South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 559 – December 3rd 2021 Editor: Roger Burgess
Main Speaker 19:30 Bob Bravington Dangers of living in space ,and why astronauts get sick

Last month's Covid-19 rules still apply at the planetarium
The Christmas Buffet will be provided at this meeting

- Life on Mars search could be misled by false fossils, study says

Date: November 16, 2021
Source: University of Edinburgh

Mars explorers searching for signs of ancient life could be fooled by fossil-like specimens created by chemical processes, research suggests.
Rocks on Mars may contain numerous types of non-biological deposits that look similar to the kinds of fossils likely to be found if the planet ever supported life, a study says.
Telling these false fossils apart from what could be evidence of ancient life on the surface of Mars -- which was temporarily habitable four billion years ago -- is key to the success of current and future missions, researchers say.
Astrobiologists from the Universities of Edinburgh and Oxford reviewed evidence of all known processes that could have created lifelike deposits in rocks on Mars.
They identified dozens of processes -- with many more likely still undiscovered -- that can produce structures that mimic those of microscopic, simple lifeforms that may once have existed on Mars.
Among the lifelike specimens these processes can create are deposits that look like bacterial cells and carbon-based molecules that closely resemble the building blocks of all known life.
Because signs of life can be so closely mimicked by non-living processes, the origins of any fossil-like specimens found on Mars are likely to be very ambiguous, the team says.
They call for greater interdisciplinary research to shed more light on how lifelike deposits could form on Mars, and thereby aid the search for evidence of ancient life there and elsewhere in the solar system.
The research is published in the *Journal of the Geological Society*.
Dr Sean McMahon, Chancellor's Fellow in Astrobiology at the University of Edinburgh's School of Physic and Astronomy, said: "At some stage a Mars rover will almost certainly find something that looks a lot like a fossil, so being able to confidently distinguish these from structures and substances made by chemical reactions is vital. For every type of fossil out there, there is at least one non-biological process that creates very similar things, so there is a real need to improve our understanding of how these forms."
Julie Cosmidis, Associate Professor of Geobiology at the University of Oxford, said: "We have been fooled by life-mimicking processes in the past. On many occasions, objects that looked like fossil microbes were described in ancient rocks on Earth and even in meteorites from Mars, but after deeper examination they turned out to have non-biological origins. This article is a cautionary tale in which we call for further research on life-mimicking processes in the context of Mars, so that we avoid falling into the same traps over and over again."

- Rocky exoplanets are even stranger than we thought

A new astrogeology study suggests that most nearby rocky exoplanets are quite unlike anything in our Solar System

Date: November 2, 2021
Source: Association of Universities for Research in Astronomy (AURA)

Rocky planet and star illustration (stock image).

Credit: © MonstaBot / stock.adobe.com

An astronomer from NSF's NOIRLab has teamed up with a geologist from California State University, Fresno, to make the first estimates of rock types that exist on planets orbiting nearby stars. After studying the chemical composition of "polluted" white dwarfs, they have concluded that most rocky planets orbiting nearby stars are more diverse and exotic than previously thought, with types of rocks not found anywhere in our Solar System.

Astronomers have discovered thousands of planets orbiting stars in our galaxy -- known as exoplanets. However, it's difficult to know what exactly these planets are made of, or whether any resemble Earth. To try to find out, astronomer Siyi Xu of NSF's NOIRLab partnered with geologist Keith Putirka of California State University, Fresno, to study the atmospheres of what are known as polluted white dwarfs. These are the dense, collapsed cores of once-normal stars like the Sun that contain foreign material from planets, asteroids, or other rocky bodies that once orbited the star but eventually fell into the white dwarf and "contaminated" it's atmosphere. By looking for elements that wouldn't naturally exist in a white dwarf's atmosphere (anything other than hydrogen and helium), scientists can figure out what the rocky planetary objects that fell into the star were made of.

Putirka and Xu looked at 23 polluted white dwarfs, all within about 650 light-years of the Sun, where calcium, silicon, magnesium, and iron had been measured with precision using the W. M. Keck Observatory in Hawai'i, the Hubble Space Telescope, and other observatories. The scientists then used the measured abundances of those elements to reconstruct the minerals and rocks that would form from them. They found that these white dwarfs have a much wider range of compositions than any of the inner planets in our Solar System, suggesting their planets had a wider variety of rock types. In fact, some of the compositions are so unusual that Putirka and Xu had to create new names (such as "quartz pyroxenites" and "periclase dunites") to classify the novel rock types that must have existed on those planets.

"While some exoplanets that once orbited polluted white dwarfs appear similar to Earth, most have rock types that are exotic to our Solar System," said Xu. "They have no direct counterparts in the Solar System."

Putirka describes what these new rock types might mean for the rocky worlds they belong to. "Some of the rock types that we see from the white dwarf data would dissolve more water than rocks on Earth and might impact how oceans are developed," he explained. "Some rock types might melt at much lower temperatures and produce thicker crust than Earth rocks, and some rock types might be weaker, which might facilitate the development of plate tectonics."

Earlier studies of polluted white dwarfs had found elements from rocky bodies, including calcium, aluminium, and lithium. However, Putirka and Xu explain that those are minor elements (which typically make up a small part of an Earth rock) and measurements of major elements (which make up a large part of an Earth rock), especially silicon, are needed to truly know what kind of rock types would have existed on those planets.

In addition, Putirka and Xu state that the high levels of magnesium and low levels of silicon measured in the white dwarfs' atmospheres suggest that the rocky debris detected likely came from the interiors of the planets -- from the mantle, not their crust. Some previous studies of polluted white dwarfs reported signs that continental crust existed on the rocky planets that once orbited those stars, but Putirka and Xu found no evidence of crustal rocks. However, the observations do not completely rule out that the planets had continental crust or other crust types. "We believe that if crustal rock exists, we are unable to see it, probably because it occurs in too small a fraction compared to the mass of

other planetary components, like the core and mantle, to be measured," Putirka stated.
According to Xu, the pairing of an astronomer and a geologist was the key to unlocking the secrets hidden in the atmospheres of the polluted white dwarfs. "I met Keith Putirka at a conference and was excited that he could help me understand the systems that I was observing. He taught me geology and I taught him astronomy, and we figured out how to make sense of these mysterious exoplanetary systems."
The pair's results are published in the 2 November 2021 issue of *Nature Communications*.
Notes
[1] "Normal" or existing rock classification methods are based on the fact that olivine and orthopyroxene are the dominant minerals in Earth's mantle (and the mantles of other rocky planets in our Solar System). For many exoplanets, though, olivine might be absent and quartz present, or orthopyroxene could be absent and periclase is present, and so a new classification nomenclature was developed. The new rock type classifications proposed by Putirka and Xu include: "quartz pyroxenites," which have more than 10% each of orthopyroxene, clinopyroxene, and quartz; "quartz orthopyroxenites," which have more than 10% orthopyroxene and quartz, and less than 10% clinopyroxene; "periclase dunites," which have more than 10% each of periclase and olivine, and less than 10% clinopyroxene; "periclase wehrlites," which contain more than 10% each of periclase, olivine, and clinopyroxene; and "periclase clinopyroxenites," which have less than 10% olivine and more than 10% each of periclase and clinopyroxene.

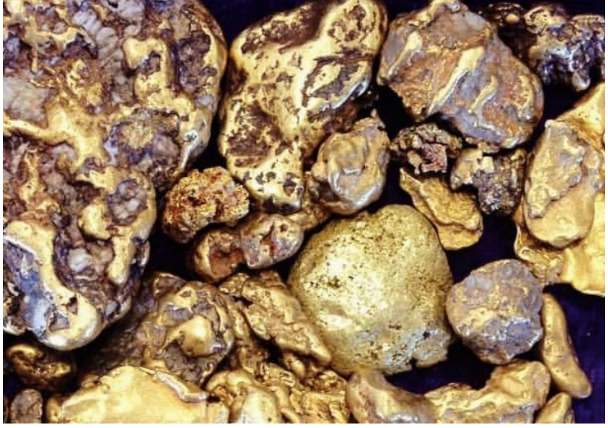
- Carbon dioxide cold traps on the moon are confirmed for the first time

