Space News Update — May 10, 2016 —

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1. ALMA Measures Mass of Black Hole with Extreme Precision

Combined image of NGC 1332 shows the central disk of gas surrounding the supermassive black hole at the center of the galaxy. New ALMA observations traced the motion of the disk, providing remarkably precise measurements of the black hole's mass: 660 million times the mass of our Sun. The red region in the ALMA image represents emission that has been redshifted by gas rotating away from us; the blue represents emission blue-shifted by gas rotating toward us. The range of colors represents rotational speeds up to 500 kilometers per second. Credit: A. Barth (UCI), ALMA (NRAO/ESO/NAOJ); NASA/ESA Hubble; Carnegie-Irvine Galaxy Survey.

Supermassive black holes, some weighing millions to billions of times the mass of the Sun, dominate the centers of their host galaxies. To determine the actual mass of a supermassive black hole, astronomers must measure the strength of its gravitational pull on the stars and clouds of gas that swarm around it.

Using the Atacama Large Millimeter/submillimeter Array (ALMA), a team of astronomers has delved remarkably deep into the heart of a nearby elliptical galaxy to study the motion of a disk of cold interstellar gas encircling the supermassive black hole at its center. These observations provide one of the most accurate mass measurements to date for a black hole outside of our Galaxy, helping set the scale for these cosmic behemoths.

To obtain this result, Aaron Barth, an astronomer at the University of California, Irvine, and lead author on a paper published in the *Astrophysical Journal Letters*, and his team used ALMA to measure the speed of carbon monoxide gas in orbit around the black hole at the center of NGC 1332, a massive elliptical galaxy approximately 73 million light-years from Earth in the direction of the southern constellation Eridanus.

"Measuring the mass of a black hole accurately is very challenging, even with the most powerful telescopes on Earth or in space," Barth said. "ALMA has the revolutionary ability to observe disks of cold gas around supermassive black holes at small enough scales that we can clearly distinguish the black hole's influence on the disk's rotational speed."

The ALMA observations reveal details of the disk's structure on the order of 16 light-years across. They also measure the disk's rotation well within the estimated 80 light-year radius of the black hole's "sphere of influence" – the region where the black hole's gravity is dominant.
Near the disk's center, ALMA observed the gas traveling at more than 500 kilometers per second. By comparing these data with simulations, the astronomers calculated that the black hole at the center of NGC 1332 has a mass 660 million times greater than our Sun, plus or minus ten percent. This is about 150 times the mass of the black hole at the center of the Milky Way, yet still comparatively modest relative to the largest black holes known to exist, which can be many billions of solar masses.

ALMA's close-in observations were essential, the researchers note, to avoid confounding the black hole measurement with the gravitational influence of other material – stars, clouds of interstellar gas, and dark matter – that comprises most of the galaxy's overall mass.

"This black hole, though individually massive, accounts for less than one percent of the mass of all the stars in the galaxy," noted Barth. "Most of a galaxy's mass is in the form of dark matter and stars, and on the scale of an entire galaxy, even a giant black hole is just a tiny speck in the center. The key to detecting the influence of the black hole is to observe orbital motion on such small scales that the black hole's gravitational pull is the dominant force." This observation is the first demonstration of this capability for ALMA.

Astronomers use various techniques to measure the mass of black holes. All of them, however, rely on tracing the motion of objects as close to the black hole as possible. In the Milky Way, powerful ground-based telescopes using adaptive optics can image individual stars near the galactic center and precisely track their trajectories over time. Though remarkably accurate, this technique is feasible only within our own Galaxy; other galaxies are too distant to distinguish the motion of individual stars.

To make similar measurements in other galaxies, astronomers either examine the aggregate motion of stars in a galaxy's central region, or trace the motion of gas disks and mega-masers -- natural cosmic radio sources.

Previous studies of NGC 1332 with ground- and space-based telescopes gave wildly different estimates for the mass of this black hole, ranging from 500 million to 1.5 billion times the mass of the Sun.

The new ALMA data confirm that the lower estimates are more accurate.

Crucially, the new ALMA observations have higher resolution than any of the past observations. ALMA also detects the emission from the densest, coldest component of the disk, which is in a remarkably orderly circular motion around the black hole.

