South Downs Mercury

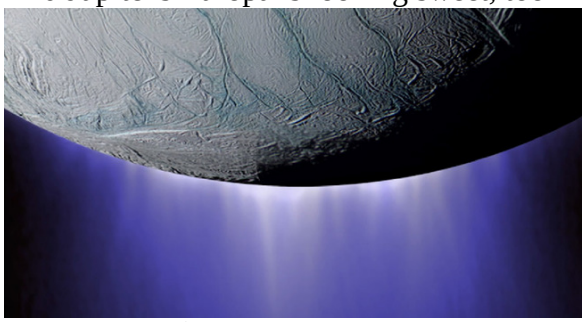
The monthly circular of South Downs Astronomical Society
Issue: 507 – April 2017 Editor: Roger Burgess

- Next meeting Friday 4th May Lecture room of the South Downs Planetarium, Chichester, at 7.30pm. Please support a raffle we are organizing this month

- Main Talk Colin Stuart "Pole Stars of Other Planets"

- Astronomy breakthrough: Loads of ingredients for life found on Saturn's Enceladus

And Jupiter's Europa is looking sweet, too



Artist's impression of plumes on Enceladus
13 Apr 2017 at 23:08, Katyanna Quach

Tantalizing new evidence of hydrothermal vents on Enceladus and liquid water on Europa have reignited hopes that alien life may exist in our Solar System, NASA announced today 13th April.
First, some quick facts: Enceladus is Saturn's sixth largest moon – smaller than Europa and easily identifiable by a bright surface riddled with craters and a series of streaks. Europa is Jupiter's fourth largest moon – slightly smaller than our own moon. It's very smooth, white and covered in red patches. Both moons have been objects of intense interest for astrobiologists for quite some time. Data taken during flybys from the Galileo and Cassini space crafts hinted at liquid oceans and rocky cores hidden beneath icy crusts on Europa and Enceladus. Now, after digging through 12 years of data from the Cassini probe, scientists have uncovered the best evidence yet that life could exist somewhere beyond Earth. The Ion and Neutral Mass Spectrometer on the spacecraft has detected a whiff of hydrogen in the gassy plumes belching out from Enceladus. Observations show the spray is made up of about 98 per cent water vapour, one per cent hydrogen, and the rest is a mixture of carbon dioxide, methane and ammonia. The tiny presence of hydrogen is a big find. It suggests that the gas is being produced in a series of complex chemical reactions happening in hydrothermal vents on the bottom of the moon's ocean. Hydrothermal vents may have been the source of life on Earth. The warm environments provide the right conditions for simple microbes to exist. But they need energy to survive. On Enceladus, hydrogen could be the food source for alien microbes. "Although we can't detect life, we've found that there's a food source there for it. It would be like a candy store for microbes," said Hunter Waite, lead author of the Cassini study. A chemical reaction known as "methanogenesis" converts carbon dioxide and hydrogen into methane and water, a process that may be happening on Enceladus. Methane contains some of the critical elements needed to form amino acids – the building blocks of protein. Mary Voytek, a senior astrobiologist at NASA, said there were roughly four main ingredients for life: water, time, energy and the right chemical elements – including carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur. Scientists predict Enceladus has most of these boxes ticked. There is no clear indication that it harbours phosphorus or sulphur, but they suspect they might be contained in its rocky core. Now we need to see if enough time has passed for life to exist, she added.

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More details on Enceladus can be found in a paper published in Science.

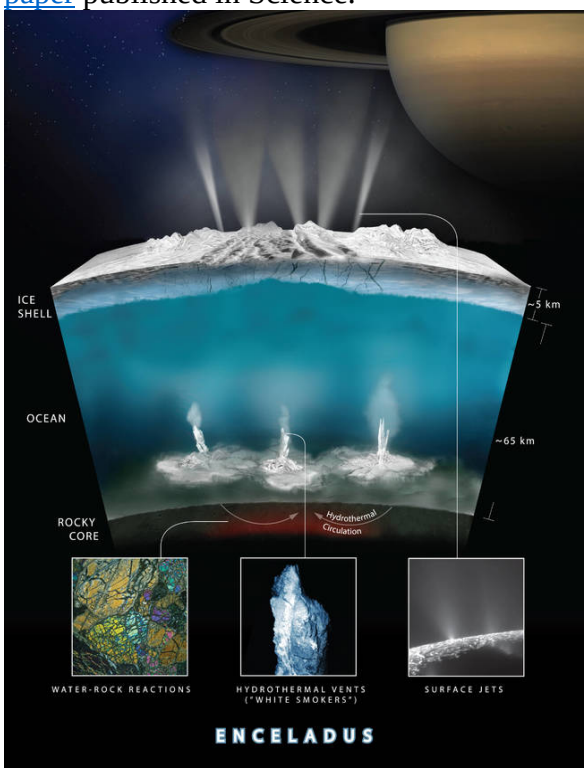
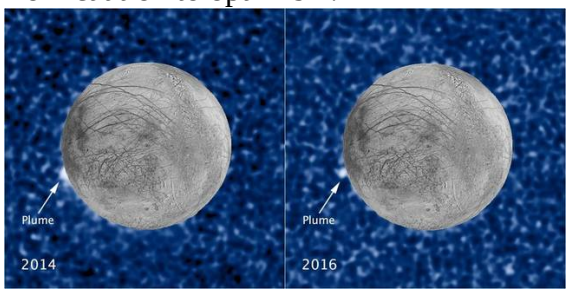


Diagram of hypothetical hydrothermal vents on Enceladus (Image credit: NASA/JPL-Caltech)

A similar situation is unfolding on Europa. New snapshots taken from the Hubble Space Telescope reveals cracks in the surface where water vapour is sprayed out. William Sparks, a researcher at NASA's Space Telescope Science Institute, said the showers were spotted in 2014. Two years later, scientists found a second plume erupting from the same place. A thermal map of Europa reveals the sweet spot to be unusually hot – it was considered a thermal anomaly at the time. But now, if the temperature is connected to the plumes – just like on Enceladus – it suggests that cryovolcanism is also happening on Europa. "Repeatability gives us a lot more faith," Sparks said. "The pendulum has swung from caution to optimism."



Possible plume activity spotted on Europa (Image credit: NASA/ESA/STScI/USGS)

Water vapour may be warming the surrounding surface from below the surface, and after it is ejected, from above, when it rains back down as a fine mist. Both possibilities are explored in a paper published in The Astrophysical Journal. Scientists will have a chance to explore Europa's watery world as NASA prepares for the Europa Clipper mission.

"If there are plumes on Europa, as we now strongly suspect, with the Europa Clipper we will be ready for them," said Jim Green, Director of Planetary Science at NASA.

The hotspot will be a target area for the powerful ultraviolet camera on board the Europa Clipper spacecraft. It will provide measurements a thousand times closer than the Hubble Space Telescope. A separate lander robot will assess the possibility of life on the moon by searching for key elements on its surface. The mission is expected to launch in the early 2020s. "This is the closest we've come, so far, to identifying a place with some of the ingredients needed for a habitable environment," said Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate at headquarters in Washington. "These results demonstrate the interconnected nature of NASA's science missions that are getting us closer to answering whether we are indeed alone or not."

- Wet, wild Mars stripped off by hot young star, left barren and red faced

31 Mar 2017 at 05:02, Katyanna Quach

Powerful solar wind and radiation have stripped away most of the Martian atmosphere, transforming the planet from one that could have been wet and with the potential to harbour life, to the barren dusty place it is today. NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission was launched in 2013 to study the planet's upper atmosphere, ionosphere and interactions with the sun, and to see how they changed over time. In the latest results, Bruce Jakosky, principal investigator for the MAVEN and a professor at the Laboratory for Atmospheric and Space Physics said: "We've determined that most of the gas ever present in the Mars

