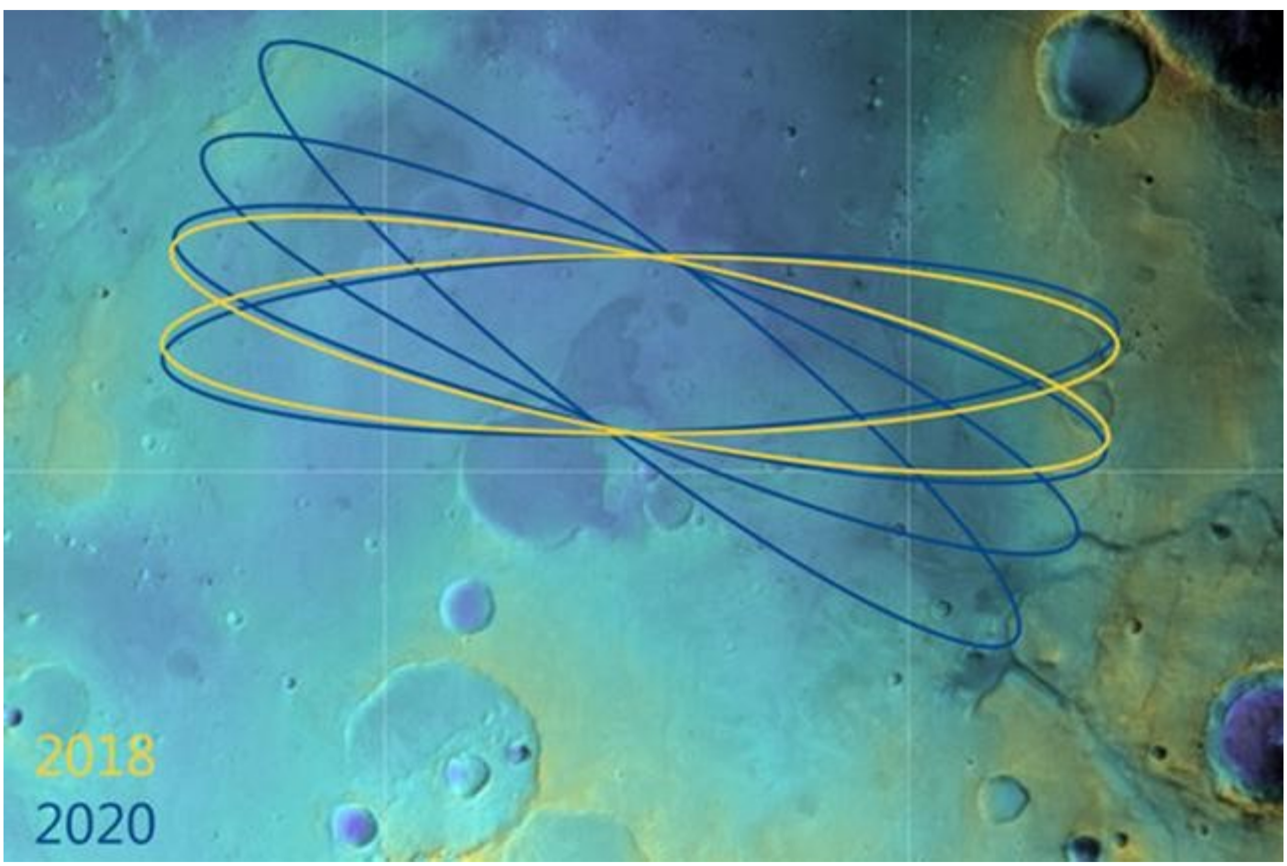
Instant AstroSpace Updates

Even though NASA has not yet approved a follow-on mission for **New Horizons** (Pluto mission), spacecraft controllers performed 4 engine firings that aimed it at another object in the Kuiper Belt, known as 2014 MU69, still about a billion miles and 3 years away. Now was the most efficient time to re-aim.

The software in the ChemCam aboard Mars rover **Curiosity** was reloaded in order to add new kinds of data analysis. ChemCam analyzes the spectra from laser vaporizations of rocks and soil several yards (m) away from the rover.

On Halloween, an **asteroid** roughly 1300 ft (400 m) across flew by Earth a little farther than the Moon, and it was **imaged** in radar, producing the best resolution images yet of such an object. Its very elliptical and inclined orbit suggests that it might be a dead comet rather than an asteroid.

