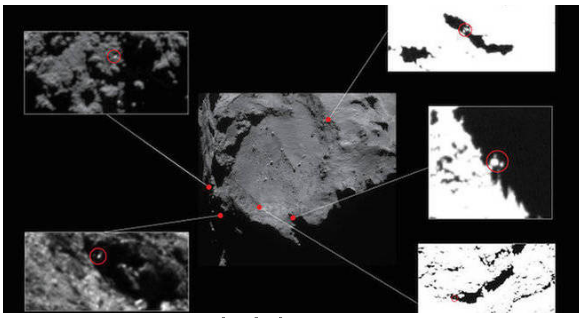
South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 508 – June 2017 Editor: Roger Burgess

- Next meeting Friday 2nd June Lecture room of the South Downs Planetarium, Chichester, at 7.30pm. Please support a raffle we are organizing this month

- Main Talk Andrew Drummond "Helium – on Earth, in the Beginning, in Stars"

- Comet 67P's oxygen could be a breath of *fresh* air. Maybe the comet's surprise molecules aren't billions of years old after all



9 May 2017 at 07:33, Richard Chirgwin

One of the big surprises in the Rosetta probe's visit to Comet 67P/Churyumov–Gerasimenko was the 2015 announcement that the rock was surrounded by a thin cloud of molecular oxygen. The discovery, announced in October 2015, set astronomers scratching their heads. Since, it was assumed at the time, the oxygen had accompanied the comet for billions of years, how had it survived? A pair of Caltech astronomers have now offered an alternative: the O_2 isn't a primordial gas billions of years old. Rather, it's produced by a reaction that pulls oxygen atoms out of the water ice the comet carries.

The pair, Yunxi Yao and Konstantinos Giapis of Caltech's Division of Chemistry and Chemical Engineering, published their work here in *Nature Communications*.

As they note in the abstract, space scientists have previously considered ways in which oxygen could be produced on the comet: photolysis and radiolysis of water, solar wind–surface interactions, and gas-phase collisions have all been observed in cometary environments. None of these fitted for 67P, which is one reason the O_2 Rosetta spotted was thought to be ancient. Yao's and Giapis' hypothesis is that the oxygen comes from the interaction between the solar wind and charged water, H_2O^+. This, they write, abstracts an oxygen atom from the surface, which forms an "excited precursor state, which dissociates to produce O2−. Subsequent photo-detachment leads to molecular O2". Science News explains the mechanism here:

"As the sun evaporates water from the comet's surface, ultraviolet light could strip an electron from the water, giving it a positive charge. Then, fast-moving particles in the solar wind could shoot the ionized water back toward the comet's surface, where it could collide with rust or sand particles. Atoms of oxygen from the water could pair with atoms of oxygen from the rust or sand, creating O_2."

The researchers have conducted experiments showing the reaction can work like this, but it will take missions with the right equipment to test whether such things happen out in space.

- Vigorous tiny vibrations help our universe swell, say particle Physicists

Quantum fluctuations may be key to explaining why we're all drifting apart

16 May 2017 at 06:10, Katyanna Quach

Not only is our universe is expanding, its expansion is accelerating. How and why this

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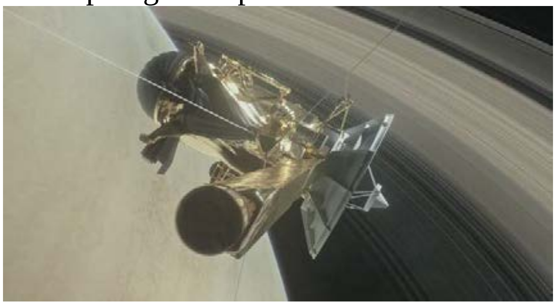
is happening remains one of the greatest unsolved mysteries in science. This month, academics suggested it is caused by every point in space oscillating between expansion and contraction – and rather than these changes canceling each other out, there is a tiny net effect that causes the universe to gradually expand overall. “Space-time is not as static as it appears, it’s constantly moving,” said Qingdi Wang, a PhD student at the University of British Columbia, Canada, who led a team looking into these tiny fluctuations. "This happens at very tiny scales, billions and billions times smaller even than an electron." Physicists reckon the universe's expansion is caused by dark energy pushing matter away. Although we don't know exactly what dark energy is, there is one top candidate: it's called vacuum energy, and it's said to be constantly altered by the fluctuation of virtual particles popping in and out of existence. It is a background energy found throughout the universe, and it's linked to Heisenberg's uncertainty principle in quantum mechanics.

If you apply the theory of quantum mechanics to this vacuum energy concept, it ends up having more energy than the total energy of all the particles in our reality: this would cause the place to explode. Clearly, we're all still here, unfortunately, so scientist must be missing something. We're told Wang and co have calculated that vacuum energy can exist without blowing apart the universe, and have done so in a way that puts forward the idea that each point in space is yo-yoing between expansion and contraction, with a small net increase in the direction of expansion. Their work was published in Physical Review D on Friday. William Unruh, co-author of their paper and a professor of physics and astronomy at the university, compared the effect to waves rippling through an ocean. The vacuum energy process is “similar to the waves we see on the ocean,” Unruh said. “They are not affected by the intense dance of the individual atoms that make up the water on which those waves ride.” The fluctuations happen at the Planck scale at 10^{-33} cm, so it's difficult to prove. But the researchers hope it may be tested indirectly in the future. “Accelerated expansion is already a well-known observation of the universe with tons of experimental results. Our theory successfully explained this phenomenon. We are going to generalize the theory to being able to explain the evolution of the universe in more details, predict some new patterns which might be observed in future in the cosmic microwave background radiation." Nobel Prize winning astrophysicists Saul Perlmutter, Brian Schmidt, and Adam Reiss, discovered that the universe was enlarging at an increasing rate in 1998. The trio found that the redshift for observed supernovae was larger than expected. It suggested the exploding stars were moving away at a faster pace than previously believed and that the universe’s expansion had to be accelerating. Now we're a little closer to understanding how and why.

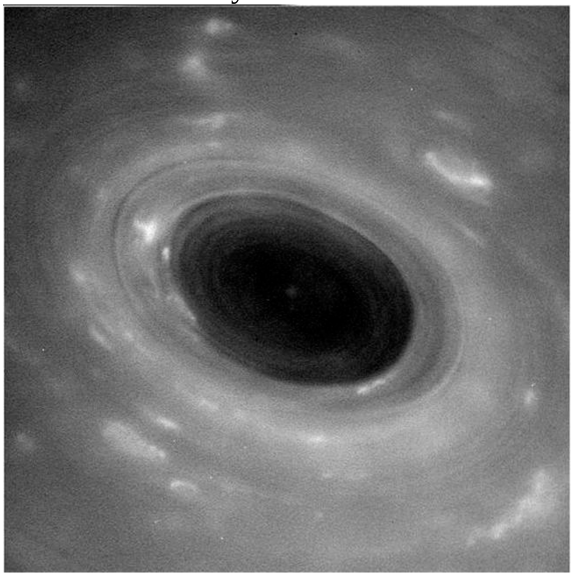
- NASA's Cassini snaps pic inside Saturn's ring – peace among the stars