atmosphere has been lost to space – about 65 percent of the argon that was ever in the atmosphere has been lost." Today, Mars has a thin atmosphere mainly made up of carbon dioxide and other trace gases like nitrogen or methane. But it's too sparse and too cold to sustain liquid water – a chemical essential for life. There is evidence that the ancient Martian climate was once wet and warm enough for water to flow on the surface. Images of what look like dry riverbeds and minerals have been spotted by NASA's Curiosity rover.
But the solar wind, a thin stream of electrically charged particles that's constantly bombarding the Red Planet's atmosphere, eroded it away. Scientists predict that the loss was greater in the past, since the Sun was younger and more active, emitting far more intense ultraviolet radiation and winds.
These processes would have controlled how Mars' climate changed, altering the chances of habitability. Although no signs of life have been found yet, scientists say it's possible that simple, microbial life could have existed at the surface. As the atmosphere thinned, the planet grew colder and life could have been forced to go underground or into rare surface oases. Using data gathered by the MAVEN's Neutral Gas and Ion Mass Spectrometer instrument, NASA's Sample Analysis at Mars, and the Curiosity rover, scientists estimated how much gas had disappeared.
First, the team started by measuring the abundance of two different isotopes of argon. Isotopes are atoms of the same element but with various masses due to different neutron numbers in the nucleus. Since the lighter isotope of argon escapes more readily, over time the concentration of the heavier isotope of argon builds up. By seeing how argon levels changed at different altitudes, the scientists could estimate what fraction of gas was lost to space. Argon was chosen because it's a noble gas – it does not react chemically with any other element so it couldn't have been removed by being locked away in rocks. The only way to remove it is through "sputtering" by the solar wind. In sputtering, ions from the solar wind smash into the gas molecules at high speed, knocking them out of the atmosphere. Once the team had measured the amount of argon lost by sputtering, they could calculate the efficiency of sputtering to determine how it stripped away other gases like carbon dioxide as well.
"We determined that the majority of the planet's CO_2 also has been lost to space by sputtering," said Jakosky. "There are other processes that can remove CO_2, so this gives the minimum amount of CO_2 that's been lost to space." As a greenhouse gas, CO_2 traps and emits heat, so losing this would have cooled the planet and any surface water down. More details of the study have been published as a paper in Science Magazine. The MAVEN is just one of several missions geared toward studying Mars. All knowledge will culminate in the Journey to Mars mission, which will see a group of astronauts travel to the Red Planet to test if life can survive there. President Donald Trump signed a bill last Tuesday, pledging $19.5bn in NASA funding covering the budget for 2018 and including human exploration of Mars as a priority.

- How hard will it be to measure Planet Nine?

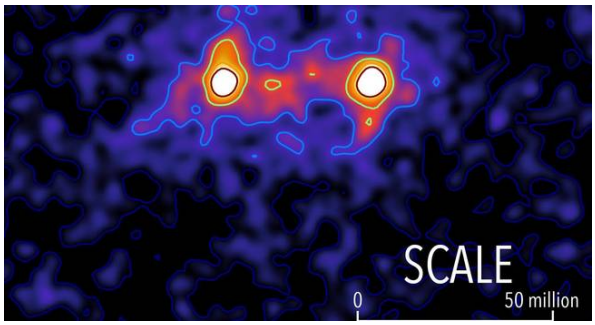
First, find it, which is hard. Second, see if it occludes stars, which is really, really hard

31 Mar 2017 at 02:57, Richard Chirgwin

Planet 9 will be easier to find if we know what we're looking for, so a French astronomer has set himself the task of trying to wrap the enigma in some parameters. When the idea of a ninth planet (using the guidelines that excluded Pluto from planet status) was mooted last year, the CalTech group that ran the orbital maths reckoned it would mass about ten times more than Earth. That estimate came with some uncertainty; it could be as big as 30 times Earth's mass. That's what Jean Schneider of Paris University looks at here. Since we haven't seen the planet yet – a crowd effort is now underway – Schneider can't offer hard numbers, but stresses the importance of being able to run the calculations when we do get an observation. Direct imaging, he says, will deliver the object's spectra, but “cannot provide the size and mass of the planet. Without a value for the radius, one cannot infer the planet albedo from its brightness, while this parameter is

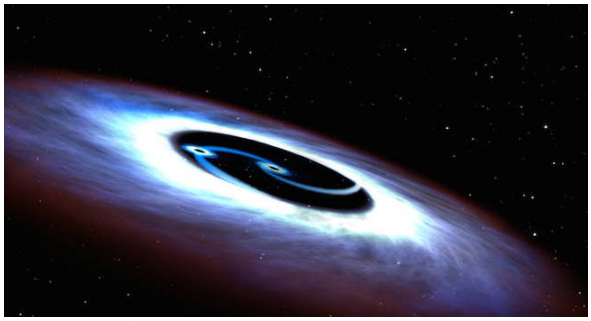
essential to constrain physical characteristics of the planet surface," the paper says.
Schneider proposes different mechanisms for each of radius and mass: when we spot the planet, we watch it occlude stars to estimate its radius; and when it passes a star, estimate its mass from microlensing (the effect of gravity on passing light, first predicted by Einstein). How many stars might Planet Nine occlude in any given period? That's problematic: a ten-year survey of the region the planet's probably traversing would only yield a 20 per cent likelihood of an occlusion. That estimate obviously improves if we get an observation of Planet Nine. A successful observation would also give 30-metre telescopes a chance to get an observation of any atmosphere the planet might have, along with things like rings and satellites.

- Far out: Dark matter bridges millions of light-years long spotted between galaxies. Threads of elusive particles form cosmic cobwebs



Example ... False colour snap showing one of the dark matter bridges between, in this case, two galaxies (Image credit: University of Waterloo)
13 Apr 2017 at 05:01, Katyanna Quach
Astrophysicists have for the first time spotted filaments of dark matter forming bridges between galaxies tens of millions of light-years apart.
Dark matter – the ghostly substance that is thought to make up about a quarter of our universe – is strangely hard to find. Some physicists believe dark matter is made up of weakly interacting massive particles (WIMPs) and some believe it's all about axions.
But it can be detected through its gravitational effects. Now Michael Hudson, professor of astronomy, and Seth Epps, a former master's student, at the University of Waterloo, Canada, used weak gravitational lensing to home in on the presence of dark matter.
Einstein's theory of general relativity dictates that the gravitational effects of mass bend space time, bending passing light rays, too. It causes images of distant galaxies to distort and bend around the invisible mass of dark matter. Epps and Hudson analysed photos of 23,000 galaxy pairs floating 4.5 billion light-years away, taken with the Canada-France-Hawaii Telescope.
They combined the images to map the web of dark matter between the galaxies. The method outlined in a paper published by Monthly Notices of the Royal Astronomical Society explains why multiple images of galaxy pairs are needed.
The signal from an individual thread of dark matter is very weak, as the filament density is much lower than the surrounding density of matter in a galaxy or cluster of galaxies. The images of the galaxies have to be stacked together to work out the "ensemble average" distribution of the elusive substance.
"The image represents the average filament from the 23,000 pairs of galaxies. The colours are a false colour image showing the density of dark matter. The highest density of dark matter corresponds to the white colour, less dark matter is orange then red and lowest density of dark matter is shown in blue then black. The composite image showed that dark matter signals were strongest between systems less than 40 million light years apart.
"For decades, researchers have been predicting the existence of dark-matter filaments between galaxies that act like a web-like superstructure connecting galaxies together," said Hudson. "This image moves us beyond predictions to something we can see and measure."
The next step is to build a larger, more detailed dataset so that the researchers can begin to unravel some other properties such as the mass of the dark matter.
"By using this technique, we're not only able to see that these dark matter filaments in the universe exist, we're able to see the extent to which these filaments connect galaxies together," said Epps.

- Riddle of cannibal black hole pairs solved ... nearly: Astronomers explain all Stargazers perform gravity wave 'palaeontology' in simulations

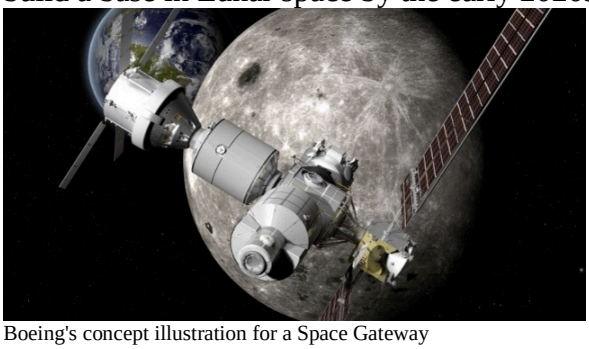


Artist's view of a binary black hole ... Pic credit: NASA, ESA and G Bacon (STScI)
6 Apr 2017 at 07:29, Katyanna Quach