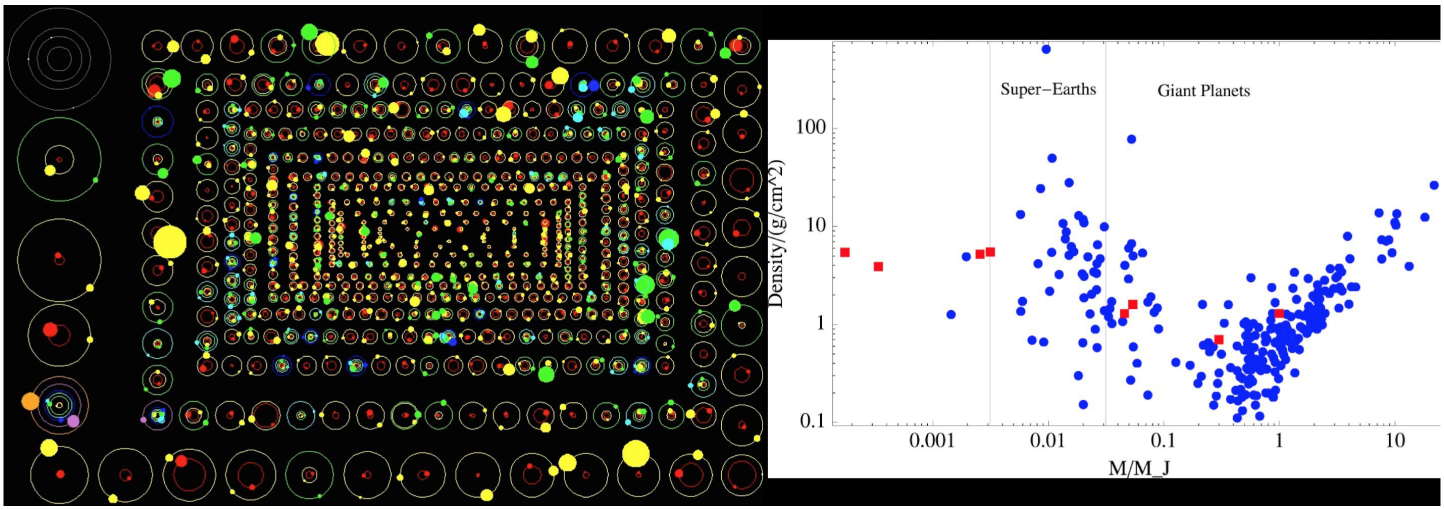
ExoMars (European/Russian Mars mission) consists of several spacecraft: an orbiter and a lander launching next year and a rover with a separate surface platform 2 years later. The landing site for the rover has just been selected as Oxia Planum, where it will search for evidence of past or present primitive life.



Our Solar System Is Almost Normal, But Not Quite

by Ethan Siegel

It was just over 20 years ago that the very first exoplanet was found and confirmed to be orbiting a star not so different from our own sun. Fast forward to the present day, and the stellar wobble method, wherein the gravitational tug of a planet perturbs a star's motion, has been surpassed in success by the transit method, wherein a planet transits across the disk of its parent star, blocking a portion of its light in a periodic fashion. Thanks to these methods and NASA's Kepler spacecraft, we've identified many thousands of candidate planets, with nearly 2,000 of them having been confirmed, and their masses and densities measured.



Images credit: NASA / Kepler Dan Fabricky (L), of a selection of the known Kepler exoplanets; Rebecca G. Martin and Mario Livio (2015) ApJ 810, 105 (R), of 287 confirmed exoplanets relative to our eight solar system planets.

The gas giants found in our solar system actually turn out to be remarkably typical: Jupiter-mass planets are very common, with less-massive and more-massive giants both extremely common. Saturn—the least dense world in our solar system—is actually of a fairly typical density for a gas giant world. It turns out that there are many planets out there with Saturn's density or less. The rocky worlds are a little harder to quantify, because our methods and missions are much better at finding higher-mass planets than low-mass ones. Nevertheless, the lowest mass planets found are comparable to Earth and Venus, and range from just as dense to slightly less dense. We also find that we fall right into the middle of the "bell curve" for how old planetary systems are: we're definitely typical in that regard.

