South Downs Mercury

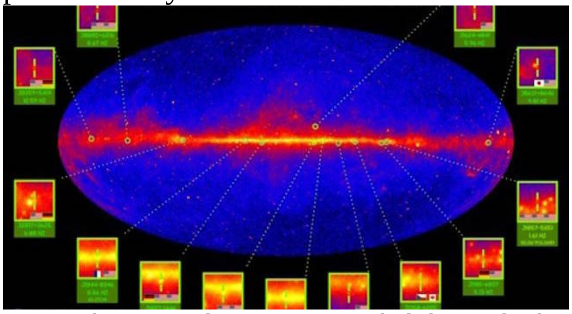
The monthly circular of South Downs Astronomical Society
Issue: 504 – February 2017 Editor: Roger Burgess

- Next meeting Friday 3rd February Lecture room of the South Downs Planetarium, Chichester, at 7.30pm. Please support a raffle we are organizing this month

- Main Talk Graham Bryant " Aurora"

- Home Einsteins help turn up 13 new pulsars

Distributed 'supercomputer' prises open Fermi 'scope's secrets, sometimes with just 10 photons a day



Einstein@home's 13 pulsars. Image: Knispel/Clark/Max Planck Institute for Gravitational Physics/NASA/DOE/Fermi LAT Collaboration

15 Jan 2017 at 23:57, Richard Chirgwin

The Einstein@home project has announced the discovery of 13 neutron stars in its distributed analysis of gamma ray data from the orbiting Fermi telescope. The bunch of "young" pulsars are believed to have formed between tens and hundreds of thousands of years ago, and among them are three particular curiosities: two that are spinning slower than any known gamma ray pulsar, and one that changed rotation during the observation. Spotting the critters at all is a challenge. As the Einstein@home announcement from the Max Planck Institute explains, even Fermi's Large Area Telescope only detects around ten photons each day from the typical pulsar. With around 440,000 volunteers taking part since the project was launched in 2005, Einstein@home boasts 1.6 Petaflops of computing capacity, which would earn it a very high place in the Top 500 supercomputer rankings. Researchers need to comb years' worth of data with fine resolution to identify new sources, and that's where Einstein@home comes into play, using the kind of "spare computing cycles" approach pioneered by the far less successful Seti@home project. Einstein@home has, the Max Planck Institute says, become the go-to for "blind" searches, looking for gamma ray pulsars without data in other wavelengths. It's made all such discoveries in the last four years, turning up 21 sources, which make up one-third of the total blind-search discoveries in any survey. The most recent study, published in *The Astrophysical Journal*, used 10,000 years' worth of CPU time over a year. The scientists probed 118 candidate sources, out of 1,000 unidentified sources in the Fermi-LAT "Third Source Catalogue", and created a new search scheme for the project "to analyse the detected gamma ray photons for hidden periodicities." The release notes that the slow-spinning pulsars are harder to find, because they emit fewer gamma rays than those spinning faster. "Another newly discovered pulsar experienced a strong 'glitch', a sudden speedup of unknown origin in its otherwise regular rotation. Glitches are observed in other young pulsars and might be related to re-arrangements of the neutron star interior but are not well understood," the release says

- Astronomers link ALIEN STRUCTURE ON VENUS to Solar System's biggest ever gravity wave Akatsuki probe finds huge thing lurking in planet's clouds

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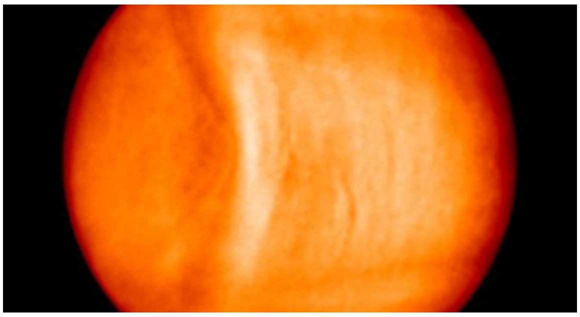


Give us a wave ... The mysterious structure on Venus (Photo source: JAXA)

18 Jan 2017 at 07:19, Katyanna Quach

An enormous, mysteriously stationary structure high over the surface of Venus may be the largest gravity wave in the Solar System, according to Japanese astronomers. In 2015, cameras on board the Japan Aerospace Exploration Agency (JAXA) spacecraft Akatsuki captured images of a humungous boomerang-shaped bulge measuring more than 10,000km (6,214mi) across the cloud-tops of Venus, at 65km (40mi) in altitude. Scientists have been studying the strange erection, which is just weirdly hanging there in the planet's atmosphere, and published their findings in *Nature Geoscience* this week. We're told that huge features spotted over Venus's surface typically move slightly faster or slower than the alien world's remorseless wind. However, over several days of observation, the mystery structure hardly budges from its position as the planet’s fast-moving background winds billow by. Essentially, it remains in place, just floating way up high ominously covering nearly the diameter of Venus, despite the high-speed winds screaming past it. While named after the goddess of love, Venus is no angel: its miserable hells cape is shrouded in thick sulphur dioxide clouds peppered with drops of sulphuric acid. Its upper atmosphere rotates faster than the planet, causing the clouds to shift westwards as they are blown away by a background wind that moves at approximately 100 metres per second (223 miles per hour). Numerical simulations of Venus’s atmosphere, using observations from the Akatsuki craft, suggest that the bow-shaped structure may have resulted from a stationary gravity wave produced near the mountain ranges below the clouds, before it spread upwards. Exactly how the stationary wave is produced continues to baffle astronomers, but it's believed the mountains are key. “The formation and propagation of a mountain gravity wave, [however], remain difficult to reconcile with assumed near-surface conditions on Venus,” the researchers admit.
The Japanese probe's long-wave infrared camera detected the bow-shaped formation as an unusually warm shape between the high-temperature regions at the northern and southern poles. Bow structures aren’t uncommon on Venus: previous sightings have been spotted in ultraviolet images, but they have always moved at the same speed of the planet’s surface winds and were not as large. Researchers hope to produce more detailed simulations to explore the idea of a stationary gravity wave. “Since gravity waves transfer momentum, mountain-induced waves may be important for the climatology of Venus,” the team's paper states. JAXA’s mission to study Venus was initially shaky. Akatsuki failed to enter the planet’s orbit in December 2010, and made a second successful orbital burn to get the spacecraft out of the Sun’s orbit and into Venus’s five years later.

- You know what, maybe Tabby's star ate a planet, ponder space eggheads

So much for the 'alien megastructure' theories

13 Jan 2017 at 05:56, Richard Chirgwin

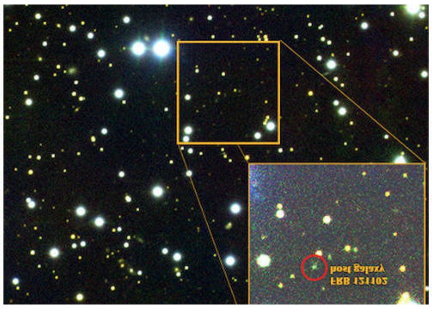
Tabby's star – formally KIC 8462852 – has attracted a new and possibly-plausible explanation for its excess of twinkle: the remnants of a planet destroyed in a collision. That hypothesis comes from Brian Metzger and Nicholas Stone of Columbia University's Astrophysics Laboratory, and Ken Shen of UC Berkeley's Department of Astronomy and Theoretical Astrophysics Centre. Over at Arxiv, they explain a hypothesis that's a lot more plausible than the “alien megastructure” idea that occupied a lot of synapses in 2016. In case this is the first you've heard of Tabby's star: it's a mostly unremarkable F-type main sequence star with just one interesting characteristic, its light isn't stable. It shows both short term “twinkles” and a long-term dimming. Since it was the first time such a phenomenon had been observed, there was no straightforward explanation for its dimming. Possibilities offered up included instrument calibration (debunked), a comet halo (also debunked), and most famously, a partly-constructed “Dyson sphere” (which NASA played killjoy about). Metzger, Nicholas and Shen write that they took their idea from “an initial suggestion by Wright & Sigurdsson” and, doing the maths, suggest a planet spiralled into the star, leaving debris that causes the dimming. The paper suggests a collision could leave two artefacts:

- A brightening that happened before it was observed, followed by a long-term dimming which is in observations between 1890 to 1989. This was caused by “gravitational energy released as the body spirals into the outer layers of the star”; and
- Transient dimming “due to obscuration by planetary debris from an earlier partial disruption of the same in spiralling bodies, or due to evaporation and out-gassing from a tidally detached moon system”.