Astrophysicists are one step closer to understanding how pairs of merging black holes form in the far reaches of the cosmos. The dramatic melding of two black holes produced the first gravitational waves detected by the Earth-based Advanced Laser Interferometer Gravitational-wave Observatory (LIGO). While these waves confirmed Einstein's theory of general relativity, questions were raised about how the holes were formed in the first place: it's rather rare for two such terrifying voids to smash into each other. Using computer simulations, a team of scientists from the University of Birmingham, UK, and the University of Amsterdam, in the Netherlands, has modelled the types of stars that eventually evolve to become pairs of merging black holes. Their results were published Wednesday in Nature Communications, and shed light on how massive stars wind up as cannibalistic black holes meandering through the universe.
These giant voids rarely encounter objects in their path. We're told that before two holes collide, they may start out as huge stars no further than a fifth of the distance between our Earth and the Sun apart – that's just 18.6 million miles or 29.9 million kilometres, and very close by astronomical standards.
However, black holes are typically formed from massive stars that grow to be much larger than this gap and thus are further from their neighbours than the magic distance. Therefore, the stars have to be squeezed tightly together, a scenario described as "isolated binary evolution via a common-envelope phase." "Getting massive stars so close together is one of the main challenges, since massive stars expand during their lives to become up to a thousand times the size of the sun. In our model, massive stars are brought close together through a process known as a common envelope, where at some point both stars orbit inside of the same envelope," Simon Stevenson, first author of the paper and a PhD student at the University of Birmingham, explained.
According to the scientists, the stars start out at wide distances from each other, passing mass to one another within a bubble of gas and dust. As gas leaks from the system, the doomed stars lose energy, and their orbits shrink, thus bringing them closer together.
"They then spiral in towards each other, shedding this outer envelope. This leaves a much closer binary, in which the stars can eventually form black holes that merge and are observed by LIGO," Stevenson continued.
These strict constraints make merger events rare. By scrutinizing the observations made by LIGO, the researchers can piece together the holes' histories. Professor Ilya Mandel, senior author of the paper and researcher at the University of Birmingham, compares it to "a kind of palaeontology for gravitational waves." "A palaeontologist, who has never seen a living dinosaur, can figure out how the dinosaur looked and lived from its skeletal remains. In a similar way, we can analyse the mergers of black holes, and use these observations to figure out how those stars interacted during their brief but intense lives."
The simulations have also revealed the typical properties of stars that go on to become a merging black hole. For example, the team found that a collision of two black holes with unequal masses means that the stars were probably formed almost completely from hydrogen and helium. The study is still in its early stages, and the team will have to observe more black hole mergers to understand how to retrace the individual steps in the lives of the massive stars. Engineers are working to increase the sensitivity of an upgraded version of LIGO, which will make the detection of black hole collisions easier.

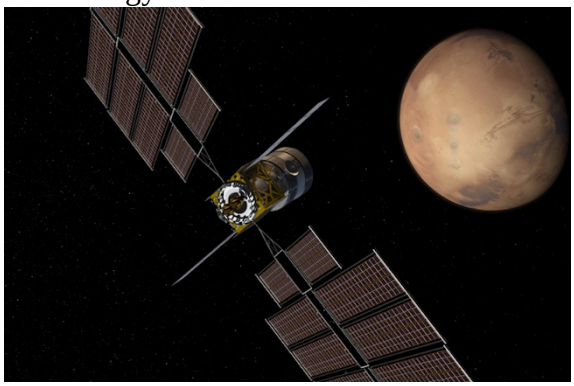
- Boeing details 'Deep Space Gateway' for Mars mission staging

Aerospace outfit says just four launches could build a base in Lunar space by the early 2020s



Boeing's concept illustration for a Space Gateway
4 Apr 2017 at 07:29, Simon Sharwood

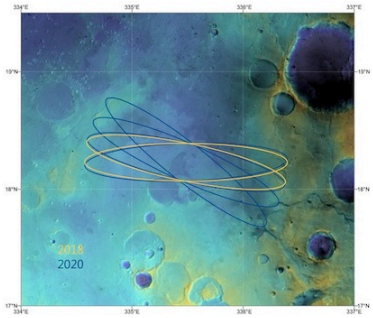
Aerospace outfit Boeing has detailed the hardware it thinks humanity will need to stage a piloted mission to Mars. Boeing is already working with NASA to develop the Space Launch System (SLS), the very heavy lifter its hoped will power a Mars shot. Now it's also offered up conceptual designs for other kit that it thinks will be useful for that mission. First, the “Deep Space Gateway”, a space station it's envisioned will be positioned in Cislunar space, which is to say in or beyond the orbit of the Moon rather than in Earth orbit. Boeing's developed a design for that facility it says could be hauled into place with just four SLS missions. NASA's fact sheet (PDF) for the SLS explains its cargo-carrying variants should have sufficient capacity to launch “a small deep-space habitat module” so we're guessing Boeing's singing from that hymn sheet with variation or two of its own. It's been ages since humans went beyond low Earth orbit so it's long been assumed we'll need to spend some time near the Moon to give deep space tech a good solid shakedown before trying to visit Mars. Boeing's announcements on Monday offer a glimpse of how that might happen, complete with visions of the Gateway as a base for lunar exploration. The Gateway would also be the staging point for the “Deep Space Transport vehicle” that would make the trek to Mars. Whether that's an SLS or something else isn't explained. We do know that both the Gateway and the Transport are real projects being worked on under NASA’s Next Space Technologies for Exploration Technologies (Next Step) program and the High Power Solar Electric Propulsion technology development effort within the NASA Space Technology Mission Directorate.



Boeing's concept illustration of a Deep Space Transport vehicle at Mars

Boeing also puts its name to a timeline that would see the Gateway aloft and assembled “in the early 2020s”. That's probably a little late to meet United States president Donald Trump's wish that the nation's 250th birthday in 2026 might be marked by “American footprints on distant worlds”. But it would still be quite an achievement!

ESA picks final two ExoMars landing site candidates



Oxia Planum, one of two possible landing sites for the ExoMars 2020 mission

29 Mar 2017 at 06:28, Simon Sharwood

The European Space Agency has narrowed its candidate list of landing sites for the ExoMars rover to two choices. ExoMars should fly in the year 2020 and will carry a rover and a stationary observer to the Red Planet. The big question is where to land both. The ESA prefers locations that offer opportunities to explore hitherto-unvisited bits of Mars and look for signs of life. It's also important that a landing site be free of obvious obstacles that will imperil a landing, like steep slopes, loose material or large rocks. Low-lying regions are also favoured, as they possess denser atmospheres necessary for the planned parachute-assisted landing mechanism. The space agency has previously considered three sites: Oxia Planum, Aram Dorsum and Mawrth Vallis. Oxia Planum had already made the final shortlist. The ESA's description of the region says it features “ancient, clay-rich outcrops [that] may have formed in aqueous conditions that could have hosted micro-organisms and the fine-grained sediments could have preserved evidence of their existence.” The other two sites each had similar characteristics, but Mawrth Vallis (Google Maps) got the nod because it is felt to offer “extensively layered, clay-rich sedimentary deposits, and a diversity of minerals that suggests a sustained presence of water over a period of several hundred million years, perhaps including localised ponds.” The detailed description explains it also features “... one of the largest exposures of phyllosilicates (clay minerals produced by chemical weathering) detected on Mars. These deposits provide a unique opportunity to evaluate aqueous activity on early Mars and

point to the possibility that habitable environments may have existed during the Noachian period (from the formation of the planet to perhaps 3.6 billion years ago). Other deposits and outcrops in the region show the highest degree of mineral alteration identified so far on Mars." Perhaps the ESA's Landing Site Selection Working Group was also tickled by the fact Mawrth Vallis borrows the Welsh word for Mars. The Working Group won't make a final decision until a year before the mission launches, so put early 2019 in your diary to learn about where ExoMars will aim to land. Then cross your fingers that the ESA has ironed out the software problem that caused the Schiaparelli Lander's parachute to misfire. That problem turned the lander into an expensive smoking crater. NASA's going through a similar selection process for its own Mars 2020 mission. In February it named three landing sites. Like the ESA, it's looking for places thought to have once been wet and warm, in the hope of finding signs of little green microbes.

