South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 500 – October 2016 Editor: Roger Burgess

- Next meeting Friday 7th October Lecture room of the South Downs Planetarium, Chichester, at 7.30pm. Please support a raffle we are organizing this month
- Main Prof Philip Burrows "Cerne"

- What the hex is up with Jupiter's North Pole?

No Hexagon like on Saturn, but still the joy of six: half a dozen megabytes of Juno data took 6^2 hours to download

NASA's Juno spacecraft captured this view as it closed in on Jupiter's North Pole, about two hours before closest approach on Aug. 27, 2016. Credits: NASA/JPL-Caltech/SwRI/MSSS
3 Sep 2016 at 04:58, Simon Sharwood

Jupiter doesn't have a colossal hexagon at its North Pole, unlike it celestial cousin Saturn. So says NASA after the six megabytes of data the Juno probe collected last weekend finally made it to Earth after requiring a day-and-a-half to download. One of the downloads was the image at top, which those of you who want more detail or are reading on mobile devices can find here on NASA's site.
The image depicts Jupiter seen from about 78,000km, just a couple of hours before the Juno probe's closest encounter with the gas giant. “It's bluer in colour up there than other parts of the planet, and there are a lot of storms,” said Scott Bolton, principal investigator of Juno from the Southwest Research Institute in San Antonio. “There is no sign of the latitudinal bands or zone and belts that we are used to - this image is hardly recognizable as Jupiter. We're seeing signs that the clouds have shadows, possibly indicating that the clouds are at a higher altitude than other features.” All of Juno's eight instruments were collecting data during the pass, with the Jovian Infrared Auroral Mapper (JIRAM) able to peer at Jupiter's poles in infrared. Alberto Adriani, JIRAM co-investigator from Istituto di Astrofisica e Planetologia Spaziali, said the data received so far revealed “warm and hot spots that have never been seen before.” We also got to see Jupiter's aurorae, which are apparently “very bright and well-structured”. These are humanity's first glimpses of Jupiter's polar regions, so we're seeing stuff that was expected and hoped-for. But, frankly, we've little idea what's going on down there. NASA is still poring over the six megabytes it retrieved and Juno will make another 35 orbits of Jupiter. If all goes well, there'll be plenty more like this – and better – to come before the probe's planned obsolescence in January 2018.

- Missing Milky Way mass blown away by bingeing supermassive black hole

Mystery of the missing baryons leads to a surprising find

The Milky Way. Pic: NASA
30 Aug 2016 at 15:55, Katyanna Quach

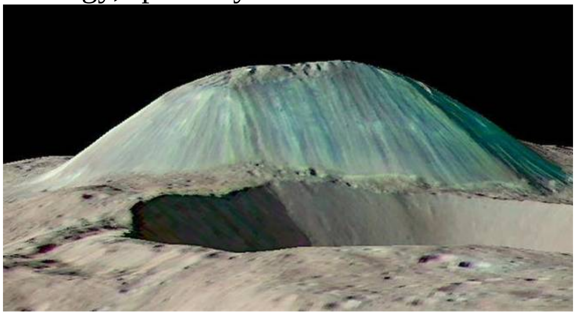
The supermassive black hole at the heart of the Milky Way galaxy was bursting with nuclear activity when humans' first ancestors roamed the Earth, according to a team of astrophysicists. On the hunt to find the

Contact us
Editor - by email at: roger@burgess.gotadsl.co.uk
Or by telephone: 01243 785325 Fax 01243 785092
Society - by email via: www.southdownsas.org.uk

galaxy's missing mass, the astrophysicists stumbled across evidence that the black hole may have been much more active in the past. The research, published in The Astrophysical Journal, shows that the total mass of the Milky Way including visible and dark matter is about one to two trillion solar masses. Five sixths of the total mass is dark matter, and one sixth is normal baryonic matter. The mass locked up in the galaxy's stars, gas and dust should be about 150 – 300 billion solar masses. But scientists have only found 65 billion solar masses of stuff and have been looking for the missing mass ever since.
"We played a cosmic game of hide-and-seek. And we asked ourselves, where could the missing mass be hiding?," said lead author Fabrizio Nicastro, a research associate at the Harvard-Smithsonian Centre for Astrophysics and astrophysicist at the Italian National Institute of Astrophysics. "We analysed archival X-ray observations from the XMM-Newton spacecraft and found that the missing mass is in the form of a million-degree gaseous fog permeating our galaxy. That fog absorbs X-rays from more distant background sources," Nicastro said. The researchers measured the absorption levels to estimate the amount of matter distributed across the galaxy. The models suggested that a bubble of gas centred around the black hole, stretching two thirds of the way to the Earth, once existed more than six million years ago.
To burst the bubble, huge amounts of energy must have come from the monstrous black hole, the researchers believe. Some of the gas was swallowed by the gaping mouth of the black hole, and other parts were blasted away by at two million miles per hour. The model fits together with the timeline of six-million-year old stars created near the galactic centre formed from the same material which flowed into the black hole. Six million years later, the shock wave created by that galaxy's active phase has finally crossed 20,000 light-years of space. Researchers believe that the mass in the hot gas was too hot to observe and could make up 130 billion solar masses – large enough to account for the missing mass.
"The different lines of evidence all tie together very well," said Martin Elvis, co-author and researcher at the Harvard-Smithsonian Centre for Astrophysics. "This active phase lasted for four to eight million years, which is reasonable for a quasar."
Nowadays, the supermassive hole is much more docile and only takes in small mouthfuls of hydrogen gas as its "food" reserves have dried up.

- Dwarf planet Ceres has a watery secret: An 11 mile wide ice volcano

Geology, space-style

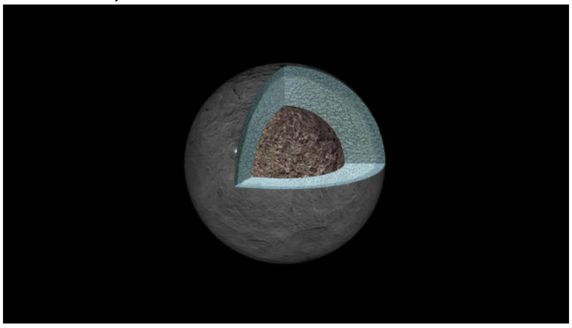


Ahuna Mons rises above a foreground impact crater, as seen by NASA's Dawn spacecraft. Photo credit: Dawn Science Team and NASA/JPL-Caltech/GSFC

2 Sep 2016 at 14:59, Katyanna Quach

Ahuna Mons, the 13,000 foot high, 11 mile wide volcano on dwarf planet Ceres is made entirely out of ice – and provides evidence that water may have once existed beneath the planet's surface. "Ahuna is truly unique, being the only mountain of its kind on Ceres," said David Williams, co-author and associate research professor in Arizona State University's School of Earth and Space Exploration. "It shows nothing to indicate a tectonic formation, so that led us to consider cryovolcanism as a method for its origin."
A team of scientists working with NASA's Dawn mission have published a paper in *Science* that shows the volcano was created by ice – unlike all the volcanoes on Earth which formed from lava. Ahuna Mons is a giant mountain with an icy volcanic dome, a so-called cryovolcano. All volcanic activity for cryovolcanoes happens at low temperatures; they spew icy magma which can consist of freezing water, ammonia or methane instead of hot bubbling lava. The lack of craters on the volcano's surface meant it was probably formed quite recently – a couple of hundred million years at most. Ottaviano Ruesch, lead author of the paper and a NASA scientist working on the Dawn mission, said: "This is the only known example of a cryovolcano that potentially formed from a salty mud mix, and which formed in the geologically recent past."
The possibility of cryovolcanism on Ceres has important implications. Not only does this confirm the dwarf planet's surface temperature of minus 40^{o}C, but it also suggests that its interior has kept warm enough for a sea of salty liquid water to exist below the planet's surface for a relatively long

time. "Ceres appears differentiated internally, with a core and a complex crust made of 30 to 40 per cent water ice mixed with silicate rock and salts," said Williams.