The traps likely contain solid carbon dioxide that could be used to sustain robot or human presence on the moon
Date: November 15, 2021
Source: American Geophysical Union
After decades of uncertainty, researchers have confirmed the existence of lunar carbon dioxide cold traps that could potentially contain solid carbon dioxide. The discovery will likely have a major influence in shaping future lunar missions and could impact the feasibility of a sustained robot or human presence on the moon.
In the permanently shadowed regions at the poles of our moon, temperatures dip below those in the coldest areas of Pluto, allowing for carbon dioxide cold traps. In these cold traps, carbon dioxide molecules could freeze and remain in solid form even during peak temperatures in the lunar summer.
Future human or robot explorers could use the solid carbon dioxide in these cold traps to produce fuel or materials for longer lunar stays. The carbon dioxide and other potential volatile organics could also help scientists better understand the origin of water and other elements on the moon.
Although cold traps have been predicted by planetary scientists for years, this new study is the first to firmly establish and map the presence of carbon dioxide cold traps. To find the coldest spots on the moon's surface, researchers analysed 11 years of temperature data from the Diviner Lunar Radiometer Experiment, an instrument flying aboard NASA's Lunar Reconnaissance Orbiter.
The new research, published in the AGU journal *Geophysical Research Letters*, which publishes high-impact, short-format reports with immediate implications spanning all Earth and space sciences, shows that these cold traps include several pockets concentrated around the lunar southern pole. The total area of these carbon dioxide traps totals 204 square kilometres, with the largest area in the Amundsen Crater hosting 82 square kilometres of traps. In these areas, temperatures continually remain below 60 degrees Kelvin (about minus 352 degrees Fahrenheit.)
The existence of carbon dioxide cold traps does not guarantee the existence of solid carbon dioxide on the moon, but this verification does make it highly likely that future missions could find carbon dioxide ice there, according to the researchers.
"I think when I started this, the question was, 'Can we confidently say there are carbon dioxide cold traps on the moon or not?'" said Norbert Schörghofer, a planetary scientist at the Planetary Science Institute and lead author on the study. "My surprise was that they're actually, definitely there. It could have been that we can't establish their existence, [they might have been] one pixel on a map... so I think the surprise was that we really found contiguous regions which are cold enough, beyond doubt."
Managing the moon

The existence of carbon dioxide traps on the moon will likely have implications for the planning of future lunar exploration and international policy regarding the resource.
If there is indeed solid carbon dioxide in these cold traps, it could potentially be used in a variety of ways. Future space explorers could use the resource in the production of steel as well as rocket fuel and biomaterials, which would both be essential for sustained robot or human presence on the moon. This potential has already attracted interest from governments and private companies.
Scientists could also study lunar carbon to understand how organic compounds form and what kind of molecules can be naturally produced in these harsh environments.
The carbon dioxide cold traps could also help scientists answer long-standing questions about the origins of water and other volatiles in the Earth-moon system, according to Paul Hayne, a planetary scientist at the University of Colorado, Boulder who was not involved in the study.
Carbon dioxide could be a tracer for the sources of water and other volatiles on the lunar surface, helping scientists to understand how they arrived on the moon and on Earth.
"These should be high-priority sites to target for future landed missions," Hayne said. "This sort of pinpoints where you might go on the lunar surface to answer some of these big questions about volatiles on the moon and their delivery from elsewhere in the solar system."

- Where does gold come from? New insights into element synthesis in the universe

Date: November 15, 2021
Source: GSI Helmholtzzentrum für Schwerionenforschung GmbH



How are chemical elements produced in our Universe? Where do heavy elements like gold and uranium come from? Using computer simulations, a research team from the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, together with colleagues from Belgium and Japan, shows that the synthesis of heavy elements is typical for certain black holes with orbiting matter accumulations, so-called accretion disks. The predicted abundance of the formed elements provides insight into which heavy elements need to be studied in future laboratories -- such as the Facility for Antiproton and Ion Research (FAIR), which is currently under construction -- to unravel the origin of heavy elements. The results are published in the journal *Monthly Notices of the Royal Astronomical Society.*
All heavy elements on Earth today were formed under extreme conditions in astrophysical environments: inside stars, in stellar explosions, and during the collision of neutron stars. Researchers are intrigued with the question in which of these astrophysical events the appropriate conditions for the formation of the heaviest elements, such as gold or uranium, exist. The spectacular first observation of gravitational waves and electromagnetic radiation originating from a neutron star merger in 2017 suggested that many heavy elements can be produced and released in these cosmic collisions. However, the question remains open as to when and why the material is ejected and whether there may be other scenarios in which heavy elements can be produced.
Promising candidates for heavy element production are black holes orbited by an accretion disk of dense and hot matter. Such a system is formed both after the merger of two massive neutron stars and during a so-called collapsar, the collapse and subsequent explosion of a rotating star. The internal composition of such accretion disks has so far not been well understood, particularly with respect to the conditions under which an excess of neutrons forms. A high number of neutrons is a basic requirement for the synthesis of heavy elements, as it enables the rapid neutron-capture process or r-process. Nearly massless neutrinos play a key role in this process, as they enable conversion between protons and neutrons.
"In our study, we systematically investigated for the first time the conversion rates of neutrons and protons for a large number of disk configurations by means of elaborate computer simulations, and we found that the disks are very rich in neutrons as long as certain conditions are met," explains Dr.

Oliver Just from the Relativistic Astrophysics group of GSI's research division Theory. "The decisive factor is the total mass of the disk. The more massive the disk, the more often neutrons are formed from protons through capture of electrons under emission of neutrinos, and are available for the synthesis of heavy elements by means of the r-process. However, if the mass of the disk is too high, the inverse reaction plays an increased role so that more neutrinos are recaptured by neutrons before they leave the disk. These neutrons are then converted back to protons, which hinders the r-process." As the study shows, the optimal disk mass for prolific production of heavy elements is about 0.01 to 0.1 solar masses. The result provides strong evidence that neutron star mergers producing accretion disks with these exact masses could be the point of origin for a large fraction of the heavy elements. However, whether and how frequently such accretion disks occur in collapsar systems is currently unclear.
In addition to the possible processes of mass ejection, the research group led by Dr. Andreas Bauswein is also investigating the light signals generated by the ejected matter, which will be used to infer the mass and composition of the ejected matter in future observations of colliding neutron stars. An important building block for correctly reading these light signals is accurate knowledge of the masses and other properties of the newly formed elements. "These data are currently insufficient. But with the next generation of accelerators, such as FAIR, it will be possible to measure them with unprecedented accuracy in the future. The well-coordinated interplay of theoretical models, experiments, and astronomical observations will enable us researchers in the coming years to test neutron star mergers as the origin of the r-process elements," predicts Bauswein.

- ❖ Astronomers team up to create new method to understand galaxy evolution

A husband-and-wife team of astronomers established the star formation history of a post-starburst galaxy using its cluster population.
Date: November 16, 2021
Source: University of Toledo
A husband-and-wife team of astronomers at The University of Toledo joined forces for the first time in their scientific careers during the pandemic to develop a new method to look back in time and change the way we understand the history of galaxies.
Until now forging parallel but separate careers while juggling home life and carpooling to cross country meets, Dr. Rupali Chandar, professor of astronomy, and Dr. J.D. Smith, director of the UToledo Ritter Astrophysical Research Centre and professor of astronomy, merged their areas of expertise.
Working along with UToledo alumnus Dr. Adam Smercina who graduated with a bachelor's degree in physics in 2015 and is currently a postdoctoral researcher at the University of Washington, they used NASA's Hubble Space Telescope to focus on a post-starburst galaxy nearly 500 million light years away called S12 that looks like a jellyfish with a host of stars streaming out of the galaxy on one side.
Smercina, the "glue" that brought Smith and Chandar together on this research, worked with Smith as an undergraduate student starting in 2012 on the dust and gas in post-starburst galaxies.
While spiral galaxies like our Milky Way have continued to form stars at a fairly steady rate, post-starburst galaxies experienced an intense burst of star formation sometime in the last half billion years, shutting down their star formation.
The resulting breakthrough research published in the *Astrophysical Journal* outlines their new method to establish the star formation history of a post-starburst galaxy using its cluster population. The approach uses the age and mass estimates of stellar clusters to determine the strength and speed of the starburst that stopped more stars from forming in the galaxy.
Using this method, the astronomers discovered that S12 experienced two periods of starburst before it stopped forming stars, not one.
"Post-starbursts represent a phase of galaxy evolution that is pretty rare today," Smith said. "We think that nearly half of all galaxies went through this phase at some point in their lives. So far, their star-forming histories have been determined almost exclusively from detailed modelling of their composite starlight."
Smith has studied post-starburst galaxies for more than a decade, and Chandar works on the stellar clusters in galaxies that are typically about three or four times closer than those in Smith's data.
"Clusters are like fossils -- they can be age-dated and give us clues to the past history of

galaxies," Chandar said. "Clusters can only be detected in these galaxies with the clear eyed-view of the Hubble Space Telescope. No clusters can be detected in even the highest quality images taken with telescopes on the ground."

