South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 506 – April 2017 Editor: Roger Burgess

- Next meeting Friday 7th April Lecture room of the South Downs Planetarium, Chichester, at 7.30pm. Please support a raffle we are organizing this month

- Main Talk Ian Sharp "Modern Planetary Imaging Techniques"

- Astronomers stunned by biggest brown dwarf ever seen – just a hop and a skip away 750 light years

Artist's impression of brown dwarf (Credit: Chuck Carter / Gregg Hallinan / Caltech)
25 Mar 2017 at 08:29, Katyanna Quach

Pic Astronomers claim to have identified the largest and purest brown dwarf ever seen, measuring in at a record-breaking 90 times the mass of Jupiter. And it's hovering fairly nearby in the Milky Way. Brown dwarves are failed stars that did not grow large enough to start the hydrogen fusing process like main-sequence stars such as the Sun. They aren't completely dull; some brown dwarves can burn deuterium and lithium, and even emit bright flares sometimes. Sitting in the constellation of Pisces 750 light years away, the star known as SDSS J010448.46+153501.8 is a ball of gas made up of more than 99.9 per cent hydrogen, and is 250 times more pure than the Sun. It is in the "halo brown dwarf transition zone" – where the stars have a surface temperature of approximately 1,200°K (926°C / 1,700°F). Using measurements taken from the European Southern Observatory's Very Large Telescope, a paper published in the *Monthly Notices of the Royal Astronomical Society* estimates the star is roughly 11-13 Gigayears (10^9) old. With a mass 90 times larger than Jupiter, it is the biggest brown dwarf ever found. It was previously classified as an M-type star, but the paper has boosted it to an L-type star, after discovering it had lower metallicity levels and a dimmer surface than expected. Dr ZengHua Zhang, lead author of the paper and researcher at the Institute of Astrophysics in the Canary Islands, said: "We really didn't expect to see brown dwarfs that are this pure. Having found one though often suggests a much larger hitherto undiscovered population – I'd be very surprised if there aren't many more similar objects out there waiting to be found."

- Astronomers clock thriving stellar nursery nestled in violent supermassive black hole. First time star formation seen in such extreme conditions

Artist's impression of an active galaxy (Image credit: ESO/M Kornmesser)
27 Mar 2017 at 20:20, Katyanna Quach

Astronomers have for the first time found stars forming within the violent outflows of material ejected from a supermassive black hole at the centre of a galaxy.
Stars are born under extreme conditions. Intense gravitational forces cause gas to collapse into a heated ball, until the pressure can be balanced with the outward radiation force generated as the star begins to shine. A

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paper published in Nature today shows that these conditions can exist around a black hole and can support star formation. Active galaxies shoot powerful jets of energy from their centres, where a hungry black hole is gobbling surrounding material. Angular momentum causes the falling gas and dust to be whisked into a frenzy around the void, causing it to pool into a disc – also known as an accretion disc. The gravitational tug and frictional forces heat the accretion disc and powerful beams of energy are ejected.
"Astronomers have thought for a while that conditions within these outflows could be right for star formation, but no one has seen it actually happening, as it's a very difficult observation," said Roberto Maiolino, leader of the study and professor of experimental astrophysics at University of Cambridge, UK. "Our results are exciting because they show unambiguously that stars are being created inside these outflows." Using spectroscopy instruments aboard the European Southern Observatory's Very Large Telescope, the researchers were able to pinpoint the radiation released from a stellar nursery growing at the core of the IRAS F23128 galaxy. IRAS F23128-5919 is actually made up of two galaxies colliding together. Energy emitted from young stars lights up nearby gas clouds, making them glow in a particular way. The light can be studied using a spectroscope to identify the source. The fast motion and velocity of these stars provide further proof that they are locked within the powerful, hot winds emitted from the black hole. "The stars that form in the wind close to the galaxy centre might slow down and even start heading back inwards, but the stars that form further out in the flow experience less deceleration and can even fly off out of the galaxy altogether," said Helen Russell, co-author of the paper and astronomer at the University of Cambridge. First impressions show that the stars detected within the powerful, hot winds ejected around the black hole are brighter and hotter than stars formed in less extreme environments. They are estimated to be less than a few tens of millions of years old. "If star formation is really occurring in most galactic outflows, as some theories predict, then this would provide a completely new scenario for our understanding of galaxy evolution," said Maiolino. The discovery could help astronomers understand how galaxies are shaped, how heavy elements are dispersed, and why the cosmic background radiation is irregular in some areas.

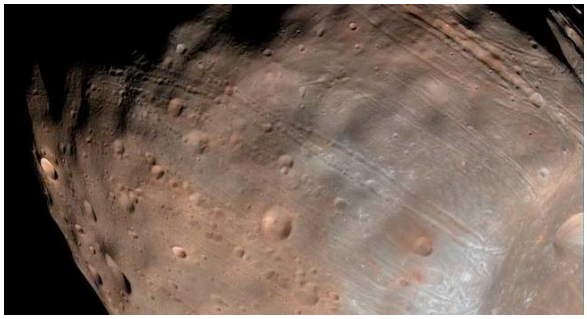
- Dark matter drought hits older galaxies: Astronomers are, rightly, baffled. Study could explain how star systems go from amorphous blobs to beautiful spirals

M74: A spiral galaxy slightly smaller than the Milky Way (Photo credit: NASA, ESA, and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration)
15 Mar 2017 at 20:47, Katyanna Quach

The mystery surrounding dark matter deepens: scientists have discovered that the puzzling substance was less dominant in our universe's early galaxies. Although no one knows what dark matter is made out of, physicists generally agree that it exists, and that it can be observed albeit indirectly.
In the 1970s, astronomers spotted stars traveling faster than expected while orbiting at the edge of spiral galaxies. This stumped eggheads everywhere. The burning balls of gas were not following the mathematical models as expected. This gap between theory and observation could be closed if astronomers took into account an invisible mass that pervaded the outer regions of elliptical galaxies. That invisible mass is what we today call dark matter. No one can say for certain what dark matter is – although it's handy in that it helps scientists explain why things don't move the way they should through space.
Curiously, the latest observations from the European Southern Observatory's Very Large Telescope show there is less dark matter in galaxies that formed ten billion years ago – during the peak of galaxy formation – compared to newer galaxies. Again, this has stumped scientists. "We were expecting that massive early rotating disks would be dominated by dark matter on the galactic scales, in analogy with typical spiral galaxies today like our own Milky Way. This is what causes the rotation velocities to remain constant in the outer parts of today's spirals,"

Natascha Förster Schreiber, a researcher at the Max Planck Institute for Extra-terrestrial Physics, Germany, told *The Register* this week. On Wednesday, a paper co-written by Förster Schreiber and many others was published in *Nature*, and it details a study of the large telescope's dark matter data. (There's a copy here on Arxiv.) "Instead, we saw the velocities drop in the distant disks we studied, which indicates that dark matter is less influential on galactic disk scales at early times." If the findings are correct, it could provide a clue to how galaxies evolve from shapeless blobs to the complex spiral structures we see today, Mark Swinbank, who was not involved with the study and is lecturer at Durham University, UK, told *The Register*. "Since the dark matter mass fraction is large in local galaxies, it has the effect of stabilizing the disk through gravity," he said. "And this is probably one of the main factors that allow the galaxies to transform from very irregular, unstable and clumpy galaxies with high star formation rates that we see in the distant Universe to the (relatively quiescent) grand spirals and massive spheroids that we see in the local Universe."

- Mars orbiter floors it to avoid hitting Moon. MAVEN was on track to come within seven seconds of Phobos



Phobos. Close up. But not as close as MAVEN was in danger of coming

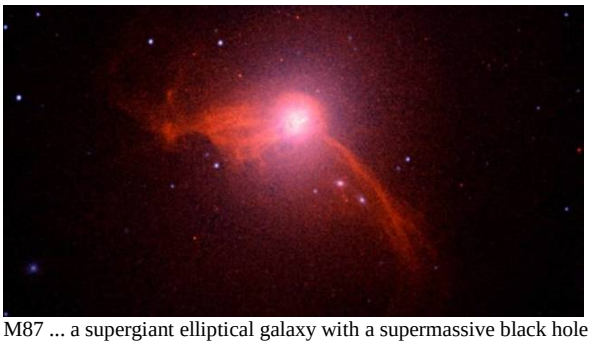
6 Mar 2017 at 07:04, Simon Sharwood

The Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft last week made a hasty burn to avoid a likely collision with Martian moon Phobos. NASA says that without the burn, the probe and the moon stood “a good chance of hitting each other on Monday, March 6th”. NASA's Jet Propulsion Laboratory (JPL) figured that out about a week ago, noting that the two objects would come within about seven seconds of a collision. NASA says Phobos is “modelled for simplicity as a 30-kilometre sphere, a bit larger than the actual moon in order to be conservative”. But as we lack precise measurements of the Moon, the space agency assumed a close encounter was deemed to “represent a high probability of colliding if no action were taken.”