Artist's impression of Ceres' internal structure. Photo Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/

The space probe on NASA's Dawn mission has also spotted other evidence of cryovolcanism on Ceres. Many craters on the surface are flatter than if they were produced from meteorite impacts, and scientists believe they were formed from water flooding from below. Several cracks on the craters shows that icy "magma" has risen underneath. Dawn will continue taking data from Ceres for about a year. Scientists will monitor any changes in Ceres' surface as journeys closer to the Sun, where it will reach its closest point in April 2018. The warmth may even trigger volcanic activity, the scientists said. Ceres isn't the only object in the Solar System with signs of cryovolcanism. Spacecraft have detected evidence of icy volcanic activity on Jupiter's moon Io, Neptune's moon Triton and Saturn's moon Enceladus.

- Curiosity rover likes big buttes but it cannot lie around

Mars' layered rocks look just like the American southwest, says Yanquiphile NASA

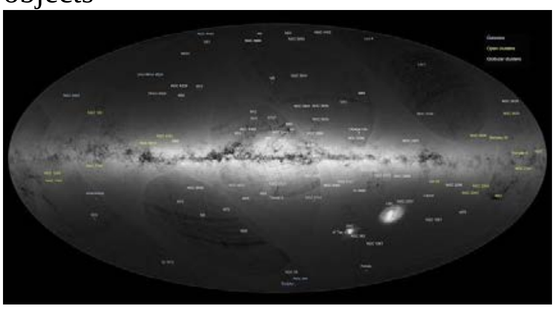
12 Sep 2016 at 02:31, Simon Sharwood

Mars looks just like the American southwest, says NASA after landing images of some big buttes on Mars. The Curiosity rover has spent the last few weeks in a region of Mars called "Murray Buttes" that apparently reveals "The layered geologic past of Mars". We're not sure what's in those layers, but NASA speculates that the image below depicts "eroded remnants of ancient sandstone that originated when winds deposited sand after lower Mount Sharp had formed." Mount Sharp is the peak inside Gale Crater, home to the laser-wielding, nuclear-powered space tank, aka Curiosity, that humanity send to Mars to punch holes in the planet and figure out if it was ever a nice place to live. Curiosity project scientist Ashwin Vasavada said peering at the buttes "has given us a better understanding of ancient sand dunes that formed and were buried, chemically changed by groundwater, exhumed and eroded to form the landscape that we see today." Vasavada also said the NASA team "has been just thrilled to go on this road trip through a bit of the American desert Southwest on Mars." Because it's not as if any other desert on Earth looks a bit like the spot below. Curiosity's been trundling past the buttes for about a month now, but drove clear of them late last week. Mission control now plans to climb Mount Sharp, because while NASA likes these big buttes the robot can't lie around in one place forever if we are to learn more about the red planet. Before Curiosity ascends the mountain, it's picked another drilling site so we can have another go at scratching the Martian surface. The image below was captured on September 8th and is a mosaic of a few snaps captured by Curiosity's Mastcam. NASA plans to release a few more similar images in coming days.

Murray Buttes on Mars. Image Credit: NASA/JPL-Caltech/MSSS

- Map to the stars: Gaia's first data dump a piece of 3D Milky Way puzzle

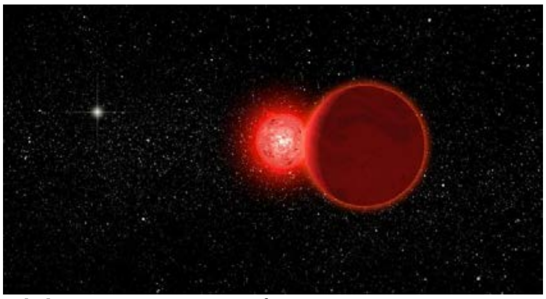
Calibrating relationships between celestial objects



Gaia's first sky map. Photo credit: ESA/Gaia/DPAC

The European Space Agency has revealed the first catalogue of stars mapped during its Gaia mission today. The Gaia space probe aims to capture over a billion stars, distant galaxies and quasars to produce the largest and most detailed three-dimensional map of the Milky Way galaxy. Nearly halfway into its mission, the probe has recorded the precise brightness, position and motion of 1,142 million stars with a tiny error of seven micro arc seconds for each star. The new star map reveals 3,194 variable stars, where 386 stars are new discoveries. Variable stars have fluctuating brightness and can be used cosmic yardsticks to measure galactic distances. By capturing the details of the variable stars in the Milky Way, Gaia will be able to measure distances more accurately. The relationship between the brightness and pulsation periods of these stars will be better calibrated which can be applied to stars beyond the Milky Way. Launched in 2013, the space probe got to work a year later. It has been circling the Sun, 1.5 million kilometres away, nearly a million miles from Earth's orbit. As Gaia scans the sky, light emitted from nearby stars enters two telescope lenses and a series of mirrors guides the light onto a tray of charge-coupled devices (CCD) in its camera. With 106 CCDs and almost a billion pixels, Gaia has a high enough resolution to measure the diameter of a human hair at a distance of 1,000 kilometres. "Gaia is at the forefront of astrometry, charting the sky at precisions that have never been achieved before," said Alvaro Giménez, ESA's Director of Science. The mission requires a lot of computational power to process huge heaps of data as Gaia beams down 40 gigabytes of data a day. It's too much data for ESA scientists to sift through, and they have created an online portal that allows anyone to play with the data and potentially discover unknown stars with interesting properties. Astronomers have been mapping the stars for hundreds of years. The first stellar catalogue was compiled by the Greek astronomer, Hipparchus of Nicaea, in second century BCE. Hipparchus made measurements using his eye and the limited instruments he had to make crude calculations. Now that technology has advanced, a lot more science can be done than just mapping the position and brightness of stars. Gaia can also provide scientists with more information about the distribution of dark matter in the Milky Way and test Einstein's theory of general relativity, by seeing how much light is deflected from the Sun and the planets.

- Cosmology is safe and the Universe is one giant version of the Barbican Whichever way you look it's all exactly the same, astronomers confirm

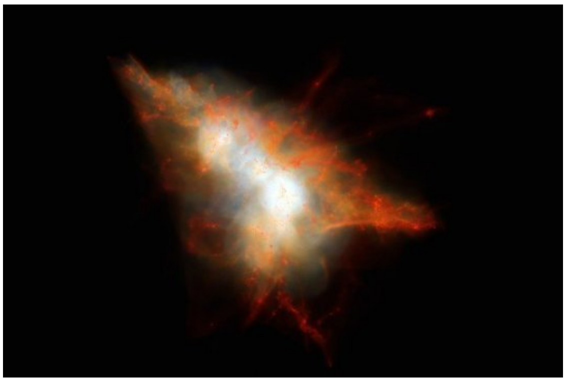


Scholzs star. Pic: University of Leicester
23 Sep 2016 at 10:29, Katyanna Quach

Scientists have confirmed that the universe is very likely the same in every direction, showing that the assumption of the universe being isotropic can be safely used in cosmology. The results, published in *Physical Review Letters* show that there is only a 1 in 121,000 chance that the universe is non-isotropic. On small scales, the universe appears clumpy. Pockets of matter can be found scattered randomly. Planets orbiting stars; stars orbiting the centre of galaxies; and galaxies orbiting each other in galaxy clusters. When viewed on large scales, however, scientists have always assumed that the universe is filled with an even distribution of matter in all directions. The universe looks the same to every viewer, regardless of their position. Cosmologists call this the cosmological principle. The vast majority of calculations in cosmology are based on this fundamental principle, so if the latest test had found it to be false, all predictions based on the principle would be wrong. To test the theory, scientists from University College London and Imperial College London analysed the Cosmic Microwave Background (CMB) left over from the energetic blast of the Big Bang. The temperature fluctuations of the background radiation have been mapped in 2009 and 2013 by the European Space Agency's Planck satellite. For the first time, scientists scrutinised not only the intensity of the radiation but the polarisation too.
The different possible variations of the universe being non-isotropic, such as if it had a preferred direction of expansion or axis of rotation was considered by considering what the corresponding hypothetical CMB map would look like. If the universe was spinning, then the CMB would have spiral patterns. If it was expanding at varying rates in different