Many past black hole measurements made with optical telescopes, including the Hubble Space Telescope, focused on emission from the hot, ionized gas orbiting in the central regions of galaxies. Ionized-gas disks tend to be much more turbulent than cold disks, which leads to lower precision when measuring a black hole's mass.

"ALMA can map out the rotation of gas disks in galaxy centers with even sharper resolution than the Hubble Space Telescope," noted UCI graduate student Benjamin Boizelle, a co-author on the study. "This observation demonstrates a technique that can be applied to many other galaxies to measure the masses of supermassive black holes to remarkable precision."

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.
2. Kepler Spacecraft K2 Mission Campaigns Resume

NASA officials will announce the planet-hunting Kepler space telescope’s latest discoveries at a news conference today (May 10). Here is a guide to the past and planned Kepler search campaigns.

After its recovery from Emergency Mode late last month, the Kepler spacecraft science operations have now resumed as planned, with K2 Campaign 9 beginning on April 22. Campaign 9 involves the spacecraft looking toward the Galactic Center to primarily search for gravitational microlensing events. In addition to microlensing targets, a number of Director’s Discretionary Targets (DDTs) were approved.

Each K2 Campaign has a duration of approximately 80 days and remains fixed upon a single boresight position. Here are some of the details the previous, current, and planned upcoming K2 Campaign fields.

Here are the scheduled Campaign Field Dates and Comments:

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†Note: field 9 is a forward-facing campaign (+VV), enabling simultaneous observations to be made from the ground.
Other fields show on the illustration are currently being considered for Campaign 14 and beyond. These campaign fields are not final and will change to optimize science and accommodate engineering constraints (e.g. the availability of guide stars).

Mission Manager Q&A: Recovering The Kepler Spacecraft To Hunt For Exoplanets Again with NASA's Kepler and K2’s mission manager Charlie Sobeck

Q. Take us back to the days immediately following the spacecraft emergency declaration. What steps did the team take to recover the spacecraft from emergency? Who was involved? How did the team respond to the high-stakes nature of the situation?

A: Normal operations are conducted with a staff that consists of a flight director and flight operators working at the University of Colorado’s Laboratory for Atmospheric and Space Physics (LASP) in Boulder Colorado, and a mission operations manager and flight engineers at Ball Aerospace, also in Boulder. The staff at the LASP is the folks that are directly talking with the spacecraft, receiving the data and issuing commands through the DSN. The folks at Ball Aerospace have the responsibility to oversee that work and in addition, calculate and write the commands and determine what commands should be sent, in what sequence and with what timing. In our parlance, LASP is the mission operations center, and Ball operates the flight planning center. These are both professional and experienced organizations.

When the spacecraft was found to be in Emergency Mode, a network of phone calls went out to bring in additional staff and expertise. In particular, the mission director, the project systems engineer and the project manager from Ames were called in, as well as the Ball program manager. These additions would provide real-time, authoritative decisions, such as the declaration of a spacecraft emergency, and the ability to bring on specific resource as required. Resources such as the people who designed and built the spacecraft in the first place.

Throughout the process the team was focused and professional. I was impressed with the commitment, which everyone on the team demonstrated, and the cool, thoughtful approach that was taken. As part of my roll, I alerted Ames and NASA management of the problem and kept them informed with regular status updates. Again, I was impressed with everyone’s ability to help when they could, and to stay out of the way when they couldn’t.

Q. Has the fuel-intensive emergency mode impacted remaining plans for the K2 mission? Will fuel conservation measures be needed or will plans be altered?

A: It is too early to adjust any plans based on the fuel status. It’s clear that this emergency consumed fuel at an accelerated rate, but it’s not clear how much was consumed, or why. It appears to me as though we lost more fuel than I had hoped, but less than I had feared. With the fuel loss, there has been a noticeable drop in the fuel tank pressure, but the pressure drop in not linear, so it isn’t immediately obvious what this means. I suspect it will take a few months of normal usage to recalibrate our fuel estimates. Generally we do this annually, and it seems that each year our estimates of our fuel efficiency is better than the year before.