The paper notes that since one star is exhibiting two unusual phenomena, it's reasonable to suggest they're related.

- ❖ Puny galaxy packs a big punch: A gazillion joules' worth of radio bursts

Astronomers get best fix so far on mysterious 'FRB' location



FRB 121102's host galaxy (Image: *Gemini Observatory/AURA/NSF/NRC*)
5 Jan 2017 at 03:05, Richard Chirgwin

Sorry to say this, but fast radio bursts *still* aren't alien communications. There is a surprise, however, in the latest science about them – the only repeating burst yet known comes from a "puny" galaxy with no obvious sources for such a cataclysmic cosmic event. We don't know quite what they are, but the galactic mysteries abbreviated to "FRB" are Douglas-Adams-level "space is big." The FRB whose location has just been pinpointed to a few billion light years distant releases enough energy in milliseconds to run Earth for 30 *billion* years: 10 million trillion trillion joules. (*Thanks to Bryan Gaensler for also clarifying that the "10 million trillion trillion" joules is an estimate of the energy released in each burst.)* FRBs have intrigued astronomers ever since the first observation in 2007 (confirmed in 2013) led to a concerted effort to find more (so far, 20 are known). The amount of energy released in such a short time tells us something big is happening, but what? That's what makes localisation important: it provides a chance to observe what's in a galaxy that might be generating the radio waves. The team that traced FRB 121102 to a galaxy roughly 3.2 billion light years away (972 mega parsecs) was led by Shami Chatterjee of Cornell University. FRB 121102 was first spotted by the Arecibo radio telescope in Puerto Rico, but unlike other sources, it wasn't a one-off event. Because it's a repeating FRB, astronomers had the chance to get a better fix on its position, using the 27 receivers in the Karl G Jansky Very Large Array in New Mexico, and the 21 dishes in the European Very-Long-Baseline Interferometry Network. With those observations in place, the researchers then turned to the Gemini North telescope in Hawaii for optical observations, delivering the image above. The host galaxy is genuinely tiny, and that sets a new puzzle for astronomers. Team member Cees Bassa of the Netherlands Institute for Radio Astronomy said in a statement, "I think the whole team was surprised to see that our exotic source is hosted by a very puny and faint galaxy." Scientists have previously speculated that one-off FRBs could be caused by collisions between black holes or between neutron stars, but neither of these can apply to the repeating FRB 121102. As University of Toronto director of the Dunlap Institute for Astronomy and Astrophysics Bryan Gaensler put it:
The researchers offer the hypothesis that FRB 121102 is caused by the leftovers from a supernova, being energised by a young and rapidly spinning neutron star – but a lot more observation will be needed to test that idea. The work is published in *Nature*, and the analysis of the Gemini optical observations is at the Institute of Physics here.

- ❖ NASA eyes up supermassive black holes, neutron stars

Hidden wonders of the universe

Black hole – spaghetti visualisation. Artist's impression. NASA/JPL-Caltech, CC BY-SA
4 Jan 2017 at 15:13, Katyanna Quach

NASA will embark on a new mission to explore supermassive black holes, neutron stars, and pulsars hidden within the depths of space. The Imaging X-ray Polarimetry Explorer (IXPE) mission was chosen among 14 other proposals during the rigorous selection process for NASA's Astrophysics Explorer programmes. It's expected to launch in 2018 and will cost $188m – a modest price tag compared to NASA's largest missions on the Flagship programme often valued at over $1bn. The IXPE mission will send three telescopes to analyse the powerful cosmic X-rays emitted from objects with extreme gravitational, electric, and magnetic fields. The telescopes will operate alongside the Hubble Space Telescope, Chandra X-ray Observatory, and XMM Newton to spot X-ray emissions from some of the most energetic objects in space. "We cannot directly image what's going on near objects like black holes and neutron stars, but studying the polarization of X-rays emitted from their surrounding environments reveals the physics of these enigmatic objects," said Paul Hertz, NASA's astrophysics division director for the Science Mission Directorate. Under Barack Obama's administration, NASA's 2017 fiscal year budget [PDF] is $19bn, a slight decrease of $300m from the space agency's final spending bill in 2016. It is unknown how the current President-elect, Donald Trump, will affect NASA's budget in the future, but its Explorer programme is designed to be cheap and quicker to execute. Although missions on the Explorer programme are smaller, the scientific payload can be great. It has launched more than 90 missions, and has made a list of important discoveries such as Earth's Van Allen radiation belts, magnetosphere, and the shape of its gravity field. The Cosmic Background mission in 1989 led to the 2006 Nobel Prize for uncovering the near-perfect blackbody and anisotropies of the cosmic microwave background radiation

- Astronomers glimpse sighting of ultra-rare circular galaxy

Double-ring phenomena for the 0.1 per cent fans

Hoag's Object is a rare phenomenon, but PGC 1000714 is stranger still

4 Jan 2017 at 10:26, Gavin Clarke

A rarer-than-rare galaxy 359 million light years away from Earth has been spotted by physicists. Designated PGC 1000714 [pay walled], the galaxy is a ring-shape system orbiting a cooler centre without any connection between the two – a formation referred to as Hoag's Object. Just 0.1 per cent of all observed galaxies are Hoag-type systems; the majority follow the hub and spiral-arm standard like our own Milky Way or the neighbouring Andromeda. PGC 1000714 is rarer still, though. Hoag's Object, discovered 67 years ago by astronomer Arthur Allan Hoag and named after him, features a single ring of blue stars orbiting a yellow core. PGC 1000714 features a second ring of blue stars with both rings orbiting a red core.

Nobody has yet managed to adequately explain the formation of the original Hoag's Object – never mind the related-yet-different PGC 1000714, which was spotted by scientists at the University of Minnesota Duluth and the North Carolina Museum of Natural Sciences. Burcin Mutlu-Pakdil, lead author of a paper on this work, said in a statement: "The different colours of the inner and outer ring suggest that this galaxy has experienced two different formation periods."

Galaxy rings are regions where stars have formed from colliding gas – hence the reason for the different colours. "From these initial single snapshots in time, it's impossible to know how the rings of this particular galaxy were formed," Mutlu-Pakdil said. One possibility is that the outer ring may be the result of this galaxy incorporating portions of a once-nearby gas-rich dwarf galaxy.

The galaxy was spotted and analysed using multi-waveband images from observations in the southern hemisphere, using a large-diameter telescope in the Chilean mountains. These images were used to determine the ages of the two main features of the galaxy, the outer ring and the central body.

The outer ring is 0.13 billion years old and the red core 5.5 billion years. Higher-resolution images are needed to infer the age of the inner ring.

The original Hoag's Object, spotted in 1950, shows a ring of blue stars spanning 100,000 light years and lying 600 million light years away in Serpens Constellation.