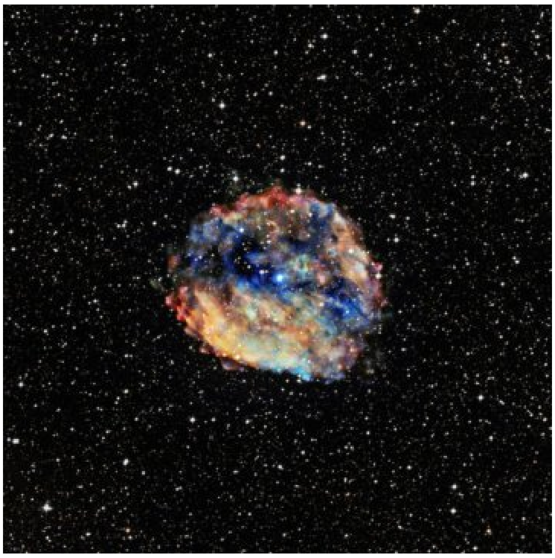
directions, then the CMB would have patches of hot and cold spots. No CMB maps found matched up to a non-isotropic universe, however, leading scientists to believe that the universe is probably directionless. Daniela Saadeh, a cosmology PhD student from University College London said: "You can never rule it out completely, but we now calculate the odds that the universe prefers one direction over another at just 1 in 121,000. We're very glad that our work vindicates what most cosmologists assume. For now, cosmology is safe."

- An international team of researchers using ALMA and other telescopes has discovered the power source illuminating a so-called Lyman-alpha Blob -- a rare, brightly glowing, and enormous concentration of gas in the distant universe



This rendering shows a snapshot from a cosmological simulation of a Lyman-alpha Blob similar to LAB-1. This simulation tracks the evolution of gas and dark matter using one of the latest models for galaxy formation running on the NASA Pleiades supercomputer. This view shows the distribution of gas within the dark matter halo, colour coded so that cold gas (mainly neutral hydrogen) appears red and hot gas appears white. Embedded at the centre of this system are two strongly star-forming galaxies, but these are surrounded by hot gas and many smaller satellite galaxies that appear as small red clumps of gas here. Lyman-alpha photons escape from the central galaxies and scatter off the cold gas associated with these satellites to give rise to an extended Lyman-alpha Blob. *Credit: J.Geach/D.Narayanan/R.Crain* Until now, astronomers wondered why these huge clouds of gas shined so brightly. The answer, in this example at least, appears to be two galaxies at the heart of the blob undergoing furious star formation and lighting up their surroundings. These large galaxies, which are destined to eventually merge into a single elliptical galaxy, are in the midst of a swarm of smaller galaxies. This appears to be an early phase in the formation of a massive cluster of galaxies. Lyman-alpha Blobs (LABs) are gigantic clouds of hydrogen gas that can span hundreds of thousands of light-years and are found at very large cosmic distances. The name reflects the characteristic wavelength of ultraviolet light that they emit, known as Lyman-alpha radiation. Since their discovery, the processes that give rise to LABs have been an astronomical puzzle. New observations with ALMA have now cleared up the mystery. One of the largest Lyman-alpha Blobs known, and the most thoroughly studied, is SSA22-Lyman-alpha blob 1, or LAB-1. Embedded in the core of a huge cluster of galaxies in the early stages of formation, it was the very first such object to be discovered -- in 2000 -- and is located so far away that its light has taken about 11.5 billion years to reach us. A team of astronomers, led by Jim Geach, from the Centre for Astrophysics Research of the University of Hertfordshire, UK, has now used ALMA's unparalleled ability to observe light from cool dust clouds in distant galaxies to peer deeply into LAB-1. This allowed them to pinpoint and resolve several sources of submillimetre emission. The astronomers then combined the ALMA images with observations from the Multi Unit Spectroscopic Explorer (MUSE) instrument mounted on ESO's Very Large Telescope (VLT), which map the Lyman-alpha light. This showed that the ALMA sources are located in the very heart of the Lyman-alpha Blob, where they are forming stars at a rate over 100 times that of the Milky Way. Deep imaging with the NASA/ESA Hubble Space Telescope and spectroscopy at the W. M. Keck Observatory also revealed that the ALMA sources are surrounded by numerous faint companion galaxies that could be bombarding the central ALMA sources with material, helping to drive their high star formation rates. The team then turned to a sophisticated simulation of galaxy formation, known as the Feedback in Realistic Environments (FIRE), to demonstrate that the giant glowing cloud of Lyman-alpha emission can be explained if ultraviolet light produced by star formation in the ALMA sources scatters off the surrounding hydrogen gas. This would give rise to the Lyman-alpha Blob we see. Jim Geach, lead author of the new study accepted for publication in the *Astrophysical Journal*, explains: "Think of a streetlight on a foggy night -- you see the diffuse glow because light is scattering off the tiny water droplets. A similar thing is happening here, except the streetlight is an intensely star-forming galaxy and the fog is a huge cloud of intergalactic gas. The galaxies are illuminating their surroundings." Understanding how galaxies form and evolve is a massive challenge. Astronomers think Lyman-alpha Blobs are important because they seem to be the places where the most massive galaxies in the universe form. In particular, the extended Lyman-alpha glow provides information on what is happening in the primordial gas clouds surrounding young galaxies, a region that is very difficult to study, but critical to understand. "Unveiling the galaxies shrouded in LAB-1 did more than just put to bed the longstanding issue of the gas cloud's glow," said Desika Narayanan of Haverford College in Pennsylvania and coauthor of the paper. "It provided a rare opportunity to see how young, growing galaxies behaved when the universe was quite young." Jim Geach concludes, "What's exciting about these blobs is that we are getting a rare glimpse of what's happening around these young, growing galaxies. For a long time, the origin of the extended Lyman-alpha light has been controversial. But with the combination of new observations and cutting-edge simulations, we think we have solved a 15-year-old mystery: Lyman-alpha Blob-1 is the site of formation of a massive elliptical galaxy that will one day be the heart of a giant cluster. We are seeing a snapshot of the assembly of that galaxy 11.5 billion years ago."

- ❖ Unusual short burst of X-rays coming from slowest-spinning neutron star. A new record-holder for the slowest spinning neutron star has been found thanks to clues first detected by NASA's Swift space observatory. Spinning neutron stars are the class of stars with the most powerful magnetic fields in the universe. Swift's X-Ray Telescope captured a short burst of unusual X-rays on June 22, 2016 coming from an object roughly 9,000 light-years from Earth.