So action was taken.

A quick squirt of MAVEN's engines gave it an extra 0.4 metres per second of velocity. The probe and Phobos therefore occupied the same volume of space after a far-more-comfortable interval of two-and-a-half minutes. MAVEN is said to have executed its burn “flawlessly” and, having avoided Phobos and a near-certain mission-ending bonk, continues its atmosphere-sniffing work. This isn't MAVEN's first near-miss: in January 2015 it came within two kilometres of the Mars Reconnaissance Orbiter, leading NASA to call for a Martian traffic cop to handle the increasing orbital traffic around the red planet. MAVEN's part of the problem, as it became the fifth active human-made satellite at Mars. ExoMars arrived last year, bringing the total to six. Humanity has sent another eight craft to orbit Mars. It's assumed they're still in orbit, but most have broken and can't be contacted.

- Blast from the past: Mass birth of early supermassive black holes explained at last. UV photons prevent gravitational collapse



M87 ... a supergiant elliptical galaxy with a supermassive black hole ~5bn solar masses at its core

(Photo credit: NASA/CXC/SAO/W Forman et al)

14 Mar 2017 at 08:03, Katyanna Quach

The earliest supermassive black holes have always puzzled astronomers. These ancient voids – about a billion times the mass of the Sun – were discovered more than a decade ago and formed only 800,000 years after the Big Bang. It should take millions of years for black holes to accumulate that much mass, so finding these giants that formed at such an early stage in the universe was a surprise.

A paper published in *Nature Astronomy* shows scientists may be one step closer to figuring out how these objects grew so quickly. “The collapse of the galaxy and the

formation of a million-solar-mass black hole takes 100,000 years – a blip in cosmic time," said Zoltan Haiman, co-author of the study and astronomy professor at Columbia University. "A few hundred million years later, it has grown into a billion-solar-mass supermassive black hole. This is much faster than we expected." Researchers from Dublin City University, Ireland, Columbia University, US, Georgia Institute of Technology, US, and the University of Helsinki, Finland, believe the problem boils down to radiation. Mathematical simulations show black holes can grow to monstrous sizes if a neighbouring galaxy flushes the host galaxy with an intense burst of Lyman-Werner radiation. Ultraviolet photons whizzing around the host galaxy with an energy of 12.6 eV prevent the surrounding gas from gravitational collapse. The clumping of gas to form denser pockets of material in a galaxy is the first stage of star formation. Since this process is halted by radiation, the birth of stars is impossible. It's an important requirement to create the right conditions for supermassive black holes to thrive. If mass from the surrounding gas is locked away in stars far away from the black hole, then it can't be gobbled up and there is less chance of the black hole reaching billions of solar masses.

A previous study in 2008 led by Haiman and his colleagues found that a surge of radiation could split molecular hydrogen (H_2) into atomic hydrogen (H) and cause a black hole and its host galaxy to collapse without generating new stars. But that's not the only factor needed to explain the presence of these behemoths. Another previous paper led by Eli Visbal, co-author of the current study and researcher at Columbia University, calculated that the neighbour galaxy would have to be at least 100 million times more massive than the Sun to emit enough radiation to prevent star formation in the host galaxy. Giant galaxies of that size are relatively rare. But in the early epochs of the universe, they must have existed, the researchers argue. The theory of how supermassive black holes grew so early may not be as far-fetched, as the latest simulations show the radiation-emitting galaxies don't have to be as large as previously estimated. They can be smaller and closer to the host galaxy. But "the nearby galaxy can't be too close or too far away, and like the Goldilocks principle, too hot or too cold," said John Wise, co-author of the paper and an associate astrophysics professor at Georgia Institute of Technology. Other theories that could explain supermassive black holes include galaxies merging with one another. The merger theory has a growing body of evidence, as the collision of galaxies is quite common, especially in clusters. The Andromeda galaxy is hurtling towards the Milky Way and is predicted to collide in about four billion years. But both theories still need further testing. Researchers hope to test their theory when NASA's James Webb Space Telescope is launched next year. "Understanding how supermassive black holes form tells us how galaxies, including our own, form and evolve, and ultimately, tells us more about the universe in which we live," said John Regan, lead author of the study and a postdoctoral researcher at Dublin City University.

- A big day for the ESA: Sentinel snaps and ExoMars brakes. That's snaps as in uses cameras and brakes as in slows down

The Italian town of Brindisi and surrounds shot by ESA's new Sentinel B satellite

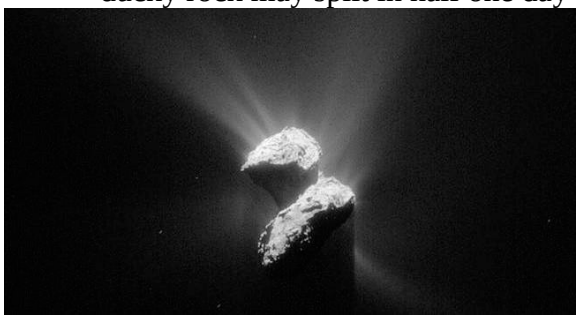
17 Mar 2017 at 05:58, Simon Sharwood

If you're trying to sell something to the European Space Agency, today could be the day to move in and close the deal because there should be smiles all round after two missions achieved important milestones.

The most visible achievement is depicted above (here for mobile readers): the Italian port city of Brindisi, as photographed by the Sentinel-B satellite. Sentinel-B only went aloft last week and is the second of two birds in the Copernicus Earth-observation mission. Publication of the first snap it's sent home is lovely proof of concept for the satellite's ten-metres-per-pixel resolution and an important step in its three-month commissioning process. The ESA's announcement says the word "Brindisi" translates to English as "toast", as in to toast an occasion with a drink. Your correspondent's ancient history lessons taught that the town was the port from which

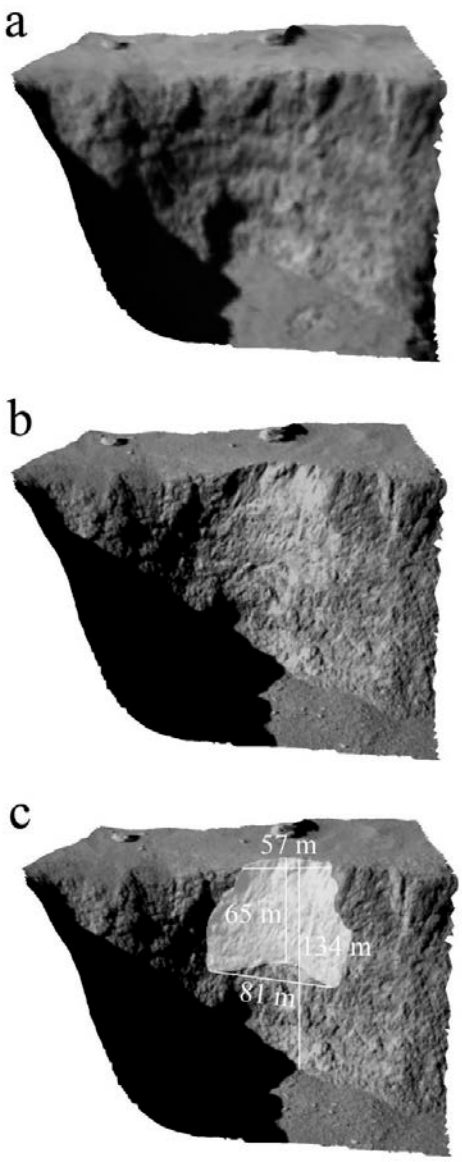
countless Roman soldiers set out to conquer points east, perhaps also an appropriate evocation for the first photo.
But we digress from the second piece of good news, which comes from Mars where the agency's ExoMars craft has been in orbit since October 19th, 2016. The agency says that in the first week of March the orbiter successfully tested its various instruments and they all checked out.
That's important because for the next year ExoMars is going to be busy lowering its orbit so it can get a really good sniff of Mars' atmosphere. To do so it will conduct a few burns to get closer to Mars' atmosphere and "repeatedly surf in and out of the atmosphere at closest approach, pulling down its furthest point over the course of the year."
By March 2018, it's expected ExoMars will be in a pretty-much-round orbit, 400km above Mars. From there its atmosphere-analysing instruments will be able to take better readings as we quest for compounds like methane that would indicate biological processes are at work.
ExoMars' formal science program will commence in March 2018, so knowing its instruments are in good order now is good news as the mission starts to slow down.