Probe plunges deep into dark cosmic hole



Cassini ... Artist's impression of the plucky NASA probe
27 Apr 2017 at 19:33, Iain Thomson

Photo NASA's Cassini probe has made its first dive inside Saturn's rings, skimming about 1,900 miles (3,000KM) over the surface of the gas giant's stormy atmosphere. America's space engineers briefly lost contact with their craft during its descent on Wednesday. That's because the dish antenna used to phone home to Earth acted as a shield to deflect any loose rocky debris. Having made its flyby unscathed, the probe reoriented the high-gain antenna, and beamed back to base the first close-up images of Saturn's weather systems. "No spacecraft has ever been this close to Saturn before. We could only rely on predictions, based on our experience with Saturn's other rings, of what we thought this gap between the rings and Saturn would be like," said Cassini project manager Earl Maize of NASA's Jet Propulsion Laboratory. "I am delighted to report that Cassini shot through the gap just as we planned and has come out the other side in excellent shape." The probe passed within about 200 miles (300KM) of the innermost ring of Saturn during its trip, at a speed of 77,000MPH (124,000KPH). At that velocity, any impact with space litter would be catastrophic, but it appears the zone between the rings and the planet was free of any cosmic dreck of consequence. On its trip, Cassini photographed the turbulent upper atmosphere, capturing images of a vast circular storm and the clouds that form on the outer layer of the planet. The images were then sent over a billion miles (1.6bn km) to our home world, via the Deep Space Network, processed by scientists, and shared with the world on Thursday.



Stormy weather ... A snap taken by Cassini during its first ring plunge (Source)

The probe will make another 21 flybys inside Saturn's rings, approximately once a week, before it takes its kamikaze dive into the planet itself in September. "In the grandest tradition of exploration, NASA's Cassini spacecraft has once again blazed a trail, showing us new wonders and demonstrating where our curiosity can take us if we dare," said Jim Green, director of the Planetary Science Division at NASA Headquarters in Washington, DC.

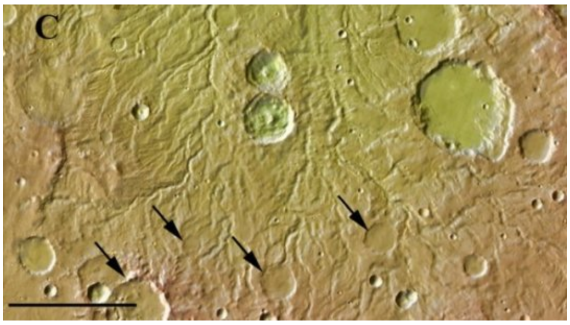
- Nukes tests caused space weather, say NASA scientists. Artificial Van Allen belts, auroras, geomagnetic storms, just another day in the Cold War

18 May 2017 at 06:28, Richard Chirgwin

Space weather is usually driven by the Sun – but a bunch of data about Cold War nuclear tests has given NASA scientists the chance to measure whether humans can affect what goes on in Earth's neighbourhood. The once-classified data records high-altitude detonations that happened between 1958 and 1962, conducted both by America and the USSR, at altitudes between 16 miles (25.7 km) and 250 miles (402 km). And what impressive effects those blasts had: some of them destroyed the electronics on satellites (by 1961, less than four years after Russia hoisted the first Sputnik, there were 115 satellites in orbit, so there was plenty of electronics up there). NASA Goddard explains some of the mechanisms involved: Upon detonation, a first blast wave expelled an expanding fireball of plasma, a hot gas of electrically charged particles. This created a geomagnetic disturbance, which distorted Earth’s magnetic field lines and induced an electric field on the surface. Some of the blasts created “artificial Van Allen belts” – charged particles held in place by magnetic fields, lasting weeks to years. Those phenomena were what damaged satellites. Goddard notes that the characteristic energies of fission-produced particles are different from those naturally caused in the Van Allen belts. The data also lets scientists delve into how nukes caused aurorae. The “Teak” test over Johnston Island in August 1958 cause an aurora seen by Western Samoa's Apia Observatory. “Observing how the tests caused aurora can provide insight into what the natural auroral mechanisms are too”, NASA notes. The Argus tests, also in 1958, created two geomagnetic storms seen from Sweden to Arizona, at the time measured travelling at 1,860 miles per second (nearly 3,000 km per second) and the second at less than a quarter that speed.

- How hard did it rain on Mars?

New study reveals how changes in Martian rainfall shaped the planet
Date: May 16, 2017
Source: Elsevier

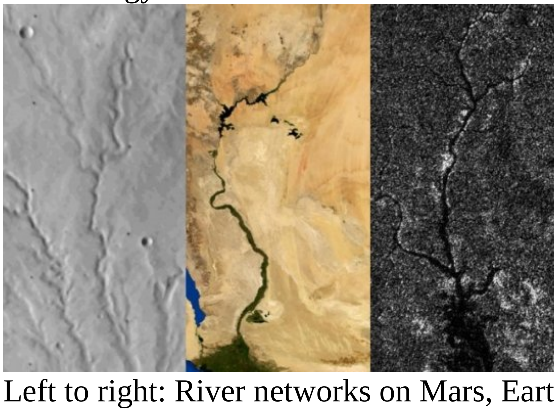


Valley networks on Mars show evidence for surface runoff driven by rainfall.
Credit: Image courtesy of Elsevier

Heavy rain on Mars reshaped the planet's impact craters and carved out river-like channels in its surface billions of years ago, according to a new study published in *Icarus*. In the paper, researchers from the Smithsonian Institution and the Johns Hopkins University Applied Physics Laboratory show that changes in the atmosphere on Mars made it rain harder and harder, which had a similar effect on the planet's surface as we see on Earth. The fourth planet from the sun, Mars has geological features like the Earth and moon, such as craters and valleys, many of which were formed through rainfall. Although there is a growing body of evidence that there was once water on Mars, it does not rain there today. But in their new study, geologists Dr. Robert Craddock and Dr. Ralph Lorenz show that there was rainfall in the past -- and that it was heavy enough to change the planet's surface. To work this out, they used methods tried and tested here on Earth, where the erosive effect of the rain on the Earth's surface has important impacts on agriculture and the economy. Valley networks on Mars show evidence for surface runoff driven by rainfall. "Many people have analysed the nature of rainfall on the Earth, but no one had thought to apply the physics to understanding the early Martian atmosphere," said Dr. Craddock of the Smithsonian Institution. To understand how rainfall on Mars has changed over time, the researchers had to consider how the Martian atmosphere has changed. When Mars first formed 4.5 billion years ago, it had a much more substantial atmosphere with a higher pressure than it does now. This pressure influences the size of the raindrops and how hard they fall. Early on in the planet's existence, water droplets would have been very small, producing something like fog rather than rain; this would not have been capable of carving out the planet we know today. As the atmospheric pressure decreased over millions of years, raindrops got bigger and rainfall became heavy enough to cut into the soil and start to alter the craters. The water could then be channelled and able to cut through the planet's surface, creating valleys. "By using basic physical principles to understand the relationship between the atmosphere, raindrop size and rainfall intensity, we have shown that Mars would have seen some pretty big raindrops that would have been able to make more drastic changes to the surface than the earlier fog-like droplets," commented Dr. Lorenz of John Hopkins University, who has also studied liquid methane rainfall on Saturn's moon Titan, the only other world in the solar system apart from Earth where rain falls onto the surface at the present day. They showed that very early on, the atmospheric pressure on Mars would have been about 4 bars (the Earth's surface today is 1 bar) and the raindrops at this pressure could not have been bigger than 3mm across, which would not have penetrated the soil. But as the atmospheric pressure fell to 1.5 bars, the droplets could grow and fall harder, cutting into the soil. In Martian conditions at that time, had the pressure been the same as we have on Earth, raindrops would have been about 7.3mm -- a millimetre bigger than on Earth. "There will always be some unknowns, of course, such as how high a storm cloud may have risen into the Martian atmosphere, but we made efforts to apply the range of published variables for rainfall on Earth," added Dr. Craddock. "It's unlikely that rainfall on early Mars would have been dramatically different than what's described in our paper. Our findings provide new, more definitive, constraints about the history of water and the climate on Mars."