- NASA taps ESA satellite Swarm for salty ocean temperature tales

Magnetic method explored, NASA tells

9 Jan 2017 at 09:36, Rik Myslewski

Research scientists working at NASA have hit upon a potentially revolutionary way of measuring the heat hidden deep in Earth's oceans: track the subtle shifts in our planet's magnetic field caused by tides, swells, eddies, and even tsunamis. Put simply, the salt in ocean water makes it conductive, and as it ebbs and flows it drags Earth's magnetic field to and fro. Highly sensitive magnetic-field sensors such as those aboard the European Space Agency's three-satellite Swarm mission can detect those magnetic shifts, and research scientist Robert Tyler of the University of Maryland and his NASA Goddard Space Flight Centre colleague Terence Sabaka have demonstrated – at least at the proof-of-concept level – that such data can be used to determine the ocean's hidden heat content. "The higher the conductivity of the ocean, the better the dragging," said Tyler, speaking at last month's American Geophysical Union Fall Meeting in San Francisco, California, "and the higher the temperature of the water, the better the conductivity." To fully understand this effect, we need to take a bit of a dive into terminology to understand the difference between *conductance* and *conductivity*. If you'd prefer to skip this geekery, scroll down to "So what?" Conductance, measured in *Siemens*, is the degree to which an actual object – or area of ocean – conducts electricity. Conductivity, measured in Siemens per meter, is the degree to which the substance that comprises an object conducts electricity, irrespective of the specific amount, shape, or configuration. Conductance (units of S) is the electrical conductivity (units of S/m) integrated through the ocean's depth. Still not clear enough? This might help. What's important is that Tyler, working with colleagues at the National Oceanic and Atmospheric Administration (NOAA), examined the global data set of ocean temperature and salinity (the concentration of salt and other inorganic compounds). "From this, we calculated the conductivity and then found that while conductivity varies with salinity and temperature in a regional way, conductance really varies primarily with only the depth-integral of temperature (heat content). The upshot is that if we infer conductance from magnetic data this can be converted into heat content." Bingo. A new way to measure fully depth-integrated ocean heat content.

So what?

As has been proven repeatedly in multiple peer-reviewed studies, and accepted as reality by the vast majority of the world's climate scientists, the Earth is increasingly experiencing an imbalance its incoming and outgoing solar energy. This imbalance is due to an increase in atmospheric concentrations of certain gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and others, the molecular structures of which absorb and re-radiate infrared energy at specific wavelengths, thus returning some of that energy to warm the Earth's land, oceans, ice sheets, and lower atmosphere (troposphere). Although the amount of this heat imbalance is currently tiny – about 0.6±0.4 watts per meter squared (W/m^2) out of the full incoming 340 W/m^2 – that's enough to throw our planet's heat balance out of whack, causing changes in the climate. What's more, according to Tim Boyer of NOAA's National Centres for Environmental Information, also speaking at AGU's Fall Meeting: "More than 90 per cent of that imbalance in the Earth's heat balance is going into the oceans." But there are still uncertainties about how that heat content is distributed in the ocean, and that's a problem when it comes to developing models to accurately predict ocean currents, short and long-term heat-content variability, ice-sheet robustness, future phytoplankton distribution, fishery migrations, and the like. What's more, even though the ocean as a whole is warming, certain parts are either cooling or warming at a slower rate. Since heat-content distribution effects change the dynamics of the oceans, better data is needed to be able to better understand and predict ocean behaviour. Today, our best data for ocean heat content comes from Argo, a global collection of sensor-equipped floats that sink to 2,000 metres every 10 days, then rise to the surface and report temperature and salinity from different depths, as well as info on the direction and velocity of currents. There are more than 3,700 Argo floats operational in the world's oceans. Bad news: most of the ocean is deeper than 2,000 meters. Sorta good news: there is a new generation [PDF] of deep-diving systems being developed, tested, and deployed. These include two that can dive to 4,000 metres: Deep-Arvor, designed by the French oceanographic institute Ifremer and built by NKE Instrumentation, and Deep NINJA, designed by the Japanese research group JAMSTEC and built by Tsurumi-Seiki. Diving to 6,000 metres are two Deep Argo systems: Deep SOLO [PDF], designed by and built at the Scripps Institution of Oceanography, and Deep APEX, designed by the University of Washington [PDF] and built by Teledyne Webb Research. The reason for the "sorta" qualifier is that these new systems are still in their early stages, and it remains unclear if they'll ever be deployed – and funded – anywhere near as effectively and robustly as the current near-global 2,000m Argo system. Enter Tyler and his magnetic field heat-content assessments, which theoretically could determine heat content throughout the oceans' depths. His work is still in its early stages, however; his current computational proof-of-concept model relies on theoretically generated ocean-tide magnetic fields, and not real-world, somewhat-noisy magnetic data – although his model's results are highly correlated with real-world magnetic-field data from land observatories such as those participating in INTERMAGNET, and from Germany's CHAMP minisatellite.

Describing his model's development, Tyler said "I developed a hybrid finite-difference/spherical-harmonic approach for solving the electromagnetic induction equation near the global surface. It happens to be written in the MATLAB language, though using somewhat generic Krylov-subspace solution methods and spherical-harmonic transforms accessible in most other languages (i.e. there's nothing really "MATLAB" about the solution method)." Tyler's magnetic-field method of determining ocean heat content has a powerful ally in the Swarm satellite trio. This mission, building on the earlier work of Denmark's Ørsted and Germany's CHAMP missions, consists of three satellites, Swarm Alpha, Bravo, and Charlie; Alpha and Charlie fly essentially side by side in a polar orbit at an altitude of 462km, and Bravo circles the planet above them at 510km in a polar orbit offset from those of its brethren. Launched in 2013, they've already made discoveries about the subtle interactions of the oceans and the Earth's mantle, and thus its magnetic field. Swarm provides a broad range of high-resolution, quality-assured data, publicly available both through direct FTP download and through a data visualisation, manipulation, and retrieval interface called VirES (explanatory video here). If – when – Tyler and his team succeed in precisely discerning signal from noise in the cavalcade of Swarm data and effectively transforming those data into ocean heat-content information, the goal of satellite-based, whole-globe ocean-heat monitoring may be realised.

So what else?

Let's say that Tyler and his team successfully partner with Swarm and its voluminous data. Who'd then benefit? Well, Catherine Walker of NASA's Jet Propulsion Laboratory, for one. Walker studies the interaction of the warming Southern Ocean with the receding glaciers and melting ice sheets of Antarctica. Unfortunately, Argo data is of little use to her – not only are Argo floats sparse in the Southern Ocean, but around Antarctica that ocean is covered in sea ice half the year.