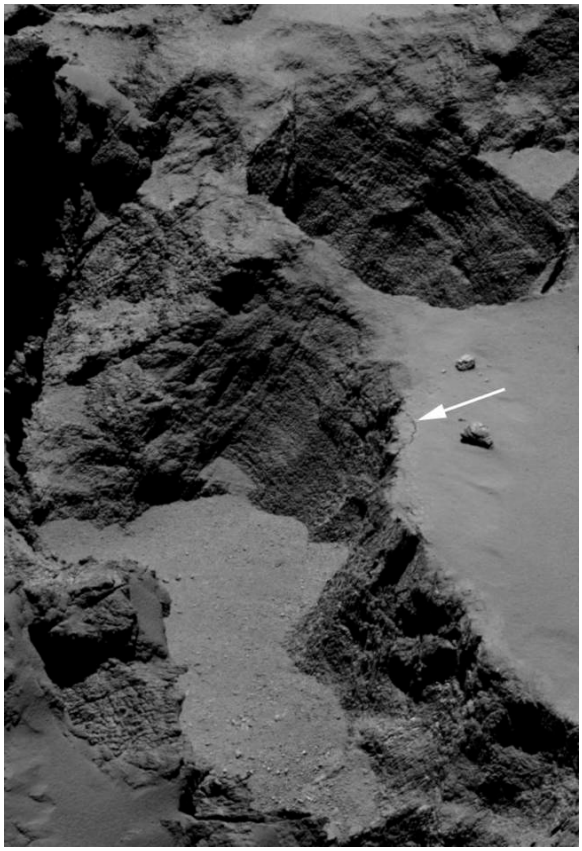
- Now THAT'S a landslide victory: Astronomers snap avalanche on a comet in science first. Plus: Rubber-ducky rock may split in half one day



Flares of gas and dust burst from comet surface as icy interior layers vaporize
22 Mar 2017 at 06:01, Katyanna Quach

Pics Scientists have seen a landslide on a comet for the first time ever, it was announced on Tuesday.
Images captured by the Rosetta space probe show a 134-metre (439-foot) cliff – nicknamed Aswan – on the surface of Comet 67P/Churyumov–Gerasimenko crumbling away to reveal the spotless icy interior hiding under its surface.
The European Space Agency's Rosetta spacecraft orbited the rubber-duck-shaped comet for two years, before it was ordered to crash gently into the comet's dark depths in 2016. Now astronomers are poring over photos from the probe, and were stunned to see snaps of the cosmic landslide.
Scientists had observed outbursts of material ejected violently from the comet's nucleus frequently during the mission. But a study published in *Nature Astronomy* on Tuesday reveals the first time an eruption has been definitively linked to a collapse of a rocky ridge.
a – before the landslide; b & c – after the landslide (Photo credit: ESA/Rosetta/MPS for OSIRIS Team)
Close-up snaps taken in September 2014 show a 70-metre (229-foot) long, one-metre (3.28-foot) wide crack on the cliff edge.
Aswan is located in the Seth region of the comet – a corner of the main body of the comet.

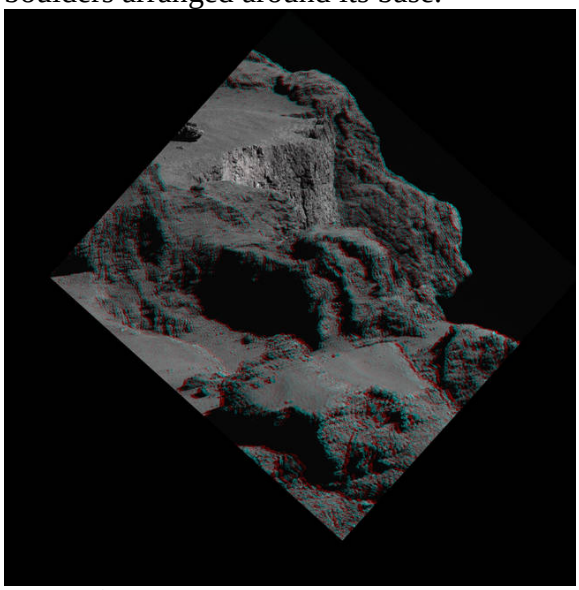




Large crack visible near cliff edge (Photo credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA)

As the comet shuffled along its orbit, getting closer to the Sun, it was warmed by the Sun's rays. Its icy interior began vaporizing at an increased rate, pulling more dust from its surface out into space.

The fireworks of dust and gas can be seen clearly in many images taken by Rosetta's OSIRIS and Navigation cameras. One particular picture taken on July 10, 2015 was traced back to the Seth region. Zooming in on the area, researchers found a large fracture in the face of the Aswan cliff and many large boulders arranged around its base.



Eroded surface reveals bright ice (Photo credit: ESA/Rosetta/MPS for OSIRIS Team)

"The last time we saw the fracture intact was on 4 July, and in the absence of any other outburst events recorded in the following ten-day period, this is the most compelling evidence that we have that the observed outburst was directly linked to the collapse of the cliff," said Maurizio Pajola, a researcher at the University of Padova, who led the study.

The landslide exposed a layer of ice which was estimated to be at least six times brighter than the overall sooty surface of the comet. The brightness faded by half by December as the water-ice vaporized away. By August 2016, a year after the landslide, most of the new cliff edge had faded back to its original colour.

As the first mission to orbit and land on a comet, all eyes were on Rosetta. But it wasn't exactly a smooth journey. Launched in 2004, it took Rosetta a decade and gravity assists from four planetary flybys to get the mothership into the comet's orbit.

Its probe, Philae, successfully plopped on the surface, but the failure of its anchoring harpoons caused the lander to bounce around before landing in an unfortunate spot of shade. Receiving little sunshine, its batteries quickly drained dry.

Repeated attempts by ESA scientists trying to establish communication with the probe failed – although it did manage to send back close-ups of the comet's surface as it descended. Philae briefly flickered back to life as the comet neared its closest approach to the Sun in June 2015, sending back a second burst of data – before operations were permanently shut down in July of that year.

Luckily, the science payload could continue with Rosetta. Evidence of the comet's landslide joins a list of notable discoveries, including mysterious sinkholes covering its porous surface, it's rich in hydrocarbons, and a high ratio of deuterium to hydrogen in its water – making it unlikely that a floating rock like Comet 67P passed water to Earth.

Meanwhile, a separate NASA-led study published Tuesday in *Science* confirms Comet 67P was "was a very active place - full of growing fractures, collapsing cliffs and massive rolling boulders". There's even a big crack in the neck of the comet that is growing, threatening to break the structure in half.

"We saw a massive cliff collapse and a large crack in the neck of the comet get bigger and bigger," said Ramy El-Maarry, leader of the study and researcher from the US Rosetta

science team from the University of Colorado, USA.
"The crack was extending – indicating that the comet may split up one day. And we discovered that boulders the size of a large truck could be moved across the comets surface a distance as long as one-and-a-half football fields."