- History of Titan's landscape resembles that of Mars, not Earth

Rivers on three worlds tell different tales
Date: May 18, 2017
Source: Massachusetts Institute of Technology



Left to right: River networks on Mars, Earth, and Titan. Researchers report that Titan, like Mars but unlike Earth, has not undergone any active plate tectonics in its recent past.
Credit: Benjamin Black/NASA/Visible Earth/JPL/Cassini RADAR team. Adapted from images from NASA Viking, NASA/Visible Earth, and NASA/JPL/Cassini RADAR team

The environment on Titan, Saturn's largest moon, may seem surprisingly familiar: Clouds condense and rain down on the surface, feeding rivers that flow into oceans and lakes. Outside of Earth, Titan is the only other planetary body in the solar system with actively flowing rivers, though they're fed by liquid methane instead of water. Long ago, Mars also hosted rivers, which scoured valleys across its now-arid surface. Now MIT scientists have found that despite these similarities, the origins of topography, or surface elevations, on Mars and Titan are very different from that on Earth. In a paper published in *Science*, the researchers report that Titan, like Mars but unlike Earth, has not undergone any active plate tectonics in its recent past. The upheaval of mountains by plate tectonics deflects the paths that rivers take. The team found that this tell-tale signature was missing from river networks on Mars and Titan. "While the processes that created Titan's topography are still enigmatic, this rules out some of the mechanisms we're most familiar with on Earth," says lead author Benjamin Black, formerly an MIT graduate student and now an assistant professor at the City College of New York. Instead, the authors suggest Titan's topography may grow through processes like changes in the thickness of the moon's icy crust, due to tides from Saturn. The study also sheds some light on the evolution of the landscape on Mars, which once harboured a huge ocean and rivers of water. The MIT team provides evidence that the major features of Martian topography formed very early in the history of the planet, influencing the paths of younger river systems, even as volcanic eruptions and asteroid impacts scarred the planet's surface. "It's remarkable that there are three worlds in the solar system where flowing rivers have carved into the landscape, either presently or in the past," says Taylor Perron, associate professor of geology in MIT's Department of Earth, Atmospheric and Planetary Sciences (EAPS). "There's this amazing opportunity to use the landforms the rivers have created to learn how the histories of these worlds are different." Perron and Black's co-authors include former MIT undergraduate Elizabeth Bailey and researchers from the University of California at Berkeley, the University of California at Santa Cruz, and Stanford University.

Fuzzy flows

Since 2004, NASA's Cassini spacecraft has been circling Saturn and sending back to Earth stunning images of the planet's rings and moons. Images of Titan's surface have given scientists a first view of the moon's river valleys, rolling sand dunes, and active weather patterns. Cassini has also made rough measurements of Titan's topography in some locations, though these measurements are much coarser in resolution. Perron and Black wondered whether they might refine their view of Titan's topography by applying what is known about the topography on Earth and Mars, and how their rivers have evolved. For instance, on Earth, the process of plate tectonics has continuously reshaped the landscape, pushing mountain ranges up between colliding continental plates, and opening ocean basins as landmasses slowly pull apart. Rivers, therefore, are constantly adapting to changes in topography, sidestepping around growing mountain ranges to reach the ocean. Mars, on the other hand, is thought to have been shaped mostly during the period of primordial accretion and the so-called Late Heavy Bombardment, when asteroids carved out massive impact basins and pushed up huge volcanoes. Scientists now have well-resolved maps of river networks and topography on both Earth and Mars, along with a growing understanding of their respective histories. Perron and Black used this foundation to gain insight into Titan's topographic history. "We know something about rivers, and something about topography, and we expect that rivers are interacting with topography as it evolves," Black says. "Our goal was to use those pieces to crack the code of what formed the topography in the first place."

Conforming with topography

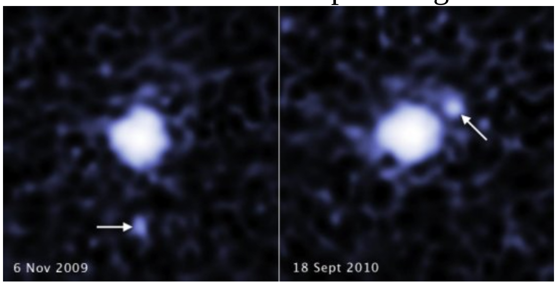
The team first compiled a map of river networks for Earth, Mars, and Titan. Such maps were previously made by others for Earth and Mars; Black generated a river map for Titan using images taken by Cassini. For all three maps, the researchers marked the direction each river appeared to flow. They then compared topographic maps for all three planetary bodies, at varying degrees of resolution. Maps of Earth are sharp in detail, as are those for Mars, showing mountain peaks and impact basins in high relief. By contrast, due to Titan's thick, hazy atmosphere, the global map of Titan's topography is extremely fuzzy, showing only the broadest features. In order to make direct comparisons between topographies, the researchers dialled down the resolution of maps for Earth and Mars, to match the resolution available for Titan. They then superimposed maps of each planetary body's river networks, onto their respective topographies, and marked every river that appeared to flow downhill. Of course, rivers only flow downhill. But the team observed that rivers might appear to flow uphill, simply because a map at low resolution may not capture finer details such as mountain ranges which would divert a river's flow. When the researchers tallied the percentage of rivers on Titan that appeared to flow downhill, the number more closely matched with Mars. They also compared what they called "topographic conformity" -- the degree of divergence between a topography's slope and the direction of a river's flow. Here too, they found that Titan resembled Mars over Earth. "One prediction we can make is that, when we eventually get more refined topographic maps of Titan, we will see topography that looks more like Mars than Earth," Perron says. "Titan might have broad-scale highs and lows, which might have formed some time ago, and the rivers have been eroding into that topography ever since, as opposed to having new mountain ranges popping up all the time, with rivers constantly fighting against them."

Filling in a picture

One last question the researchers looked to answer was how cratering due to asteroid impacts on Mars has reshaped its topography. Black used a simulation that the group previously developed, to model river erosion on Mars with different impact cratering histories. He found that the pattern of river networks on Mars today limits the extent to which cratering has remodelled the surface of Mars. This suggests that the biggest impact craters formed very early in Mars' history, and that later pummelling by asteroids mostly dented and dinged the surface. As Cassini's mission is scheduled to come to an end in September, Perron says further investigation of Titan's surface will help to guide future missions to the distant moon. "Any way of filling in the details of what Titan's surface is like, beyond what we can see directly in the images and topography Cassini has collected, will be valuable for planning a return," Perron says.