Composite photo of the slowest-spinning neutron star discovered so far (9-2016): background stars photographed in optical wavelengths; colourful cloud is the supernova remnant RCW 103, photographed in X-ray wavelengths, with the white neutron star at its centre.

Credit: Image: X-ray: NASA/CXC/University of Amsterdam/N.Rea et al; Optical: Digital Sky Survey

The X-ray burst detected by Swift had intense, extremely rapid fluctuations measured in milliseconds. This intriguing fingerprint quickly triggered additional observations by teams of astronomers worldwide who obtained observing time with additional space observatories including NASA's Chandra X-ray Observatory and NASA's Nuclear Spectroscopic Telescope Array (NuSTAR). A paper by one team that includes astronomers at Penn State, NASA, Los Alamos National Laboratory, and universities in Italy, the United Kingdom, and Germany has been accepted for future publication in the *Monthly Notices of the Royal Astronomical Society*. "Observations with multiple space telescopes have revealed that, while other neutron stars spin multiple times a minute, this object rotates only once about every 6.5 hours -- making it by far the slowest-spinning star in its class discovered to date," said David Burrows, professor of astronomy and astrophysics at Penn State. "The data collected by Chandra show that this object has properties of a magnetar -- a type of neutron star with extremely powerful magnetic fields trillions of times as powerful as those of the Sun that can erupt with enormous bursts of energy." The object is located in the centre of a colourful cloud of material consisting of the remains of an ancient star that exploded as a massive supernova. This supernova remnant, named RCW103, and the intriguing object at its centre, can be detected with an X-ray telescope like the one on Swift but is invisible at wavelengths that human eyes can see. "This object has been of interest to Penn State astronomers for a long time," Burrows said. "Gordon Garmire, now a Penn State Evan Pugh Professor Emeritus of Astronomy and Astrophysics, discovered in 1979 that the supernova surrounding this object was producing X-rays. He also discovered a huge X-ray flare shooting out into space from this object." Now the Swift observatory, which first detected the very unusual, very short X-ray spike produced by this object, has helped to reveal at the heart of this supernova remnant an object that the data collected so far suggest could be one of the most extreme rotating magnetized neutron stars ever detected; in other words, an extreme magnetar. NASA has confirmed that new data from this trio of high-energy telescopes, and archival data from Chandra, Swift and the European Space Agency's XMM-Newton observatory, all show that the object has the properties of a magnetar, making it only the 30th known.

- ❖ Astronomers capture best view ever of disintegrating comet

Using Hubble telescope, team gathers data on size, speed and path of debris

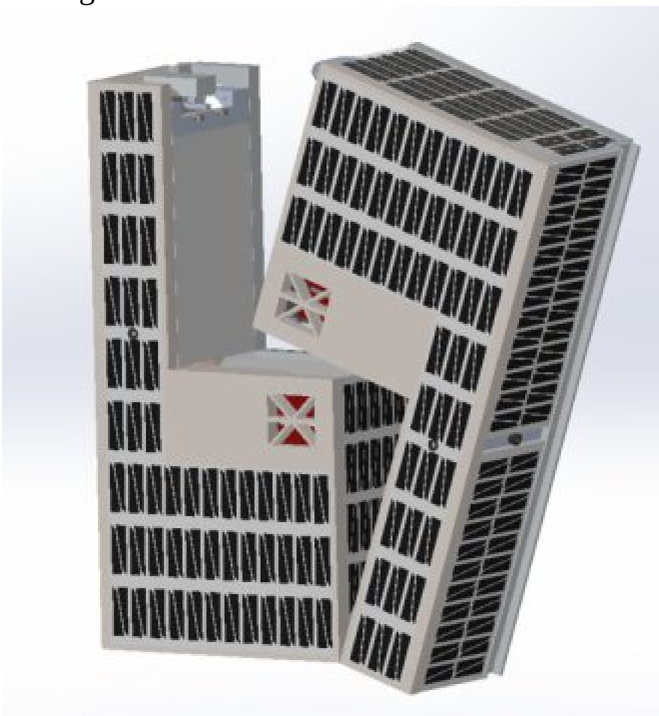
Astronomers have captured the sharpest, most detailed observations of a comet breaking apart 67 million miles from Earth, using NASA's Hubble Space Telescope. The images suggest that the roughly 4.5-billion-year-old comet, named 332P/Ikeya-Murakami, or comet 332P, may be spinning so fast that material is ejected from its surface. The resulting debris is now scattered along a 3,000-mile-long trail, larger than the width of the continental United States.

The comet breaks apart: This NASA Hubble Space Telescope image reveals the ancient comet 332P/Ikeya-Murakami disintegrating as it approaches the sun. The observations represent one of the sharpest views of an icy comet breaking apart. The comet debris consists of a cluster of building-size chunks near the centre of the image. They form a 3,000-mile-long trail, larger than the width of the continental U.S. The fragments are drifting away from the comet, dubbed comet 332P, at a leisurely pace, roughly the walking speed of an adult.
Credit: NASA, ESA and David Jewitt/UCLA

In a series of images taken over three days in January 2016, Hubble showed 25 fragments consisting of a mixture of ice and dust that are drifting away from the comet at a pace equivalent to the walking speed of an adult, said UCLA astrophysicist David Jewitt, who led the research team. The images suggest that the roughly 4.5-billion-year-old comet, named 332P/Ikeya-Murakami, or comet 332P, may be spinning so fast that material is ejected from its surface. The resulting debris is now scattered along a 3,000-mile-long trail, larger than the width of the continental United States. These observations provide insight into the volatile behaviour of comets as they approach the sun and begin to vaporize, unleashing powerful forces. "We know that comets sometimes disintegrate, but we don't know much about why or how," Jewitt said. "The trouble is that it happens quickly and without warning, so we don't have much chance to get useful data. With Hubble's fantastic resolution, not only do we see really tiny, faint bits of the comet, but we can watch them change from day to day. That has allowed us to make the best measurements ever obtained on such an object." The three-day observations show that the comet shards brighten and dim as icy patches on their surfaces rotate into and out of sunlight. Their shapes change, too, as they break apart. The icy relics comprise about four percent of the parent comet and range in size from roughly 65 feet wide to 200 feet wide. They are separating at only a few miles per hour as they orbit the sun at more than 50,000 miles per hour. The Hubble images show that the parent comet changes brightness frequently, completing a rotation every two to four hours. A visitor to the comet would see the sun rise and set in as little as an hour, Jewitt said. The comet is much smaller than astronomers thought, measuring only 1,600 feet across, about the length of five football fields. Comet 332P was discovered in November 2010, after it surged in brightness and was spotted by two Japanese amateur astronomers. Based on the Hubble data, the research team suggests that sunlight heated the surface of the comet, causing it to expel jets of dust and gas. Because the nucleus is so small, these jets act like rocket engines, spinning up the comet's rotation, Jewitt said. The faster spin rate loosened chunks of material, which are drifting off into space. The research team calculated that the comet probably shed material over a period of months, between October and December 2015. Jewitt suggested that some of the ejected pieces have themselves fallen to bits in a kind of cascading fragmentation. "We think these little guys have a short lifetime," he said. Hubble's sharp vision also spied a chunk of material close to the comet, which may be the first salvo of another outburst. The remnant from still another flare-up, which may have occurred in 2012, is also visible. The fragment may be as large as comet 332P, suggesting the comet split in two. But the remnant wasn't spotted until Dec. 31, 2015, by a telescope in Hawaii. That discovery prompted Jewitt and colleagues to request Hubble Space Telescope time to study the comet in detail. "In the past, astronomers thought that comets die when they are warmed by sunlight, causing their ices to simply vaporize away," Jewitt said. "But it's starting to look like fragmentation may be more important. In comet 332P we may be seeing a comet fragmenting itself into oblivion." The researchers estimate that comet 332P contains enough mass for 25 more outbursts. "If the comet has an episode every six years, the equivalent of one orbit around the sun, then it will be gone in 150 years," Jewitt said. "It's just the blink of an eye, astronomically speaking. The trip to the inner solar system has doomed it." The icy visitor hails from the Kuiper belt, a vast swarm of objects at the outskirts of our solar system. As the comet traveled across the system, it was deflected by the planets, like a ball bouncing around in a pinball machine, until Jupiter's gravity set its current orbit, Jewitt said.