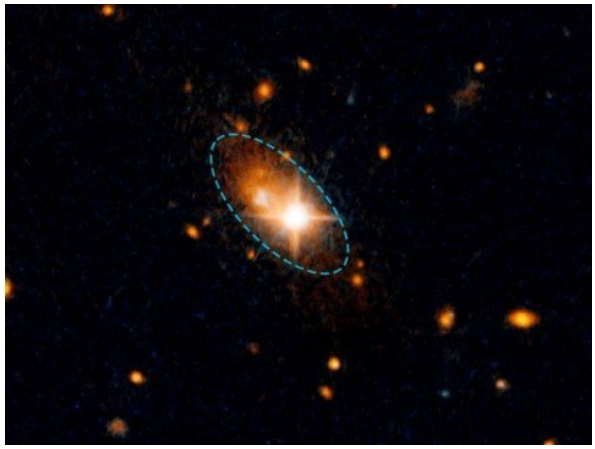
- NASA finds India's missing lunar orbiter with Earth-bound radar. Now that we can spot things the size of a fridge 380,000km away, dodging debris or asteroids should be easier

Lost and found: ISRO's Chandrayaan-1 has been missing since 2009
14 Mar 2017 at 01:58, Richard Chirgwin

In 2009, a lunar orbiter launched by India went quiet and was never heard from again. Fast-forward eight years and NASA say it's spotted it using an Earth-based radar. The Indian Space Research Organisation's Chandrayaan-1 orbiter was supposed to spend two years on its mission, but after 312 days its communications systems conked out. As NASA explains, it couldn't simply extrapolate the little orbiter's last-known orbit because the moon is “riddled with mascons (regions with higher-than-average gravitational pull) that can dramatically affect a spacecraft's orbit over time”. The agency's orbital calculations suggested, however, that the refrigerator-sized spacecraft was most likely around 200 km from the surface, and because it was in a polar orbit, the scientists knew it would always pass the poles. NASA scientists therefore beamed microwaves from the 70m dish at the Goldstone Deep Space Communication complex in California, aimed at a point about 160 km above the moon's north pole. The 100m dish at the Green Bank Telescope in West Virginia was used as the receiver.
“Chandrayaan-1 was predicted to complete one orbit around the moon every two hours and eight minutes. Something that had a radar signature of a small spacecraft did cross the beam twice during four hours of observations, and the timings between detections matched the time it would take Chandrayaan-1 to complete one orbit and return to the same position above the moon's pole.”
As a proof-of-concept, the mission scientists had previously used the radar technique to spot NASA's Lunar Reconnaissance Orbiter, a much easier task since that craft's navigators knew precisely where to look.
Finding Chandrayaan-1 isn't merely an intellectual exercise – its part of NASA's efforts both in asteroid-spotting and lunar exploration. “Ground-based radars could possibly play a part in future robotic and human missions to the moon, both for a collisional hazard assessment tool and as a safety mechanism for spacecraft that encounter navigation or communication issues”, the NASA statement adds. Collision hazards are also an issue a long way farther out: there are around 14 spacecraft assumed to be in orbit around Mars, but eight of them failed in one way or another and don't respond to contact. NASA's Maven spacecraft, which last week had an orbit adjustment to dodge the risk of a collision with Phobos, had a near-miss with the Mars Reconnaissance Orbiter in January 2015. And that's a known hazard. Since Mars is beyond the reach of Earth-bound radars, NASA wants better protocols so everyone knows where their Mars spacecraft are.

- Gravitational wave kicks monster black hole out of galactic core

Date: March 23, 2017
Source: Space Telescope Science Institute (STScI)



This image, taken by NASA's Hubble Space Telescope, reveals an unusual sight: a runaway quasar fleeing from its galaxy's central hub. A quasar is the visible, energetic signature of a black hole. Black holes cannot be observed directly, but they are the energy source at the heart of quasars -- intense, compact gushers of radiation that can outshine an entire galaxy. The green dotted line marks the visible periphery of the galaxy. The quasar, named 3C 186, appears as a bright star just off-centre. The quasar and its host galaxy reside 8 billion light-years from Earth. Researchers estimate that it took the equivalent energy of 100 million supernovas exploding simultaneously to jettison the black hole. The most plausible explanation for this propulsive energy is that the monster object was

given a kick by gravitational waves unleashed by the merger of two hefty black holes at the centre of the host galaxy. The Hubble image combines visible and near-infrared light taken by the Wide Field Camera 3.
Credit: NASA, ESA, and M. Chiaberge (STScI and JHU)

Astronomers have uncovered a supermassive black hole that has been propelled out of the centre of a distant galaxy by what could be the awesome power of gravitational waves. Though there have been several other suspected, similarly booted black holes elsewhere, none has been confirmed so far. Astronomers think this object, detected by NASA's Hubble Space Telescope, is a very strong case. Weighing more than 1 billion suns, the rogue black hole is the most massive black hole ever detected to have been kicked out of its central home. Researchers estimate that it took the equivalent energy of 100 million supernovas exploding simultaneously to jettison the black hole. The most plausible explanation for this propulsive energy is that the monster object was given a kick by gravitational waves unleashed by the merger of two hefty black holes at the centre of the host galaxy. First predicted by Albert Einstein, gravitational waves are ripples in space that are created when two massive objects collide. The ripples are similar to the concentric circles produced when a hefty rock is thrown into a pond. Last year, the Laser Interferometer Gravitational-Wave Observatory (LIGO) helped astronomers prove that gravitational waves exist by detecting them emanating from the union of two stellar mass black holes, which are several times more massive than the sun. Hubble's observations of the wayward black hole surprised the research team. "When I first saw this, I thought we were seeing something very peculiar," said team leader Marco Chiaberge of the Space Telescope Science Institute (STScI) and Johns Hopkins University, in Baltimore, Maryland. "When we combined observations from Hubble, the Chandra X-ray Observatory, and the Sloan Digital Sky Survey, it all pointed towards the same scenario. The amount of data we collected, from X-rays to ultraviolet to near-infrared light, is definitely larger than for any of the other candidate rogue black holes."

Chiaberge's paper will appear in the March 30 issue of *Astronomy & Astrophysics.*

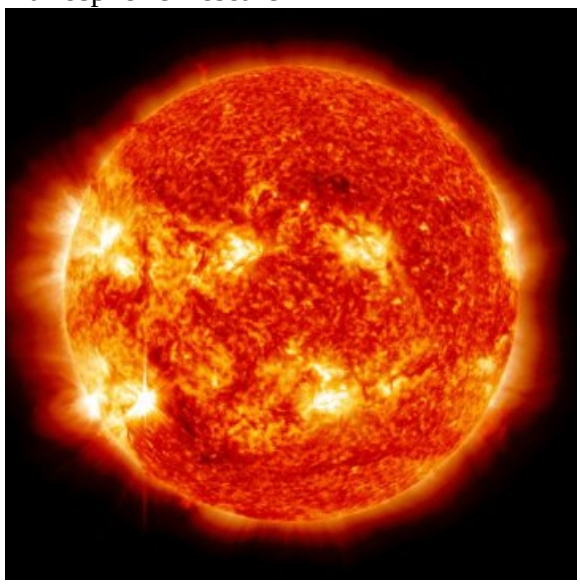
Hubble images taken in visible and near-infrared light provided the first clue that the galaxy was unusual. The images revealed a bright quasar, the energetic signature of a black hole, residing far from the galactic core. Black holes cannot be observed directly, but they are the energy source at the heart of quasars -- intense, compact gushers of radiation that can outshine an entire galaxy. The quasar, named 3C 186, and its host galaxy reside 8 billion light-years away in a galaxy cluster. The team discovered the galaxy's peculiar features while conducting a Hubble survey of distant galaxies unleashing powerful blasts of radiation in the throes of galaxy mergers. "I was anticipating seeing a lot of merging galaxies, and I was expecting to see messy host galaxies around the quasars, but I wasn't really expecting to see a quasar that was clearly offset from the core of a regularly shaped galaxy," Chiaberge recalled. "Black holes reside in the centre of galaxies, so it's unusual to see a quasar not in the centre." The team calculated the black hole's distance from the core by comparing the distribution of starlight in the host galaxy with that of a normal elliptical galaxy from a computer model. The black hole had travelled more than 35,000 light-years from the centre, which is more than the distance between the sun and the centre of the Milky Way. Based on spectroscopic observations taken by Hubble and the Sloan survey, the researchers estimated the black hole's mass and measured the speed of gas trapped near the behemoth object. Spectroscopy divides light into its component colours, which can be used to measure velocities in space. "To our surprise, we discovered that the gas around the black hole was flying away from the galaxy's centre at 4.7 million miles an hour," said team member Justin Ely of STScI. This measurement is also a gauge of the black hole's velocity, because the gas is gravitationally locked to the monster object. The astronomers calculated that the black hole is moving so fast it would travel from Earth to the moon in three minutes. That's fast enough for the black hole to escape the galaxy in 20 million years and roam through the universe forever. The Hubble image revealed an interesting clue that helped explain the black hole's wayward location. The host galaxy has faint arc-shaped features called tidal tails, produced by a gravitational tug between two colliding galaxies. This evidence suggests a possible union between the 3C 186 system and another galaxy, each with central,

massive black holes that may have eventually merged.