- Astronomers perform largest-ever survey of high-mass binary star systems

An international group of researchers has identified and characterized 82 binaries in a satellite galaxy of the Milky Way
Date: April 20, 2017
Source: Fundação de Amparo à Pesquisa do Estado de São Paulo

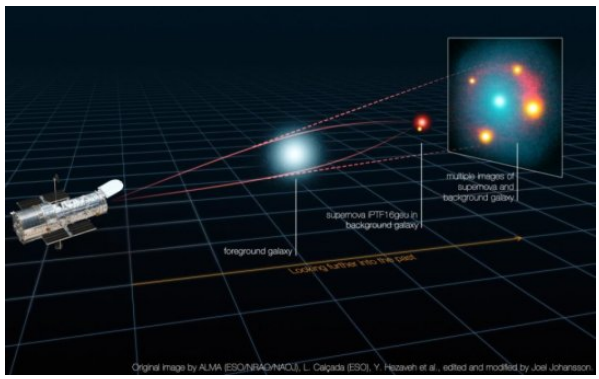
The Milky Way.
Credit: © mandritoiu / Fotolia

In addition to solo stars like our Sun, the universe contains binary systems comprising two massive stars that interact with each other. In many binaries the two stars are close enough to exchange matter and may even merge, producing a single high-mass star that spins at great speed. Until now the number of known high-mass binaries has been very small, basically confined to those identified in our galaxy, the Milky Way. An international group of astronomers led by researchers at the University of São Paulo's Institute of Astronomy, Geophysics & Atmospheric Sciences (IAG-USP) in Brazil, have just extended the list of by identifying and characterizing 82 new high-mass binaries located in the Tarantula Nebula, also known as 30 Doradus, in the Large Magellanic Cloud. The LMC is a satellite galaxy of the Milky Way and is about 160,000 light years from Earth. The results of the study are described in article published in the journal *Astronomy & Astrophysics*.
"By identifying and characterizing these 82 high-mass binaries, we have more than doubled the number of these objects, and in a completely new region with very different conditions from those found in the Milky Way," said Leonardo Andrade de Almeida, a postdoctoral fellow at IAG-USP and first author of the study. In research supervised by Augusto Damineli Neto, a full professor at IAG and a co-author of the article, Almeida analysed the data obtained during the VLT-FLAMES Tarantula Survey and Tarantula Massive Binary Monitoring observation campaigns performed by the European Southern Observatory (ESO) from 2011. Using FLAMES/GIRAFFE, a spectrograph coupled to ESO's Very Large Telescope (VLT), which has four 8 m primary mirrors and operates in Chile's Atacama Desert, the observation campaigns collected spectral data for over 800 high-mass objects in the region of the Tarantula Nebula, so named because its glowing filaments resemble spider legs.
From this total of 800 observed objects, the astronomers who worked on the two surveys identified 100 candidate binaries of spectral type O (very hot and massive) in a sample of 360 stars based on parameters such as the amplitude of variations in their radial velocity (the velocity of motion away from or toward an observer). For the last two years, Almeida has collaborated with colleagues in other countries on an analysis of these 100 candidate high-mass binaries using the FLAMES/GIRAFFE spectrograph and has managed to characterize 82 of them completely. "This represents the largest survey and spectroscopic characterization of massive binary systems every performed," he said. "It was only possible thanks to the

technological capabilities of the FLAMES/GIRAFFE spectrograph."
The scientific instrument developed by ESO can be used to obtain spectra for a number of objects simultaneously, and weaker objects can be observed because it is coupled to the VLT, which has large mirrors and captures more light, Almeida explained. "We can collect 136 spectra in a single observation using FLAMES/GIRAFFE," he said. "Nothing similar could be done before. Our instruments could only observe individual objects and it took much longer to characterize them." Spectroscopic analysis of the 82 binaries showed that properties such as mass ratio, orbital period (the time taken to complete one orbit) and orbital eccentricity (the amount by which the orbit deviates from a perfect circle) were highly similar to those observed in the Milky Way. This was unexpected since the LMC embodies a phase of the universe prior to the Milky Way when the largest number of high-mass stars were formed. For this reason, its metallicity -- the proportion of its matter made up of chemical elements different from hydrogen and helium, the primordial atoms that gave rise to the first stars -- is only half that of the binaries found in the Milky Way, whose metallicity is very close to the Sun's. "At the beginning of the universe, stars were metal-poor but chemical evolution increased their metallicity," Almeida said. This analysis of binaries in the LMC, he added, provides the first direct constraints on the properties of massive binaries in galaxies whose stars were formed in the early universe and have the LMC's metallicity. "The discoveries made during the study may provide better measurements for use in more realistic simulations of how high-mass stars evolved in the different phases of the universe. If so, we'll be able to obtain more precise estimates of the rate at which black holes, neutron stars and supernovae were formed in each phase, for example," he said. High-mass stars are the most important drivers of the chemical evolution of the universe. Because they are more massive, they produce more heavy metals, evolve more rapidly, and end their lives as supernovae, ejecting all their matter into the interstellar medium. This matter is recycled to form a new population of stars. However, Almeida went on, estimates of the chemical evolution of the universe and astrophysical predictions of the number of black holes usually take into account sole stars like our Sun, which evolve more simply. According him, when you include binaries in computing these projections, the result changes dramatically. So when making astrophysical predictions you need to consider these massive objects.

- ❖ Light rays from a supernova bent by the curvature of space-time around a galaxy

Date: April 20, 2017
Source: Stockholm University



The light from the supernova iPTF16geu and of its host galaxy is warped and amplified by the curvature of space mass of a foreground galaxy. In the case of the point-like supernova, the light is split into four images. These have been resolved with the Hubble Space Telescope.
Credit: Original image by ALMA (ESO/NRAO/NAOJ), L. Calçada (ESO), Y. Hezaveh et al, edited and modified by Joel Johansson

An international research team led by Ariel Goobar at Stockholm University has detected for the first time multiple images from a gravitationally lensed Type Ia supernova. The new observations suggest promising new avenues for the study of the accelerated expansion of the Universe, gravity and distribution of dark matter in the universe. Type Ia supernovae, nature's own "standard candles," have been used for many years by astronomers to measure cosmological distances. These studies led to the discovery of the accelerated expansion of the Universe, a sensational discovery that won the 2011 Nobel Prize in Physics. Professor Ariel Goobar at the Department of Physics at Stockholm University was a member of the team led by one of the Nobel laureates, Saul Perlmutter. An international team of physicists and astronomers led from

Stockholm University has now seen, for the first time, the rare appearance of multiple images of the same exploding star dubbed iPTF16geu, which belongs to a class of supernovae known as Type Ia. The phenomenon, called strong gravitational lensing is a result of the intense warping of the supernova light by an intervening galaxy positioned between us and the star in near perfect alignment. In this special case, the supernova appeared magnified, but also multiplied. The new observations provide a promising new tool to test key cosmological theories about the accelerating expansion of the universe and the distribution of a mysterious substance known as dark matter. Type Ia supernovae are abundant and frequently used by astronomers to accurately measure distances in the universe. Gravitational lensing -- the curving of space due to gravity -- has also been observed many times since the early 20th century when it was predicted by Einstein. Yet, imaging a gravitationally lensed Type Ia supernova had proven formidably difficult, until now. "Resolving, for the first time, multiple images of a strongly lensed "standard candle" supernova is a major breakthrough. We can measure the light focusing power of gravity more accurately than ever before, and probe physical scales that may have seemed out of reach until now," says Ariel Goobar, Professor at Oskar Klein Centre, Stockholm University and a lead author of the study, published today in the journal *Science*. Goobar and his group are partners in two Caltech-led international scientific collaborations -- iPTF (intermediate Palomar Transient Factory) and GROWTH (Global Relay of Observatories Watching Transients Happen). The iPTF takes advantage of the Palomar Observatory and its unique capabilities to scan the skies and discover, in near real time, fast-changing cosmic events such as supernovae. GROWTH manages a global network of researchers and telescopes that can swiftly perform follow-up observations to study these transient events in detail. Within two months of detection, the team observed iPTF16geu supernova with NASA/ESA Hubble Space Telescope, and the adaptive-optics instruments on the Keck Observatory atop Mauna Kea, Hawaii, and the VLT telescopes in Chile. Apart from producing a striking visual effect, capturing the image of the strongly lensed Type Ia supernova such as iPTF16geu is extremely useful scientifically. Astronomers can now measure very accurately how much time it takes for the light from each of the multiple images of the supernova to reach us. The difference in the time of arrival can then be used to estimate with a high precision the expansion rate of the universe known as the Hubble constant. Currently, the different methods to measure the Hubble constant produce slightly different results but even these small changes can result in significantly different scenarios for the predicted evolution and expansion of the universe. The study of iPTF16geu is already delivering interesting results. Based on current knowledge of supernovae and gravitational lensing, observing an event such as iPTF16geu is rather improbable. Moreover, using data from Keck and Hubble the team finds that the lensing galaxy needs a great deal of substructure to account for the observed differences in the four supernova images, and the total lens magnification. This may introduce new questions about the way matter clumps in the universe and challenge astronomers' understanding of gravitational lensing at small scales. "The discovery of iPTF16geu is truly like finding a somewhat weird needle in a haystack. It reveals to us a bit more about the universe, but mostly triggers a wealth of new scientific questions. That's why I love science and astronomy" -- says Rahman Amanullah, a postdoctoral fellow at Stockholm University and a co-author on the study.