- Moon orbits third largest dwarf planet in our solar system

Date: May 18, 2017
Source: NASA/Goddard Space Flight Centre



These two images, taken a year apart, reveal a moon orbiting the dwarf planet 2007 OR10. Each image, taken by the Hubble Space Telescope's Wide Field Camera 3, shows the companion in a different orbital position around its parent body. 2007 OR10 is the third-largest known dwarf planet, behind Pluto and Eris, and the largest unnamed world in the solar system. The pair is located in the Kuiper Belt, a realm of icy debris left over from the solar system's formation.
Credit: NASA, ESA, C. Kiss (Konkoly Observatory), and J. Stansberry (STScI)

The combined power of three space observatories, including NASA's Hubble Space Telescope, has helped astronomers uncover a moon orbiting the third largest dwarf planet, catalogued as 2007 OR10. The pair resides in the frigid outskirts of our solar system called the Kuiper Belt, a realm of icy debris left over from our solar system's formation 4.6 billion years ago. With this discovery, most of the known dwarf planets in the Kuiper Belt larger than 600 miles across have companions. These bodies provide insight into how moons formed in the young solar system. "The discovery of satellites around all of the known large dwarf planets -- except for Sedna -- means that at the time these bodies formed billions of years ago, collisions must have been more frequent, and that's a constraint on the formation models," said Csaba Kiss of the Konkoly Observatory in Budapest, Hungary. He is the lead author of the science paper announcing the moon's discovery. "If there were frequent collisions, then it was quite easy to form these satellites."

The objects most likely slammed into each other more often because they inhabited a crowded region. "There must have been a fairly high density of objects, and some of them were massive bodies that were perturbing the orbits of smaller bodies," said team member John Stansberry of the Space Telescope Science Institute in Baltimore, Maryland. "This gravitational stirring may have nudged the bodies out of their orbits and increased their relative velocities, which may have resulted in collisions." But the speed of the colliding objects could not have been too fast or too slow, according to the astronomers. If the impact velocity was too fast, the smash-up would have created lots of debris that could have escaped from the system; too slow and the collision would have produced only an impact crater. Collisions in the asteroid belt, for example, are destructive because objects are traveling fast when they smash together. The asteroid belt is a region of rocky debris between the orbits of Mars and the gas giant Jupiter. Jupiter's powerful gravity speeds up the orbits of asteroids, generating violent impacts. The team uncovered the moon in archival images of 2007 OR10 taken by Hubble's Wide Field Camera 3. Observations taken of the dwarf planet by NASA's Kepler Space Telescope first tipped off the astronomers of the possibility of a moon circling it. Kepler revealed that 2007 OR10 has a slow rotation period of 45 hours. "Typical rotation periods for Kuiper Belt Objects are under 24 hours," Kiss said. "We looked in the Hubble archive because the slower rotation period could have been caused by the gravitational tug of a moon. The initial investigator missed the moon in the Hubble images because it is very faint." The astronomers spotted the moon in two separate Hubble observations spaced a year apart. The images show that the moon is gravitationally bound to 2007 OR10 because it moves with the dwarf planet, as seen against a background of stars. However, the two observations did not provide enough information for the astronomers to determine an orbit. "Ironically, because we don't know the orbit, the link between the satellite and the slow rotation rate is unclear," Stansberry said. The astronomers calculated the diameters of both objects based on observations in far-infrared light by the Herschel Space Observatory, which measured the thermal emission of the distant worlds. The dwarf planet is about 950 miles across, and the moon is estimated to be 150 miles to 250 miles in diameter. 2007 OR10, like Pluto, follows an eccentric orbit, but it is currently three times farther than Pluto is from the sun. 2007 OR10 is a member of an exclusive club of nine dwarf planets. Of those bodies, only Pluto and Eris are larger than 2007 OR10. It was discovered in 2007 by astronomers Meg Schwamb, Mike Brown, and David Rabinowitz as part of a survey to search for distant solar system bodies using the Samuel Oschin Telescope at the Palomar Observatory in California.

The team's results appeared in *The Astrophysical Journal Letters*.

- ❖ Observatories combine to crack open the Crab Nebula

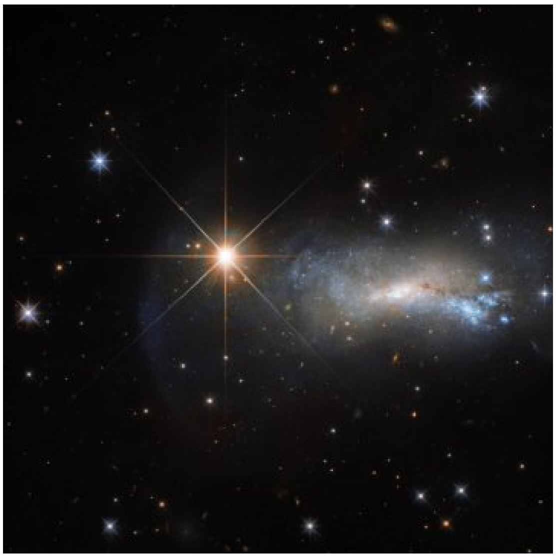
Date: May 10, 2017
Source: NASA/Goddard Space Flight Centre

An image of the Crab Nebula, a supernova remnant that was assembled by combining data from five telescopes spanning nearly the entire breadth of the electromagnetic spectrum: the Very Large Array, the Spitzer Space Telescope, the Hubble Space Telescope, the XMM-Newton Observatory, and the Chandra X-ray Observatory.
Credit: NASA, ESA, NRAO/AUI/NSF and G. Dubner (University of Buenos Aires)

Astronomers have produced a highly detailed image of the Crab Nebula, by combining data from telescopes spanning nearly the entire breadth of the electromagnetic spectrum, from radio waves seen by the Karl G. Jansky Very Large Array (VLA) to the powerful X-ray glow as seen by the orbiting Chandra X-ray Observatory. And, in between that range of wavelengths, the Hubble Space Telescope's crisp visible-light view, and the infrared perspective of the Spitzer Space Telescope. The Crab Nebula, the result of a bright supernova explosion seen by Chinese and other astronomers in the year 1054, is 6,500 light-years from Earth. At its centre is a super-dense neutron star, rotating once every 33 milliseconds, shooting out rotating lighthouse-like beams of radio waves and light -- a pulsar (the bright dot at image centre). The nebula's intricate shape is caused by a complex interplay of the pulsar, a fast-moving wind of particles coming from the pulsar, and material originally ejected by the supernova explosion and by the star itself before the explosion. This image combines data from five different telescopes: The VLA (radio) in red; Spitzer Space Telescope (infrared) in yellow; Hubble Space Telescope (visible) in green; XMM-Newton (ultraviolet) in blue; and Chandra X-ray Observatory (X-ray) in purple. The new VLA, Hubble, and Chandra observations all were made at nearly the same time in November of 2012. A team of scientists led by Gloria Dubner of the Institute of Astronomy and Physics (IAFE), the National Council of Scientific Research (CONICET), and the University of Buenos Aires in Argentina then made a thorough analysis of the newly revealed details in a quest to gain new insights into the complex physics of the object. They are reporting their findings in the Astrophysical Journal. "Comparing these new images, made at different wavelengths, is providing us with a wealth of new detail about the Crab Nebula. Though the Crab has been studied extensively for years, we still have much to learn about it," Dubner said.