Based on this visible evidence, along with theoretical work, the researchers developed a scenario to describe how the behemoth black hole could be expelled from its central home. According to their theory, two galaxies merge, and their black holes settle into the centre of the newly formed elliptical galaxy. As the black holes whirl around each other, gravity waves are flung out like water from a lawn sprinkler. The hefty objects move closer to each other over time as they radiate away gravitational energy. If the two black holes do not have the same mass and rotation rate, they emit gravitational waves more strongly along one direction. When the two black holes collide, they stop producing gravitational waves. The newly merged black hole then recoils in the opposite direction of the strongest gravitational waves and shoots off like a rocket. The researchers are lucky to have caught this unique event because not every black-hole merger produces imbalanced gravitational waves that propel a black hole in the opposite direction. "This asymmetry depends on properties such as the mass and the relative orientation of the back holes' rotation axes before the merger," said team member Colin Norman of STScI and Johns Hopkins University. "That's why these objects are so rare." An alternative explanation for the offset quasar, although unlikely, proposes that the bright object does not reside within the galaxy. Instead, the quasar is located behind the galaxy, but the Hubble image gives the illusion that it is at the same distance as the galaxy. If this were the case, the researchers should have detected a galaxy in the background hosting the quasar. If the researchers' interpretation is correct, the observations may provide strong evidence that supermassive black holes can actually merge. Astronomers have evidence of black-hole collisions for stellar-mass black holes, but the process regulating supermassive black holes is more complex and not completely understood. The team hopes to use Hubble again, in combination with the Atacama Large Millimetre/submillimetre Array (ALMA) and other facilities, to more accurately measure the speed of the black hole and its gas disk, which may yield more insight into the nature of this bizarre object.

- ❖ Planetary waves, first found on Earth, are discovered on sun .Waves may influence space weather, offer a source of predictability

Date: March 27, 2017
Source: National Centre for Atmospheric Research/University Corporation for Atmospheric Research



The Sun.
Credit: NASA/SDO

The same kind of large-scale planetary waves that meander through the atmosphere high above Earth's surface may also exist on the Sun, according to a new study led by a scientist at the National Centre for Atmospheric Research (NCAR). Just as the large-scale waves that form on Earth, known as Rossby waves, influence local weather patterns, the waves discovered on the Sun may be intimately tied to solar activity, including the formation of sunspots, active regions, and the eruption of solar flares. "The discovery of magnetized Rossby waves on the Sun offers the tantalizing possibility that we can predict space weather much further in advance," said NCAR scientist Scott McIntosh, lead author of the paper. The study will be published March 27 in the journal *Nature Astronomy*. Co-authors are William Cramer of Yale University, Manuel Pichardo Marcano of Texas Tech University, and Robert Leamon of the University of Maryland, College Park. The research was funded by the National Science Foundation (NSF), which is NCAR's sponsor, and by NASA.

An unprecedented view of the Sun

On Earth, Rossby waves are associated with the path of the jet stream and the formation of low- and high-pressure systems, which in turn influence local weather events. The waves form in rotating fluids -- in the atmosphere and in the oceans. Because the Sun is also rotating, and because it's made largely of plasma that acts, in some ways, like a vast magnetized ocean, the existence of Rossby-like waves should not come as a surprise, said McIntosh, who directs NCAR's High Altitude Observatory. And yet scientists have lacked the tools to distinguish this wave pattern until recently. Unlike Earth, which is scrutinized at numerous angles by satellites in space, scientists historically have been able to study the Sun from only one viewpoint: as seen from the direction of Earth. But for a brief period, from 2011 to 2014, scientists had the unprecedented opportunity to see the Sun's entire atmosphere at once. During that time, observations from NASA's Solar Dynamics Observatory (SDO), which sits between the Sun and the Earth, were supplemented by measurements from NASA's Solar TErrestrial RElations Observatory (STEREO) mission, which included two spacecraft orbiting the Sun. Collectively, the three observatories provided a 360-degree view of the Sun until contact was lost with one of the STEREO spacecraft in 2014. McIntosh and his co-authors mined the data collected during the window of full solar coverage to see if the large-scale wave patterns might emerge. "By combining the data from all three satellites we can see the entire sun and that's important for studies like this because you want the measurements to all be at the same time," said Dean Pesnell, SDO project scientist at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "They're pushing the boundary of how we use solar data to understand the interior of the sun and where the magnetic field of the sun comes from."

Finding waves in the data

The team used images taken by instruments on SDO and STEREO to identify and track coronal bright points. These small bright features dot the entire face of the Sun and have been used to track motions deeper in the solar atmosphere. The scientists plotted the combined data on Hovmöller diagrams, a diagnostic tool developed by meteorologists to highlight the role of waves in Earth's atmosphere. What emerged from the analysis were bands of magnetized activity that propagate slowly across the Sun -- just like the Rossby waves found on Earth. The discovery could link a range of solar phenomena that are also related to the Sun's magnetic field, including the formation of sunspots, their lifetimes, and the origin of the Sun's 11-year solar cycle. "It's possible that it's all tied together, but we needed to have a global perspective to see that," McIntosh said. "We believe that people have been observing the impacts of these Rossby-like waves for decades, but haven't been able to put the whole picture together." With a new understanding of what the big picture might really look like, scientists could take a step closer to predicting the Sun's behaviour. "The discovery of Rossby-like waves on the Sun could be important for the prediction of solar storms, the main drivers of space weather effects on Earth," said Ilia Roussev, program director in NSF's Division of Atmospheric and Geospace Sciences. "Bad weather in space can hinder or damage satellite operations, and communication and navigation systems, as well as cause power-grid outages leading to tremendous socioeconomic losses. Estimates put the cost of space weather hazards at $10 billion per year." But to advance our predictive capabilities, scientists must first gain a better understanding of the waves and the patterns that persist on them, which would require once again having a 360-degree view of the Sun. "To connect the local scale with the global scale, we need to expand our view," McIntosh said. "We need a constellation of spacecraft that circle the Sun and monitor the evolution of its global magnetic field."

- Astronomers find unexpected, dust-obscured star formation in distant galaxy. Large Millimetre Telescope in Mexico allows deeper look into the early Universe

Date: March 23, 2017
Source: University of Massachusetts at Amherst

Hubble Space Telescope image of the field containing a massive foreground galaxy cluster, MACSJ0717.5+3745. Pope and colleagues' dusty galaxy is denoted by the red squares which show three images of the same gravitationally lensed background galaxy. A zoom in of each multiple image is shown in the right panels.
Credit: Original image by NASA, European Space Agency and the Hubble Space Telescope Frontier Fields team. Colour composite from Wikimedia Commons/Judy Schmidt; annotations and zoom panels added by A. Montana.