The K2 mission has always been fundamentally limited by fuel, so to perform the maximum amount of science observations conserving fuel is an ongoing job. As we gain experience in operating the spacecraft in its two-wheel mode, we learn ways to improve our efficiency. Several steps have already been taken, which have doubled our initial mission duration estimates, but we’ve probably already made most of the gains that can be expected, so I don’t expect a lot more.

Measure the quantity of a liquid in space is a difficult business, so how much fuel we have left is uncertain. It has been our plan to continue operating the K2 mission until the fuel runs out. Meaning that at some point we will begin a campaign and will never hear back from the spacecraft.

Source: NASA and NASA
3. Enceladus Jets: Surprises in Starlight

The gravitational pull of Saturn changes the amount of particles spraying from the south pole of Saturn's active moon Enceladus at different points in its orbit. More particles make the plume appear much brighter in the infrared image at left. Credits: NASA/JPL-Caltech/University of Arizona/Cornell/SSI

During a recent stargazing session, NASA's Cassini spacecraft watched a bright star pass behind the plume of gas and dust that spews from Saturn's icy moon Enceladus. At first, the data from that observation had scientists scratching their heads. What they saw didn't fit their predictions.

The observation has led to a surprising new clue about the remarkable geologic activity on Enceladus: It appears that at least some of the narrow jets that erupt from the moon's surface blast with increased fury when the moon is farther from Saturn in its orbit.

Exactly how or why that's happening is far from clear, but the observation gives theorists new possibilities to ponder about the twists and turns in the "plumbing" under the moon's frozen surface. Scientists are eager for such clues because, beneath its frozen shell of ice, Enceladus is an ocean world that might have the ingredients for life.

It's a Gas, Man

During its first few years after arriving at Saturn in 2004, Cassini discovered that Enceladus continuously spews a broad plume of gas and dust-sized ice grains from the region around its south pole. This plume extends hundreds of miles into space, and is several times the width of the small moon itself. Scores of narrow jets burst from the surface along great fractures known as "tiger stripes" and contribute to the plume. The activity is understood to originate from the moon's subsurface ocean of salty liquid water, which is venting into space.

Cassini has shown that more than 90 percent of the material in the plume is water vapor. This gas lofts dust grains into space where sunlight scatters off them, making them visible to the spacecraft's cameras. Cassini has even collected some of the particles being blasted off Enceladus and analyzed their composition.

Not the Obvious Explanation

Previous Cassini observations saw the eruptions spraying three times as much icy dust into space when Enceladus neared the farthest point in its elliptical orbit around Saturn. But until now, scientists hadn't had an opportunity to see if the gas part of the eruptions -- which makes up the majority of the plume's mass -- also increased at this time.
So on March 11, 2016, during a carefully planned observing run, Cassini set its gaze on Epsilon Orionis, the central star in Orion’s belt. At the appointed time, Enceladus and its erupting plume glided in front of the star. Cassini’s ultraviolet imaging spectrometer (or UVIS) measured how water vapor in the plume dimmed the star’s ultraviolet light, revealing how much gas the plume contained. Since lots of extra dust appears at this point in the moon’s orbit, scientists expected to measure a lot more gas in the plume, pushing the dust into space.

But instead of the expected huge increase in water vapor output, the UVIS instrument only saw a slight bump -- just a 20 percent increase in the total amount of gas.

Cassini scientist Candy Hansen quickly set to work trying to figure out what might be going on. Hansen, a UVIS team member at the Planetary Science Institute in Tucson, led the planning of the observation. "We went after the most obvious explanation first, but the data told us we needed to look deeper," she said. As it turned out, looking deeper meant paying attention to what was happening closer to the moon's surface.

Hansen and her colleagues focused their attention on one jet known informally as "Baghdad I." The researchers found that, while the amount of gas in the overall plume didn't change much, this particular jet was four times more active than at other times in Enceladus' orbit. Instead of supplying just 2 percent of the plume's total water vapor, as Cassini previously observed, it was now supplying 8 percent of the plume's gas.