But there are a few big surprises, which is to say there are three major ways our solar system is an outlier among the planets we've observed:

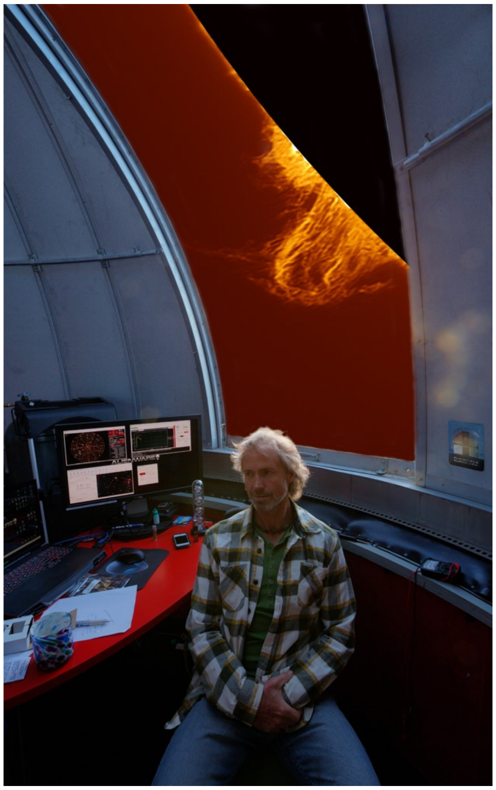
- All our solar system's planets are significantly farther out than the average distance for exoplanets around their stars. More than half of the planets we've discovered are closer to their star than Mercury is to ours, which might be a selection effect (closer planets are easier to find), but it might indicate a way our star is unusual: being devoid of very close-in planets.

- All eight of our solar system's planets' orbits are highly circular, with even the eccentric Mars and Mercury only having a few percent deviation from a perfect circle. But most exoplanets have significant eccentricities, which could indicate something unusual about us.

- And finally, one of the most common classes of exoplanet—a super-Earth or mini-Neptune, with 1.5-to-10 times the mass of Earth—is completely missing from our solar system. Until we develop the technology to probe for lower-mass planets at even greater distances around other star systems, we won't truly know for certain how unusual we really are!

Pro Am Collaboration at Lowell Observatory: An Insider's View by Matt Francis

(originally published at https://lowell.edu/matt-francis/)



I moved to Prescott, AZ in 2011 in search of darker skies. I luckily found a property that came with an existing Observatory and immediately began working on refurbishing it. I had already ordered most of the equipment and was waiting for the main instrument (a 24-inch PlaneWave CDK) to be built. By early 2012, I was ready to start initial tests of some of the equipment and begin the long road of "learning" observatory operations and the myriad nuances related to operating so much equipment at the same time.

One of my first tests was to see if I could detect an extra-solar planet. My friend Steve Peterson from Kitt Peak Observatory had given me tips on how I might do this. After a few attempts, some failures and some partial successes, I was able to get a light curve of WASP 43b. I had heard of a talk about extra-solar planet detection being given in Prescott by Travis Barman of Lowell Observatory that April so I took my light curve and went to the presentation. There I met Rusty Tweed and Travis Barman, with whom I showed my light curve, and they recommended I get in touch with Lowell Observatory to join the Lowell Amateur Research Initiative, a pro-am collaboration effort there.

My first project with LARI was to collect asteroid rotational light curves using MPO Canopus software. The learning curve on this software was long and difficult and the project was cancelled after the project leader retired. I then joined Deidre Hunter's "Little Things" dwarf galaxy imaging project in November 2013.