Pushing the limits of the largest single-aperture millimetre telescope in the world, and coupling it with gravitational lensing, University of Massachusetts Amherst astronomer Alexandra Pope and colleagues report that they have detected a surprising rate of star formation, four times higher than previously detected, in a dust-obscured galaxy behind a Frontier Fields cluster. As Pope explains, "This very distant, relatively typical galaxy is known to us, and we knew it was forming stars, but we had no idea what its real star-formation rate was because there is so much dust surrounding it. Previous observations couldn't reach past that. Finding out that 75 percent of its star formation was obscured by dust is remarkable and intriguing. These observations clearly show that we have more to learn." She adds, "Historians want to know how civilizations were built up, and we astronomers want to know where and how the elements in the universe were formed and where everything is made of, came from." The study is accepted for publication in *The Astrophysical Journal*. The new tool that has made such revelations possible is the 50-meter Large Millimetre Telescope (LMT) which has been observing as a 32-meter telescope located on an extinct volcano in central Mexico in "early science mode" since 2013. Operated jointly by UMass Amherst and Mexico's Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE), it offers astonishing new power to peer into dusty galaxies, the astrophysicist says. Pope, an expert at analysing how dust masks star formation, says tracing dust-obscured galaxies at early epochs offers good signposts for understanding how the universe became enriched with metals over time. "We know at the basic level that metals are formed in stars, but the rate of build up over cosmic time we don't know," she points out. "We know what we see today but we don't know how it came about, and we want to fill in that picture." Overall, she and colleagues write, "This remarkable lower-mass galaxy showing signs of both low metallicity and high dust content may challenge our picture of dust production in the early universe." Before the AzTEC camera on the LMT took observations of this galaxy, astronomers relied on Hubble Space Telescope images to study star formation, Pope says. But most star formation is obscured by dust, so the Hubble images could not make a complete census of the build-up of stars in this galaxy. "Previous millimetre observations have been limited to the most extreme dusty galaxies. With this study, we have detected a surprisingly high rate of dust-obscured star formation in a typical galaxy in the early universe." With gravitational lensing, researchers use a foreground mass -- another galaxy or a galaxy cluster -- as a lens. As light from very distant, background galaxies passes through, it is magnified. "This technique offers a way to see things that are much fainter than your telescope can see," she notes. As traced in Hubble images, the lensed galaxy they studied in the Frontier Fields cluster showed it forming only about four solar masses of new stars per year, which is a "fairly typical" observation and unsurprising to astronomers today, Pope says. "But then the LMT observations revealed another 15 solar masses per year, which means we had been missing about three-quarters of the star formation going on." She adds, "We are not yet at the level of detecting all of the star formation going on, but we are getting better. One of the big goals for us is to push observations at longer wavelengths and to trace these very dusty galaxies at early epochs. We are pushing observations in this direction and the fact that Hubble found only one quarter of the star formation in this distant normal galaxy is a huge motivation for doing a lot more studies like this." As early as next year, Pope and her colleague Grant Wilson will install on the LMT a new state-of-the-art imaging system he is building, dubbed TolTEC. It will offer mapping speed 100 times faster than the LMT's current capability making it the fastest millimetre-wavelength

polarimetric camera on Earth for conducting deep surveys of the universe, Wilson says. It should allow astronomers to create a census of star-forming galaxies, and observations that require five years to complete today will be done in a little over one week. Pope says, "Currently, our census of dust-obscured star formation activity in galaxies is severely incomplete, especially in the distant universe. With TolTEC on the LMT, we will be able to make a complete census of dust-obscured star formation activity in galaxies over 13 billion years of cosmic time.

- ❖ Universe's ultraviolet background could provide clues about missing galaxies

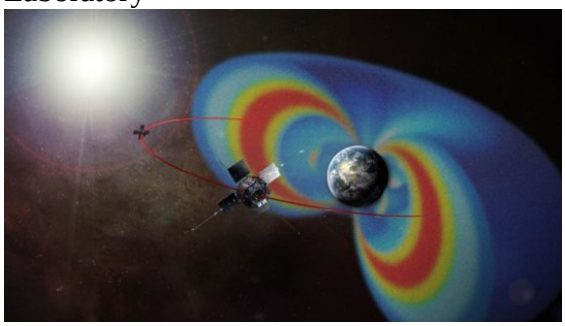
Date: March 22, 2017
Source: Durham University

Galaxy UGC 7321 is surrounded by hydrogen gas, and as this gas is irradiated with UV radiation, it emits a diffuse red glow through a process known as fluorescence. This image shows the light emitted by stars inside the galaxy, surrounded by a red ring that represents the fluorescent emission induced by the UV radiation.
Credit: M. Fumagalli/T. Theuns/S. Berry

Astronomers have developed a way to detect the ultraviolet (UV) background of the Universe, which could help explain why there are so few small galaxies in the cosmos. UV radiation is invisible but shows up as visible red light when it interacts with gas. An international team of researchers led by Durham University, UK, has now found a way to measure it using instruments on Earth. The researchers said their method can be used to measure the evolution of the UV background through cosmic time, mapping how and when it suppresses the formation of small galaxies. The study could also help produce more accurate computer simulations of the evolution of the Universe. The findings are published today (Wednesday, 22 March) in the journal *Monthly Notices of the Royal Astronomical Society*. UV radiation -- a type of radiation also given out by our Sun -- is found throughout the Universe and strips smaller galaxies of the gas that forms stars, effectively stunting their growth. It is believed to be the reason why some larger galaxies like our Milky Way don't have many smaller companion galaxies. Simulations show that there should be more small galaxies in the Universe, but UV radiation essentially stopped them from developing by depriving them of the gas they need to form stars. Larger galaxies like the Milky Way were able to withstand this cosmic blast because of the thick gas clouds surrounding them. Lead author Dr Michele Fumagalli, in the Institute for Computational Cosmology and Centre for Extragalactic Astronomy, at Durham University, said: "Massive stars and supermassive black holes produce huge amounts of ultraviolet radiation, and their combined radiation builds-up this ultraviolet background. “This UV radiation excites the gas in the Universe, causing it to emit red light in a similar way that the gas inside a fluorescent bulb is excited to produce visible light. "Our research means we now have the ability to measure and map this UV radiation which will help us to further refine models of galaxy formation." Co-author Professor Simon Morris, in the Centre for Extragalactic Astronomy, Durham University, added: "Ultimately this could help us learn more about the evolution of the Universe and why there are so few small galaxies." Researchers pointed the Multi Unit Spectroscopic Explorer (MUSE), an instrument of the European Southern Observatory's Very-Large Telescope, in Chile, at the galaxy UGC 7321, which lies at a distance of 30 million light years from Earth. MUSE provides a spectrum, or band of colours, for each pixel in the image allowing the researchers to map the red light produced by the UV radiation illuminating the gas in that galaxy. The research, funded in the UK by the Science and Technology Facilities Council, could also help scientists predict the temperature of the cosmic gas with more accuracy. Co-author Professor Tom Theuns, in Durham University's Institute for Computational Cosmology, said: "Ultraviolet radiation heats the cosmic gas to temperatures higher than that of the surface of the Sun. "Such hot gas will not cool to make stars in small galaxies. This explains why there are so few small galaxies in the Universe, and also why our Milky Way has so few small satellite galaxies."

- Less radiation in inner Van Allen belt than previously believed

New study shows scientists the 'snowflake in a rainstorm'
Date: March 21, 2017
Source: DOE/Los Alamos National Laboratory



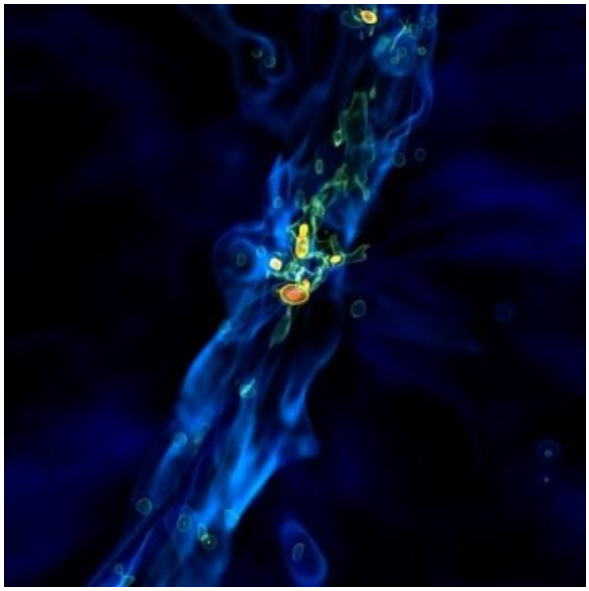
Van Allen Probes circle radiation belts. This artist's rendering of the Van Allen Probes mission shows the path of its two spacecraft through the radiation belts that surround Earth, which are made visible in false colour.
Credit: NASA