- Newly discovered exoplanet may be best candidate in search for signs of life

Transiting rocky super-Earth found in habitable zone of quiet red dwarf star
Date: April 19, 2017
Source: ESO

This artist's impression shows the exoplanet LHS 1140b, which orbits a red dwarf star 40 light-years from Earth and may be the new holder of the title 'best place to look for signs of life beyond the Solar System'. Using ESO's HARPS instrument at La Silla, and other telescopes around the world, an international team of astronomers discovered this super-Earth orbiting in the habitable zone around the faint star LHS 1140. This world is a little larger and much more massive than the Earth and has likely retained most of its atmosphere. *Credit: ESO/spaceengine.org*

The newly discovered super-Earth LHS 1140b orbits in the habitable zone around a faint red dwarf star named LHS 1140, in the constellation of Cetus (The Sea Monster) [1]. Red dwarfs are much smaller and cooler than the Sun and, although LHS 1140b is ten times closer to its star than the Earth is to the Sun, it only receives about half as much sunlight from its star as the Earth and lies in the middle of the habitable zone. The orbit is seen almost edge-on from Earth and as the exoplanet passes in front of the star once per orbit it blocks a little of its light every 25 days. "This is the most exciting exoplanet I've seen in the past decade," said lead author Jason Dittmann of the Harvard-Smithsonian Centre for Astrophysics (Cambridge, USA). "We could hardly hope for a better target to perform one of the biggest quests in science -- searching for evidence of life beyond Earth." "The present conditions of the red dwarf are particularly favourable -- LHS 1140 spins more slowly and emits less high-energy radiation than other similar low-mass stars," explains team member Nicola Astudillo-Defru from Geneva Observatory, Switzerland [2]. For life as we know it to exist, a planet must have liquid surface water and retain an atmosphere. When red dwarf stars are young, they are known to emit radiation that can be damaging for the atmospheres of the planets that orbit them. In this case, the planet's large size means that a magma ocean could have existed on its surface for millions of years. This seething ocean of lava could feed steam into the atmosphere long after the star has calmed to its current, steady glow, replenishing the planet with water. The discovery was initially made with the MEarth facility, which detected the first tell-tale, characteristic dips in light as the exoplanet passed in front of the star. ESO's HARPS instrument, the High Accuracy Radial velocity Planet Searcher, then made crucial follow-up observations which confirmed the presence of the super-Earth. HARPS also helped pin down the orbital period and allowed the exoplanet's mass and density to be deduced [3]. The astronomers estimate the age of the planet to be at least five billion years. They also deduced that it has a diameter 1.4 times larger than the Earth -- almost 18,000 kilometres. But with a mass around seven times greater than the Earth, and hence a much higher density, it implies that the exoplanet is probably made of rock with a dense iron core. This super-Earth may be the best candidate yet for future observations to study and characterise its atmosphere, if one exists. Two of the European members of the team, Xavier Delfosse and Xavier Bonfils both at the CNRS and IPAG in Grenoble, France, conclude: "The LHS 1140 system might prove to be an even more important target for the future characterisation of planets in the habitable zone than Proxima b or TRAPPIST-1. This has been a remarkable year for exoplanet discoveries!" [4,5]. In particular, observations coming up soon with the NASA/ESA Hubble Space Telescope will be able to assess exactly how much high-energy radiation is showered upon LHS 1140b, so that its capacity to support life can be further constrained. Further into the future -- when new telescopes like ESO's Extremely Large Telescope are operating -- it is likely that we will be able to make detailed observations of the atmospheres of exoplanets, and LHS 1140b is an exceptional candidate for such studies.

Notes

[1] The habitable zone is defined by the range of orbits around a star, for which a planet possesses the appropriate temperature needed for liquid water to exist on the planet's surface.

[2] Although the planet is located in the zone in which life as we know it could potentially exist, it probably did not enter this region until approximately forty million years after the formation of the red dwarf star. During this phase, the exoplanet would have been subjected to the active and volatile past of its host star. A young red dwarf can easily strip away the water from the atmosphere of a

planet forming within its vicinity, leading to a runaway similar to that on Venus.

[3] This effort enabled other transit events to be detected by MEarth so that the astronomers could nail down the detection of the exoplanet once and for all.

[4] The planet around Proxima Centauri is much closer to Earth, but it probably does not transit its star, making it very difficult to determine whether it holds an atmosphere.

[5] Unlike the TRAPPIST-1 system, no other exoplanets around LHS 1140 have been found. Multi-planet systems are thought to be common around red dwarfs, so it is possible that additional exoplanets have gone undetected so far because they are too small.

- Milky Way: Hydrogen halo lifts the veil of our galactic home

Astronomers find missing mass in the hydrogen halo that surrounds our home galaxy
Date: April 18, 2017
Source: University of Arizona

What our Milky Way might look like to alien astronomers: This image of NGC 2683, a spiral galaxy also known as the "UFO Galaxy" due to its shape, was taken by the Hubble Space Telescope. Since trying to find out what the Milky Way looks like is a bit like trying to picture an unfamiliar house while being confined to a room inside, studies like this one help us gain a better idea of our cosmic home.
Credit: ESA/Hubble & NASA

Sometimes it takes a lot of trees to see the forest. In the case of the latest discovery made by astronomers at the University of Arizona, exactly 732,225. Except that in this case, the "forest" is a veil of diffuse hydrogen gas enshrouding the Milky Way, and each "tree" is another galaxy observed with the 2.5-meter telescope of the Sloan Digital Sky Survey.

After combining this staggering number of spectra -- recorded patterns of wavelengths revealing clues about the nature of a cosmic target -- UA astronomers Huanian Zhang and Dennis Zaritsky report the first detections of diffuse hydrogen wafting about in a vast halo surrounding the Milky Way. Such a halo had been postulated based on what astronomers knew about other galaxies, but never directly observed. Astronomers have long known that the most prominent features of a typical spiral galaxy such as our Milky Way -- a central bulge surrounded by a disk and spiral arms -- account only for the lesser part of its mass. The bulk of the missing mass is suspected to lie in so-called dark matter, a postulated but not yet directly observed form of matter believed to account for the majority of matter in the universe. Dark matter emits no electromagnetic radiation of any kind, nor does it interact with "normal" matter (which astronomers call baryonic matter), and is therefore invisible and undetectable through direct imaging. The dark matter of a typical galaxy is thought to reside in a more or less spherical halo that extends 10 to 30 times farther out than the distance between the centre of our galaxy and the sun, according to Zaritsky, a professor in the UA's Department of Astronomy and deputy director of the UA's Steward Observatory. "We infer its existence through dynamical simulations of galaxies," Zaritsky explains. "And because the ratio of normal matter to dark matter is now very well known, for example from measuring the cosmic microwave background, we have a pretty good idea of how much baryonic matter should be in the halo. But when we add all the things we can see with our instruments, we get only about half of what we expect, so there has to be a lot of baryonic matter waiting to be detected." By combining such a large number of spectra, Zaritsky and Zhang, a postdoctoral fellow in the Department of Astronomy/Steward Observatory, covered a large portion of space surrounding the Milky Way and found that diffuse hydrogen gas engulfs the entire galaxy, which would account for a large part of the galaxy's baryonic mass. "It's like peering through a veil," Zaritsky said. "We see diffuse hydrogen in every direction we look." He pointed out that this is not the first time gas has been detected in halos around galaxies, but in those instances, the hydrogen is in a different physical state. "There are cloudlets of