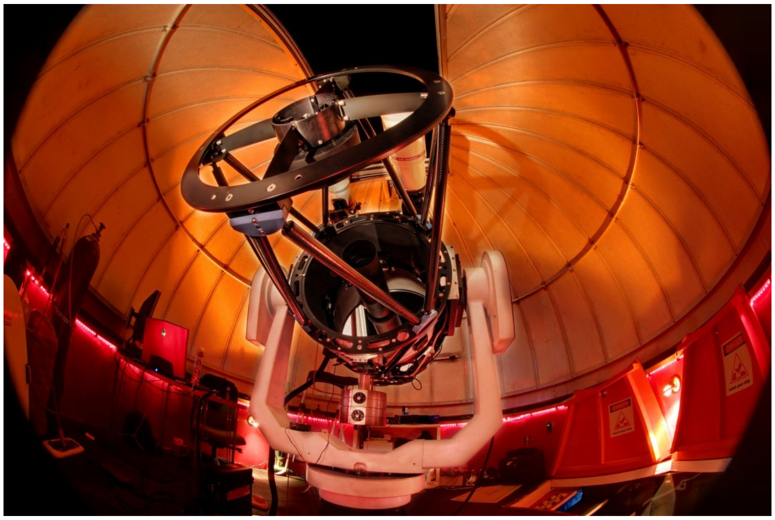
This project is especially exciting to me because it is more relevant to my primary interest which is cosmology. I can't tell you how intellectually refreshing it is to interface with Lowell staff members and be a part of the Lowell Observatory mission. Just being on the Lowell campus is inspiring and I am grateful to have this opportunity to contribute. With this in mind I was very anxious to begin collecting data for this new project.

Imaging the faint dwarf galaxies for the "Little Things" project requires sub-exposure times of up to 1200 seconds, where previously I had only taken 400 second unguided sub-exposures. Not only did this mean learning how to use guide stars, but also more sophisticated observatory automation that would allow imaging through the night for multiple nights. This began a journey of learning new techniques, and discovering problems with my observatory previously unknown to me. So, in between work/personal travel I learned a lot about operating an observatory. The following list is meant to describe my own learning curve with my observatory and equipment and I hope it inspires others to consider trying their hand at a Pro/Am collaboration . Without the knowledgeable, helpful people I have met through the LARI program, it would have taken a very long time for all of these issues to come to light. I am motivated to make my observatory a model of efficiency so that I can continue to be a part of this wonderful community. Here is a list of what I have worked through:

- Using guide stars: This meant I had to define my Field Of View (FOV) indicators in TheSkyX (TSX) planetarium software in order to select suitable guide stars. Since my equipment is somewhat specialized, there was no simple choice in TSX – which meant calculation of my off-axis guide chip placement/orientation and then testing by trial and error. This took weeks as I was also having intermittent TSX crashes at the same time.

- It took me three tries to find the most compatible observatory automation software. The first one was too simple and did not offer enough control. The second turned out to be too sophisticated for my needs. I finally settled on CCD Autopilot – but coming to this conclusion took many months.

- I had intermittent (I really hate that word now…) problems with TSX losing communication and crashing. I am still running a much older version as I have tried to update this twice which caused complete shutdown of the observatory. Currently I am using TheSky6 with CCDAP. Because everyone I know uses TheSky with virtually no problems, I have to conclude that my system is particularly sensitive to communication hardware and software.



- Next I discovered a problem with my dome. The initial push the dome needs to get it rotating as it tracks the mount through the night would "intermittently" cause a voltage drop low enough to break communication with the USB devices – causing the automated run to stop. I currently have 4 USB hubs, in addition to two serial to USB devices which are inherently sensitive. I ended up having to purchase an uninterruptible power supply and switch all of my USB hubs to industrial grade hubs. (This helped the problem, but has not completely solved it.) By the way, this turned out to be part of the reason why TheSkyX was crashing as well.

- Along the way, I also discovered a problem with my derotation at altitudes above 75 degrees. This was solved by PlaneWave with a beta software update.

- Then there's the processing of the raw image data. In order to keep things consistent, I needed to learn PixInsight to process the images. Luckily, another astronomer with the project (Steve Leshin) has helped me immensely to learn this powerful image processing software. (And I'm still learning…)