- Exploration team shoots for the moon with water-propelled satellite

Cislunar Explorers, a team of Cornell University students guided by Mason Peck, a former senior official at NASA and associate professor of mechanical and aerospace engineering, is attempting to boldly go where no CubeSat team has gone before: around the moon. Not only is Peck's group attempting to make a first-ever moon orbit with a satellite no bigger than a cereal box, made entirely with off-the-shelf materials, it's doing so with propellant that you can obtain simply by turning on a faucet.



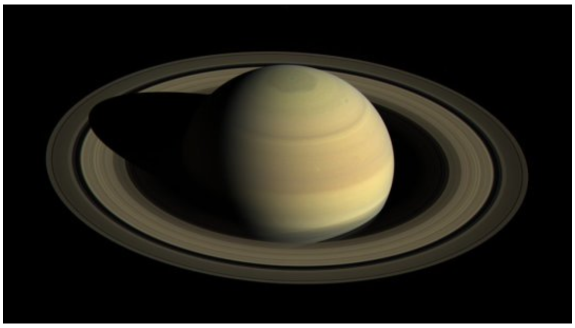
A rendering of the Cislunar Explorers CubeSat separating after deployment.
Credit: Kyle Doyle

Not only is Peck's group attempting to make a first-ever moon orbit with a satellite no bigger than a cereal box, made entirely with off-the-shelf materials, it's doing so with propellant that you can obtain simply by turning on a faucet. "This has a very important goal, and that is to demonstrate that you can use water as a propellant," said Peck, who served as NASA's chief technologist in 2012-13. The Cislunar Explorers -- cislunar means "between the Earth and the moon" -- are in phase 3 of the four-phase Ground Tournament portion of the Cube Quest Challenge, sponsored by NASA's Space Technology Mission Directorate Centennial Challenge Program. The challenge is offering a total of $5.5 million to teams that meet the challenge objectives: designing, building and delivering flight-worthy, small satellites capable of advanced operations near and beyond the moon. So far, Cornell's group has two top-three finishes, including a first-place finish in

Ground Tournament 2 in the spring. The top three finishers will earn a ride on NASA's Space Launch System (SLS) rocket in early 2018, to compete in either the Deep Space Derby or the Lunar Derby. Cornell's team will compete in the latter, which focuses on propulsion for small spacecraft and near-Earth communications. And while winning the competition is the team's main objective, it's not the only one, Peck said. "Of course, we'd like to be the first CubeSat to orbit the moon," he said, "but even if we don't, if we can successfully demonstrate that water is all you need to travel in space, we've gone a long way toward achieving some important goals." Among them: Proving the ability to use resources available in space and ending our reliance on Earth-bound technologies to explore space further. "Massless" space exploration has been a goal of Peck's for years. If all goes according to plan, the Cislunar Explorers' CubeSat will take off aboard the SLS rocket and, somewhere between Earth and the moon, be jettisoned from the payload bay. The satellite is actually two "L"-shaped halves, and they will split apart and gradually separate miles from each other, both on a course for the moon's atmosphere. The twin satellites will spin as they go, their spin creating angular momentum -- think a spinning top -- that will help keep them from tumbling off course. With energy captured from the sun, water stored in tanks at the bottom of the "L" is electrolyzed into hydrogen and oxygen gases, which will combust in short bursts, 30 minutes to an hour apart, to provide propulsion. The spinning will also separate the liquid water from the combustible gases. As the craft enters the moon's gravitational pull, it will slow down and be swung into a distant Earth orbit, eventually reconnecting with the moon days later. It's during this second rendezvous that Peck and his team plan for the satellite to be traveling slowly enough to be sucked into lunar orbit, some 6,200 miles above the surface of the moon. In addition to the water-based propulsion, the other core technology to be demonstrated by the team is optical navigation, said project manager Kyle Doyle, a doctoral student in aerospace engineering. According to Doyle, cameras on board the craft will constantly take pictures of the sun, Earth and moon and compare their apparent sizes and separation with their ephemerides -- where these bodies should be at the time the pictures were taken. "Using fairly simple geometry, the spacecraft can say, 'OK, I must be here, because these bodies look like this,'" Doyle said. "It's very much like ancient explorers using the sun and moon to navigate. What's old is new again." The competition is scheduled to end one year after the SLS launch.

❖ Cassini begins epic final year at Saturn

After more than 12 years studying Saturn, its rings and moons, NASA's Cassini spacecraft has entered the final year of its epic voyage. The conclusion of the historic scientific odyssey is planned for September 2017, but not before the spacecraft completes a daring two-part endgame.



Since NASA's Cassini spacecraft arrived at Saturn, the planet's appearance has changed greatly. This view shows Saturn's northern hemisphere in 2016, as that part of the planet nears its northern hemisphere summer solstice in May 2017.

Credit: NASA/JPL-Caltech/Space Science Institute

Beginning on November 30, Cassini's orbit will send the spacecraft just past the outer edge of the main rings. These orbits, a series of 20, are called the F-ring orbits. During these weekly orbits, Cassini will approach to within 4,850 miles (7,800 kilometres) of the centre of the narrow F ring, with its peculiar kinked and braided structure. "During the F-ring orbits we expect to see the rings, along with the small moons and other structures embedded in them, as never before," said Linda Spilker, Cassini project scientist at NASA's Jet Propulsion Laboratory, Pasadena, California. "The last time we got this close to the rings was during arrival at Saturn in 2004, and we saw only their backlit side. Now we have dozens of opportunities to examine their structure at extremely high resolution on both sides."

The Last Act: A Grand Finale

Cassini's final phase -- called the Grand Finale -- begins in earnest in April 2017. A close flyby of Saturn's giant moon Titan will reshape the spacecraft's orbit so that it passes through the gap between Saturn and the rings -- an unexplored space only about 1,500 miles (2,400 kilometres) wide. The spacecraft is expected to make 22 plunges through this gap, beginning with its first dive on April 27. During the Grand Finale, Cassini will make the closest-ever observations of Saturn, mapping the planet's magnetic and gravity fields with exquisite precision and returning ultra-close views of the atmosphere. Scientists also hope to gain new insights into Saturn's interior structure, the precise length of a Saturn day, and the total mass of the rings -- which may finally help settle the question of their age. The spacecraft will also directly analyse dust-sized particles in the main rings and sample the outer reaches of Saturn's atmosphere -- both first-time measurements for the mission. "It's like getting a whole new mission," said Spilker. "The scientific value of the F ring and Grand Finale orbits is so compelling that you could imagine a whole mission to Saturn designed around what we're about to do."