Smith has led several large multi-wavelength projects to better understand the evolutionary history of post-starburst galaxies. He discovered, for example, that the raw fuel for star formation -- gas and dust -- is still present in surprising quantities in some of these systems including S12, even though no stars are currently being formed.

"While studying the light from these galaxies at multiple wavelengths has helped establish the time that the burst happened, we hadn't been able to determine how strong and how long the burst that shutoff star formation actually was," Smith said. "And that's important to know to better understand how these galaxies evolve."

The astronomers used well-studied cluster masses and star formation rates in eight nearby galaxies to develop the new method, which could be applied to determine the recent star formation histories for a number of post-starburst systems.

The researchers applied their different approach to S-12, which is short for SDSS 623-52051-207, since it was discovered and catalogued in the Sloan Digitized Sky Survey (SDSS).

"It must have had one of the highest rates of star formation of any galaxy we have ever studied," Chandar said. "S12 is the most distant galaxy I've ever worked on."

The study indicates star formation in S12 shut off 70 million years ago after a short but intense burst formed some of the most massive clusters known, with masses several times higher than similar-age counterparts forming in actively merging galaxies. The method also revealed an earlier burst of star formation that the previous method of composite starlight modelling could not detect.

"These results suggest that S12's unusual history may be even more complicated than expected, with multiple major events compounding to fully shut off star formation," Smith said.

The research was funded by the National Science Foundation and NASA.

Chandar and Smith are two of four UToledo astronomers leading some of the first research projects on NASA's new James Webb Space Telescope scheduled to launch in December.

- Astronomers may have discovered a planet outside of our galaxy

Date: October 27, 2021
Source: Centre for Astrophysics, Harvard & Smithsonian

Whirlpool Galaxy (stock image).
Credit: © Equatore / stock.adobe.com

Signs of a planet transiting a star outside of the Milky Way galaxy may have been detected for the first time. This intriguing result, using NASA's Chandra X-ray Observatory, opens up a new window to search for exoplanets at greater distances than ever before.

The possible exoplanet candidate is located in the spiral galaxy Messier 51 (M51), also called the Whirlpool Galaxy because of its distinctive profile.

Exoplanets are defined as planets outside of our Solar System. Until now, astronomers have found all other known exoplanets and exoplanet candidates in the Milky Way galaxy, almost all of them less than about 3,000 light-years from Earth. An exoplanet in M51 would be about 28 million light-years away, meaning it would be thousands of times farther away than those in the Milky Way.

"We are trying to open up a whole new arena for finding other worlds by searching for planet candidates at X-ray wavelengths, a strategy that makes it possible to discover them in other galaxies," said Rosanne Di Stefano of the Centre for Astrophysics | Harvard & Smithsonian (CfA) in Cambridge, Massachusetts, who led the study, which was published in *Nature Astronomy.*

This new result is based on transits, events in which the passage of a planet in front of a star blocks some of the star's light and produces a characteristic dip. Astronomers using both ground-based and space-based telescopes -- like those on NASA's Kepler and TESS missions -- have searched for dips in optical light, electromagnetic radiation humans can see, enabling the discovery of thousands of planets.

Di Stefano and colleagues have instead searched for dips in the brightness of X-rays received from X-ray bright binaries. These luminous systems typically contain a neutron star or black hole pulling in gas from a closely orbiting companion star. The material near the neutron star or black hole becomes superheated and glows in X-rays.

Because the region producing bright X-rays is small, a planet passing in front of it could block most or all of the X-rays, making the transit easier to spot because the X-rays can completely disappear. This could allow exoplanets to be detected at much greater distances than current optical light transit studies, which must be able to detect tiny decreases in light because the planet only blocks a tiny fraction of the star.

The team used this method to detect the exoplanet candidate in a binary system called M51-ULS-1, located in M51. This binary system contains a black hole or neutron star orbiting a companion star with a mass about 20 times that of the Sun. The X-ray transit they found using Chandra data lasted about three hours, during which the X-ray emission decreased to zero. Based on this and other information, the researchers estimate the exoplanet candidate in M51-ULS-1 would be roughly the size of Saturn, and orbit the neutron star or black hole at about twice the distance of Saturn from the Sun.

While this is a tantalizing study, more data would be needed to verify the interpretation as an extragalactic exoplanet. One challenge is that the planet candidate's large orbit means it would not cross in front of its binary partner again for about 70 years, thwarting any attempts for a confirming observation for decades.

"Unfortunately to confirm that we're seeing a planet we would likely have to wait decades to see another transit," said co-author Nia Imara of the University of California at Santa Cruz. "And because of the uncertainties about how long it takes to orbit, we wouldn't know exactly when to look."

Can the dimming have been caused by a cloud of gas and dust passing in front of the X-ray source? The researchers consider this to be an unlikely explanation, as the characteristics of the event observed in M51-ULS-1 are not consistent with the passage of such a cloud. The model of a planet candidate is, however, consistent with the data.

"We know we are making an exciting and bold claim so we expect that other astronomers will look at it very carefully," said co-author Julia Berndtsson of Princeton University in New Jersey. "We think we have a strong argument, and this process is how science works."

If a planet exists in this system, it likely had a tumultuous history and violent past. An exoplanet in the system would have had to survive a supernova explosion that created the neutron star or black hole. The future may also be dangerous. At some point the companion star could also explode as a supernova and blast the planet once again with extremely high levels of radiation.

Di Stefano and her colleagues looked for X-ray transits in three galaxies beyond the Milky Way galaxy, using both Chandra and the European Space Agency's XMM-Newton. Their search covered 55 systems in M51, 64 systems in Messier 101 (the "Pinwheel" galaxy), and 119 systems in Messier 104 (the "Sombrero" galaxy), resulting in the single exoplanet candidate described here.

The authors will search the archives of both Chandra and XMM-Newton for more exoplanet candidates in other galaxies. Substantial Chandra datasets are available for at least 20 galaxies, including some like M31 and M33 that are much closer than M51, allowing shorter transits to be detectable. Another interesting line of research is to search for X-ray transits in Milky Way X-ray sources to discover new nearby planets in unusual environments.

The other authors of this Nature Astronomy paper are Ryan Urquhart (Michigan State University), Roberto Soria (University of the

Chinese Science Academy), Vinay Kashap (CfA), and Theron Carmichael (CfA). NASA's Marshall Space Flight Centre manages the Chandra program. The Smithsonian Astrophysical Observatory's Chandra X-ray Centre controls science from Cambridge Massachusetts and flight operations from Burlington, Massachusetts.

- Near-earth asteroid might be a lost fragment of the moon

Date: November 11, 2021
Source: University of Arizona

A near-Earth asteroid named Kamo`oalewa could be a fragment of our moon, according to a new paper published in Nature Communications Earth and Environment by a team of astronomers led by the University of Arizona.

Kamo`oalewa is a quasi-satellite -- a subcategory of near-Earth asteroids that orbit the sun but remain relatively close to Earth. Little is known about these objects because they are faint and difficult to observe. Kamo`oalewa was discovered by the PanSTARRS telescope in Hawaii in 2016, and the name -- found in a Hawaiian creation chant -- alludes to an offspring that travels on its own. The asteroid is roughly the size of a Ferris wheel -- between 150 and 190 feet in diameter -- and gets as close as about 9 million miles from Earth.

Due to its orbit, Kamo`oalewa can only be observed from Earth for a few weeks every April. Its relatively small size means that it can only be seen with one of the largest telescopes on Earth. Using the UArizona-managed Large Binocular Telescope on Mount Graham in southern Arizona, a team of astronomers led by planetary sciences graduate student Ben Sharkey found that Kamo`oalewa's pattern of reflected light, called a spectrum, matches lunar rocks from NASA's Apollo missions, suggesting it originated from the moon.

The team can't yet be sure how it may have broken loose. The reason, in part, is because there are no other known asteroids with lunar origins.

"I looked through every near-Earth asteroid spectrum we had access to, and nothing matched," said Sharkey, the paper's lead author.

The debate over Kamo`oalewa's origins between Sharkey and his adviser, UArizona associate professor Vishnu Reddy, led to another three years of hunting for a plausible explanation.