hydrogen in the galaxy halo, which we have known about for a long time, called high-velocity clouds," Zaritsky said. "Those have been detected through radio observations, and they're really clouds -- you see an edge, and they're moving. But the total mass of those is small, so they couldn't be the dominant form of hydrogen in the halo." Since observing our own galaxy is a bit like trying to see what an unfamiliar house looks like while being confined to a room inside, astronomers rely on computer simulations and observations of other galaxies to get an idea of what the Milky Way might look like to an alien observer millions of light-years away. For their study, scheduled for advance online publication on *Nature Astronomy*'s website on Apr. 18, the researchers sifted through the public databases of the Sloan Digital Sky Survey and looked for spectra taken by other scientists of galaxies outside our Milky Way in a narrow spectral line called hydrogen alpha. Seeing this line in a spectrum tells of the presence of a particular state of hydrogen that is different from the vast majority of hydrogen found in the universe. Unlike on Earth, where hydrogen occurs as a gas consisting of molecules of two hydrogen atoms bound together, hydrogen exists as single atoms in outer space, and those can be positively or negatively charged, or neutral. Neutral hydrogen constitutes a small minority compared to its ionized (positive) form, which constitutes more than 99.99 percent of the gas spanning the intergalactic gulfs of the universe. Unless neutral hydrogen atoms are being energized by something, they are extremely difficult to detect and therefore remain invisible to most observational approaches, which is why their presence in the Milky Way's halo had eluded astronomers until now. Even in other galaxies, halos are difficult to pin down. "You don't just see a pretty picture of a halo around a galaxy," Zaritsky said. "We infer the presence of galactic halos from numerical simulations of galaxies and from what we know about how they form and interact." Zaritsky explained that based on those simulations, scientists would have predicted the presence of large amounts of hydrogen gas stretching far out from the centre of the Milky Way, but remaining associated with the galaxy, and the data collected in this study confirm the presence of just that. "The gas we detected is not doing anything very noticeable," he said. "It is not spinning so rapidly as to indicate that it's in the process of being flung out of the galaxy, and it does not appear to be falling inwards toward the galactic centre, either." One of the challenges in this study was to know whether the observed hydrogen was indeed in a halo outside the Milky Way, and not just part of the galactic disk itself, Zaritsky said. "When you see things everywhere, they could be very close to us, or they could be very far away," he said. "You don't know." The answer to this question, too, was in the "trees," the more than 700,000 spectral analyses scattered across the galaxy. If the hydrogen gas were confined to the disk of the galaxy, our solar system would be expected to "float" inside of it like a ship in a slowly churning maelstrom, orbiting the galactic centre. And just like the ship drifting with the current, very little relative movement would be expected between our solar system and the ocean of hydrogen. If, on the other hand, it surrounded the spinning galaxy in a more or less stationary halo, the researchers expected that wherever they looked, they should find a predictable pattern of relative motion with respect to our solar system. "Indeed, in one direction, we see the gas coming toward us, and the opposite direction, we see it moving away from us," Zaritsky said. "This tells us that the gas is not in the disk of our galaxy, but has to be out in the halo." Next, the researchers want to look at even more spectra to better constrain the distribution around the sky and the motions of the gas in the halo. They also plan to search for other spectral lines, which may help better understand the physical state such as temperature and density of the gas.

- ❖ Hubble's cosmic bubbles

Date: April 21, 2017
Source: NASA/Goddard Space Flight Centre

This entrancing image shows a few of the tenuous threads that comprise Sh2-308, a faint and wispy shell of gas located 5,200 light-years away in the constellation of Canis Major (The Great Dog).
Credit: ESA/Hubble & NASA

This entrancing image shows a few of the tenuous threads that comprise Sh2-308, a faint and wispy shell of gas located 5,200 light-years away in the constellation of Canis Major (The Great Dog). Sh2-308 is a large bubble-like structure wrapped around an extremely large, bright type of star known as a Wolf-Rayet Star -- this particular star is called EZ Canis Majoris. These type of stars are among the brightest and most massive stars in the Universe, tens of times more massive than our own sun, and they represent the extremes of stellar evolution. Thick winds continually poured off the progenitors of such stars, flooding their surroundings and draining the outer layers of the Wolf-Rayet stars. The fast wind of a Wolf-Rayet star therefore sweeps up the surrounding material to form bubbles of gas. EZ Canis Majoris is responsible for creating the bubble of Sh2-308 -- the star threw off its outer layers to create the strands visible here. The intense and ongoing radiation from the star pushes the bubble out farther and farther, blowing it bigger and bigger. Currently the edges of Sh2-308 are some 60 light-years apart! Beautiful as these cosmic bubbles are, they are fleeting. The same stars that form them will also cause their death, eclipsing and subsuming them in violent supernova explosions.

- ❖ Hubble celebrates 27 years with two close friends

Date: April 20, 2017
Source: ESA/Hubble Information Centre

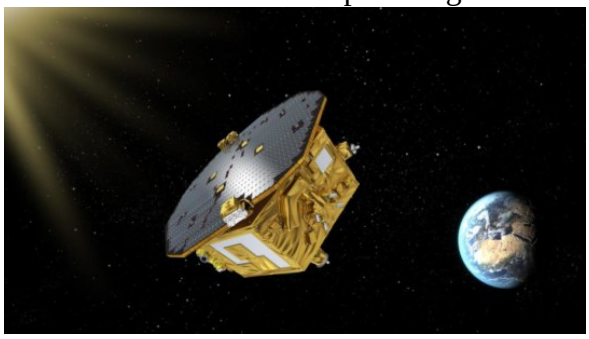
This image displays the galaxies NGC 4302 -- seen edge-on -- and NGC 4298, both located 55 million light-years away. They were observed by Hubble to celebrate its 27th year in orbit.
Credit: NASA, ESA, and M. Mutchler (STScI)

This stunning cosmic pairing of the two very different looking spiral galaxies NGC 4302 and NGC 4298 was imaged by the NASA/ESA Hubble Space Telescope. The image brilliantly captures their warm stellar glow and brown, mottled patterns of dust. As a perfect demonstration of Hubble's capabilities, this spectacular view has been released as part of the telescope's 27th anniversary celebrations. Since its launch on 24 April 1990, Hubble has been nothing short of a revolution in astronomy. The first orbiting facility of its kind, for 27 years the telescope has been exploring the wonders of the cosmos. Astronomers and the public alike have witnessed what no other humans in history have before. In addition to revealing the beauty of the cosmos, Hubble has proved itself to be a treasure chest of scientific data that astronomers can access. ESA and NASA celebrate Hubble's birthday each year with a spectacular image. This year's anniversary image features a pair of spiral galaxies known as NGC 4302 -- seen edge-on -- and NGC 4298, both located 55 million light-years away in the northern constellation of Coma Berenices (Berenice's Hair). The pair, discovered by astronomer William Herschel in 1784, form part of the Virgo Cluster, a gravitationally bound collection of nearly 2000 individual galaxies. The edge-on NGC 4302 is a bit smaller than our own Milky Way Galaxy. The tilted NGC 4298 is even smaller: only half the size of its companion. At their closest points, the galaxies are separated from each other in projection by only around 7000 light-years. Given this very close arrangement, astronomers are intrigued by the galaxies' apparent lack of any significant gravitational interaction; only a faint bridge of neutral hydrogen gas -- not visible in this image -- appears to stretch between them. The long tidal tails and deformations in their structure that are typical of galaxies lying so close to each other are missing completely. Astronomers have found very faint tails of gas streaming from the two galaxies, pointing in roughly the same direction -- away from the centre of the Virgo Cluster. They have

proposed that the galactic double is a recent arrival to the cluster, and is currently falling in towards the cluster centre and the galaxy Messier 87 lurking there -- one of the most massive galaxies known. On their travels, the two galaxies are encountering hot gas -- the intracluster medium -- that acts like a strong wind, stripping layers of gas and dust from the galaxies to form the streaming tails. Even in its 27th year of operation, Hubble continues to provide truly spectacular images of the cosmos, and even as the launch date of its companion -- the NASA/ESA/CSA James Webb Space Telescope -- draws closer, Hubble does not slow down. Instead, the telescope keeps raising the bar, showing it still has plenty of observing left to do for many more years to come. In fact, astronomers are looking forward to have Hubble and James Webb operational at the same time and use their combined capabilities to explore the Universe.

- ❖ NASA team explores using LISA Pathfinder as 'comet crumb' detector

Date: April 17, 2017
Source: NASA/Goddard Space Flight Centre



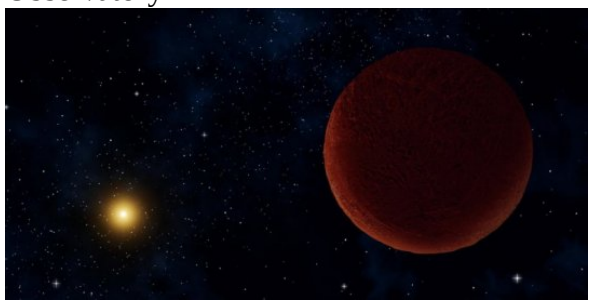
This is an illustration of LISA Pathfinder on its way to Earth-sun L1.
Credit: ESA/C. Carreau