**Call a Plumber**

This insight revealed something subtle, but important, according to Larry Esposito, UVIS team lead at the University of Colorado at Boulder. "We had thought the amount of water vapor in the overall plume, across the whole south polar area, was being strongly affected by tidal forces from Saturn. Instead we find that the small-scale jets are what's changing." This increase in the jets' activity is what causes more icy dust grains to be lofted into space, where Cassini's cameras can see them, Esposito said.

The new observations provide helpful constraints on what could be going on with the underground plumbing -- cracks and fissures through which water from the moon's potentially habitable subsurface ocean is making its way into space.

With the new Cassini data, Hansen is ready to toss the ball to the theoreticians. "Since we can only see what's going on above the surface, at the end of the day, it's up to the modelers to take this data and figure out what's going on underground."

The Cassini-Huygens mission is a cooperative project of NASA, ESA (European Space Agency) and the Italian Space Agency. JPL, a division of Caltech in Pasadena, manages the mission for NASA's Science Mission Directorate in Washington. The ultraviolet imaging spectrograph was designed and built at the University of Colorado, Boulder, where the team is based.

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*Narrow jets of gas and icy particles erupt from the south polar region of Enceladus, contributing to the moon’s giant plume. A cycle of activity in these small-scale jets may be periodically lofting extra particles into space, causing the overall plume to brighten dramatically.*

*Credits: NASA/JPL/Space Science Institute*
The Night Sky

On the weekend of 14-15 May, observers should look up to the southwestern sky to see the waxing gibbous Moon close to planet Jupiter in the constellation Leo. Source: Astronomy Now graphic by Ade Ashford.

**Tuesday, May 10**

- Three zero-magnitude stars shine after dark in May: Arcturus high in the southeast, Vega much lower in the northeast, and Capella in the northwest. They appear so bright because each is at least 60 times as luminous as the Sun, and because they're all relatively nearby: 37, 25, and 42 light-years from us, respectively.

**Wednesday, May 11**

- Jupiter’s strongly red Great Red Spot will be facing telescope users at nightfall in the Eastern and Central time zones. It transits Jupiter's central meridian around 10:48 p.m. EDT; 9:48 CDT.

**Thursday, May 12**

- The Arch of Spring spans the western sky in late twilight. Pollux and Castor form its top: they're lined up roughly horizontally in the west-northwest, about three finger-widths at arm's length apart. Look far to their lower left for Procyon, and farther to their lower right for Menkalinan and then bright Capella. The Moon passes Regulus and Jupiter on Friday and Saturday Saturday the 13th and 14th.

**Friday, May 13**

- As twilight fades, look above the first-quarter Moon for Regulus. Brighter Jupiter shines much farther to the Moon's upper left (for North America). They all descend to the southwest as night proceeds.

**Saturday, May 14**

- The two brightest things in the evening sky shine high just a few degrees apart this evening: the moon and Jupiter. Third brightest is Mars. Look for it low in the southeast after dark.

Source: Sky and Telescope

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**ISS Sighting Opportunities (from Denver)**

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Sighting information for other cities can be found at [NASA’s Satellite Sighting Information](https://nssdc.gsfc.nasa.gov/planetary/iss/isis_sight.html).

**NASA-TV Highlights**  (all times Eastern Time Zone)

**Wednesday, May 11**
- 9 a.m. - Release of the SpaceX/Dragon CRS-8 Cargo Craft from the ISS (Release time is 9:18 a.m. EDT) (all channels)
- 1 p.m. - The Smithsonian’s National Air and Space Museum Presents STEM in 30 – “Copter, Choppers and the Phrog: The Science of Vertical Flight” (all channels)

**Thursday, May 12**
- 9 a.m. - ISS Expedition 47 In-Flight Event with the Weather Channel and WISC-TV, Madison, Wisconsin with Commander Tim Kopra and Flight Engineer Jeff Williams of NASA and Flight Engineer Tim Peake of the European Space Agency (all channels)

**Friday, May 13**
- 11 a.m. - Beating the Odds/Twin Study Student Research Presentations (all channels)

Watch NASA TV online by going to the [NASA website](https://nasa.gov/).
Space Calendar