"We doubted ourselves to death," said Reddy, a co-author who started the project in 2016. After missing the chance to observe it in April 2020 due to a COVID-19 shutdown of the telescope, the team found the final piece of the puzzle in 2021.

"This spring, we got much needed follow-up observations and went, 'Wow it is real,'" Sharkey said. "It's easier to explain with the moon than other ideas."

Kamo`oalewa's orbit is another clue to its lunar origins. Its orbit is similar to the Earth's, but with the slightest tilt. Its orbit is also not typical of near-Earth asteroids, according to study co-author Renu Malhotra, a UArizona planetary sciences professor who led the orbit analysis portion of the study.

"It is very unlikely that a garden-variety near-Earth asteroid would spontaneously move into a quasi-satellite orbit like Kamo`oalewa's," she said. "It will not remain in this particular orbit for very long, only about 300 years in the future, and we estimate that it arrived in this orbit about 500 years ago," Malhotra said. Her lab is working on a paper to further investigate the asteroid's origins.

Kamo`oalewa is about 4 million times fainter than the faintest star the human eye can see in a dark sky.

"These challenging observations were enabled by the immense light gathering power, of the twin 8.4-meter telescopes of the Large Binocular Telescope," said study co-author Al Conrad, a staff scientist with the telescope.

The study also included data from the Lowell Discovery Telescope in Flagstaff, Arizona. Other co-authors on the paper include Olga Kuhn, Christian Veillet, Barry Rothberg and David Thompson from the Large Binocular Telescope; Audrey Thirouin from Lowell Observatory and Juan Sanchez from the Planetary Science Institute in Tucson. The research was funded by NASA's Near-Earth Object Observations Program.

- Black hole found hiding in star cluster outside our galaxy

Date: November 11, 2021
Source: ESO

Using the European Southern Observatory's Very Large Telescope (ESO's VLT), astronomers have discovered a small black hole outside the Milky Way by looking at how it influences the motion of a star in its close vicinity. This is the first time this detection method has been used to reveal the presence of a black hole outside of our galaxy. The method could be key to unveiling hidden black holes in the Milky Way and nearby galaxies, and to help shed light on how these mysterious objects form and evolve.

The newly found black hole was spotted lurking in NGC 1850, a cluster of thousands of stars roughly 160,000 light-years away in the Large Magellanic Cloud, a neighbour galaxy of the Milky Way.

"Similar to Sherlock Holmes tracking down a criminal gang from their missteps, we are looking at every single star in this cluster with a magnifying glass in one hand trying to find some evidence for the presence of black holes but without seeing them directly," says Sara Saracino from the Astrophysics Research Institute of Liverpool John Moores University in the UK, who led the research now accepted for publication in Monthly Notices of the Royal Astronomical Society. "The result shown here represents just one of the wanted criminals, but when you have found one, you are well on your way to discovering many others, in different clusters."

This first "criminal" tracked down by the team turned out to be roughly 11 times as massive as our Sun. The smoking gun that put the astronomers on the trail of this black hole was its gravitational influence on the five-solar-mass star orbiting it.

Astronomers have previously spotted such small, "stellar-mass" black holes in other galaxies by picking up the X-ray glow emitted as they swallow matter, or from the gravitational waves generated as black holes collide with one another or with neutron stars. However, most stellar-mass black holes don't give away their presence through X-rays or gravitational waves. "The vast majority can only be unveiled dynamically," says Stefan Dreizler, a team member based at the University of Göttingen in Germany. "When they form a system with a star, they will affect its motion in a subtle but detectable way, so we can find them with sophisticated instruments."

This dynamical method used by Saracino and her team could allow astronomers to find many more black holes and help unlock their mysteries. "Every single detection we make will be important for our future understanding of stellar clusters and the black holes in them," says study co-author Mark Gieles from the University of Barcelona, Spain.

The detection in NGC 1850 marks the first time a black hole has been found in a young cluster of stars (the cluster is only around 100 million years old, a blink of an eye on astronomical scales). Using their dynamical method in similar star clusters could unveil even more young black holes and shed new light on how they evolve. By comparing them with larger, more mature black holes in older clusters, astronomers would be able to understand how these objects grow by feeding on stars or merging with other black holes. Furthermore, charting the demographics of black holes in star clusters improves our understanding of the origin of gravitational wave sources.

To carry out their search, the team used data collected over two years with the Multi Unit Spectroscopic Explorer (MUSE) mounted at ESO's VLT, located in the Chilean Atacama Desert. "MUSE allowed us to observe very crowded areas, like the innermost regions of stellar clusters, analysing the light of every single star in the vicinity. The net result is information about thousands of stars in one shot, at least 10 times more than with any other instrument," says co-author Sebastian Kamann, a long-time MUSE expert based at Liverpool's Astrophysics Research Institute. This allowed the team to spot the odd star out whose peculiar motion signalled the presence of the black hole. Data from the University of Warsaw's Optical Gravitational Lensing Experiment and from the NASA/ESA Hubble Space Telescope enabled them to measure the mass of the black hole and confirm their findings.

ESO's Extremely Large Telescope in Chile, set to start operating later this decade, will allow astronomers to find even more hidden black holes. "The ELT will definitely revolutionise this field," says Saracino. "It will allow us to observe stars considerably fainter in the same field of view, as well as to look for black holes in globular clusters located at much greater distances."

- New method to detect Tatooine-like planets validated

Date: November 10, 2021
Source: University of Hawaii at Manoa

A new technique developed in part by University of Hawaii astronomer Nader Haghighipour has allowed scientists to quickly detect a transiting planet with two suns. Termed circumbinary planets, these objects orbit around a pair of stars. For years, these planets were merely the subject of science fiction, like Tatooine in *Star Wars*. However, thanks to NASA's successful planet-hunting Kepler and Transiting Exoplanet Survey Satellite (TESS) missions, a team of astronomers, including Haghighipour, have found 14 such bodies so far.
Kepler and TESS detect planets via the transit method, where astronomers measure the tiny dimming of a star as a planet passes in front of its host star, blocking some of the starlight. Usually, astronomers need to see at least three of these transits to pin down the planet's orbit. This becomes challenging when there are two host stars.
"Detecting circumbinary planets is much more complicated than finding planets orbiting single stars. When a planet orbits a double-star system, transits of the same star don't occur at consistent intervals," explained Haghighipour. "The planet might transit one star, and then transit the other, before transiting the first star again, and so on."
Adding to the challenge, the orbital periods of circumbinary planets are always much longer than the orbital period of the binary star. That means, in order to observe three transits, scientists need to observe the binary for a long time. While that was not a problem with the Kepler space telescope (this telescope observed only one region of the sky for 3.5 years), it makes it challenging to use the TESS telescope to detect circumbinary planets, because TESS observes one portion (or sector) of the sky for only 27 days before pointing someplace else, making it impossible to observe three transits of a planet with TESS.
In 2020, Haghighipour and his team found a way around this limitation. In an article published in The Astronomical Journal, they described a novel technique that would enable them to detect circumbinary planets using TESS, as long as the planet transited both of its host stars within the 27-day observing window.
Now, that same team of astronomers has actually found the first such circumbinary planet in TESS data, demonstrating that their technique works. The target binary is known by its catalogue designation, TIC 172900988, and was observed in a single sector by TESS, where its light curve showed signs of two transits, one across each star, separated by just five days – during the same conjunction.
"This planet's orbit takes almost 200 days - with the traditional transit method, we would have needed to wait over a year to detect two additional transits. Our new technique reduced that time to just five days, showing that despite its short window of observation, TESS can be used to detect circumbinary planets. The new planet is the proof of the validity, applicability and success of our invented technique," said Haghighipour, founder of the TESS Circumbinary Planet Working Group. "This discovery demonstrates that our new technique works and will be able to find many more planets."
The discovery of the first TESS circumbinary planet using this new technique appears in the Astronomical Journal. Haghighipour is a co-author with lead authors Veselin B. Kostov (NASA Goddard Space Flight Centre), SETI Institute, and GSFC Sellers Exoplanet Environments Collaboration.

Funding for this work was provided in part by NASA.

- Tread lightly: 'Eggshell planets' possible around other stars

Date: November 10, 2021
Source: Washington University in St. Louis

Eggshell Planets Have a Thin Brittle Crust and No Mountains or Tectonics

Planets without plate tectonics are unlikely to be habitable. But currently, we've never seen the surface of an exoplanet to determine if plate tectonics are active. Scientists piece together their likely surface structures from other evidence. Is there a way to determine what exoplanets might be eggshells, and eliminate them as potentially habitable?