- Hubble's bright shining lizard star

Date: April 28, 2017
Source: NASA/Goddard Space Flight Centre

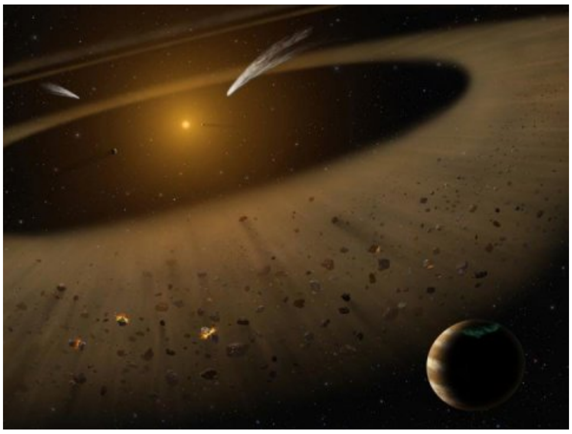


The bright object seen in this Hubble image is a single and little-studied star named TYC 3203-450-1, located in the constellation of Lacerta (The Lizard). The star is much closer than the much more distant galaxy.
Credit: NASA/ Hubble ESA

In space, being outshone is an occupational hazard. This NASA/ESA Hubble Space Telescope image captures a galaxy named NGC 7250. Despite being remarkable in its own right -- it has bright bursts of star formation and recorded supernova explosions -- it blends into the background somewhat thanks to the gloriously bright star hogging the limelight next to it. The bright object seen in this Hubble image is a single and little-studied star named TYC 3203-450-1, located in the constellation of Lacerta (The Lizard). The star is much closer than the much more distant galaxy. Only this way can a normal star outshine an entire galaxy, consisting of billions of stars. Astronomers studying distant objects call these stars "foreground stars" and they are often not very happy about them, as their bright light is contaminating the faint light from the more distant and interesting objects they actually want to study. In this case, TYC 3203-450-1 is million times closer than NGC 7250, which lies more than 45 million light-years away from us. If the star were the same distance from us as NGC 7250, it would hardly be visible in this image.

- Nearby star is a good model of our early solar system

Date: May 2, 2017
Source: Iowa State University



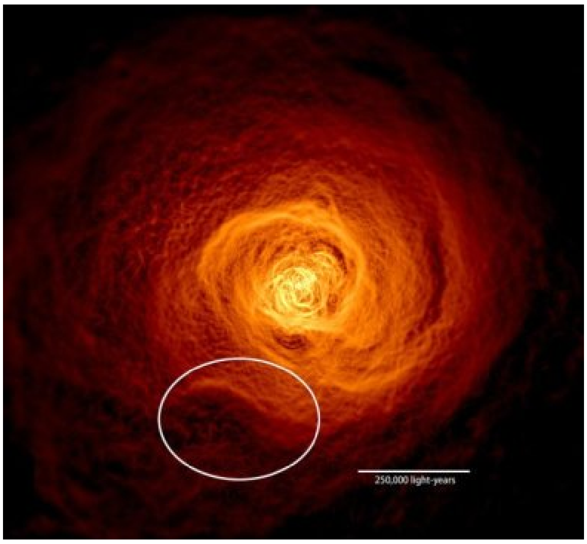
This is an artist's illustration of the epsilon Eridani system showing Epsilon Eridani b, right foreground, a Jupiter-mass planet orbiting its parent star at the outside edge of an asteroid belt. In the background can be seen another narrow asteroid or comet belt plus an outermost belt similar in size to our solar system's Kuiper Belt. The similarity of the structure of the Epsilon Eridani system to our solar system is remarkable, although Epsilon Eridani is much younger than our sun. SOFIA observations confirmed the existence of the asteroid belt adjacent to the orbit of the Jovian planet.
Credit: Illustration by NASA/SOFIA/Lynette Cook

NASA's SOFIA aircraft, a 747 loaded with a 2.5-meter telescope in the back and stripped of most creature comforts in the front, took a big U-turn over the Pacific west of Mexico. The Stratospheric Observatory for Infrared Astronomy aircraft was just beginning the second half of an overnight mission on Jan. 28, 2015. It turned north for a flight all the way to western Oregon, then back home to NASA's Armstrong Flight Research Centre in Palmdale, California. Along the way, pilots steered the plane to aim the telescope at a nearby star. Iowa State University's Massimo Marengo and other astronomers were on board to observe the mission and collect infrared data about the star. That star is called epsilon Eridani. It's about 10 light years away from the sun. It's similar to our sun, but one-fifth the age. And astronomers believe it can tell them a lot about the development of our solar system. Marengo, an Iowa State associate professor of physics and astronomy, and other astronomers have been studying the star and its planetary system since 2004. In a 2009 scientific paper, the astronomers used data from NASA's Spitzer Space Telescope to describe the star's disk of fine dust and debris left over from the formation of planets and the collisions of asteroids and comets. They reported the disk contained separate belts of asteroids, similar to the asteroid and Kuiper belts of our solar system. Subsequent studies by other astronomers questioned that finding. A new scientific paper, just published online by *The Astronomical Journal*, uses SOFIA and Spitzer data to confirm there are separate inner and outer disk structures. The astronomers report further studies will have to determine if the inner disk includes one or two debris belts. Kate Su, an associate astronomer at the University of Arizona and the university's Steward Observatory, is the paper's lead author. Marengo is one of the paper's nine co-authors. Marengo said the findings are important because they confirm epsilon Eridani is a good model of the early days of our solar system and can provide hints at how our solar system evolved. "This star hosts a planetary system currently undergoing the same cataclysmic processes that happened to the solar system in its youth, at the time in which the moon gained most of its craters, Earth acquired the water in its oceans, and the conditions favourable for life on our planet were set," Marengo wrote in a summary of the project. A major contributor to the new findings was data taken during that January 2015 flight of SOFIA. Marengo joined Su on the cold and noisy flight at 45,000 feet, above nearly all of the atmospheric water vapour that absorbs the infrared light that astronomers need to see planets and planetary debris. Determining the structure of the disk was a complex effort that took several years and detailed computer modelling. The astronomers had to separate the faint emission of the disk from the much brighter light coming from the star. "But we can now say with great confidence that there is a separation between the star's inner and outer belts," Marengo said. "There is a gap most likely created by planets. We haven't detected them yet, but I would be surprised if they are not there. Seeing them will require using the next-generation instrumentation, perhaps NASA's 6.5-meter James Webb Space Telescope scheduled for launch in October 2018." That's a lot of time and attention on one nearby star and its debris disk. But Marengo said it really is taking astronomers back in time. "The prize at the end of this road is to understand the true structure of epsilon Eridani's out-of-this-world disk, and its interactions with the cohort of planets likely inhabiting its system," Marengo wrote in a newsletter story about the project.

"SOFIA, by its unique ability of capturing infrared light in the dry stratospheric sky, is the closest we have to a time machine, revealing a glimpse of Earth's ancient past by observing the present of a nearby young sun."