LISA Pathfinder, a mission led by ESA (the European Space Agency) with contributions from NASA, has successfully demonstrated critical technologies needed to build a space-based observatory for detecting ripples in space-time called gravitational waves. Now a team of NASA scientists hopes to take advantage of the spacecraft's record-breaking sensitivity to map out the distribution of tiny dust particles shed by asteroids and comets far from Earth. Most of these particles have masses measured in micrograms, similar to a small grain of sand. But with speeds greater than 22,000 mph (36,000 kph), even micrometeoroids pack a punch. The new measurements could help refine dust models used by researchers in a variety of studies, from understanding the physics of planet formation to estimating impact risks for current and future spacecraft. "We've shown we have a novel technique and that it works," said Ira Thorpe, who leads the team at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "The next step is to carefully apply this technique to our whole data set and interpret the results." The mission's primary goal was to test how well the spacecraft could fly in formation with an identical pair of 1.8-inch (46 millimetre) gold-platinum cubes floating inside it. The cubes are test masses intended to be in free fall and responding only to gravity. The spacecraft serves as a shield to protect the test masses from external forces. When LISA Pathfinder responds to pressure from sunlight and microscopic dust impacts, the spacecraft automatically compensates by firing tiny bursts from its micro newton thrusters to prevent the test masses from being disturbed. Scientists call this drag-free flight. In its first two months of operations in early 2016, LISA Pathfinder demonstrated the process with a precision some five times better than its mission requirements, making it the most sensitive instrument for measuring acceleration yet flown. It has now reached the sensitivity level needed to build a full multi-spacecraft gravitational wave observatory. "Every time microscopic dust strikes LISA Pathfinder, its thrusters null out the small amount of momentum transferred to the spacecraft," said Goddard co-investigator Diego Janches. "We can turn that around and use the thruster firings to learn more about the impacting particles. One team's noise becomes another team's data." Much of what we know about interplanetary dust is limited to Earth's neighbourhood, thanks in large part to NASA's Long Duration Exposure Facility (LDEF). Launched into Earth orbit by the space shuttle Challenger in April 1984 and retrieved by the space shuttle Columbia in January 1990, LDEF hosted dozens of experiments, many of which were designed to better understand the meteoroid and orbital debris environment. The different compositions, orbits and histories of different asteroids and comets naturally produce dust with a range of masses and velocities. Scientists suspect the smallest and slowest particles are enhanced in Earth's neighbourhood, so the LDEF results are not

representative of the wider solar system. "Small, slow particles near a planet are most susceptible to the planet's gravitational pull, which we call gravitational focusing," Janches said. This means the micrometeoroid flux near Earth should be much higher than that experienced by LISA Pathfinder, located about 930,000 miles (1.5 million kilometres) closer to the sun. To find the impacts, Tyson Littenberg at NASA's Marshall Space Flight Centre in Huntsville, Alabama, adapted an algorithm he originally developed to search for gravitational waves in data from the ground-based detectors of the Laser Interferometer Gravitational-wave Observatory (LIGO), located in Livingston, Louisiana, and Hanford, Washington. In fact, it was one of many algorithms that played a role in the discovery of gravitational waves by LIGO, announced in February 2016. "The way it works is that we come up with a guess of what the signal might look like, then study how LIGO or LISA Pathfinder would react if this guess were true," Littenberg explained. "For LIGO, we're guessing about the waveform, the peaks and valleys of the gravitational wave. For LISA Pathfinder, we're guessing about an impact." To map out the probability of likely sources, the team generates millions of different scenarios describing what the source might be and compares them to what the spacecraft actually detects. In response to an impact, LISA Pathfinder fires its thrusters to counteract both the minute "push" from the strike and any change in the spacecraft's spin. Together, these quantities allow the researchers to determine the impact's location on the spacecraft and reconstruct the micrometeoroid's original trajectory. This may allow the team to identify individual debris streams and perhaps relate them to known asteroids and comets. "This is a very nice collaboration," said Paul McNamara, the LISA Pathfinder project scientist at ESA's Directorate of Science in Noordwijk, the Netherlands. "This is data we use for doing our science measurements, and as an offshoot of that, Ira and his team can tell us about micro particles hitting the spacecraft." Its distant location, sensitivity to low-mass particles, and ability to measure the size and direction of impacting particles make LISA Pathfinder a unique instrument for studying the population of micrometeoroids in the inner solar system. But it's only the beginning. "This is a proof of concept, but we'd hope to repeat this technique with a full gravitational wave observatory that ESA and NASA are currently studying for the future," said Thorpe. "With multiple spacecraft in different orbits and a much longer observing time, the quality of the data should really improve." LISA Pathfinder is managed by ESA and includes contributions from NASA Goddard and NASA's Jet Propulsion Laboratory in Pasadena, California. The mission launched on Dec. 3, 2015, and began orbiting a point called Earth-sun L1, roughly 930,000 miles (1.5 million km) from Earth in the sun's direction, in late January 2016. LISA stands for Laser Interferometer Space Antenna, a space-based gravitational wave observatory concept that has been studied in great detail by both NASA and ESA. It is a concept being explored for the third large mission of ESA's Cosmic Vision Plan, which seeks to launch a gravitational wave observatory in 2034.

- ❖ Meet 'DeeDee,' a distant, dim member of our solar system

Date: April 12, 2017
Source: National Radio Astronomy Observatory



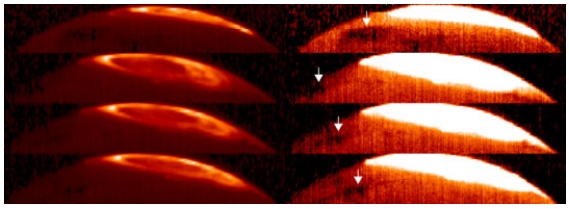
Artist concept of the planetary body 2014 UZ224, more informally known as DeeDee. ALMA was able to observe the faint millimetre-wavelength "glow" emitted by the object, confirming it is roughly 635 kilometres across. At this size, DeeDee should have enough mass to be spherical, the criteria necessary for astronomers to consider it a dwarf planet, though it has yet to receive that official designation.
Credit: Alexandra Angelich (NRAO/AUI/NSF)

Using the Atacama Large Millimetre/submillimetre Array (ALMA), astronomers have revealed extraordinary details about a recently discovered far-flung member of our solar system, the planetary body 2014 UZ224, more informally known as DeeDee. At about three times the current distance of Pluto from the Sun, DeeDee is the

second most distant known trans-Neptunian object (TNO) with a confirmed orbit, surpassed only by the dwarf planet Eris. Astronomers estimate that there are tens-of-thousands of these icy bodies in the outer solar system beyond the orbit of Neptune. The new ALMA data reveal, for the first time, that DeeDee is roughly 635 kilometres across, or about two-thirds the diameter of the dwarf planet Ceres, the largest member of our asteroid belt. At this size, DeeDee should have enough mass to be spherical, the criteria necessary for astronomers to consider it a dwarf planet, though it has yet to receive that official designation. "Far beyond Pluto is a region surprisingly rich with planetary bodies. Some are quite small but others have sizes to rival Pluto, and could possibly be much larger," said David Gerdes, a scientist with the University of Michigan and lead author on a paper appearing in the *Astrophysical Journal Letters*. "Because these objects are so distant and dim, it's incredibly difficult to even detect them, let alone study them in any detail. ALMA, however, has unique capabilities that enabled us to learn exciting details about these distant worlds." Currently, DeeDee is about 92 astronomical units (AU) from the Sun. An astronomical unit is the average distance from Earth to the Sun, or about 150 million kilometres. At this tremendous distance, it takes DeeDee more than 1,100 years to complete one orbit. Light from DeeDee takes nearly 13 hours to reach Earth. Gerdes and his team announced the discovery of DeeDee in the fall of 2016. They found it using the 4-meter Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile as part of ongoing observations for the Dark Energy Survey, an optical survey of about 12 percent of the sky that seeks to understand the as-yet mysterious force that is accelerating the expansion of the universe. The Dark Energy Survey produces vast troves of astronomical images, which give astronomers the opportunity to also search for distant solar system objects. The initial search, which includes nearly 15,000 images, identified more than 1.1 billion candidate objects. The vast majority of these turned out to be background stars and even more distant galaxies. A small fraction, however, were observed to move slowly across the sky over successive observations, the tell-tale sign of a TNO. One such object was identified on 12 separate images. The astronomers informally dubbed it DeeDee, which is short for Distant Dwarf. The optical data from the Blanco telescope enabled the astronomers to measure DeeDee's distance and orbital properties, but they were unable to determine its size or other physical characteristics. It was possible that DeeDee was a relatively small member of our solar system, yet reflective enough to be detected from Earth. Or, it could be uncommonly large and dark, reflecting only a tiny portion of the feeble sunlight that reaches it; both scenarios would produce identical optical data. Since ALMA observes the cold, dark universe, it is able to detect the heat -- in the form of millimetre-wavelength light -- emitted naturally by cold objects in space. The heat signature from a distant solar system object would be directly proportional to its size. "We calculated that this object would be incredibly cold, only about 30 degrees Kelvin, just a little above absolute zero," said Gerdes. While the reflected visible light from DeeDee is only about as bright as a candle seen halfway the distance to the moon, ALMA was able to quickly home in on the planetary body's heat signature and measure its brightness in millimetre-wavelength light. This allowed astronomers to determine that it reflects only about 13 percent of the sunlight that hits it. That is about the same reflectivity of the dry dirt found on a baseball infield. By comparing these ALMA observations to the earlier optical data, the astronomers had the information necessary to calculate the object's size. "ALMA picked it up fairly easily," said Gerdes. "We were then able to resolve the ambiguity we had with the optical data alone." Objects like DeeDee are cosmic leftovers from the formation of the solar system. Their orbits and physical properties reveal important details about the formation of planets, including Earth. This discovery is also exciting because it shows that it is possible to detect very distant, slowly moving objects in our own solar system. The researchers note that these same techniques could be used to detect the hypothesized "Planet Nine" that may reside far beyond DeeDee and Eris. "There are still new worlds to discover in our own cosmic backyard," concludes Gerdes. "The solar system is a rich and complicated place."