With Argo data being sparse, Walker and her fellow Antarctic oceanographers have turned to imaginative data sources such as MEOP (Marine Mammals Exploring the Oceans Pole to Pole), a programme in which marine mammals such as seals have satellite-communicating CTD sensors affixed to their heads. CTD stands for "conductivity, temperature, and depth" and since conductivity is directly related to salinity, when combined with temperature they produce density data that oceanographers can use to determine critical information about ocean currents. The global MEOP programme, started in 2004 and expanded to Antarctica in 2005, has as already this year collected 517,429 vertical CTD profiles from what are currently 1,197 tagged marine mammals, many of them being southern elephant seals roaming around the Antarctic. This data is useful, but not ideal – seals obviously can't be told where to go, so their data is randomly distributed. As Walker puts it: "They go wherever they want, and we get data wherever they go." But Walker needs specific and replicable data from, for example, the West Antarctic peninsula, where the seals have told her that the ocean above the continental shelf is warming and thus destabilising the floating ice shelf and the grounded ice sheet behind it. "Thanks, seals," we can imagine Walker thinking, "but I'd prefer the regularity, timeliness, and comprehensiveness of satellite-based, full-depth heat content data." Stephanie Schollaert Uz of NASA's Goddard Space Flight Centre could use some help, too. Since 1997 NASA has been monitoring phytoplankton in the ocean by tracking the concentrations of the pigment chlorophyll. Since 2002, those observations have been made using the MODIS sensor (Moderate Resolution Imaging Spectroradiometer) on NASA's Aqua satellite. Schollaert Uz said at last month's AGU meeting that these observations have "revolutionised" our understanding of phytoplankton distribution. Since it's at the base of many a food chain, knowing the health and distribution of phytoplankton concentrations – and knowing quickly and accurately – can help planners develop strategies for, among other things, fisheries management. And that's where ocean heat content comes in. As Schollaert Uz and her team have discovered in their study of how phytoplankton fared under 50 years of warm El Niño and cooler La Niña conditions in the equatorial Pacific, the little green guys prefer it cool. Tyler's ocean heat-content monitoring could provide fast and accurate information on such conditions and their extents. If Tyler and his crew get their Swarm-based ocean-monitoring system up and running, does that mean the end of the line for expensive, cumbersome, somewhat spotty Argo? "In principle, no other observational method would be needed," Principles, however, thrive best in an ideal world, and not in the messy, noisy, real world in which science is done. "In practice," he continued, "the accuracy will likely benefit and probably even depend on combining with other data. This method does not at this point obviate any other measurements." But it would certainly be useful to Boyer, Walker, Schollaert Uz, and the rest of the oceanographic community – and, by extension, to you and me.

Bootnote

Since phytoplankton concentrations dip during the warm El Niño cycle, we asked Schollaert Uz the obvious question: in an overall warming world will there be an overall decrease in that essential nutrient? Her answer was instructive of the cautious and data-centric manner of a reputable scientist. "That's a big open question, and a lot of people are wondering that," she said.

- Astronomer searches for signs of life on Wolf 1061 exoplanet

Searching for signs of life in one of the extrasolar systems closest to Earth

An artist's rendering of an exoplanet is shown. An exoplanet is a planet that exists outside Earth's solar system.
Credit: Illustration credit: NASA/Ames/JPL-Caltech

Is there anybody out there? The question of whether Earthlings are alone in the universe has puzzled everyone from biologists and physicists to philosophers and filmmakers. It's also the driving force behind San Francisco State University astronomer Stephen Kane's research into exoplanets -- planets that exist outside Earth's solar system. As one of the world's leading "planet hunters," Kane focuses on finding "habitable zones," areas where water could exist in a liquid state on a planet's surface if there's sufficient atmospheric pressure. Kane and his team, including former undergraduate student Miranda Waters, examined the habitable zone on a planetary system 14 light years away. Their findings will appear in the next issue of *Astrophysical Journal* in a paper titled "Characterization of the Wolf 1061 Planetary System." "The Wolf 1061 system is important because it is so close and that gives other opportunities to do follow-up studies to see if it does indeed have life," Kane said. But it's not just Wolf 1061's proximity to Earth that made it an attractive subject for Kane and his team. One of the three known planets in the system, a rocky planet called Wolf 1061c, is entirely within the habitable zone. With assistance from collaborators at Tennessee State University and in Geneva, Switzerland, they were able to measure the star around which the planet orbits to gain a clearer picture of whether life could exist there. When scientists search for planets that could sustain life, they are basically looking for a planet with nearly identical properties to Earth, Kane said. Like Earth, the planet would have to exist in a sweet spot often referred to as the "Goldilocks zone" where conditions are just right for life. Simply put, the planet can't be too close or too far from its parent star. A planet that's too close would be too hot. If it's too far, it may be too cold and any water would freeze, which is what happens on Mars, Kane added. Conversely, when planets warm, a "runaway greenhouse effect" can occur where heat gets trapped in the atmosphere. Scientists believe this is what happened on Earth's twin, Venus. Scientists believe Venus once had oceans, but because of its proximity to the sun the planet became so hot that all the water evaporated, according to NASA. Since water vapour is extremely effective in trapping in heat, it made the surface of the planet even hotter. The surface temperature on Venus now reaches a scalding 880 degrees Fahrenheit. Since Wolf 1061c is close to the inner edge of the habitable zone, meaning closer to the star, it could be that the planet has an atmosphere that's more similar to Venus. "It's close enough to the star where it's looking suspiciously like a runaway greenhouse," Kane said. Kane and his team also observed that unlike Earth, which experiences climatic changes such as an ice age because of slow variations in its orbit around the sun, Wolf 1061c's orbit changes at a much faster rate, which could mean the climate there could be quite chaotic. "It could cause the frequency of the planet freezing over or heating up to be quite severe," Kane said. These findings all raise the question: Is life possible on Wolf 1061c? One possibility is that the short time scales over which Wolf 1061c's orbit changes could be enough that it could actually cool the planet off, Kane said. But fully understanding what's happening on the planet's surface will take more research. In the coming years, there will be a launch of new telescopes like the James Webb Space Telescope, the successor to the Hubble Space Telescope, Kane said, and it will be able to detect atmospheric components of the exoplanets and show what's happening on the surface.

- A tale of two pulsars' tails: Plumes offer geometry lessons to astronomers

An artist's representation of what the three unusual tails of the pulsar Geminga may look like close up. NASA's Chandra X-ray Observatory is giving astronomers a better look at pulsars and their associated pulsar wind nebulae, enabling new constraints on the geometry of pulsars and why they look the way they do from Earth. *Credit: Nahks Tr'Ehn*

Like cosmic lighthouses sweeping the universe with bursts of energy, pulsars have fascinated and baffled astronomers since they were first discovered 50 years ago. In two studies, international teams of astronomers suggest that recent images from NASA's Chandra X-ray Observatory of two pulsars -- Geminga and B0355+54 -- may help shine a light on the distinctive emission signatures of pulsars, as well as their often perplexing geometry. Pulsars are a type of neutron star that are born in supernova explosions when massive stars collapse. Discovered initially by lighthouse-like beams of radio emission, more recent research has found that energetic pulsars also produce beams of high energy gamma rays. Interestingly, the beams rarely match up, said Bettina Posselt, senior research associate in astronomy and astrophysics, Penn State. The shapes of observed radio and gamma-ray pulses are often quite different and some of the objects show only one type of pulse or the other. These differences have generated debate about the pulsar model. "It's not fully understood why there are variations between different pulsars," said Posselt. "One of the main ideas here is that pulse differences have a lot to do with geometry -- and it also depends on how the pulsar's spin and magnetic axes are oriented with respect to line of sight whether you see certain pulsars or not, as well as how you see them." Chandra's images are giving the astronomers a closer than ever look at the distinctive geometry of the charged particle winds radiating in X-ray and other wavelengths from the objects, according to Posselt. Pulsars rhythmically rotate as they rocket through space at speeds reaching hundreds of kilometres a second. Pulsar wind nebulae (PWN) are produced when the energetic particles streaming from pulsars shoot along the stars' magnetic fields, form tori -- donut-shaped rings -- around the pulsar's equatorial plane, and jet along the spin axis, often sweeping back into long tails as the pulsars' quickly cut through the interstellar medium. "This is one of the nicest results of our larger study of pulsar wind nebulae," said Roger W. Romani, professor of physics at Stanford University and principal investigator of the Chandra PWN project. "By making the 3-D structure of these winds visible, we have shown how one can trace back to the plasma injected by the pulsar at the centre. Chandra's fantastic X-ray acuity was essential for this study, so we are happy that it was possible to get the deep exposures that made these faint structures visible." A spectacular PWN is seen around the Geminga pulsar. Geminga -- one of the closest pulsars at only 800 light years away from Earth -- has three unusual tails, said Posselt. The streams of particles spewing out of the alleged poles of Geminga -- or lateral tails -- stretch out for more than half a light year, longer than 1,000 times the distance between the Sun and Pluto. Another shorter tail also emanates from the pulsar. The astronomers said that a much different PWN picture is seen in the X-ray image of another pulsar called B0355+54, which is about 3,300 light years away from Earth. The tail of this pulsar has a cap of emission, followed by a narrow double tail that extends almost five light years away from the star. While Geminga shows pulses in the gamma ray spectrum, but is radio quiet, B0355+54 is one of the brightest radio pulsars, but fails to show gamma rays.