Getting Into Saturn, Literally

Since the beginning of 2016, mission engineers have been tweaking Cassini's orbital path around Saturn to position the spacecraft for the mission's final phase. They have sent the spacecraft on a series of flybys past Titan that are progressively raising the tilt of Cassini's orbit with respect to Saturn's equator and rings. This particular orientation enables the spacecraft to leap over the rings with a single (and final) Titan flyby in April, to begin the Grand Finale. "We've used Titan's gravity throughout the mission to sling Cassini around the Saturn system," said Earl Maize, Cassini project manager at JPL. "Now Titan is coming through for us once again, providing a way for Cassini to get into these completely unexplored regions so close to the planet." The Grand Finale will come to a dramatic end on Sept. 15, 2017, as Cassini dives into Saturn's atmosphere, returning data about the planet's chemical composition until its signal is lost. Friction with the atmosphere will cause the spacecraft to burn up like a meteor soon afterward. To celebrate the beginning of the final year and the adventure ahead, the Cassini team is releasing a new movie of the rotating planet, along with a colour mosaic, both taken from high above Saturn's northern hemisphere. The movie covers 44 hours, or just over four Saturn rotations.

'A Truly Thrilling Ride'

"This is the sort of view Cassini will have as the spacecraft repeatedly climbs high above Saturn's northern latitudes before plunging past the outer -- and later the inner -- edges of the rings," said Spilker. And so, although the mission's end is approaching -- with a "Cassini Final Plunge" clock already counting down in JPL mission control -- an extremely important phase of the mission is still to come. "We may be counting down, but no one should count Cassini out yet," said Curt Niebur, Cassini program scientist at NASA Headquarters in Washington. "The journey ahead is going to be a truly thrilling ride." The Cassini-Huygens mission is a cooperative project of NASA, ESA (European Space Agency) and the Italian Space Agency. NASA's Jet Propulsion Laboratory, a division of Caltech in Pasadena, manages the mission for NASA's Science Mission Directorate, Washington. JPL designed, developed and assembled the Cassini orbiter.

More information about Cassini:

http://www.nasa.gov/cassini

http://saturn.jpl.nasa.gov

- In exploring the 'now,' new theory links flow of time with Big Bang

A simple question from his wife -- Does physics really allow people to travel back in time? -- propelled a physicist on a quest to resolve a fundamental problem that had puzzled him throughout his 45-year career: Why does the arrow of time flow inexorably toward the future, constantly creating new "nows"?

That quest resulted in a book published today, *NOW: The Physics of Time* (W. W. Norton), which delves into the history of philosophers' and scientists' concepts of time, uncovers a tendency physicists have to be vague about time's passage, demolishes the popular explanation for the arrow of time and proposes a totally new theory. "Time has been a stumbling block to our understanding of the universe," said Muller, a UC Berkeley professor emeritus who for many years taught a popular introductory course, "Physics for Future Presidents," which he turned into a 2008 book of the same name. "Over my career, I've seen a lot of nonsense published about time, and I started thinking about it and realized I had a lot to say from having taught the subject over many decades, having thought about it, having been annoyed by it, having some really interesting ways of presenting it, and some whole new ideas that have never appeared in the literature." In commenting on the theory and Muller's new book, astrophysicist Neil deGrasse Tyson, host of the 2014 TV miniseries "Cosmos: A Space-time Odyssey," wrote, "Maybe it's right. Maybe it's wrong. But along the way he's given you a master class in what time is and how and why we perceive it the way we do." Muller's new idea: Time is expanding because space is expanding. "The new physics principle is that space and time are linked; when you create new space, you will create new time," Muller said.

Time kicked off by Big Bang

Ever since the Big Bang explosively set off the expansion of the universe 13.8 billion years ago, the cosmos has been growing, something physicists can measure as the Hubble expansion. They don't think of it as stars flying away from one another, however, but as stars embedded in space and space continually expanding. Muller takes his lead from Albert Einstein, who built his theory of general relativity -- the theory that explains everything from black holes to cosmic evolution -- on the idea of a four-dimensional space-time. Space is not the only thing expanding, Muller says; space-time is expanding. And we are surfing the crest of that wave, what we call "now." "Every moment, the universe gets a little bigger, and there is a little more time, and it is this leading edge of time that we refer to as *now*," he writes. "The future does not yet exist … it is being created. *Now* is at the boundary, the shock front, the new time that is coming from nothing, the leading edge of time." Because the future doesn't yet exist, we can't travel into the future, he asserts. He argues, too, that going back in time is equally improbable, since to reverse time you would have to decrease, at least locally, the amount of space in the universe. That does happen, such as when a star explodes or a black hole evaporates. But these reduce time so infinitesimally that the effect would be hidden in the quantum uncertainty of measurement -- an instance of what physicists call cosmic censorship. "The only example I could come up with is black hole evaporation, and in that case it turns out to be censored. So I couldn't come up with any way to reverse time, and my basic conclusion is that time travel is not possible," he said.

Black hole mergers create a millisecond of new time

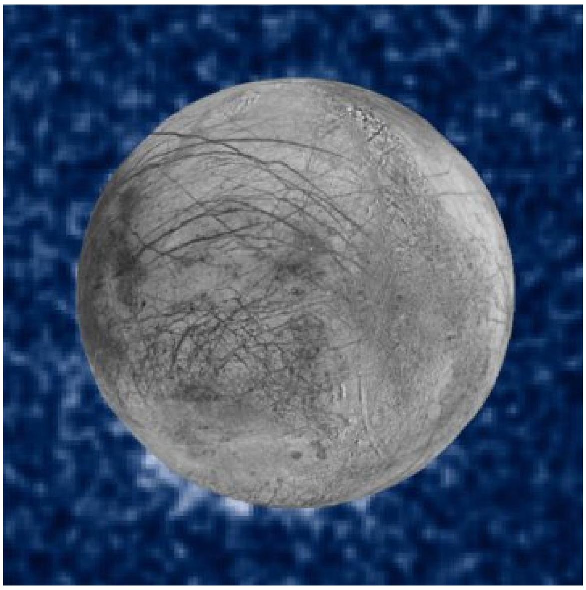
Muller's theory explaining the flow of time led to a collaboration with Caltech theoretician Shaun Maguire and a paper posted online June 25 that explains the theory in more detail -- using mathematics -- and proposes a way to test it using LIGO, an experiment that detects gravitational waves created by merging black holes. If Muller and Maguire are right, then when two black holes merge and create new space, they should also create new time, which would delay the gravitational wave signal LIGO observes from Earth. "The coalescing of two black holes creates millions of cubic miles of new space, which means a one-time creation of new time," Muller said. The black hole merger first reported by LIGO in February 2016 involved two black holes weighing about 29 and 36 times the mass of the sun, producing a final black hole weighing about 62 solar masses. The new space created in the merger would produce about 1 millisecond of new time, which is near the detection level of LIGO. A similar event at one-third the distance would allow LIGO to detect the newly created time. Whether or not the theory pans out, Muller's book makes a good case. "(Muller) forges a new path. I expect controversy!" wrote UC Berkeley Nobel laureate Saul Perlmutter, who garnered the 2011 Nobel Prize in Physics for discovering the accelerating expansion of the universe. Muller initiated the project that led to that discovery, which involved measuring the distances and velocities of supernovae. The implication of that discovery is that the progression of time is also accelerating, driven by dark energy. Over his career, Muller founded two major experimental programs that elucidated our understanding of time: a measurement of the cosmic microwave uniformity, for which he was awarded a MacArthur Prize, and the discovery of dark energy, for which he shared the 2014 Breakthrough Prize. Muller and his daughter Elizabeth co-founded Berkeley Earth, a nonprofit that reanalysed Earth's temperature record confirming global warming, and which now is a repository for historical data on global temperature and air pollution. For his newest endeavour, Muller explored previous explanations for the arrow of time and discovered that many philosophers and scientists have been flummoxed by the fact that we are always living in the 'now",:from Aristotle and Augustine to Paul Dirac -- the discoverer of antimatter, which can be thought of as normal matter moving backward in time -- and Albert Einstein. While philosophers were not afraid to express an opinion, most physicists basically ignored the issue. "No physics theories have the flow of time built into them in any way. Time was just the platform on which you did your calculations -- there was no 'now' mentioned, no flow of time," Muller said. "The idea of studying time itself did not exist prior to Einstein. Einstein gave physics the gift of time." Einstein, however, was unable to explain the flow of time into the future instead of into the past, despite the fact that the theories of physics work equally well going forward or backward in time. And although he could calculate different rates of time, depending on velocity and gravity, he had no idea why time flowed at all. The dominant idea today for the direction of time came from Arthur Eddington, who helped validate Einstein's general theory of relativity. Eddington put forward the idea that time flows in the direction of increasing disorder in the universe, or entropy. Because the Second Law of Thermodynamics asserts that entropy can never decrease, time always increases.