- 'Cold' great spot discovered on Jupiter

Date: April 11, 2017
Source: University of Leicester



The Great Cold Spot was first discovered on Jupiter using observations taken of Jupiter's auroral region by the CRIRES instrument on ESO's Very Large Telescope. The images on the left show the bright arcs of Jupiter's infrared aurora on two separate nights, the top left image on 17 October and three images taken 31 December 2012, as the planet slowly rotates. However, the Great Cold Spot cannot be seen clearly until these images are saturated so that the entire aurora becomes white, as shown on the right. Here, the planet glows as a result of the temperature of the upper atmosphere, and the distinct regions of cooling that reveal the Great Cold Spot can be seen. Based on data from VLT/ESO.
Credit: Image courtesy of University of Leicester

A second Great Spot has been discovered on Jupiter by University of Leicester astronomers, rivalling the scale of the planet's famous Great Red Spot and created by the powerful energies exerted by the great planet's polar aurorae. Dubbed the 'Great Cold Spot', it has been observed as a localised dark spot, up to 24,000 km in longitude and 12,000 km in latitude, in the gas giant's thin high-altitude thermosphere, that is around 200K (Kelvin) cooler than the surrounding atmosphere, which can range in temperature between 700K (426ºC) and 1000K (726ºC).

The results are published in *Geophysical Research Letters*.

Dr Tom Stallard, Associate Professor in Planetary Astronomy and lead author of the study, said: "This is the first time any weather feature in Jupiter's upper atmosphere has been observed away from the planet's bright aurorae. "The Great Cold Spot is much more volatile than the slowly changing Great Red Spot, changing dramatically in shape and size over only a few days and weeks, but it has re-appeared for as long as we have data to search for it, for over 15 years. That suggests that it continually reforms itself, and as a result it might be as old as the aurorae that form it -- perhaps many thousands of years old." The Great Cold Spot is thought to be caused by the effects of the magnetic field of the planet, with the massive planet's spectacular polar aurorae driving energy into the atmosphere in the form of heat flowing around the planet. This creates a region of cooling in the thermosphere, the boundary layer between the underlying atmosphere and the vacuum of space. Although we can't be sure what drives this weather feature, a sustained cooling is very likely to drive a vortex similar to the Great Red Spot. The astronomers used the CRIRES instrument on the Very Large Telescope (VLT) to observe spectral emissions of H3+, an ion of hydrogen present in large amounts in Jupiter's atmosphere, which allowed the scientists to map the mean temperature and density of the planet's atmosphere. They then used images of H3+ emission from Jupiter's ionosphere taken by NASA's Infrared Telescope Facility between 1995-2000 to compare. Through combining images taken over a period of time, including over 13,000 images taken over more than 40 nights by the Infrared Telescope Facility, the astronomers revealed the presence of the Great Cold Spot as an area of darkness amongst the hot environment of Jupiter's upper atmosphere. Dr Stallard, who is funded by the Science and Technology Facilities Council, added: "What is surprising at Jupiter is that, unlike weather systems on Earth, the Great Cold Spot has been observed at the same place across 15 years. That makes it more comparable to weather systems in Jupiter's lower atmosphere, like the Great Red Spot. "Observations and modelling of Earth's upper atmosphere have shown that, on the short term, there may be changes in the temperature and density of the upper atmosphere. “The two main differences are firstly that Earth's aurora sees dramatic changes caused by activity from the Sun, whereas Jupiter's aurora are dominated by gases from the volcanic moon Io, which are relatively slow and steady, and secondly that the atmospheric flows generated by Earth's aurora can drive heat quickly across the whole planet, making the upper atmosphere ring like a bell, while Jupiter's fast spin traps this energy nearer the poles." Dr Stallard added: "The detection of the Great Cold Spot was a real surprise to us, but there are indications that other features might also exist in Jupiter's upper atmosphere. Our next step will be to look for other features in the upper

atmosphere, as well as investigating the Great Cold Spot itself in more detail. "The Juno spacecraft is currently in orbit around Jupiter and the observations of Jupiter's aurora and upper atmosphere by the JIRAM instrument that have been released so far already provide a wealth of new information about the planet. When combined with our ongoing campaign of observations using telescopes on Earth, we hope to gain a much better understanding of this weather system in the next few years."

- ❖ NASA's MAVEN reveals Mars has metal in its atmosphere

Date: April 10, 2017
Source: NASA/Goddard Space Flight Centre

Illustration of MAVEN spacecraft at Mars. *Credit: NASA's Goddard Space Flight Centre*

Mars has electrically charged metal atoms (ions) high in its atmosphere, according to new results from NASA's MAVEN spacecraft. The metal ions can reveal previously invisible activity in the mysterious electrically charged upper atmosphere (ionosphere) of Mars. "MAVEN has made the first direct detection of the permanent presence of metal ions in the ionosphere of a planet other than Earth," said Joseph Grebowsky of NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "Because metallic ions have long lifetimes and are transported far from their region of origin by neutral winds and electric fields, they can be used to infer motion in the ionosphere, similar to the way we use a lofted leaf to reveal which way the wind is blowing." Grebowsky is lead author of a paper on this research appearing April 10 in *Geophysical Research Letters*.

MAVEN (Mars Atmosphere and Volatile Evolution Mission) is exploring the Martian upper atmosphere to understand how the planet lost most of its air, transforming from a world that could have supported life billions of years ago into a cold desert planet today. Understanding ionospheric activity is shedding light on how the Martian atmosphere is being lost to space, according to the team. The metal comes from a constant rain of tiny meteoroids onto the Red Planet. When a high-speed meteoroid hits the Martian atmosphere, it vaporizes. Metal atoms in the vapour trail get some of their electrons torn away by other charged atoms and molecules in the ionosphere, transforming the metal atoms into electrically charged ions. MAVEN has detected iron, magnesium, and sodium ions in the upper atmosphere of Mars over the last two years using its Neutral Gas and Ion Mass Spectrometer instrument, giving the team confidence that the metal ions are a permanent feature. "We detected metal ions associated with the close passage of Comet Siding Spring in 2014, but that was a unique event and it didn't tell us about the long-term presence of the ions," said Grebowsky. The interplanetary dust that causes the meteor showers is common throughout our solar system, so it's likely that all solar system planets and moons with substantial atmospheres have metal ions, according to the team. Sounding rockets, radar and satellite measurements have detected metal ion layers high in the atmosphere above Earth. There's also been indirect evidence for metal ions above other planets in our solar system. When spacecraft are exploring these worlds from orbit, sometimes their radio signals pass through the planet's atmosphere on the way to Earth, and sometimes portions of the signal have been blocked. This has been interpreted as interference from electrons in the ionosphere, some of which are thought to be associated with metal ions. However, long-term direct detection of the metal ions by MAVEN is the first conclusive evidence that these ions exist on another planet and that they are a permanent feature there. The team found that the metal ions behaved differently on Mars than on Earth. Earth is surrounded by a global magnetic field generated in its interior, and this magnetic field together with ionospheric winds forces the metal ions into layers. However, Mars has only local magnetic fields fossilized in certain regions of its crust, and the team only saw the layers near these areas. "Elsewhere, the metal ion distributions are totally unlike those observed at Earth," said Grebowsky. The research has other applications as well. For example it is unclear if the metal ions can affect the

formation or behaviour of high-altitude clouds. Also, detailed understanding of the meteoritic ions in the totally different Earth and Mars environments will be useful for better predicting consequences of interplanetary dust impacts in other yet-unexplored solar system atmospheres.
"Observing metal ions on another planet gives us something to compare and contrast with Earth to understand the ionosphere and atmospheric chemistry better," said Grebowsky.

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