"The tails seem to tell us why that is," said Posselt, adding that the pulsars' spin axis and magnetic axis orientations influence what emissions are seen on Earth. According to Posselt, Geminga may have magnetic poles quite close to the top and bottom of the object, and nearly aligned spin poles, much like Earth. One of the magnetic poles of B0355+54 could directly face the Earth. Because the radio emission occurs near the site of the magnetic poles, the radio waves may point along the direction of the jets, she said. Gamma-ray emission, on the other hand, is produced at higher altitudes in a larger region, allowing the respective pulses to sweep larger areas of the sky. "For Geminga, we view the bright gamma ray pulses and the edge of the pulsar wind nebula torus, but the radio beams near the jets point off to the sides and remain unseen," Posselt said. The strongly bent lateral tails offer the astronomers clues to the geometry of the pulsar, which could be compared to either jet contrails soaring into space, or to a bow shock similar to the shockwave created by a bullet as it is shot through the air. Oleg Kargaltsev, assistant professor of physics, George Washington University, who worked on the study on B0355+54, said that the orientation of B0355+54 plays a role in how astronomers see the pulsar, as well. The study is available online in arXiv. "For B0355+54, a jet points nearly at us so we detect the bright radio pulses while most of the gamma-ray emission is directed in the plane of the sky and misses the Earth," said Kargaltsev. "This implies that the pulsar's spin axis direction is close to our line-of-sight direction and that the pulsar is moving nearly perpendicularly to its spin axis." Noel Klingler, a graduate research assistant in physics, George Washington University, and lead author of the B0355+54 paper, added that the angles between the three vectors -- the spin axis, the line-of-sight, and the velocity -- are different for different pulsars, thus affecting the appearances of their nebulae. "In particular, it may be tricky to detect a PWN from a pulsar moving close to the line-of-sight and having a small angle between the spin axis and our line-of-sight," said Klingler. In the bow-shock interpretation of the Geminga X-ray data, Geminga's two long tails and their unusual spectrum may suggest that the particles are accelerated to nearly the speed of light through a process called Fermi acceleration. The Fermi acceleration takes place at the intersection of a pulsar wind and the interstellar material, according to the researchers, who report their findings on Geminga in the current issue of *Astrophysical Journal*. Although different interpretations remain on the table for Geminga's geometry, Posselt said that Chandra's images of the pulsar are helping astrophysicists use pulsars as particle physics laboratories. Studying the objects gives astrophysicists a chance to investigate particle physics in conditions that would be impossible to replicate in a particle accelerator on earth. "In both scenarios, Geminga provides exciting new constraints on the acceleration physics in pulsar wind nebulae and their interaction with the surrounding interstellar matter," she said.

- ❖ Galaxy murder mystery

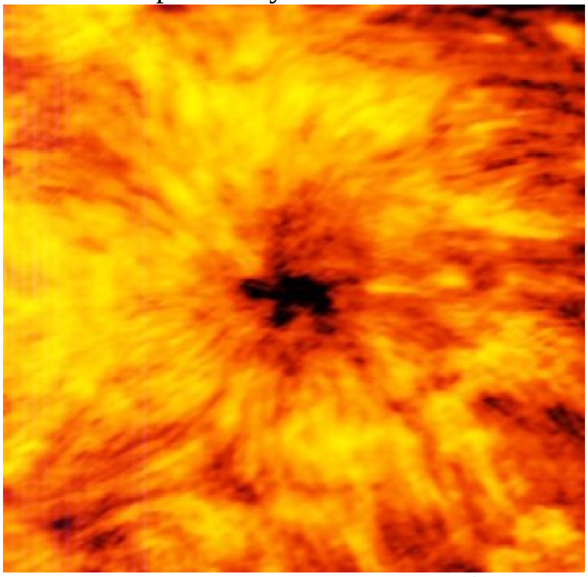

This artist's impression shows the spiral galaxy NGC 4921 based on observations made by the Hubble Space Telescope.
Credit: ICRAR, NASA, ESA, the Hubble Heritage Team. STScI/AURA

It's the big astrophysical whodunit. Across the Universe, galaxies are being killed and the question scientists want answered is, what's killing them? New research published today by a global team of researchers, based at the International Centre for Radio Astronomy Research (ICRAR), seeks to answer that question. The study reveals that a phenomenon called ram-pressure stripping is more prevalent than previously thought, driving gas from galaxies and sending them to an early death by depriving them of the material to make new stars. The study of 11,000 galaxies shows their gas -- the lifeblood for star formation -- is being violently stripped away on a widespread scale throughout the local Universe. Toby Brown, leader of the study and PhD candidate at ICRAR and Swinburne University of Technology, said the image we paint as astronomers is that galaxies are embedded in clouds of dark matter that we call dark matter halos. Dark matter is the mysterious material that despite being invisible accounts for roughly 27 per cent of our Universe, while ordinary matter makes up just 5 per cent. The remaining 68 per cent is dark energy. "During their lifetimes, galaxies can inhabit halos of different sizes, ranging from masses typical of our own Milky Way to halos thousands of times more massive," Mr Brown said.

"As galaxies fall through these larger halos, the superheated intergalactic plasma between them removes their gas in a fast-acting process called ram-pressure stripping. “You can think of it like a giant cosmic broom that comes through and physically sweeps the gas from the galaxies." Mr Brown said removing the gas from galaxies leaves them unable to form new stars. "It dictates the life of the galaxy because the existing stars will cool off and grow old," he said. "If you remove the fuel for star formation then you effectively kill the galaxy and turn it into a dead object." ICRAR researcher Dr Barbara Catinella, co-author of the study, said astronomers already knew ram-pressure stripping affected galaxies in clusters, which are the most massive halos found in the Universe. "This paper demonstrates that the same process is operating in much smaller groups of just a few galaxies together with much less dark matter," said Mr Brown. "Most galaxies in the Universe live in these groups of between two and a hundred galaxies," he said. "We've found this removal of gas by stripping is potentially the dominant way galaxies are quenched by their surrounds, meaning their gas is removed and star formation shuts down." The study was published in the journal *Monthly Notices of the Royal Astronomical Society*.

It used an innovative technique combining the largest optical galaxy survey ever completed -- the Sloan Digital Sky Survey -- with the largest set of radio observations for atomic gas in galaxies -- the Arecibo Legacy Fast ALFA survey. Mr Brown said the other main process by which galaxies run out of gas and die is known as strangulation. "Strangulation occurs when the gas is consumed to make stars faster than its being replenished, so the galaxy starves to death," he said. "It's a slow-acting process. On the contrary, what ram-pressure stripping does is bop the galaxy on the head and remove its gas very quickly -- of the order of tens of millions of years -- and astronomically speaking that's very fast."