The authors of a newly-published paper say there is.

The astronomy community hasn't settled on a single method of classifying exoplanets yet. NASA likes to group them into four classifications: gas giants, super-Earths, Neptunians, and terrestrial. But that's just a start. The Unified Astronomy Thesaurus uses 15 different exoplanet classifications. Other terms are used in scientific literature, too.

The number of classifications for exoplanets can be as granular as we'd like. Ultimately, each one is different. We're in the early stages of understanding the variety of exoplanet types, and eventually, a comprehensive classification scheme will emerge.

One type of exoplanet that's not often mentioned is the eggshell planet. They've caught researchers' attention because they have thin, brittle crusts, no mountains, and no plate tectonics.

Eggshell planets are rare, as far as astronomers know. Only a few have been identified, but selection bias might play a role there. According to a new paper titled "The Effects of Planetary and Stellar Parameters on Brittle Lithospheric Thickness," three have been found in exoplanet surveys. The lead author is Paul Byrne, Associate Professor of Earth and Planetary Sciences, at Trinity College, Dublin. The paper is published in the Journal of Geophysical Research: Planets.

Exoplanets are interesting in their own right, but a lot of what captures the interest of both scientists and the public is habitability. We want to know if there are planets out there that can support life. And while looking specifically for planets that could be habitable is one approach, another is discounting planets that, as far as we know, simply have no chance to support life.

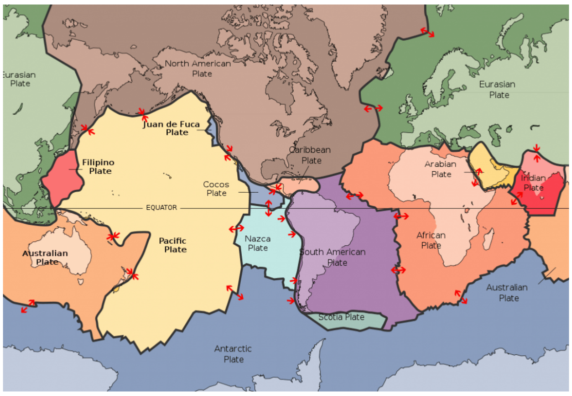
"Understanding whether you've got the possibility of plate tectonics is a really important thing to know about a world…"

Paul Byrne, Associate Professor of Earth and Planetary Sciences, Trinity College, Dublin.

There's strong evidence that plate tectonics is a necessary requirement for habitability. And since part of exoplanet hunters' focus is finding Earth-like worlds, plate tectonics is a key. Without plate tectonics, we wouldn't be here.

"Understanding whether you've got the possibility of plate tectonics is a really important thing to know about a world, because plate tectonics may be required for a large rocky planet to be habitable," said lead author Byrne. "It's therefore especially important when we're talking about looking for Earth-like worlds around other stars and when we're characterizing planetary habitability generally."

Plate tectonics occurs when a planet's lithosphere is broken into chunks that float around on the mantle. Plate tectonics can help regulate a planet's temperature by recycling the crust into the mantle over long geological timeframes. It regulates the atmosphere and helps remove carbon, avoiding a runaway greenhouse effect that could make the surface uninhabitable. The term "habitable zone," which describes the region around a star where a planet can have liquid water, is usually calculated including active plate tectonics.



Earth’s tectonic plates were mapped in the latter half of the 20th century. Image Credit: By Map: USGSDescription: Scott Nash – This file was derived from: Tectonic plates.png, Public Domain, https://commons.wikimedia.org/w/index.php?curid=535201

A planet without plate tectonics is sometimes called a “stagnant lid planet.” They occur when the mantle isn’t energetic enough to fracture the crust into chunks. Instead, the crust is a single brittle chunk that covers the planet’s entire surface. In our own Solar System, Mercury has been a stagnant lid planet for billions of years. Some planets can exhibit episodic tectonic activity, where the crust is immobile for geological periods of time.

Since we have no way of observing the surfaces of exoplanets, astronomers are keen to find a way to detect them with other evidence. As the title of the new paper makes clear, the parameters of a planet and its star can provide evidence that a planet is an Eggshell planet.

“What we’ve laid out here is essentially a how-to guide or handy manual,” lead author Byrne said. “If you have a planet of a given size, at a given distance from its star and of a given mass, then with our results you can make some estimates for a variety of other features — including whether it may have plate tectonics.”

The paper outlines how knowledge of a planet’s size, age, and distance from its star could not only identify eggshell planets but other exoplanet types, too. Since astronomers can’t see the surfaces of exoplanets and are only now beginning to study their atmospheres, a planet’s other parameters are of highlighted importance.

“We have imaged a few exoplanets, but they are splotches of light orbiting a star. We have no technical ability to actually see the surface of exoplanets yet,” Byrne said. “This paper is one of a small but growing number of studies taking a geological or geophysical perspective to try and understand the worlds that we cannot directly measure right now.”

Nobody’s ever seen the surface of an exoplanet. All we have is the work of scientific illustrators to fire our imaginations. This is an artist’s impression of the view from the most distant exoplanet discovered around the red dwarf star TRAPPIST-1. Credit: ESO/M. Kornmesser.

According to Byrne and his colleagues, the thickness of a planet’s brittle lithosphere is key to understanding if it has plate tectonics. And the lithosphere’s thickness is dictated not only by the characteristics of the planet but also its host star. “Factors inherent to the planet, such as size, interior temperature, composition, and even climate affect the thickness of this outer layer, but so too do factors specific to the host star, including how luminous and far away it is,” they write in their paper.

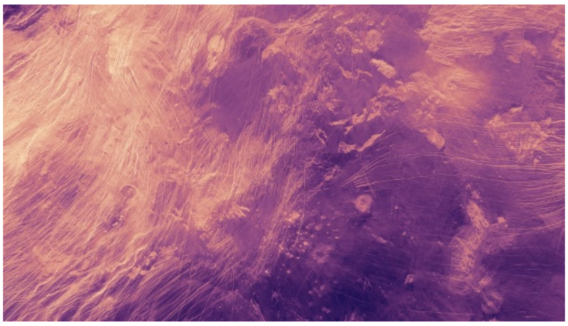
In order for a planet to have active tectonics, there needs to be a balance between a number of factors. For example, if the crust is too thick, the energy in the mantle might not be enough to trigger tectonics.

The team turned to computer models to better understand what factors lead to thicker exoplanet crusts.

The team started their models with a generic rocky world and went from there. “It was kind of Earth-sized — although we did consider size in there, too," Byrne said. "And then we spun the dials," he added. "We literally ran thousands of models."

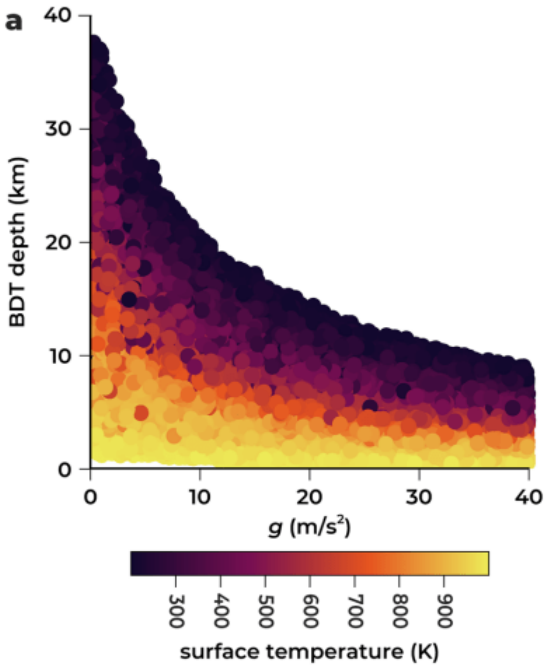
Prominent in the paper is the concept of BDT—brittle-ductile transition. The BDT is the zone in the lithosphere where dominantly brittle behaviour changes to dominantly ductile deformation. In this term ductile basically means pliable. The strength of a planet's lithosphere is heavily reliant on its thickness, so the deeper the BDT, the stronger the crust.

Multiple factors go into determining a planet's lithosphere thickness. Distance from the star, age, and planetary mass all factor into it. But the team found that surface temperature played a larger role. "Our models predict that worlds that are small, old, or far from their star likely have thick, rigid layers but, in some circumstances, planets might have an outer brittle layer only a few kilometres thick." It's these planets that the team calls eggshell planets, and that might resemble the lowlands on Venus.