The inner Van Allen belt has less radiation than previously believed, according to a recent study in the *Journal of Geophysical Research*. Observations from NASA's Van Allen probes show the fastest, most energetic electrons in the inner radiation belt are actually much rarer and harder to find than scientists expected. This is good news for spacecraft that are orbiting in the region and can be damaged by high levels of radiation. The results will also help scientists better understand -- and detect -- effects from high-altitude nuclear explosions. "Basically what we're doing is detecting very small signals against very large backgrounds," said Geoff Reeves, a space physicist at Los Alamos National Laboratory and co-author of the study. "Let's say you have a few snowflakes in a rainstorm -- but you've never seen snowflakes before. How do you ignore the rain so you can just see the snowflakes? That's what we've done here: we ignored a whole lot of protons so we could see the electrons -- and it turns out there aren't as many as we thought." The Van Allen belts are two doughnut-shaped regions of charged particles encircling Earth. Past space missions have not been able to distinguish electrons from high-energy protons in the inner radiation belt. But by using a special instrument, the Magnetic Electron and Ion Spectrometer (MagEIS), on the Van Allen Probes, scientists could look at the particles separately for the first time. What they found was surprising: almost none of these super-fast electrons, known as relativistic electrons, are present in the inner belt. Los Alamos National Laboratory has interest in the applications for space weather forecasting to protect satellites and also for monitoring the Nuclear Test Ban Treaty, which prohibits nuclear explosions in space. "A high-altitude nuclear explosion results in the creation of an artificial radiation belt," said Reeves. "We can learn about the physics of an explosion by looking at these hard-to-detect relativistic electrons. If an artificial radiation belt were ever detected, these new observations would help us understand it better." Of the two radiation belts, scientists have long understood the outer belt to be the more active one. During intense geomagnetic storms, when charged particles from the sun hurtle across the solar system, the outer radiation belt pulsates dramatically, growing and shrinking in response to the pressure of the solar particles and magnetic field. Scientists thought that the inner belt maintains a steady position above Earth's surface. The new results, however, show that's not always true. For example, during a very strong geomagnetic storm in June 2015, relativistic electrons were pushed deep into the inner belt. "When we carefully process the data and remove the contamination, we can see things that we've never been able to see before," said Seth Claudepierre, lead author and Van Allen Probes scientist at the Aerospace Corporation in El Segundo, Calif. "These results are totally changing the way we think about the radiation belt at these energies." Given the rarity of the storms that can inject relativistic electrons into the inner belts, the scientists now understand that lower levels of radiation are typical there, a result that has implications for spacecraft flying in the region. Knowing exactly how much and what type of radiation is present in any given region of space may enable scientists and engineers to design lighter and cheaper satellites tailored to withstand the specific radiation levels they'll encounter. In addition to providing a new outlook on spacecraft design, the findings open a new realm for scientists to study next. "This opens up the possibility of doing science that previously was not possible," said Shri Kanekal, Van Allen Probes deputy mission scientist at NASA's Goddard Space Flight Centre in Greenbelt, Md., and not involved with the study. "For example, we can now investigate under what circumstances these electrons penetrate the inner region and see if more intense geomagnetic storms give

electrons that are more intense or more energetic."

- ❖ Breaking the supermassive black hole speed limit

Date: March 21, 2017
Source: DOE/Los Alamos National Laboratory



This is a quasar growing under intense accretion streams.

Credit: Los Alamos National Laboratory

A new computer simulation helps explain the existence of puzzling supermassive black holes observed in the early universe. The simulation is based on a computer code used to understand the coupling of radiation and certain materials. "Supermassive black holes have a speed limit that governs how fast and how large they can grow," said Joseph Smidt of the Theoretical Design Division at Los Alamos National Laboratory, "The relatively recent discovery of supermassive black holes in the early development of the universe raised a fundamental question, how did they get so big so fast?" Using computer codes developed at Los Alamos for modelling the interaction of matter and radiation related to the Lab's stockpile stewardship mission, Smidt and colleagues created a simulation of collapsing stars that resulted in supermassive black holes forming in less time than expected, cosmologically speaking, in the first billion years of the universe. "It turns out that while supermassive black holes have a growth speed limit, certain types of massive stars do not," said Smidt. "We asked, what if we could find a place where stars could grow much faster, perhaps to the size of many thousands of suns; could they form supermassive black holes in less time."

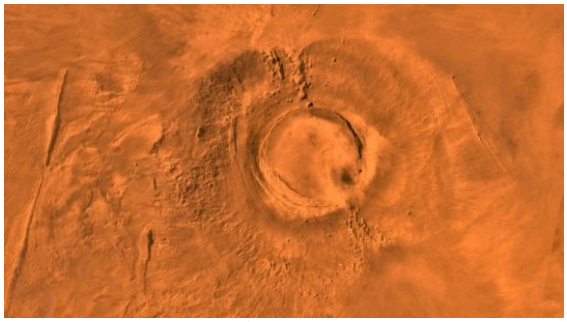
A video about the discovery is available here: https://www.youtube.com/watch?v=LD4xECbHx_I&feature=youtu.be

It turns out the Los Alamos computer model not only confirms the possibility of speedy supermassive black hole formation, but also fits many other phenomena of black holes that are routinely observed by astrophysicists. The research shows that the simulated supermassive black holes are also interacting with galaxies in the same way that is observed in nature, including star formation rates, galaxy density profiles, and thermal and ionization rates in gasses. "This was largely unexpected," said Smidt. "I thought this idea of growing a massive star in a special configuration and forming a black hole with the right kind of masses was something we could approximate, but to see the black hole inducing star formation and driving the dynamics in ways that we've observed in nature was really icing on the cake." A key mission area at Los Alamos National Laboratory is understanding how radiation interacts with certain materials. Because supermassive black holes produce huge quantities of hot radiation, their behaviour helps test computer codes designed to model the coupling of radiation and matter. The codes are used, along with large- and small-scale experiments, to assure the safety, security, and effectiveness of the U.S. nuclear deterrent. "We've gotten to a point at Los Alamos," said Smidt, "with the computer codes we're using, the physics understanding, and the supercomputing facilities, that we can do detailed calculations that replicate some of the forces driving the evolution of the Universe."

Research paper available at https://arxiv.org/pdf/1703.00449.pdf

- ❖ Mars volcano, Earth's dinosaurs went extinct about the same time

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

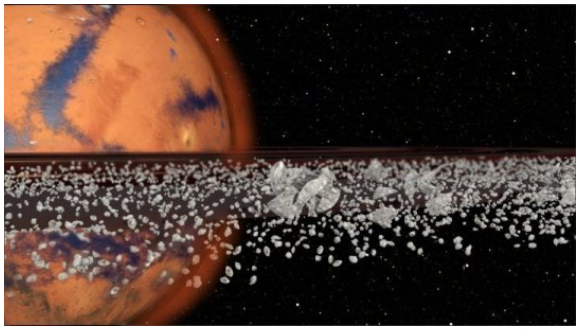


This digital-image mosaic of Mars' Tharsis plateau shows the extinct volcano Arsia Mons. It was assembled from images that the Viking 1 Orbiter took during its 1976-1980 working life at Mars.
Credit: NASA/JPL/USGS

New NASA research reveals that the giant Martian shield volcano Arsia Mons produced one new lava flow at its summit every 1 to 3 million years during the final peak of activity. The last volcanic activity there ceased about 50 million years ago -- around the time of Earth's Cretaceous-Paleogene extinction, when large numbers of our planet's plant and animal species (including dinosaurs) went extinct. Located just south of Mars' equator, Arsia Mons is the southernmost member of a trio of broad, gently sloping shield volcanoes collectively known as Tharsis Montes. Arsia Mons was built up over billions of years, though the details of its lifecycle are still being worked out. The most recent volcanic activity is thought to have taken place in the caldera -- the bowl-shaped depression at the top -- where 29 volcanic vents have been identified. Until now, it's been difficult to make a precise estimate of when this volcanic field was active. "We estimate that the peak activity for the volcanic field at the summit of Arsia Mons probably occurred approximately 150 million years ago -- the late Jurassic period on Earth -- and then died out around the same time as Earth's dinosaurs," said Jacob Richardson, a postdoctoral researcher at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "It's possible, though, that the last volcanic vent or two might have been active in the past 50 million years, which is very recent in geological terms." Richardson is presenting the findings on March 20, 2017, at the Lunar and Planetary Science Conference in The Woodlands, Texas. The study also is published in *Earth and Planetary Science Letters*. Measuring about 68 miles (110 kilometres) across, the caldera is deep enough to hold the entire volume of water in Lake Huron, and then some. Examining the volcanic features within the caldera required high-resolution imaging, which the researchers obtained from the Context Camera on NASA's Mars Reconnaissance Orbiter. The team mapped the boundaries of the lava flows from each of the 29 volcanic vents and determined the stratigraphy, or layering, of the flows. The researchers also performed a technique called crater counting -- tallying up the number of craters at least 330 feet (100 meters) in diameter -- to estimate the ages of the flows. Using a new computer model developed by Richardson and his colleagues at the University of South Florida, the two types of information were combined to determine the volcanic equivalent of a batting line-up for Arsia Mons' 29 vents. The oldest flows date back about 200 million years. The youngest flows probably occurred 10 to 90 million years ago -- most likely around 50 million years ago. The modelling also yielded estimates of the volume flux for each lava flow. At their peak about 150 million years ago, the vents in the Arsia Mons' caldera probably collectively produced about 1 to 8 cubic kilometres of magma every million years, slowly adding to the volcano's size. "Think of it like a slow, leaky faucet of magma," said Richardson. "Arsia Mons was creating about one volcanic vent every 1 to 3 million years at the peak, compared to one every 10,000 years or so in similar regions on Earth." A better understanding of when volcanic activity on Mars took place is important because it helps researchers understand the Red Planet's history and interior structure. "A major goal of the Mars volcanology community is to understand the anatomy and lifecycle of the planet's volcanoes. Mars' volcanoes show evidence for activity over a larger time span than those on Earth, but their histories of magma production might be quite different," said Jacob Bleacher, a planetary geologist at Goddard and a co-author on the study. "This study gives us another clue about how activity at Arsia Mons tailed off and the huge volcano became quiet."