- The sun in detail: Contorted centre of sunspot nearly twice the size of Earth



ALMA observes a giant sunspot. This ALMA image of an enormous sunspot was taken at a wavelength of 1.25 millimetres. Sunspots are transient features that occur in regions where the Sun's magnetic field is extremely concentrated and powerful. They have lower temperatures than their surrounding regions, which is why they appear relatively dark.
Credit: ALMA (ESO/NAOJ/NRAO)

New images taken with the Atacama Large Millimetre/submillimetre Array (ALMA) in Chile have revealed otherwise invisible details of our Sun, including a new view of the dark, contorted centre of a sunspot that is nearly twice the diameter of the Earth. The images are the first ever made of the Sun with a facility where ESO is a partner. The results are an important expansion of the range of observations that can be used to probe the physics of our nearest star. The ALMA antennas had been carefully designed so they could image the Sun without being damaged by the intense heat of the focussed light. Astronomers have harnessed ALMA's capabilities to image the millimetre-wavelength light emitted by the Sun's chromosphere -- the region that lies just above the photosphere, which forms the visible surface of the Sun. The solar campaign team, an international group of astronomers with members from Europe, North America and East Asia [1], produced the images as a demonstration of ALMA's ability to study solar activity at longer wavelengths of light than are typically available to solar observatories on Earth. Astronomers have studied the Sun and probed its dynamic surface and energetic atmosphere in many ways through the centuries. But, to achieve a fuller understanding, astronomers need to study it across the entire electromagnetic spectrum, including the millimetre and submillimetre portion that ALMA can observe. Since the Sun is many billions of times brighter than the faint objects ALMA typically observes, the ALMA antennas were specially designed to allow them to image the Sun in exquisite detail using the technique of radio interferometry -- and avoid damage from the intense heat of the focussed sunlight [2]. The result of this work is a series of images that demonstrate ALMA's unique vision and ability to study our Sun. The data from the solar observing campaign are being released this week to the worldwide astronomical community for further study and analysis. The team observed an enormous sunspot at wavelengths of 1.25 millimetres and 3 millimetres using two of ALMA's receiver bands. The images reveal differences in temperature between parts of the Sun's chromosphere [3]. Understanding the heating and dynamics of the chromosphere are key areas of research that will be addressed in the future using ALMA. Sunspots are transient features that occur in regions where the Sun's magnetic field is extremely concentrated and powerful. They are lower in temperature than the surrounding regions, which is why they appear relatively dark. The difference in appearance between the two images is due to the different wavelengths of emitted light being observed. Observations at shorter wavelengths are able to probe deeper into the Sun, meaning the 1.25 millimetre images show a layer of the chromosphere that is deeper, and therefore closer to the photosphere, than those made at a wavelength of 3 millimetres. ALMA is the first facility where ESO is a partner that allows astronomers to study the nearest star, our own Sun. All other existing and past ESO facilities need to be protected from the intense solar radiation to avoid damage. The new ALMA capabilities will expand the ESO community to include solar astronomers.

Notes

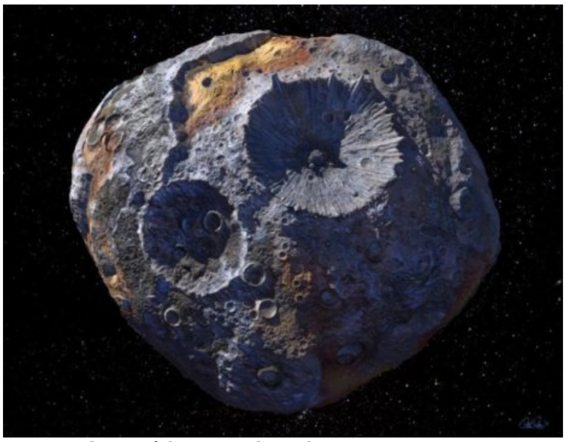
[1] The ALMA Solar Campaign team includes: Shin'ichiro Asayama, East Asia ALMA Support Centre, Tokyo, Japan; Miroslav Barta, Astronomical Institute of the Czech Academy of Sciences, Ondrejov, Czech Republic; Tim Bastian, National Radio Astronomy Observatory, USA; Roman Brajsa, Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia; Bin Chen, New Jersey Institute of Technology, USA; Bart De Pontieu, LMSAL, USA;

Gregory Fleishman, New Jersey Institute of Technology, USA; Dale Gary, New Jersey Institute of Technology, USA; Antonio Hales, Joint ALMA Observatory, Chile; Akihiko Hirota, Joint ALMA Observatory, Chile; Hugh Hudson, School of Physics and Astronomy, University of Glasgow, UK; Richard Hills, Cavendish Laboratory, Cambridge, UK; Kazumasa Iwai, National Institute of Information and Communications Technology, Japan; Sujin Kim, Korea Astronomy and Space Science Institute, Daejeon, Republic of Korea; Neil Philips, Joint ALMA Observatory, Chile; Tsuyoshi Sawada, Joint ALMA Observatory, Chile; Masumi Shimojo (interferometry lead), NAOJ, Tokyo, Japan; Giorgio Siringo, Joint ALMA Observatory, Chile; Ivica Skokic, Astronomical Institute of the Czech Academy of Sciences, Ondrejov, Czech Republic; Sven Wedemeyer, Institute of Theoretical Astrophysics, University of Oslo, Norway; Stephen White (single dish lead), AFRL, USA; Pavel Yagoubov, ESO, Garching, Germany and Yihua Yan, NAO, Chinese Academy of Sciences, Beijing, China.

[2] Indeed, this lesson has been learned the hard way: the Swedish-ESO Submillimetre Telescope (SEST) had a fire in its secondary mirror assembly after the telescope was accidentally pointed at the Sun.

[3] A map of the whole disc of the Sun was also made with a single ALMA antenna, using a technique called fast-scanning, at a wavelength of 1.25 millimetres. The accuracy and speed of observing with a single ALMA antenna makes it possible to produce a map of the entire solar disc in just a few minutes. These maps show the distribution of temperatures in the chromosphere over the whole disc at low spatial resolution and therefore complement the detailed interferometric images of individual regions of interest.

❖ Deep-space mission to metal asteroid Psyche to offer unique look into violent collisions that created Earth, terrestrial planets


Artist rendition of the asteroid Psyche.
Credit: Image by Peter Rubin/ASU

Arizona State University's Psyche Mission, a journey to a metal asteroid, has been selected for flight, marking the first time the school will lead a deep-space NASA mission and the first time scientists will be able to see what is believed to be a planetary core. The mission's spacecraft is expected to launch in 2023, arriving at the asteroid in 2030, where it will spend 20 months in orbit, mapping it and studying its properties. It will be part of NASA's Discovery Program, a series of lower-cost, highly focused robotic space missions that are exploring the solar system. The Psyche project is capped at $450 million. "This mission, visiting the asteroid Psyche, will be the first time humans will ever be able to see a planetary core," said principal investigator Lindy Elkins-Tanton, director of ASU's School of Earth and Space Exploration (SESE). "Having the Psyche Mission selected for NASA's Discovery Program will help us gain insights into the metal interior of all rocky planets in our solar system, including Earth." Psyche, an asteroid orbiting the sun between Mars and Jupiter, is made almost entirely of nickel-iron metal. As such, it offers a unique look into the violent collisions that created Earth and the other terrestrial planets. The scientific goals of the Psyche mission are to understand the building blocks of planet formation and explore first-hand a wholly new and unexplored type of world. The mission team seeks to determine whether Psyche is a protoplanetary core, how old it is, whether it formed in similar ways to Earth's core, and what its surface is like. "The knowledge this mission will create has the potential to affect our thinking about planetary science for generations to come," ASU President Michael M. Crow said. "We are in a new era of exploration of our solar system with new public-private sector partnerships helping unlock new worlds of discovery, and ASU will be at the forefront of that research."