- Scientists find giant wave rolling through the Perseus galaxy cluster

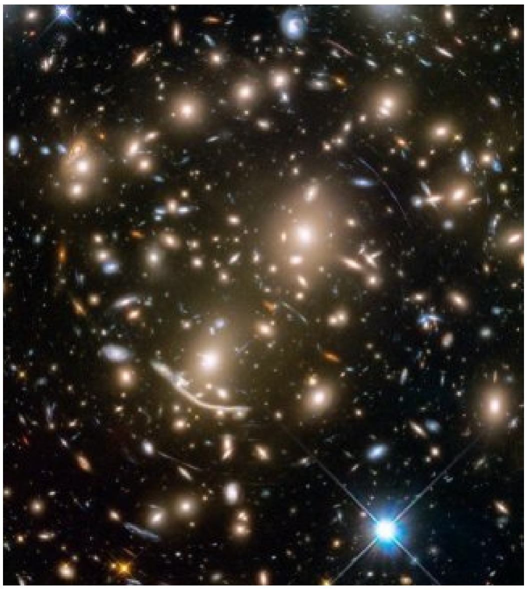
Date: May 2, 2017
Source: NASA/Goddard Space Flight Centre



This X-ray image of the hot gas in the Perseus galaxy cluster was made from 16 days of Chandra observations. Researchers then filtered the data in a way that brightened the contrast of edges in order to make subtle details more obvious. An oval highlights the location of an enormous wave found to be rolling through the gas.
Credit: NASA's Goddard Space Flight Centre/Stephen Walker et al

Combining data from NASA's Chandra X-ray Observatory with radio observations and computer simulations, an international team of scientists has discovered a vast wave of hot gas in the nearby Perseus galaxy cluster. Spanning some 200,000 light-years, the wave is about twice the size of our own Milky Way galaxy. The researchers say the wave formed billions of years ago, after a small galaxy cluster grazed Perseus and caused its vast supply of gas to slosh around an enormous volume of space. "Perseus is one of the most massive nearby clusters and the brightest one in X-rays, so Chandra data provide us with unparalleled detail," said lead scientist Stephen Walker at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "The wave we've identified is associated with the flyby of a smaller cluster, which shows that the merger activity that produced these giant structures is still ongoing." A paper describing the findings appears in the June 2017 issue of the journal *Monthly Notices of the Royal Astronomical Society* and is available online. Galaxy clusters are the largest structures bound by gravity in the universe today. Some 11 million light-years across and located about 240 million light-years away, the Perseus galaxy cluster is named for its host constellation. Like all galaxy clusters, most of its observable matter takes the form of a pervasive gas averaging tens of millions of degrees, so hot it only glows in X-rays. Chandra observations have revealed a variety of structures in this gas, from vast bubbles blown by the supermassive black hole in the cluster's central galaxy, NGC 1275, to an enigmatic concave feature known as the "bay." The bay's concave shape couldn't have formed through bubbles launched by the black hole. Radio observations using the Karl G. Jansky Very Large Array in central New Mexico show that the bay structure produces no emission, the opposite of what scientists would expect for features associated with black hole activity. In addition, standard models of sloshing gas typically produced structures that arc in the wrong direction. Walker and his colleagues turned to existing Chandra observations of the Perseus cluster to further investigate the bay. They combined a total of 10.4 days of high-resolution data with 5.8 days of wide-field observations at energies between 700 and 7,000 electron volts. For comparison, visible light has energies between about two and three electron volts. The scientists then filtered the Chandra data to highlight the edges of structures and reveal subtle details. Next, they compared the edge-enhanced Perseus image to computer simulations of merging galaxy clusters developed by John ZuHone, an astrophysicist at the Harvard-Smithsonian Centre for Astrophysics in Cambridge, Massachusetts. The simulations were run on the Pleiades supercomputer operated by the NASA Advanced Supercomputing Division at Ames Research Centre in Silicon Valley, California. Although he was not involved in this study, ZuHone collected his simulations into an online catalogue to aid astronomers studying galaxy clusters. "Galaxy cluster mergers represent the latest stage of structure formation in the cosmos," ZuHone said. "Hydrodynamic simulations of merging clusters allow us to produce features in the hot gas and tune physical parameters, such as the magnetic field. Then we can attempt to match the detailed characteristics of the structures we observe in X-rays." One simulation seemed to explain the formation of the bay. In it, gas in a large cluster similar to Perseus has settled into two components, a "cold" central region with temperatures around 54 million degrees Fahrenheit (30 million Celsius) and a surrounding zone where the gas is three times hotter. Then a small galaxy cluster containing about a thousand times the mass of the Milky Way skirts the larger cluster, missing its centre by around 650,000 light-years. The flyby creates a gravitational disturbance that churns up the gas like cream stirred into coffee, creating an expanding spiral of cold gas. After about 2.5 billion years, when the gas has risen nearly 500,000 light-years from the centre, vast waves form and roll at its periphery for hundreds of millions of years before dissipating. These waves are giant versions of Kelvin-Helmholtz waves, which show up wherever there's a velocity difference across the interface of two fluids, such as wind blowing over water. They can be found in the ocean, in cloud formations on Earth and other planets, in plasma near Earth, and even on the sun. "We think the bay feature we see in Perseus is part of a Kelvin-Helmholtz wave, perhaps the largest one yet identified, that formed in much the same way as the simulation shows," Walker said. "We have also identified similar features in two other galaxy clusters, Centaurus and Abell 1795." The researchers also found that the size of the waves corresponds to the strength of the cluster's magnetic field. If it's too weak, the waves reach much larger sizes than those observed. If too strong, they don't form at all. This study allowed astronomers to probe the average magnetic field throughout the entire volume of these clusters, a measurement that is impossible to make by any other means.

A lot of galaxies need guarding
Date: May 4, 2017
Source: Space Telescope Science Institute (STScI)

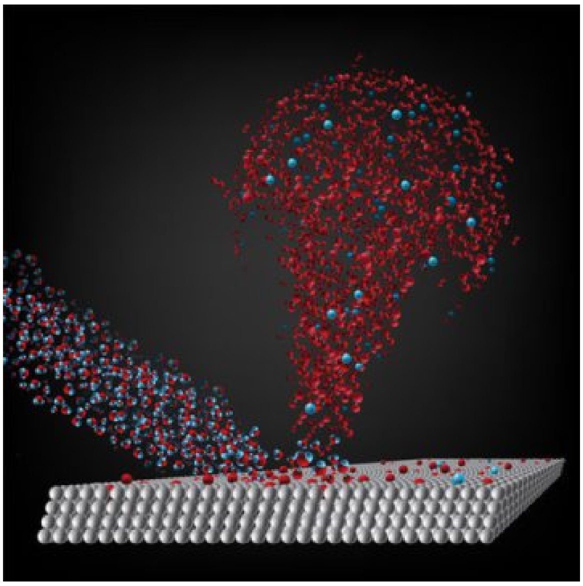


Like the quirky characters in the upcoming film Guardians of the Galaxy Vol. 2, NASA's Hubble Space Telescope has some amazing superpowers, specifically when it comes to observing galaxies across time and space. One stunning example is galaxy cluster Abell 370, which contains a vast assortment of several hundred galaxies tied together by the mutual pull of gravity. That's a lot of galaxies to be guarding, and just in this one cluster! Photographed in a combination of visible and near-infrared light with the Hubble's Advanced Camera for Surveys and Wide Field Camera 3 in Sept. 2009 to Feb. 2015, the immense cluster is a rich mix of galaxy shapes. Entangled among the galaxies are mysterious-looking arcs of blue light. These are actually distorted images of remote galaxies behind the cluster. These far-flung galaxies are too faint for Hubble to see directly. Instead, the gravity of the cluster acts as a huge lens in space, magnifying and stretching images of background galaxies like a funhouse mirror. Abell 370 is located approximately 4 billion light-years away in the constellation Cetus, the Sea Monster. It is the last of six galaxy clusters imaged in the recently concluded Frontier Fields project -- an ambitious, community-developed collaboration among NASA's Great Observatories and other telescopes that harnessed the power of massive galaxy clusters and probed the earliest stages of galaxy development.
Credit: NASA, ESA, and J. Lotz and the HFF Team (STScI)