This false colour image of lowlands on Venus' surface shows fine, light lines that are likely tectonic in nature. The darker areas are smooth volcanic plains. The image is a mosaic made of radar data from NASA's Magellan mission. The area in the image is about 1,400 km (870 miles) across. Image Credit: NASA.

Venusian lowlands are vast plains of lava. And they're largely flat, too, with only wrinkled ridges. According to Byrne, the lithosphere in those areas is thin due to the planet's extremely high surface temperatures.



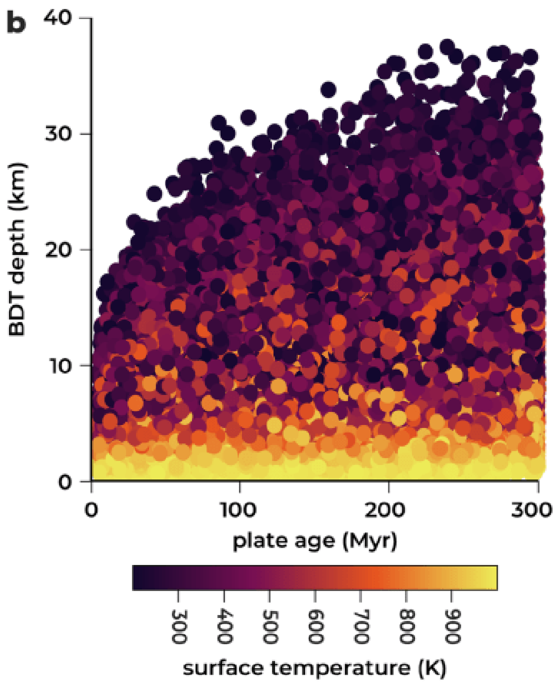
This figure from the study shows the relationship between BDT depth and surface temperature. Each of the dots is one simulation result. (*g/ms*^{2} *is a measure of surface gravitational acceleration.)* Image Credit: Byrne et al 2021.

When it comes to exoplanets, mainstream media likes to announce the discovery of two categories of planets. Earth-like planets are always covered, and so are extremely weird planets, like the one that might rain molten iron.

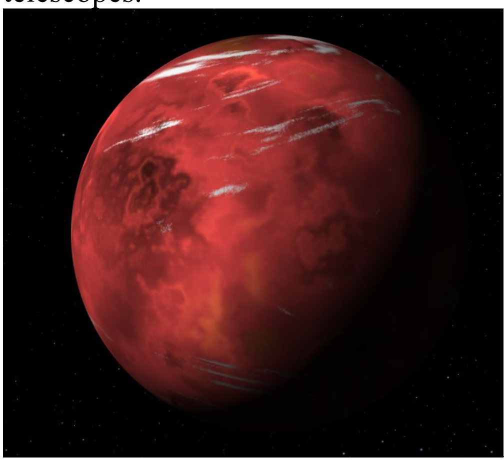
But that's just a kind of cherry-picking. In the larger scientific picture, it's imperative to grow our overall understanding of exoplanets. That's where this study fits in, according to the authors.

"Our overall goal is more than just understanding the vagaries of exoplanets," Byrne said. "Ultimately we want to help contribute to identifying the properties that make a world habitable. And not just temporarily, but habitable for a long time, because we think life probably needs a while to get going and become sustainable."

Is the number of planets that sustain habitability small? Quite likely. And one of the factors that sustains habitability is long-term plate tectonics. Without that, life might be unlikely to develop complexity.



This figure from the study shows BDT depth and plate age, or planet age, with surface temperature keyed at the bottom. Plate age is used as a proxy for heat flow. Each of the dots is one simulation result. Image Credit: Byrne et al 2021. Finding life somewhere else is a primal, driving force in science. And for these researchers, that centres around the planet Earth and how unique it might turn out to be. “That is the big reach,” Byrne said. “Ultimately most of this work is tied into this final destination, which is ‘how unique, or not, is Earth?’ One of the many things we are going to need to know is what kinds of properties influence a world like Earth. And this study helps address some of that question by showing the kinds of ways these parameters interact, what other outcomes might be possible and which worlds we should prioritize for study with new-generation telescopes.”

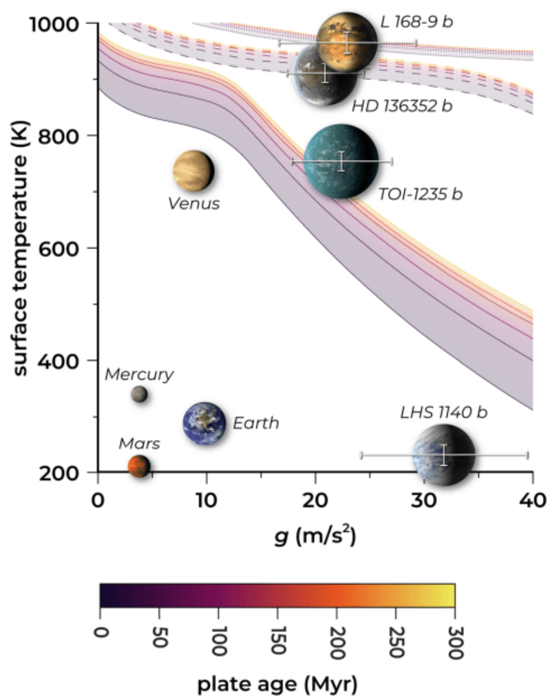


An artist’s illustration of exoplanet TOI 1235 b, a suspected eggshell planet. Image Credit: NASA

The authors acknowledge the simplicity of their model. Without detailed observations of exoplanet surface characteristics, this work is necessarily a starting point. “Of course, our study is necessarily simplistic, since we have essentially no geological observations of exoplanets with which to constrain our parameter space,” they write.

But it still serves a valuable purpose. It’s a kind of framework for understanding targets for further observation. “A key prediction we make here is that so-called eggshell planets will have little elevated topography. This prediction can be tested with future generations of telescopes capable of searching for constructional or orogenic topography on exoplanets,” they clarify.

As more powerful telescopes come online, astronomers will eventually be able to observe exoplanets much more closely. But we know of thousands of exoplanets, with more being discovered all the time. Observing time at the world’s most powerful observatories is always in high demand. Modelling studies like this one are a way of pre-sorting potential observation targets. The authors say that we already know of three of these eggshell planets: TOI-1235 b, HD 136352 b, and L 168-9 b. They’re all very close to their stars and are likely far too hot to be habitable no matter if they have plate tectonics or not, but they’re good test cases for the overall method of detecting eggshell planets.

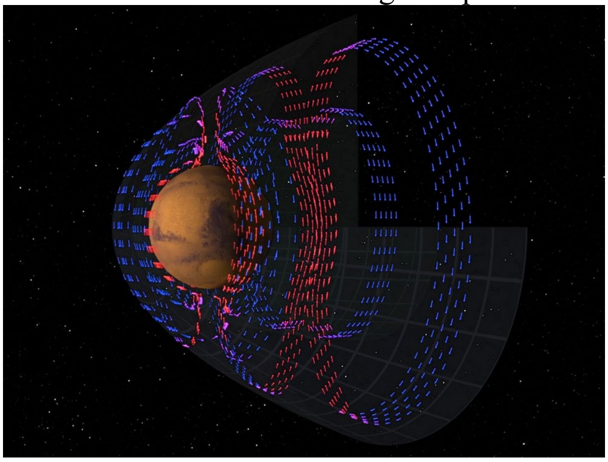


This figure from the study shows the three suspected eggshell planets as well as Mercury, Venus, Earth, and Mars. They're all shown in relation to their age, surface gravitational acceleration, and surface temperature. LHS 1140 b is also shown because surface gravity and surface temperature estimates are available for them, as they are for the other exoplanets. All four exoplanets are super-Earths. Image Credit: Byrne et al 2021.

Should those three be the focus of observation in the future? "We propose that these planets be examined with planned and future space telescopes to test if our models are correct," the authors write.

And if the models are correct, the search for habitable planets will take another step forward.