- May 10 - Comet 243P/NEAT At Opposition (3.645 AU)
- May 10 - Amor Asteroid 2016 HM3 Near-Earth Flyby (0.069 AU)
- May 10 - Asteroid 4825 Ventura Closest Approach To Earth (1.532 AU)
- May 10 - Asteroid 3162 Nostalgia Closest Approach To Earth (2.589 AU)
- May 10 - Lecture: But What About the Stellar Occultation Data of Pluto's Atmosphere?, Mountain View, California
- May 11 - Comet P/2010 P4 (WISE) At Opposition (2.853 AU)
- May 11 - Comet 75D/Kohoutek At Opposition (3.492 AU)
- May 11 - Asteroid 9725 Wainscoat Closest Approach To Earth (1.085 AU)
- May 11 - Asteroid 3749 Balam (2 Moons) Closest Approach To Earth (1.349 AU)
- May 11 - Asteroid 3594 Scotti Closest Approach To Earth (1.566 AU)
- May 11 - Asteroid 73769 Delphi Closest Approach To Earth (3.520 AU)
- May 11 - Asteroid 5254 Ulysses Closest Approach To Earth (4.864 AU)
- May 11 - Jacqueline Cochran's 110th Birthday (1906)
- May 11 - Theodore Von Karman's 135th Birthday (1881)
- May 11 - Colloquium: The Martian - Science Fiction and Science Fact, Greenbelt, Maryland
- May 12 - Comet 253P/PANSTARRS At Opposition (3.365 AU)
- May 12 - Comet P/2009 S2 (McNaught) At Opposition (3.464 AU)
- May 12 - Comet C/2014 M1 (PANSTARRS) At Opposition (4.876 AU)
- May 12 - Aten Asteroid 2016 JE6 Near-Earth Flyby (0.063 AU)
- May 12 - Asteroid 5036 Tuttle Closest Approach To Earth (1.886 AU)
- May 12 - Asteroid 6639 Marchis Closest Approach To Earth (1.914 AU)
- May 12 - Asteroid 945 Barcelona Closest Approach To Earth (1.983 AU)
- May 12 - Asteroid 216 Kleopatra (2 Moons) Closest Approach To Earth (2.452 AU)
- May 13 - Mercury Passes 0.4 Degrees From Venus
- May 13 - Comet 100P/Hartley At Opposition (1.045 AU)
- May 13 - Comet 77P/Longmore Perihelion (2.336 AU)
- May 13 - Comet 236P/LINEAR At Opposition (3.190 AU)
- May 13 - Comet P/2001 R6 (LINEAR-Skiff) At Opposition (4.272 AU)
- May 13 - Asteroid 22824 von Neumann Closest Approach To Earth (1.528 AU)
- May 13 - Asteroid 7328 Casanova Closest Approach To Earth (1.710 AU)
- May 13 - Asteroid 1143 Odysseus Closest Approach To Earth (4.553 AU)
- May 13 - 35th Anniversary (1981), Salem Meteorite Fall (Hit House in Oregon)
- May 13 - Aleksandr Kaleri's 60th Birthday (1956)
- May 13 - 155th Anniversary (1861), John Tebbutt's Discovery of the Great Comet of 1861
- May 13 - Lecture: The Air We (Can't) Breathe - A History of Air on Venus, Earth and Mars, Pasadena, California
- May 14 - Astronomy Day

Source: JPL Space Calendar
Earlier this year scientists presented evidence for Planet Nine, a Neptune-mass planet in an elliptical orbit 10 times farther from our Sun than Pluto. Since then theorists have puzzled over how this planet could end up in such a distant orbit.

New research by astronomers at the Harvard-Smithsonian Center for Astrophysics (CfA) examines a number of scenarios and finds that most of them have low probabilities. Therefore, the presence of Planet Nine remains a bit of a mystery.

"The evidence points to Planet Nine existing, but we can't explain for certain how it was produced," says CfA astronomer Gongjie Li, lead author on a paper accepted for publication in the Astrophysical Journal Letters.

Planet Nine circles our Sun at a distance of about 40 billion to 140 billion miles, or 400 - 1500 astronomical units. (An astronomical unit or A.U. is the average distance of the Earth from the Sun, or 93 million miles.) This places it far beyond all the other planets in our solar system. The question becomes: did it form there, or did it form elsewhere and land in its unusual orbit later?