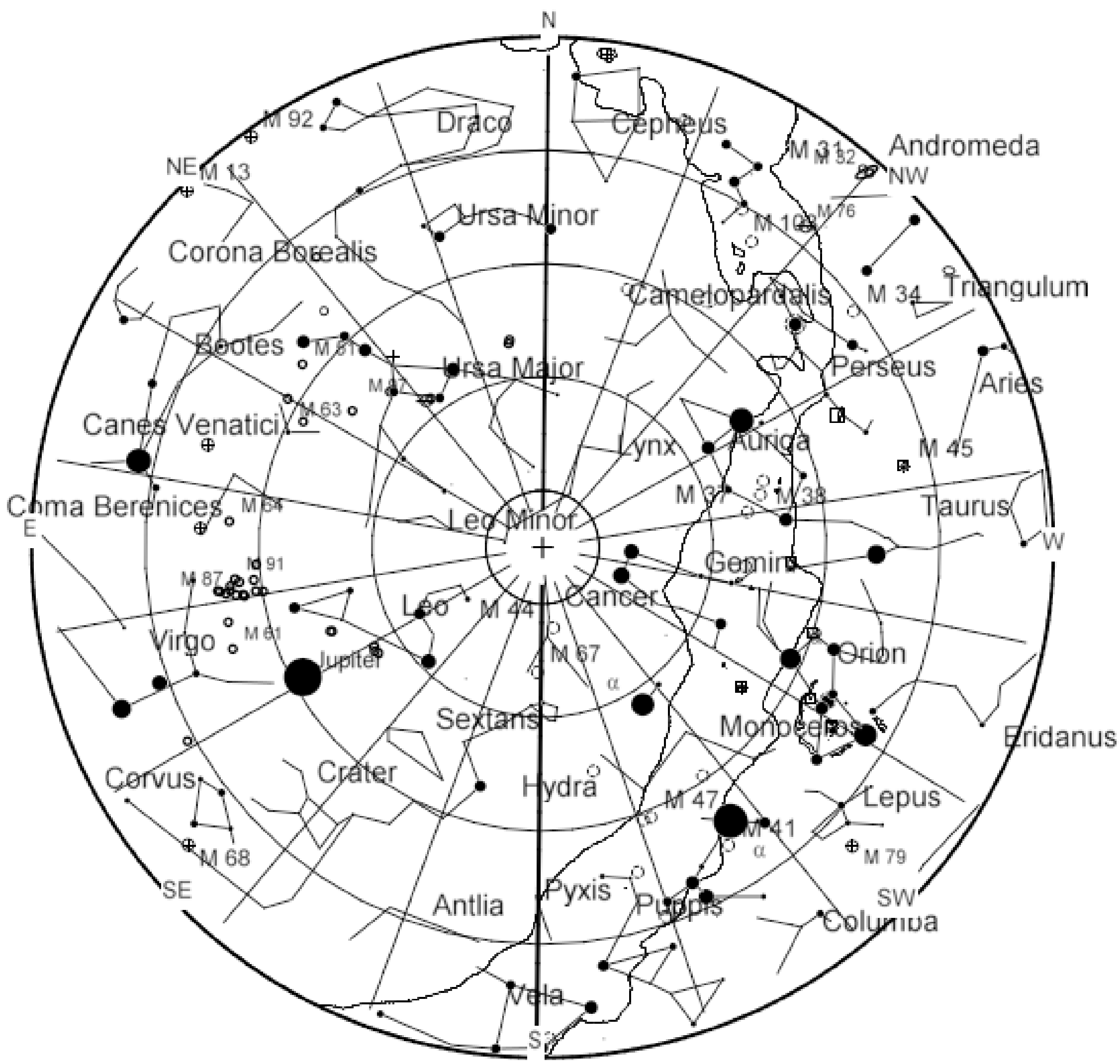
- Between working out the above issues and learning all that is needed to contribute to LARI, I had to keep my schedule of contributing to Slooh Community Observatory for my public outreach initiative, and my personal/work schedule which slowed my progress with LARI.

In short, the target objects for HDLT came and went while I struggled to get my observatory to the point that I could contribute. As I write this I am approximately at 70% completion of my first object for HDLT. As the moon continues to wane after the middle part of February I expect to collect the remaining images and finally submit my first results after more than a year of discovery and learning.

In the midst of all this I keep my schedule for contributing to 'Slooh' Community Observatory for my public outreach initiative, and my personal/work schedule. It has slowed my progress with the HDLT, LARI project, but Dr. Hunter is happy that I am a part of the project no matter the pace, and as they say "the joy is in the journey".

In case anyone is wondering…. the benefits of joining LARI have far outweighed any frustrations I have with troubleshooting and learning new things. Everyone at Lowell has been very helpful and they are all an amazing group of people. Because of LARI I have also met intelligent, interesting people outside of Lowell with a common interest with whom I have become friends. I feel being part of LARI has accelerated not just my ability to image faint objects, but also observatory management that would have taken perhaps years to eventually learn.

WHOLE SKY CHART
DECEMBER 2015



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