Psyche -- a window into planetary cores

Every world explored so far by humans (except gas giant planets such as Jupiter or Saturn) has a surface of ice or rock or a mixture of the two, but their cores are thought to be metallic. These cores, however, lie far below rocky mantles and crusts and are considered unreachable in our lifetimes. Psyche, an asteroid that appears to be the exposed nickel-iron core of a protoplanet, one of the building blocks of the sun's planetary system, may provide a window into those cores. The asteroid is most likely a survivor of violent space collisions, common when the solar system was forming. Psyche follows an orbit in the outer part of the main asteroid belt, at an average distance from the sun of about 280 million miles, or three times farther from the sun than Earth. It is roughly the size of Massachusetts (about 130 miles in diameter) and dense (7,000 kg/m³). "Being selected to lead this ambitious mission to the all-metal asteroid Psyche is a major milestone that reflects ASU's outstanding research capacity," said Sethuraman Panchanathan, executive vice president and chief research and innovation officer at ASU. "It speaks to our innovative spirit and our world-class scientific expertise in space exploration."

Mission instrument payload

The spacecraft's instrument payload will include magnetometers, multispectral imagers, a gamma ray and neutron spectrometer, and a radio-science experiment. The multispectral imager, which will be led by an ASU science team, will provide high-resolution images using filters to discriminate between Psyche's metallic and silicate constituents. It consists of a pair of identical cameras designed to acquire geologic, compositional and topographic data. The gamma ray and neutron spectrometer will detect, measure and map Psyche's elemental composition. The instrument is mounted on a 7-foot (2-meter) boom to distance the sensors from background radiation created by energetic particles interacting with the spacecraft and to provide an unobstructed field of view. The science team for this instrument is based at the Applied Physics Laboratory at Johns Hopkins University. The magnetometer, which is led by scientists at MIT and UCLA, is designed to detect and measure the remnant magnetic field of the asteroid. It's composed of two identical high-sensitivity magnetic field sensors located at the middle and outer end of the boom. The Psyche spacecraft will also use an X-band radio telecommunications system, led by scientists at MIT and NASA's Jet Propulsion Laboratory. This instrument will measure Psyche's gravity field and, when combined with topography derived from on board imagery, will provide information on the interior structure of the asteroid.

The Psyche mission team

In addition to Elkins-Tanton, ASU SESE scientists on the Psyche mission team include Jim Bell, deputy principal investigator and co-investigator, co-investigator Erik Asphaug, and co-investigator David Williams.

NASA's Jet Propulsion Laboratory managed by Caltech is the managing organization and will build the spacecraft with industry partner Space Systems Loral (SSL). JPL's contribution to the Psyche mission team includes over 75 people, led by project manager Henry Stone, project scientist Carol Polanskey, project systems engineer David Oh and deputy project manager Bob Mase. SSL contribution to the Psyche mission team includes over 50 people led by SEP Chassis deputy program manager Peter Lord and SEP Chassis program manager Steve Scott.

Other co-investigators are David Bercovici (Yale University), Bruce Bills (JPL), Richard Binzel (Massachusetts Institute of Technology), William Bottke (Southwest Research Institute -- SwRI), Ralf Jaumann (Deutsches Zentrum für Luft -- und Raumfahrt), Insoo Jun (JPL), David Lawrence (Johns Hopkins University/Applied Physics Laboratory -- APL), Simon Marchi (SwRI), Timothy McCoy (Smithsonian Institution), Ryan Park (JPL), Patrick Peplowski (APL), Thomas Prettyman, (Planetary Science Institute), Carol Raymond (JPL), Chris Russell (UCLA), Benjamin Weiss (MIT), Dan Wenkert (JPL), Mark Wieczorek (Institut de Physique du Globe de Paris), and Maria Zuber (MIT).

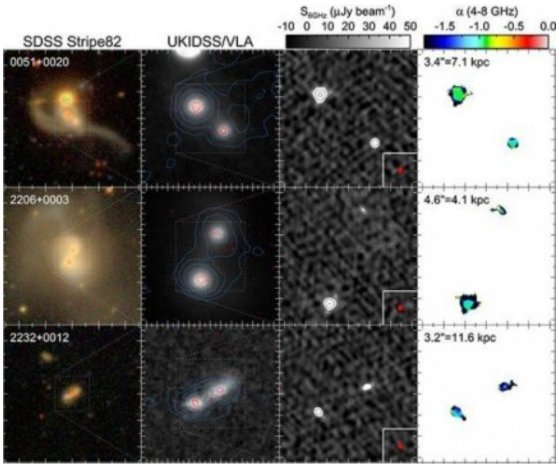
- How Earth's previous moons collided to form the moon: New theory

A team of Israeli researchers suggests that the Moon we see every night is not Earth's first moon, but rather the last in a series of moons that orbited the Earth in the past.
Credit: © Gudellaphoto / Fotolia

The Moon, and the question of how it was formed, has long been a source of fascination and wonder. Now, a team of Israeli researchers suggests that the Moon we see every night is not Earth's first moon, but rather the last in a series of moons that orbited Earth in the past. The findings by the team of researchers from the Technion-Israel Institute of Technology and the Weizmann Institute of Science are published in *Nature Geoscience*. The newly proposed theory by researchers Prof. Hagai Perets, of the Technion, and Weizmann Institute Profs. Raluca Rufo (lead author)and Oded Aharonson, runs counter to the commonly held "giant impact" paradigm that the moon is a single object that was formed following a single giant collision between a small Mars-like planet and the ancient Earth. "Our model suggests that the ancient Earth once hosted a series of moons, each one formed from a different collision with the proto-Earth," said co-author Prof. Perets. "It's likely that such moonlets were later ejected, or collided with Earth or with each other to form bigger moons." To check the conditions for the formation of such mini-moons or moonlets the researchers ran 800 simulations of impacts with Earth. The new model is consistent with science's current understanding of the formation of Earth. In its last stages of the growth, Earth experienced many giant impacts with other bodies. Each of these impacts contributed more material to the proto-Earth, until it reached its current size. "We believe Earth had many previous moons," said Prof. Perets, who added that, "a previously formed moon could therefore already exist when another moon-forming giant impact occurs." The tidal forces from Earth could cause moons to slowly migrate outwards (the current Moon is slowly doing that at a pace of about 1 cm a year). A pre-existing moon would slowly move out by the time another moon forms. However, their mutual gravitational attraction would eventually cause the moons to affect each other, and change their orbits. "It's likely that small moons formed through the process could cross orbits, collide and merge," said lead author Prof. Rufo. "A long series of such moon-moon collisions could gradually build-up a bigger moon -- the Moon we see today."

- ❖ Understanding blended galaxies

Astrophysicist wins grant to find and characterize super massive black holes associated with merging galaxies



This image shows three instances of merging galaxies located at least a billion light years from Earth. Each galaxy is as large as the Milky Way and contains about 100 billion stars. Violent gravitational interactions created the tidal tails shown and triggered massive black hole accretion at the galactic nuclei. These systems were first confirmed by Hai Fu in 2015.
Credit: Hai Fu, University of Iowa