- ❖ An Absolutely Bonkers Plan to Give Mars an Artificial Magnetosphere

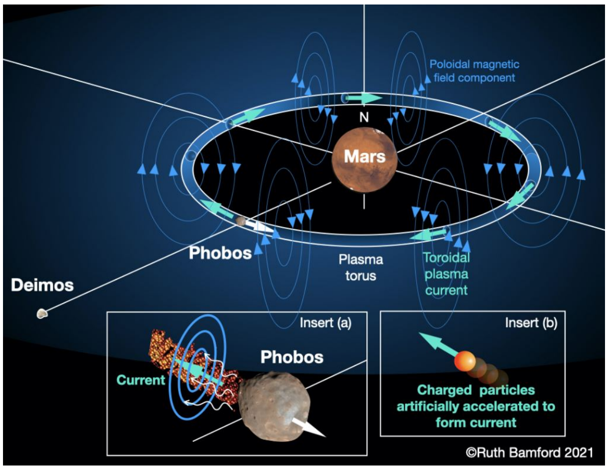


Terraforming Mars is one of the great dreams of humanity. Mars has a lot going for it. Its day is about the same length as Earth's, it has plenty of frozen water just under its surface, and it likely could be given a reasonably breathable atmosphere in time. But one of the things it lacks is a strong magnetic field. So if we want to make Mars a second Earth, we'll have to give it an artificial one.

The reason magnetic fields are so important is that they can shield a planet from solar wind and ionizing particles. Earth's magnetic field prevents most high-energy charged particles from reaching the surface. Instead, they are deflected from Earth, keeping us safe. The magnetic field also helps prevent solar winds from stripping Earth's atmosphere over time. Early Mars had a thick, water-rich atmosphere, but it was gradually depleted without the protection of a strong magnetic field.

Unfortunately, we can't just recreate Earth's magnetic field on Mars. Our field is generated by a dynamo effect in Earth's core, where the convection of iron alloys generates Earth's geomagnetic field. The interior of Mars is smaller and cooler, and we can't simply "start it up" to create a magnetic dynamo. But there are a few ways we can create an artificial magnetic field, as a recent study shows.

Ideas for generating a Martian magnetic field have been proposed before, and usually involve either ground-based or orbital solenoids that create some basic level of magnetic protection. In the TV series *The Expanse*, you can see a couple of scenes where you [catch a glimpse of them](). While this latest study acknowledges that might work, it proposes an even better solution.



A torus of charged particles could give Mars a magnetic field. Credit: Ruth Bamford

As the study points out, if you want a good planetary magnetic field, what you really need is a strong flow of charged particles, either within the planet or around the planet. Since the former isn't a great option for Mars, the team looks at the latter. It turns out you can create a ring of charged particles around Mars, thanks to its moon Phobos.

Phobos is the larger of the two Martian moons, and it orbits the planet quite closely. So closely that it makes a trip around Mars every 8 hours. So the team proposes using Phobos by ionizing particles from its surface, then accelerating them so they create a plasma torus along the orbit of Phobos. This would create a magnetic field strong enough to protect a terraformed Mars.

It's a bold plan, and while it seems achievable the engineering hurdles would be significant. But as the authors point out, this is the time for ideas. Start thinking about the problems we need to solve, and how we can solve them, so when humanity does reach Mars, we will be ready to put the best ideas to the test.

- Jet from giant galaxy M87: Computer modelling explains black hole observations

Further confirmation of Einstein's theory of general relativity

Date: November 4, 2021

Source: Goethe University Frankfurt

The galaxy Messier 87 (M87) is located 55 million light years away from Earth in the Virgo constellation. It is a giant galaxy with 12,000 globular clusters, making the Milky Way's 200 globular clusters appear modest in comparison. A black hole of six and a half billion sun masses is harboured at the centre of M87. It is the first black hole for which an image exists, created in 2019 by the international research collaboration Event Horizon Telescope.

This black hole (M87*) shoots a jet of plasma at near the speed of light, a so-called relativistic jet, on a scale of 6,000 light years. The tremendous energy needed to power this jet probably originates from the gravitational pull of the black hole, but how a jet like this comes about and what keeps it stable across the enormous distance is not yet fully understood.

The black hole M87* attracts matter that rotates in a disc in ever smaller orbits until it is swallowed by the black hole. The jet is launched from the centre of the accretion disc surrounding M87, and theoretical physicists at Goethe University, together with scientists from Europe, USA and China, have now modelled this region in great detail.

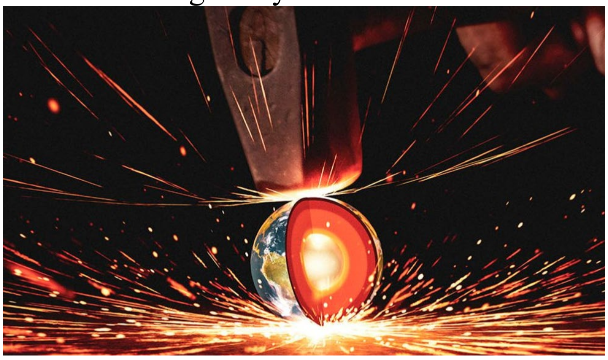
They used highly sophisticated three-dimensional supercomputer simulations that use the staggering amount of a million CPU hours per simulation and had to simultaneously solve the equations of general relativity by Albert Einstein, the equations of electromagnetism by James Maxwell, and the equations of fluid dynamics by Leonhard Euler.

The result was a model in which the values calculated for the temperatures, the matter densities and the magnetic fields correspond remarkably well with what deduced from the astronomical observations. On this basis, scientists were able to track the complex motion of photons in the curved spacetime of the innermost region of the jet and translate this into radio images. They were then able to compare these computer modelled images with the observations made using numerous radio telescopes and satellites over the past three decades.

Dr Alejandro Cruz-Osorio, lead author of the study, comments: "Our theoretical model of the electromagnetic emission and of the jet morphology of M87 matches surprisingly well with the observations in the radio, optical and infrared spectra. This tells us that the supermassive black hole M87* is probably highly rotating and that the plasma is strongly magnetized in the jet, accelerating particles out to scales of thousands of light years."

Professor Luciano Rezzolla, Institute for Theoretical Physics at Goethe University Frankfurt, remarks: "The fact that the images we calculated are so close to the astronomical observations is another important confirmation that Einstein's theory of general relativity is the most precise and natural explanation for the existence of supermassive black holes in the centre of galaxies. While there is still room for alternative explanations, the findings of our study have made this room much smaller."

- There's So Much Pressure at the Earth's Core, it Makes Iron Behave in a Strange Way



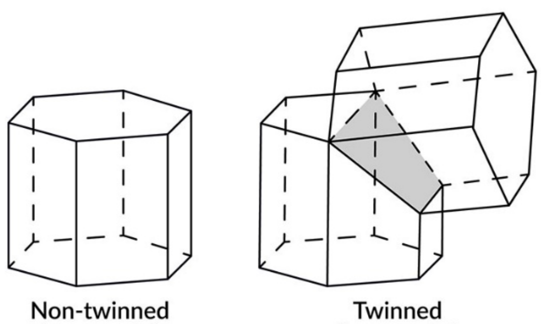
It's one of nature's topsy-turvy tricks that the deep interior of the Earth is as hot as the Sun's surface. The sphere of iron that resides there is also under extreme pressure: about 360 million times more pressure than we experience on the Earth's surface. But how can scientists' study what happens to the iron at the centre of the Earth when it's largely unobservable?

With a pair of lasers.

Earth is not the only body with an iron core. Mercury, Venus, and Mars have them, too. In fact, any world that was ever molten is likely to have an iron core, since iron's density makes it fall toward the centre of a world's gravity. Astronomers think that some iron asteroids are actually cores from planetesimals that lost the rest of their mass due to collisions. What happens to the iron when two planets collide? What happens to the iron at the Earth's core? In both scenarios, the iron is subjected to extreme heat and pressure. Most of what scientists do know about iron in these extreme conditions comes from laboratory experiments involving lesser temperatures and pressures. But researchers at the DOE's SLAC (Stanford Linear Accelerator Centre) wanted to recreate the extremes at the Earth's centre as best they could to test iron's behaviour.

The researchers, led by Sébastien Merkel of the Université de Lille, published a paper reporting their findings. The paper's title is "Femtosecond Visualization of hcp-Iron Strength and Plasticity under Shock Compression" and it's published in the journal Physical Review Letters.

Under normal conditions on the Earth's surface, iron is arranged a certain way naturally. The atoms are arranged in nanoscopic cubes, with an iron atom in the centre and one at each corner. When under sufficiently high pressure, the irons rearrange into hexagonal prisms. That configuration allows more iron to be compressed into the same space.



When under sufficient pressure iron forms hexagonal prisms. Image Credit: S. Merkel/University of Lille, France

This much is already known.

But what happens when the pressure is increased even further, to the same levels as the Earth's outer core? To find out, the team of researchers used two lasers.