Entropy and time

This idea has been the go-to explanation since. Even Stephen Hawking, in his book *A Brief History of Time*, doesn't address the issue of the flow of time, other than to say that its "self-evident" that increasing time comes from increasing entropy. Muller argues, however, that it is not self-evident: it is just wrong. Life and everything we do on Earth, whether building houses or making teacups, involves decreasing the local entropy, even though the total entropy of the universe increases. "We are constantly discarding excess entropy like garbage, throwing it off to infinity in the form of heat radiation," Muller says. "The entropy of the universe does indeed go up, but the local entropy, the entropy of the Earth and life and civilization, is constantly decreasing." "During my first big experiment, the measurement of the cosmic microwave radiation, I realized there is 10 million times more entropy in that radiation than there is in all of the mass of the universe, and it's not changing with time. Yet time is progressing," he said. "The idea that the arrow of time is set by entropy does not make any predictions, it is simply a statement of a correlation. And to claim it is causation makes no sense." In his book, Muller explains the various paradoxes that arise from the way the theories of relativity and quantum mechanics treat time, including the Schrodinger's cat conundrum and spooky action at a distance that quantum entanglement allows. Neither of these theories addresses the flow of time, however. Theories about wormholes that can transport you across the universe or back in time are speculative and, in many cases, wrong. The discussion eventually leads Muller to explore deep questions about the ability of the past to predict the future and what that says about the existence of free will. Muller admits that his new theory about time may have observable effects only in the cosmic realm, such as our interpretation of the red shift -- the stretching of light waves caused by the expansion of space -- which would have to be modified to reflect the simultaneous expansion of time. The two effects may not be distinguishable throughout most of the universe's history, but the creation of time might be discernible during the rapid cosmic inflation that took place just after the Big Bang, when space and time expanded much, much faster than today. He is optimistic that in the next few years LIGO will verify or falsify his theory. "I think my theory is going to have an impact on calculations of the very early universe," Muller said. "I don't see any way that it affects our everyday lives. But it is fascinating."

- Hubble spots possible water plumes erupting on Jupiter's moon Europa

Astronomers have imaged what may be water vapour plumes erupting off the surface of Jupiter's moon Europa. This finding bolsters other Hubble observations suggesting the icy moon erupts with high altitude water vapour plumes.



This composite image shows suspected plumes of water vapour erupting at the 7 o'clock position off the limb of Jupiter's moon Europa. The plumes, photographed by NASA's Hubble's Space Telescope Imaging Spectrograph, were seen in silhouette as the moon passed in front of Jupiter. Hubble's ultraviolet sensitivity allowed for the features -- rising over 100 miles (160 kilometres) above Europa's icy surface -- to be discerned. The water is believed to come from a subsurface ocean on Europa. The Hubble data were taken on January 26, 2014. The image of Europa, superimposed on the Hubble data, is assembled from data from the Galileo and Voyager missions.

Credit: NASA/ESA/W. Sparks (STScI)/USGS Astrogeology Science Centre

The observation increases the possibility that missions to Europa may be able to sample Europa's ocean without having to drill through miles of ice. "Europa's ocean is considered to be one of the most promising places that could potentially harbour life in the solar system," said Geoff Yoder, acting associate administrator for NASA's Science Mission Directorate in Washington. "These plumes, if they do indeed exist, may provide another way to sample Europa's subsurface." The plumes are estimated to rise about 125 miles (200 kilometres) before, presumably, raining material back down onto Europa's surface. Europa has a huge global ocean containing twice as much water as Earth's oceans, but it is protected by a layer of extremely cold and hard ice of unknown thickness. The plumes provide a tantalizing opportunity to gather samples originating from under the surface without having to land or drill through the ice. The team, led by William Sparks of the Space Telescope Science Institute (STScI) in Baltimore observed these finger-like projections while viewing Europa's limb as the moon passed in front of Jupiter. The original goal of the team's observing proposal was to determine whether Europa has a thin, extended atmosphere, or exosphere. Using the same observing method that detects atmospheres around planets orbiting other stars, the team realized if there was water vapour venting from Europa's surface, this observation would be an excellent way to see it. "The atmosphere of an extrasolar planet blocks some of the starlight that is behind it," Sparks explained. "If there is a thin atmosphere around Europa, it has the potential to block some of the light of Jupiter, and we could see it as a silhouette. And so we were looking for absorption features around the limb of Europa as it transited the smooth face of Jupiter." In 10 separate occurrences spanning 15 months, the team observed Europa passing in front of Jupiter. They saw what could be plumes erupting on three of these occasions. This work provides supporting evidence for water plumes on Europa. In 2012, a team led by Lorenz Roth of the Southwest Research Institute in San Antonio, detected evidence of water vapour erupting from the frigid south polar region of Europa and reaching more than 100 miles (160 kilometres) into space. Although both teams used Hubble's Space Telescope Imaging Spectrograph instrument, each used a totally independent method to arrive at the same conclusion. "When we calculate in a completely different way the amount of material that would be needed to create these absorption features, it's pretty similar to what Roth and his team found," Sparks said. "The estimates for the mass are similar, the estimates for the height of the plumes are similar. The latitude of two of the plume candidates we see corresponds to their earlier work." But as of yet, the two teams have not simultaneously detected the plumes using their independent techniques. Observations thus far have suggested the plumes could be highly variable, meaning that they may sporadically erupt for some time and then die down. For example, observations by Roth's team within a week of one of the detections by Sparks' team failed to detect any plumes. If confirmed, Europa would be the second moon in the solar system known to have water vapour plumes. In 2005, NASA's Cassini orbiter detected jets of water vapour and dust spewing off the surface of Saturn's moon Enceladus. Scientists may use the infrared vision of NASA's James Webb Space Telescope, which is scheduled to launch in 2018, to confirm venting or plume activity on Europa. NASA also is formulating a mission to Europa with a payload that could confirm the presence of plumes and study them from close range during multiple flybys. "Hubble's unique capabilities enabled it to capture these plumes, once again demonstrating Hubble's ability to make observations it was never designed to make," said Paul Hertz, director of the Astrophysics Division at NASA Headquarters in Washington. "This observation opens up a world of possibilities, and we look forward to future missions -- such as the James Webb Space Telescope -- to follow up on this exciting discovery." The work by Sparks and his colleagues will be published in the Sept. 29 issue of *The Astrophysical Journal*. The Hubble Space Telescope is a project of international cooperation between NASA and ESA (the European Space Agency.) NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope. STScI, which is operated for NASA by the Association of Universities for Research in Astronomy in Washington, conducts Hubble science operations. For images and more information about Europa and Hubble, visit:

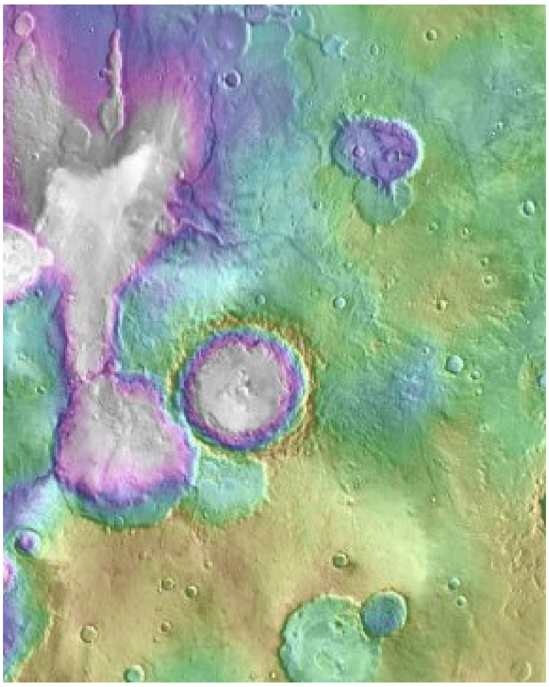
http://www.nasa.gov/hubble

And

http://hubblesite.org/news/2016/33

- Some ancient Mars lakes formed long after others

Lakes and snowmelt-fed streams on Mars formed much later than previously thought possible, according to new findings. The recently discovered lakes and streams appeared roughly a billion years after an earlier era of wet conditions on ancient Mars. These results suggest the surface conditions at this later time may also have been suitable for microbial life on the Red Planet.



Valleys much younger than well-known ancient valley networks on Mars are evident near the informally named "Heart Lake" on Mars.
Credit: NASA/JPL-Caltech/ASU

The recently discovered lakes and streams appeared roughly a billion years after a well-documented, earlier era of wet conditions on ancient Mars. These results provide insight into the climate history of the Red Planet and suggest the surface conditions at this later time may also have been suitable for microbial life. "We discovered valleys that carried water into lake basins," said Sharon Wilson of the Smithsonian Institution, Washington, and the University of Virginia, Charlottesville. "Several lake basins filled and overflowed, indicating there was a considerable amount of water on the landscape during this time." Wilson and colleagues found evidence of these features in Mars' northern Arabia Terra region by analysing images from the Context Camera and High Resolution Imaging Science Experiment camera on the Mars Reconnaissance Orbiter and additional data from NASA's Mars Global Surveyor and the European Space Agency's Mars Express. "One of the lakes in this region was comparable in volume to Lake Tahoe," Wilson said, referring to a California-Nevada lake that holds about 45 cubic miles (188 cubic kilometres) of water. "This particular Martian lake was fed by an inlet valley on its southern edge and overflowed along its northern margin, carrying water downstream into a very large, water-filled basin we nicknamed 'Heart Lake.'" The chain of lakes and valleys that are part of the Heart Lake valley system extends about 90 miles (about 150 kilometres). Researchers calculate Heart Lake held about 670 cubic miles of water (2,790 cubic kilometres), more than in Lake Ontario of North America's Great Lakes. Wilson and co-authors of the report in the *Journal of Geophysical Research, Planets*, map the extent of stream-flow in "fresh shallow valleys" and their associated former lakes. They suggest that the runoff that formed the valleys may have been seasonal. To bracket the time period when the fresh shallow valleys in Arabia Terra formed, scientists started with age estimates for 22 impact craters in the area. They assessed whether or not the valleys carved into the blankets of surrounding debris ejected from the craters, as an indicator of whether the valleys are older or younger than the craters. They concluded that this fairly wet period on Mars likely occurred between two and three billion years ago, long after it is generally thought that most of Mars' original atmosphere had been lost and most of the remaining water on the planet had frozen. The characteristics of the valleys support the interpretation that the climate was cold: "The rate at which water flowed through these valleys is consistent with runoff from melting snow," Wilson said, "These weren't rushing rivers. They have simple drainage patterns and did not form deep or complex systems like the ancient valley networks from early Mars." They note that similar valleys occur elsewhere on Mars between about 35 and 42 degrees latitude, both north and south of the equator. The similar appearance and widespread nature of these fresh, shallow valleys on Mars suggest they formed on a global scale rather than a local or regional scale. "A key goal for Mars exploration is to understand when and where liquid water was present in sufficient volume to alter the Martian surface and perhaps provide habitable environments," said Mars Reconnaissance Orbiter Project Scientist Rich Zurek of NASA's Jet Propulsion Laboratory, Pasadena, California. "This paper presents evidence for episodes of water modifying the surface on early Mars for possibly several hundred million years later than previously thought, with some implication that the water was emplaced by snow, not rain." The findings will likely prompt more studies to understand how conditions warmed enough on the frozen planet to allow an interval with flowing water. One possibility could be an extreme change in the planet's tilt, with more direct illumination of polar ice. Wilson's co-authors are Alan Howard of the University of Virginia; Jeffrey Moore of the NASA Ames Research Centre, Moffett Field, California; and John Grant of the Smithsonian. NASA's Mars orbiter missions are advancing understanding about the Red Planet that serves in preparation for human-crew missions to Mars beginning in the 2030s. For more about NASA's Journey to Mars, visit:

http://www.nasa.gov/content/nasas-journey-to-mars

- ❖ Biggest radio telescope on Earth ready to receive alien signals

What a dish
Xinhua News Agency/REX/Shutterstock
By Emily Benson

Time to power up the largest radio telescope in the world. China’s Five-hundred-metre Aperture Spherical Telescope, or FAST, began spying on outer space on 25 September. FAST will measure radio waves in space, allowing us to study the rotation of galaxies, monitor the behaviour of pulsars and keep an eye out for signals sent by aliens. It is situated in a remote, mountainous area of Guizhou Province in south-western China, which will help protect it from radio-wave interference, like signals sent by cell phones and Wi-Fi. Construction began in 2011, spurring the relocation of a small village. The telescope will go through a testing and debugging phase before full operation begins, according to the Chinese Academy of Sciences. The telescope, named for the size of its dish – 500 metres across – is about 200 metres wider than its closest rival, the Arecibo Observatory in Puerto Rico, built in the early 1960s. That means that it will be able to see dimmer objects than the Arecibo telescope can detect, says Michael Nolan at the Lunar and Planetary Laboratory at the University of Arizona in Tucson. “Being bigger means it collects more light,” Nolan says. “So if you’re looking at a faint signal, it’ll be brighter in the bigger telescope.”

Squishable dish

The curved bowl of a radio telescope directs the light it catches into a detection device, usually suspended above the dish. A parabola-shaped disc focuses light into a single point, but can cause distortion as the telescope targets different parts of the sky. Smaller telescopes can move their dishes to observe different regions of space, but FAST is too big to steer. To avoid that problem, FAST’s mirrored panels and its receiver are designed to move in conjunction, allowing scientists to create a parabola-shaped bowl pointed at whatever part of the sky is under observation. “They’re going to have that be a flexible mirror that they can deform to point at the right place,” Nolan says. “Instead of turning it, they’re just going to squash it to be the right shape.” The construction of the telescope shows that observatories like Arecibo aren’t a relic of the past, says Robert Minchin at the Arecibo Observatory. “That they put the money into building FAST is a vote of confidence that telescopes of the Arecibo pattern, these large single-dish telescopes, do have a future,” he says. “As far as we’re concerned, imitation is the greatest form of flattery,” says Christopher Salter, also at the Arecibo Observatory. “It’s very nice to have another sibling very much like ourselves.”

How to find us