In roughly four billion years, the Milky Way will be no more. Indeed, our home galaxy is on course to collide and unite with the Andromeda Galaxy, at present some two million light years away. Of course, we don't notice that the two galaxies are drawing closer together. "To the human perspective, our galaxy doesn't appear to be changing," says University of Iowa astrophysicist Hai Fu, "but in the history of the universe, it is changing all the time." Galaxies have been merging for most of the universe's 13-billion-year history, and scientists have been observing these mergers for some time. What they don't fully understand is how mergers occur. Fu, an assistant professor in physics and astronomy, aims to clarify the phenomenon by observing supermassive black holes (with a mass of about one billion suns), which are at the centre of most galaxies. Astrophysicists believe large galaxies grow by devouring

smaller ones. In such cases, the black holes of both are expected to orbit each other and eventually merge. Fu and his team won a three-year, $405,011 grant from the National Science Foundation to find and characterize these celestial events. "What we're trying to see is the late stages of merging galaxies, when two galaxies are so close together they unleash tidal forces of energy, kind of like the pulsing tidal forces caused when the sun and moon line up with Earth but much, much more intense," he says. Fu will scan a large chunk of the night sky -- imagine the moon multiplied 1,200 across the sky and you'll have a sense of the size -- to find evidence of black holes' accretion, or mass-gathering.
"Pairs of galaxies with accreting black holes are rare and difficult to find," Fu says, "and that's why we need such a large area to survey." Black holes aren't always accreting. But those that are resemble someone on an eating binge. Accreting black holes hungrily absorb material around them. Slowly, as they munch on more and more cosmic food, they pull their host galaxies closer together.
"They're no longer on a diet," Fu says.
All that eating unleashes a torrent of energy, intense bursts of light called quasars that are so bright they nearly obscure the galaxies themselves. Those quasars should be easy to observe, even at great distances, but most of the light they produce is actually extinguished by the dust brewed up in the merging activity. Thankfully, supermassive black holes also emit radio waves, and those emissions "come to the rescue because they don't get extinguished by the dust," Fu says. Fu and his team will examine radio-emission maps captured by the Very Large Array, one of the world's premier astronomical radio observatories, located in New Mexico and operated by the National Radio Astronomy Observatory, an NSF facility. The group will confirm its findings through optical observations at the W.M. Keck Observatory, located on Mauna Kea, a dormant volcano in Hawaii. The NSF grant also will fund the student-led building of an "augmented reality sandbox" to demonstrate gravity's influence in the universe, such as on the orbits of planets, the accretion disk around a black hole or neutron star, and the complex orbits of stars in elliptically shaped galaxies. Nine undergraduates have so far been involved in the project; they divided into teams to write the software programming, build the sandbox (with actual sand), and create an app for Android tablets. The sandbox will be used in astronomy classes, physics demonstrations for K-12 students in the greater Iowa City area, and exhibitions at the UI Museum of Natural History and the UI Mobile Museum.
The sandbox is expected to be complete by the end of the spring 2017 semester.
"It is quite impressive," Fu says. "The students may not necessarily like taking exams, but they work really well in teams."

- ❖ Hubble's front row seat when galaxies collide

IRAS 14348-1447 is located over a billion light-years away from us. It is one of the most gas-rich examples known of an ultra-luminous infrared galaxy, a class of cosmic objects that shine characteristically -- and incredibly -- brightly in the infrared part of the spectrum. Almost 95% of the energy emitted by IRAS 14348-1447 is in the far-infrared!
Credit: ESA/Hubble & NASA

IRAS 14348-1447 is located over a billion light-years away from us. It is one of the most gas-rich examples known of an ultra-luminous infrared galaxy, a class of cosmic objects that shine characteristically -- and incredibly -- brightly in the infrared part of the spectrum. Almost 95% of the energy emitted by IRAS 14348-1447 is in the far-infrared!
Credit: ESA/Hubble & NASA
This delicate smudge in deep space is far more turbulent than it first appears. Known as IRAS 14348-1447 -- a name derived in part from that of its discoverer, the Infrared Astronomical Satellite (IRAS for short) -- this celestial object is actually a combination of two gas-rich spiral galaxies. This doomed duo approached one another too closely in the past, gravity causing them to affect and tug at each other and slowly, destructively, merge into one. The image was taken by Hubble's Advanced Camera for Surveys (ACS).
IRAS 14348-1447 is located over a billion light-years away from us. It is one of the most gas-rich examples known of an ultra luminous

infrared galaxy, a class of cosmic objects that shine characteristically -- and incredibly -- brightly in the infrared part of the spectrum. Almost 95% of the energy emitted by IRAS 14348-1447 is in the far-infrared! The huge amount of molecular gas within IRAS 14348-1447 fuels its emission, and undergoes a number of dynamical processes as it interacts and moves around; these very same mechanisms are responsible for IRAS 14348-1447's own whirling and ethereal appearance, creating prominent tails and wisps extending away from the main body of the galaxy.

- Searching for planets in the Alpha Centauri system

This image shows the closest stellar system to the Sun, the bright double star Alpha Centauri AB and its distant and faint companion Proxima Centauri. In late 2016 ESO signed an agreement with the Breakthrough Initiatives to adapt the VLT instrumentation to conduct a search for planets in the Alpha Centauri system. Such planets could be the targets for an eventual launch of miniature space probes by the Breakthrough Starshot Initiative.
Credit: ESO/B. Tafreshi (twanight.org)/Digitized Sky Survey 2 Acknowledgement: Davide De Martin/Mahdi Zamani

ESO has signed an agreement with the Breakthrough Initiatives to adapt the Very Large Telescope instrumentation in Chile to conduct a search for planets in the nearby star system Alpha Centauri. Such planets could be the targets for an eventual launch of miniature space probes by the Breakthrough Starshot initiative. ESO, represented by the Director General, Tim de Zeeuw, has signed an agreement with the Breakthrough Initiatives, represented by Pete Worden, Chairman of the Breakthrough Prize Foundation and Executive Director of the Breakthrough Initiatives. The agreement provides funds for the VISIR (VLT Imager and Spectrometer for mid-Infrared) instrument, mounted at ESO's Very Large Telescope (VLT) to be modified in order to greatly enhance its ability to search for potentially habitable planets around Alpha Centauri, the closest stellar system to the Earth. The agreement also provides for telescope time to allow a careful search programme to be conducted in 2019.
The discovery in 2016 of a planet, Proxima b, around Proxima Centauri, the third and faintest star of the Alpha Centauri system, adds even further impetus to this search. Knowing where the nearest exoplanets are is of paramount interest for Breakthrough Starshot, the research and engineering programme launched in April 2016, which aims to demonstrate proof of concept for ultra-fast light-driven "nanocraft," laying the foundation for the first launch to Alpha Centauri within a generation. Detecting a habitable planet is an enormous challenge due to the brightness of the planetary system's host star, which tends to overwhelm the relatively dim planets. One way to make this easier is to observe in the mid-infrared wavelength range, where the thermal glow from an orbiting planet greatly reduces the brightness gap between it and its host star. But even in the mid-infrared, the star remains millions of times brighter than the planets to be detected, which calls for a dedicated technique to reduce the blinding stellar light. The existing mid-infrared instrument VISIR on the VLT will provide such performance if it were enhanced to greatly improve the image quality using adaptive optics, and adapted to employ a technique called coronagraphy to reduce the stellar light and thereby reveal the possible signal of potential terrestrial planets.
Breakthrough Initiatives will pay for a large fraction of the necessary technologies and development costs for such an experiment, and ESO will provide the required observing capabilities and time. The new hardware includes an instrument module contracted to Kampf Telescope Optics (KTO), Munich, which will host the wave front sensor, and a novel detector calibration device. In addition, there are plans for a new coronagraph to be developed jointly by University of Liège (Belgium) and Uppsala University (Sweden).
Detecting and studying potentially habitable planets orbiting other stars will be one of the main scientific goals of the upcoming European Extremely Large Telescope (E-ELT). Although the increased size of the E-ELT will be essential to obtaining an image of a planet at larger distances in the Milky Way, the light collecting power of the VLT is just sufficient to image a planet around the nearest star, Alpha Centauri. The developments for VISIR will also be beneficial for the future

METIS instrument, to be mounted on the E-ELT, as the knowledge gained and proof of concept will be directly transferable. The huge size of the E-ELT should allow METIS to detect and study exoplanets the size of Mars orbiting Alpha Centauri, if they exist, as well as other potentially habitable planets around other nearby stars.