Much like the eclectic group of space rebels in the upcoming film Guardians of the Galaxy Vol. 2, NASA's Hubble Space Telescope has some amazing superpowers, specifically when it comes to observing innumerable galaxies flung across time and space. A stunning example is a galaxy cluster called Abell 370 that contains an astounding assortment of several hundred galaxies tied together by the mutual pull of gravity. That's a lot of galaxies to be guarding, and just in this one cluster! Photographed in a combination of visible and near-infrared light, the immense cluster is a rich mix of galaxy shapes. The brightest and largest galaxies in the cluster are the yellow-white, massive, elliptical galaxies containing many hundreds of billions of stars each. Spiral galaxies -- like our Milky Way -- have younger populations of stars and are bluish. Entangled among the galaxies are mysterious-looking arcs of blue light. These are actually distorted images of remote galaxies behind the cluster. These far-flung galaxies are too faint for Hubble to see directly. Instead, the cluster acts as a huge lens in space that magnifies and stretches images of background galaxies like a funhouse mirror. The massive gravitational field of the foreground cluster produces this phenomenon. The collective gravity of all the stars and other matter trapped inside the cluster warps space and affects light traveling through the cluster, toward Earth. Nearly a hundred distant galaxies have multiple images caused by the lensing effect. The most stunning example is "the Dragon," an extended feature that is probably several duplicated images of a single background spiral galaxy stretched along an arc. Astronomers chose Abell 370 as a target for Hubble because its gravitational lensing effects can be used for probing remote galaxies that inhabited the early universe. Abell 370 is located approximately 4 billion light-years away in the constellation Cetus, the Sea Monster. It is the last of six galaxy clusters imaged in the recently concluded Frontier Fields project. This ambitious, community-developed collaboration among NASA's Great Observatories and other telescopes harnessed the power of massive galaxy clusters and probed the earliest stages of galaxy development. The program reveals galaxies that are 10 to 100 times fainter than any previously observed.

- ❖ Chemical engineer explains oxygen mystery on comets

Date: May 8, 2017
Source: California Institute of Technology

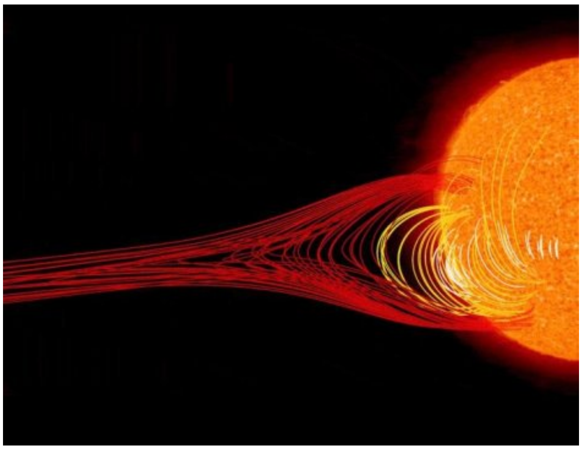


Konstantinos Giapis has shown how molecular oxygen may be produced on the surface of comets using lab experiments. He and his postdoctoral scholar Yunxi Yao fired high-speed water molecules (left) at oxidized silicon and iron surfaces, observing the production of a plume that included molecular oxygen. Oxygen atoms are red, and hydrogen, blue. Giapis says similar conditions exist on the comet 67P/Churyumov–Gerasimenko, where the European Space Agency's Rosetta mission detected molecular oxygen.
Credit: Caltech

A Caltech chemical engineer who normally develops new ways to fabricate microprocessors in computers has figured out how to explain a nagging mystery in space -- why comets expel oxygen gas, the same gas we humans breathe. The discovery that comets produce oxygen gas -- also referred to as molecular oxygen or O_2 -- was announced in 2015 by researchers studying the comet 67P/Churyumov-Gerasimenko with the European Space Agency's Rosetta spacecraft. The mission unexpectedly found abundant levels of molecular oxygen in the comet's atmosphere. Molecular oxygen in space is highly unstable, as oxygen prefers to pair up with hydrogen to make water, or carbon to make carbon dioxide. Indeed, O_2 has only been detected twice before in space in star-forming nebulas. Scientists have proposed that the molecular oxygen on comet 67P/Churyumov-Gerasimenko might have thawed from its surface after having been frozen inside the comet since the dawn of the solar system 4.6 billion years ago. But questions persist because some scientists say the oxygen should have reacted with other chemicals over all that time. A professor of chemical engineering at Caltech, Konstantinos P. Giapis, began looking at the Rosetta data because the chemical reactions happening on the comet's surface were similar to those he has been performing in the lab for the past 20 years. Giapis studies chemical reactions involving high-speed charged atoms, or ions, colliding with semiconductor surfaces as a means to create faster computer chips and larger digital memories for computers and phones. "I started to take an interest in space and was looking for places where ions would be accelerated against surfaces," says Giapis. "After looking at measurements made on Rosetta's comet, in particular regarding the energies of the water molecules hitting the comet, it all clicked. What I've been studying for years is happening right here on this comet." In a new *Nature Communications* study, Giapis and his co-author, postdoctoral scholar Yunxi Yao, demonstrate in the lab how the comet could be producing oxygen. Basically, water vapour molecules stream off the comet as the cosmic body is heated by the sun. The water molecules become ionized, or charged, by ultraviolet light from the sun, and then the sun's wind blows the ionized water molecules back toward the comet. When the water molecules hit the comet's surface, which contains oxygen bound in materials such as rust and sand, the molecules pick up another oxygen atom from these surfaces and O_2 is formed. In other words, the new research implies that the molecular oxygen found by Rosetta need not be primordial after all but may be produced in real time on the comet. "We have shown experimentally that it is possible to form molecular oxygen dynamically on the surface of materials similar to those found on the comet," says Yao. "We had no idea when we built our laboratory setups that they would end up applying to the astrophysics of comets," says Giapis. "This original chemistry mechanism is based on the seldom-considered class of Eley-Rideal reactions, which occur when fast-moving molecules, water in this case, collide with surfaces and extract atoms residing there, forming new molecules. All necessary conditions for such reactions exist on comet 67P." Other astrophysical bodies, such as planets beyond our solar system, or exoplanets, might also produce molecular oxygen with a similar "abiotic" mechanism -- without the need for life. This may influence how researchers search for signs of life on exoplanets in the future. "Oxygen is an important molecule, which is very elusive in interstellar space," says astronomer Paul Goldsmith of JPL, which is managed by Caltech for NASA. Goldsmith is the NASA project scientist for the European Space Agency's Herschel mission, which made the first confirmed detection of molecular oxygen in space in 2011. "This production mechanism studied in Professor Giapis's laboratory could be operating in a range of environments and shows the important connection between laboratory studies and astrochemistry."