- ❖ Does Mars have rings? Not right now, but maybe one day

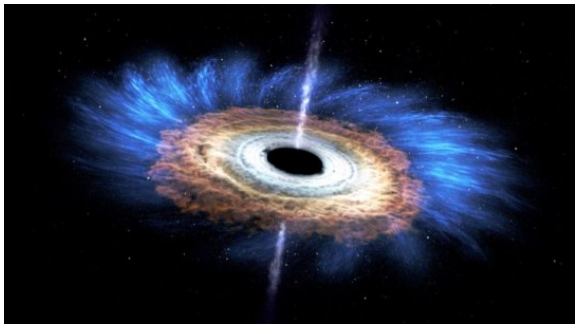
Date: March 21, 2017
Source: Purdue University



Phobos, a Martian moon, might eventually disintegrate and form a ring around the red planet, according to a new theory by Purdue University scientists. The NASA-funded research indicates that this process of moons breaking apart into rings and then reforming as moons may have happened several times over billions of years. *Credit: Image by Purdue University Envision Centre*

As children, we learned about our solar system's planets by certain characteristics -- Jupiter is the largest, Saturn has rings, Mercury is closest to the sun. Mars is red, but it's possible that one of our closest neighbours also had rings at one point and may have them again someday. That's the theory put forth by Purdue University scientists, whose findings were published in the journal *Nature Geoscience*. David Minton, assistant professor of Earth, atmospheric and planetary sciences, and Andrew Hesselbrock, a doctoral student in physics and astronomy, developed a model that suggests that debris that was pushed into space from an asteroid or other body slamming into Mars around 4.3 billion years ago and alternates between becoming a planetary ring and clumping up to form a moon. A theory exists that Mars' large North Polar Basin or Borealis Basin, which covers about 40 percent of the planet in its northern hemisphere, was created by that impact, sending debris into space. "That large impact would have blasted enough material off the surface of Mars to form a ring," Hesselbrock said. Hesselbrock and Minton's model suggests that as the ring formed and the debris slowly moved away from the planet and spread out, it began to clump and eventually formed a moon. Over time, Mars' gravitational pull would have pulled that moon toward the planet until it reached the Roche limit, the distance within which the planet's tidal forces will break apart a celestial body that is held together only by gravity. Phobos, one of Mars' moons, is getting closer to the planet. According to the model, Phobos will break apart upon reaching the Roche limit and become a set of rings in roughly 70 million years. Depending on where the Roche limit is, Minton and Hesselbrock believe this cycle may have repeated between three and seven times over billions of years. Each time a moon broke apart and reformed from the resulting ring, its successor moon would be five times smaller than the last, according to the model, and debris would have rained down on the planet, possibly explaining enigmatic sedimentary deposits found near Mars' equator. "You could have had kilometre-thick piles of moon sediment raining down on Mars in the early parts of the planet's history, and there are enigmatic sedimentary deposits on Mars with no explanation as to how they got there," Minton said. "And now it's possible to study that material." Other theories suggest that the impact with Mars that created the North Polar Basin led to the formation of Phobos 4.3 billion years ago, but Minton said it's unlikely the moon could have lasted all that time. Also, Phobos would have had to form far from Mars and would have had to cross through the resonance of Deimos, the outer of Mars' two moons. Resonance occurs when two moons exert gravitational influence on each other in a repeated periodic basis, as major moons of Jupiter do. By passing through its resonance, Phobos would have altered Deimos' orbit. But Deimos' orbit is within one degree of Mars' equator, suggesting it has had no effect on Phobos. "Not much has happened to Deimos' orbit since it formed," Minton said. "Phobos passing through these resonances would have changed that." Richard Zurek of NASA's Jet Propulsion Laboratory, Pasadena, California, is the project scientist for NASA's Mars Reconnaissance Orbiter, whose gravity mapping provided support for the hypothesis that the northern lowlands were formed by a massive impact. "This research highlights even more ways that major impacts can affect a planetary body," he said. Minton and Hesselbrock will now focus their work on either the dynamics of the first set of rings that formed or the materials that have rained down on Mars from disintegration of moons.

NASA's Swift mission maps a star's 'death spiral' into a black hole
Date: March 20, 2017
Source: NASA/Goddard Space Flight Centre



This artist's rendering shows the tidal disruption event named ASASSN-14li, where a star wandering too close to a 3-million-solar-mass black hole was torn apart. The debris gathered into an accretion disk around the black hole. New data from NASA's Swift satellite show that the initial formation of the disk was shaped by interactions among incoming and outgoing streams of tidal debris.
Credit: NASA's Goddard Space Flight Centre

Some 290 million years ago, a star much like the sun wandered too close to the central black hole of its galaxy. Intense tides tore the star apart, which produced an eruption of optical, ultraviolet and X-ray light that first reached Earth in 2014. Now, a team of scientists using observations from NASA's Swift satellite have mapped out how and where these different wavelengths were produced in the event, named ASASSN-14li, as the shattered star's debris circled the black hole. "We discovered brightness changes in X-rays that occurred about a month after similar changes were observed in visible and UV light," said Dheeraj Pasham, an astrophysicist at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, and the lead researcher of the study. "We think this means the optical and UV emission arose far from the black hole, where elliptical streams of orbiting matter crashed into each other." Astronomers think ASASSN-14li was produced when a sun-like star wandered too close to a 3-million-solar-mass black hole similar to the one at the centre of our own galaxy. For comparison, the event horizon of a black hole like this is about 13 times bigger than the sun, and the accretion disk formed by the disrupted star could extend to more than twice Earth's distance from the sun. When a star passes too close to a black hole with 10,000 or more times the sun's mass, tidal forces outstrip the star's own gravity, converting the star into a stream of debris. Astronomers call this a tidal disruption event. Matter falling toward a black hole collects into a spinning accretion disk, where it becomes compressed and heated before eventually spilling over the black hole's event horizon, the point beyond which nothing can escape and astronomers cannot observe. Tidal disruption flares carry important information about how this debris initially settles into an accretion disk. Astronomers know the X-ray emission in these flares arises very close to the black hole. But the location of optical and UV light was unclear, even puzzling. In some of the best-studied events, this emission seems to be located much farther than where the black hole's tides could shatter the star. Additionally, the gas emitting the light seemed to remain at steady temperatures for much longer than expected. ASASSN-14li was discovered Nov. 22, 2014, in images obtained by the All Sky Automated Survey for Supernovae (ASASSN), which includes robotic telescopes in Hawaii and Chile. Follow-up observations with Swift's X-ray and Ultraviolet/Optical telescopes began eight days later and continued every few days for the next nine months. The researchers supplemented later Swift observations with optical data from the Las Cumbres Observatory headquartered in Goleta, California. In a paper describing the results published March 15 in *The Astrophysical Journal Letters*, Pasham, Cenko and their colleagues show how interactions among the infilling debris could create the observed optical and UV emission. Tidal debris initially falls toward the black hole but overshoots, arcing back out along elliptical orbits and eventually colliding with the incoming stream. "Returning clumps of debris strike the incoming stream, which results in shock waves that emit visible and ultraviolet light," said Goddard's Bradley Cenko, the acting Swift principal investigator and a member of the science team. "As these clumps fall down to the black hole, they also modulate the X-ray emission there." Future observations of other tidal disruption events will be needed to further clarify the origin of optical and ultraviolet light.