The first laser was an optical laser used to induce a shock wave that subjected the iron in the lab to extreme temperatures and pressures. The second laser was SLAC's Linac Coherent Light Source (LCLS) X-ray free-electron laser. The LCLS allowed the team to observe the iron on an atomic level as it was subjected to extreme conditions.

"We didn't quite make inner core conditions," says co-author Arianna Gleason, a scientist in the High-Energy Density Science (HEDS) Division at SLAC. "But we achieved the conditions of the outer core of the planet, which is really remarkable."

Other materials like quartz, titanium, zircon, and calcite have been tested in similar ways. But nobody had ever observed iron under such extreme temperature and pressure.

"As we continue to push it, the iron doesn't know what to do with this extra stress," says Gleason. "And it needs to relieve that stress, so it tries to find the most efficient mechanism to do that."

In response to all that stress, the iron does something called "twinning."

"We were able to make a measurement in a billionth of a second. Freezing the atoms where they are in that nanosecond is really exciting."

Arianna Gleason, co-author, SLAC.

Twinning is when atoms rearrange themselves so that they share crystal lattice points symmetrically. Different materials exhibit different types of twinning, all governed by well-understood laws. In iron's case, the hexagonal prisms rotate to the side nearly 90 degrees. The point of attachment is called the twin plane or the compositional surface.

When iron twins like this, it becomes extraordinarily strong. At first. But as time goes on, that strength disappears.

“Twinning allows iron to be incredibly strong — stronger than we first thought — before it starts to flow plastically on much longer time scales,” Gleason said.

This discovery revolved around a sample of iron the size of a strand of human hair. The iron was shocked by the optical laser into extreme heat and pressure. In a press release, lead author Sébastien Merkel described what it was like during the experiments. “The control room is just above the experimental room,” he said. “When you trigger the discharge, you hear a loud pop.”

Then the LCLS observed the iron’s reaction in nanosecond scales to see how the atoms rearranged themselves. Prior to the experiment, the team didn’t know how fast the iron would respond and if they’d be able to measure the changes. “We were able to make a measurement in a billionth of a second,” co-author Gleason said. “Freezing the atoms where they are in that nanosecond is really exciting.”

The team’s results were highlighted by an editor at Physical Review Letters. In a comment, the corresponding editor Merric Stephens said, “Initially, the shock wave changed the iron’s structure from body-cantered-cubic to hexagonal-close-packed, something the team expected to happen. The hexagonal structure then deformed elastically for several nanoseconds before yielding, after which it accommodated strain by rearranging itself into pairs of twinned crystals—a process that continued even after the stress had fallen below the yield stress.”

According to the researchers, just being able to measure changes that happen so fast is a successful result in itself. “The fact that the twinning happens on the time scale that we can measure it as an important result in itself,” Merkel said.

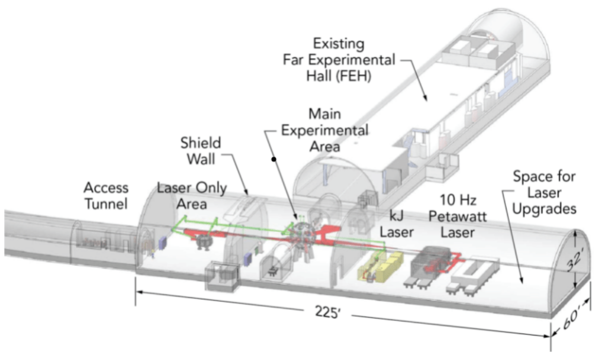
Prior to this experiment, much of our understanding of iron comes from observing the element under less extreme conditions then modelling it forward, to higher extremes. But these results are an important step forward.

“Now we can give a thumbs up, thumbs down on some of the physics models for really fundamental deformation mechanisms,” Gleason says. “That helps to build up some of the predictive capability we’re lacking for modelling how materials respond at extreme conditions.”

Gleason says that the newly-upgraded LCLS allowed this experiment to come to fruition, and will lead to more. “The future is bright now that we’ve developed a way to make these measurements,” Gleason says. “The recent X-ray undulator upgrade as part of the LCLS-II project allows higher X-ray energies — enabling studies on thicker alloys and materials that have lower symmetry and more complex X-ray fingerprints.”

This experiment produced results nobody had ever observed before. But even with the success, the team wasn’t able to duplicate the extreme conditions at the Earth’s inner core. They were only able to duplicate the outer core. But in the future, that’ll change.

“… we’re going to get more powerful optical lasers with the approval to proceed with a new flagship petawatt laser facility, known as MEC-U,” says Gleason. “That’ll make future work even more exciting because we’ll be able to get to the Earth’s inner core conditions without any problem.” The new laser will be housed in an underground facility connected to SLAC’s existing LCLS. The petawatt laser will produce a million billion watts and will be able to study materials in the most extreme environments imaginable. The Matter in Extreme Conditions Upgrade (MEC-U) “… promises to dramatically improve our understanding of the conditions needed to produce fusion energy and to replicate a wide range of astrophysical phenomena here on Earth,” according to the Department of Energy.



In a new underground experimental facility coupled to SLAC's Linac Coherent Light Source (LCLS), two state-of-the-art laser systems – a high-power petawatt laser and a high-energy kilojoule laser – will feed into two new experimental areas dedicated to the study of hot dense plasmas, astrophysics, and planetary science. (Gilliss Dyer/SLAC National Accelerator Laboratory)

There's been plenty of thinking and theorizing about the state of iron in the extreme conditions at the Earth's core. Scientists surmised that twinning would take place, as it does for other materials, but weren't certain. Now there's experimental data to support some of that thinking and to disprove other conclusions.

- Likely home of Martian meteorites pinpointed

Date: November 4, 2021
Source: Curtin University
Curtin University researchers have pinpointed the likely origin of a group of meteorites ejected from Mars, using a machine learning algorithm that analyses high-resolution planetary images.
The new research, published in *Nature Communications*, identified meteorites that landed on Earth likely originated from Mars' Tooting crater, located in the Tharsis region, which is the largest volcanic province in the solar system.
About 166 Martian rocks have landed on Earth over the past 20 million years, however their precise origins on Mars were unknown.
Lead researcher Dr Anthony Lagain, from Curtin University's Space Science and Technology Centre in the School of Earth and Planetary Sciences, said the new findings would help provide the context to unravel the geological history of the Red Planet.
"In this study, we compiled a new database of 90 million impact craters using a machine learning algorithm that allowed us to determine the potential launch positions of Martian meteorites," Dr Lagain said.
"By observing the secondary crater fields -- or the small craters formed by the ejecta that was thrown out of the larger crater formed recently on the planet, we found that the Tooting crater is the most likely source of these meteorites ejected from Mars 1.1 million years ago.
"For the first time, through this research, the geological context of a group of Martian meteorites is accessible, 10 years before NASA's Mars Sample Return mission is set to send back samples collected by the Perseverance rover currently exploring the Jezero crater."
Co-Lead Professor Gretchen Benedix, also from Curtin University's Space Science and Technology Centre, said the algorithm that made this possible was a major step forward in how scientists can use the terabytes of planetary data available.
"We would not have been able to recognise the youngest craters on Mars without counting the tens of millions of craters smaller than one kilometre across," Professor Benedix said.
"This finding implies that volcanic eruptions occurred in this region 300 million years ago, which is very recent at a geological time scale. It also provides new insights on the structure of the planet, beneath this volcanic province."
Dr Lagain said the research would help create a better understanding of the formation and the evolution of Mars, as well as Earth, potentially offering benefits for other industry sectors on our planet.
"Mapping craters on Mars is a first step. The algorithm we developed can be retrained to perform automated digital mapping of any celestial body. It can be applied to Earth to assist with managing agriculture, the environment and even potentially natural disasters such as fires or floods," Dr Lagain said.
The algorithm was developed in-house by an interdisciplinary group that included members from CSIRO, the Curtin Institute for Computation and the School of Civil and Mechanical Engineering with funding from the Australian Research Council.
Using the fastest supercomputer in the Southern Hemisphere, the Pawsey Supercomputing Centre, and the Curtin HIVE (Hub for Immersive Visualisation and eResearch), researchers analysed a very large volume of high-resolution planetary images through a machine learning algorithm to detect impact craters.
The research also involved experts from Curtin's Space Science and Technology Centre, Curtin's Earth Dynamics Research Group, the Western Australian Museum, the CSIRO -- Pawsey Supercomputing Centre, the University of Toulouse in France, and the University Félix Houphouët-Boigny in Africa.