Li and her co-author Fred Adams (University of Michigan) conducted millions of computer simulations in order to consider three possibilities. The first and most likely involves a passing star that tugs Planet Nine outward. Such an interaction would not only nudge the planet into a wider orbit but also make that orbit more elliptical. And since the Sun formed in a star cluster with several thousand neighbors, such stellar encounters were more common in the early history of our solar system.

However, an interloping star is more likely to pull Planet Nine away completely and eject it from the solar system. Li and Adams find only a 10 percent probability, at best, of Planet Nine landing in its current orbit. Moreover, the planet would have had to start at an improbably large distance to begin with.

CfA astronomer Scott Kenyon believes he may have the solution to that difficulty. In two papers submitted to the Astrophysical Journal, Kenyon and his co-author Benjamin Bromley (University of Utah) use computer simulations to construct plausible scenarios for the formation of Planet Nine in a wide orbit.

"The simplest solution is for the solar system to make an extra gas giant," says Kenyon.
They propose that Planet Nine formed much closer to the Sun and then interacted with the other gas giants, particularly Jupiter and Saturn. A series of gravitational kicks then could have boosted the planet into a larger and more elliptical orbit over time.

"Think of it like pushing a kid on a swing. If you give them a shove at the right time, over and over, they'll go higher and higher," explains Kenyon. "Then the challenge becomes not shoving the planet so much that you eject it from the solar system."

That could be avoided by interactions with the solar system's gaseous disk, he suggests.

Kenyon and Bromley also examine the possibility that Planet Nine actually formed at a great distance to begin with. They find that the right combination of initial disk mass and disk lifetime could potentially create Planet Nine in time for it to be nudged by Li's passing star.

"The nice thing about these scenarios is that they're observationally testable," Kenyon points out. "A scattered gas giant will look like a cold Neptune, while a planet that formed in place will resemble a giant Pluto with no gas."

Li's work also helps constrain the timing for Planet Nine's formation or migration. The Sun was born in a cluster where encounters with other stars were more frequent. Planet Nine's wide orbit would leave it vulnerable to ejection during such encounters. Therefore, Planet Nine is likely to be a latecomer that arrived in its current orbit after the Sun left its birth cluster.

Finally, Li and Adams looked at two wilder possibilities: that Planet Nine is an exoplanet that was captured from a passing star system, or a free-floating planet that was captured when it drifted close by our solar system. However, they conclude that the chances of either scenario are less than 2 percent.

Li and Adams' paper has been accepted for publication in the Astrophysical Journal Letters and is available online. Kenyon and Bromley have submitted their findings to the Astrophysical Journal in two papers available online: one on in-situ formation and one on gas-giant scattering.

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.
Space Image of the Week

Hubble Spies the Barred Spiral Galaxy NGC 4394

Image credit: ESA/Hubble & NASA, Acknowledgement: Judy Schmidt
Text credit: European Space Agency

Explanation: Discovered in 1784 by the German–British astronomer William Herschel, NGC 4394 is a barred spiral galaxy situated about 55 million light-years from Earth. The galaxy lies in the constellation of Coma Berenices (Berenice's Hair) and is considered to be a member of the Virgo Cluster.

NGC 4394 is the archetypal barred spiral galaxy, with bright spiral arms emerging from the ends of a bar that cuts through the galaxy's central bulge. These arms are peppered with young blue stars, dark filaments of cosmic dust, and bright, fuzzy regions of active star formation. At the center of NGC 4394 lies a region of ionized gas known as a low-ionization nuclear emission-line region (LINER). LINERs are active regions that display a characteristic set of emission lines in their spectra—mostly from weakly ionized atoms of oxygen, nitrogen and sulphur.

Although LINER galaxies are relatively common, it’s still unclear where the energy comes from to ionize the gas. In most cases it is thought to be the influence of a black hole at the center of the galaxy, but it could also be the result of a high level of star formation. In the case of NGC 4394, it is likely that gravitational interaction with a nearby neighbor has caused gas to flow into the galaxy’s central region, providing a new reservoir of material to fuel the black hole or to make new stars.

Source: NASA