- Space weather model simulates solar storms from nowhere

Date: May 8, 2017
Source: NASA/Goddard Space Flight Centre



Watch the evolution of a stealth CME in this simulation. Differential rotation creates a twisted mass of magnetic fields on the sun, which then pinches off and speeds out into space. The image of the sun is from NASA's STEREO. Coloured lines depict magnetic field lines, and the different colours indicate in which layers of the sun's atmosphere they originate. The white lines become stressed and form a coil, eventually erupting from the sun.

Credit: NASA's Goddard Space Flight Centre/ARMS/Joy Ng, producer

Our ever-changing sun continuously shoots solar material into space. The grandest such events are massive clouds that erupt from the sun, called coronal mass ejections, or CMEs. These solar storms often come first with some kind of warning -- the bright flash of a flare, a burst of heat or a flurry of solar energetic particles. But another kind of storm has puzzled scientists for its lack of typical warning signs: They seem to come from nowhere, and scientists call them stealth CMEs. Now, an international team of scientists, led by the Space Sciences Laboratory at University of California, Berkeley, and funded in part by NASA, has developed a model that simulates the evolution of these stealthy solar storms. The scientists relied upon NASA missions STEREO and SOHO for this work, fine-tuning their model until the simulations matched the space-based observations. Their work shows how a slow, quiet process can unexpectedly create a twisted mass of magnetic fields on the sun, which then pinches off and speeds out into space -- all without any advance warning. Compared to typical CMEs, which erupt from the sun as fast as 1800 miles per second, stealth CMEs move at a rambling gait -- between 250 to 435 miles per second. That's roughly the speed of the more common solar wind, the constant stream of charged particles that flows from the sun. At that speed, stealth CMEs aren't typically powerful enough to drive major space weather events, but because of their internal magnetic structure they can still cause minor to moderate disturbances to Earth's magnetic field. To uncover the origins of stealth CMEs, the scientists developed a model of the sun's magnetic fields, simulating their strength and movement in the sun's atmosphere. Central to the model was the sun's differential rotation, meaning different points on the sun rotate at different speeds. Unlike Earth, which rotates as a solid body, the sun rotates faster at the equator than it does at its poles. The model showed differential rotation causes the Sun's magnetic fields to stretch and spread at different rates. The scientists demonstrated this constant process generates enough energy to form stealth CMEs over the course of roughly two weeks. The sun's rotation increasingly stresses magnetic field lines over time, eventually warping them into a strained coil of energy. When enough tension builds, the coil expands and pinches off into a massive bubble of twisted magnetic fields -- and without warning -- the stealth CME quietly leaves the sun. Such computer models can help researchers better understand how the sun affects near-Earth space, and potentially improve our ability to predict space weather, as is done for the nation by the U.S. National Oceanic and Atmospheric Administration. A paper published in the *Journal of Geophysical Research* on Nov. 5, 2016, summarizes this work.

- ❖ Two James Webb instruments are best suited for exoplanet atmospheres

Date: May 9, 2017
Source: Penn State

The James Webb Space Telescope will launch in late 2018, and will be poised to answer fundamental questions about the start of the universe, the birth of stars and galaxies, and the origin of life.
Credit: NASA/Desiree Stove

The best way to study the atmospheres of distant worlds with the James Webb Space Telescope, scheduled to launch in late 2018, will combine two of its infrared instruments, according to a team of astronomers. "We wanted to know which combination of observing modes (of Webb) gets you the maximum information content for the minimum cost," says Natasha Batalha, graduate student in astronomy and astrophysics and astrobiology, Penn State, and lead scientist on this project. "Information content is the total amount of information we can get from a planet's atmospheric spectrum, from temperature and composition of the gas -- like water and carbon dioxide -- to atmospheric pressures." Batalha and Michael Line, assistant professor, School of Earth and Space Science, Arizona State University, developed a mathematical model to predict the quantity of information that different Webb instruments could extract about an exoplanet's atmosphere. Their model predicts that using a combination of two infrared instruments -- the Near Infrared Imager and Slit less Spectrograph (NIRISS) and the G395 mode on the Near Infrared Spectrograph (NIRSpec) -- will provide the highest information content about an exoplanet's atmosphere. NIRISS is a versatile camera and spectrograph that will observe infrared wavelengths similar to those the Hubble Telescope covers. NIRISS, according to Batalha and Line, should be combined with the G395 mode on NIRSpec, which will observe targets in longer infrared wavelengths at Webb's highest resolution. Three main characteristics affect how much information an instrument can extract -- resolution, maximum observable brightness, and wavelength range. These combined determine the total observable fraction of the information content of a planet's atmospheric spectrum. Both NIRISS and NIRSpec will observe near-infrared wavelengths, the region of the electromagnetic spectrum in which the stars that exoplanets orbit around shine brightest. NIRISS is poised to measure a strong signature of water and NIRSpec can do the same for methane and carbon dioxide, three chemical compounds that provide a substantial amount of information about an atmosphere. Batalha and Line tested each of ten likely observing methods on its own and in every possible combination with the other methods to determine which would maximize the total information content. They retrieved the information from a set of simulated planets with temperatures and compositions that cover the range of previously observed exoplanet atmospheres. By comparing the retrievable information content in each planet's atmosphere, Batalha and Line found that this one combination of NIRISS and NIRSpec modes gives the most information regardless of the exoplanet's temperature or composition. The researchers published these results in *The Astronomical Journal*. "We won't know a planet's temperature ahead of time," says Batalha. "If you're going to do a shot in the dark observation, you have the greatest chance of getting the information you want with this combination of instruments." As an exoplanet crosses between its host star and Earth's telescopes, some of the star's light passes through the exoplanet's atmosphere. The exo-atmosphere leaves its fingerprint in the star's light -- the planet's transmission spectrum -- from which astronomers can learn about the exo-atmosphere's temperature, chemical composition and structure. The researchers' information content analysis focuses on the information retrievable from the transmission spectrum of a planet. While Webb will not launch until late 2018, but astronomers are already planning the first set of observations they would like from the telescope. "If we can strategize now," says Batalha, "by the time the first cycle of formal proposals comes around we can ensure that we are picking the best modes for larger proposals and not waste valuable observing time. This way everyone starts on an even playing field with the science." While they highlight two NIRISS and NIRSpec modes as the best combination for observing most exo-atmospheres, Batalha and Line explain that the other modes will still be useful to observe different features of exo-atmospheres that the astronomers have not tested for, like clouds, haze and atmospheres hot enough to emit their own light. "In the future," Batalha says, "there will be a push to characterize the first Earth 2.0. If we don't nail this down now and master the art of characterizing exo-atmospheres, we will never accurately characterize Earth 2.0."

How to find us