South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 561 – February 4th 2022 Editor: Roger Burgess
Main Speaker 19:30 Graham Bryant Canals of Mars
The meeting will be accessible via Zoom

Last month's Covid-19 rules still apply at the planetarium but may change.
A reminder to member who have not yet renewed subscriptions were due in December

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- Unusual team finds gigantic planet hidden in plain sight

Gas giant is much closer to Earth than others like it

Date: January 13, 2022
Source: University of California – Riverside

A UC Riverside astronomer and a group of eagle-eyed citizen scientists have discovered a giant gas planet hidden from view by typical stargazing tools.
The planet, TOI-2180 b, has the same diameter as Jupiter, but is nearly three times more massive. Researchers also believe it contains 105 times the mass of Earth in elements heavier than helium and hydrogen. Nothing quite like it exists in our solar system.
Details of the finding have been published in the *Astronomical Journal* and presented at the American Astronomical Society virtual press event on Jan. 13.
"TOI-2180 b is such an exciting planet to have found," said UCR astronomer Paul Dalba, who helped confirm the planet's existence. "It hits the trifecta of 1) having a several-hundred-day orbit, 2) being relatively close to Earth (379 lightyears is considered close for an exoplanet), and 3) us being able to see it transit in front of its star. It is very rare for astronomers to discover a planet that checks all three of these boxes."
Dalba also explained that the planet is special because it takes 261 days to complete a journey around its star, a relatively long time compared to many known gas giants outside our solar system. Its relative proximity to Earth and the brightness of the star it orbits also make it likely astronomers will be able to learn more about it.
In order to locate exoplanets, which orbit stars other than our sun, NASA's TESS satellite looks at one part of the sky for a month, then moves on. It is searching for dips in brightness that occur when a planet crosses in front of a star.
"The rule of thumb is that we need to see three 'dips' or transits before we believe we've found a planet," Dalba said. A single transit event could be caused by a telescope with a jitter, or a star masquerading as a planet. For these reasons, TESS isn't focused on these single transit events. However, a small group of citizen scientists is.
Looking over TESS data, Tom Jacobs, a group member and former U.S. naval officer, saw light dim from the TOI-2180 star, just once. His group alerted Dalba, who specializes in studying planets that take a long time to orbit their stars.
Using the Lick Observatory's Automated Planet Finder Telescope, Dalba and his colleagues observed the planet's gravitational tug on the star, which allowed them to calculate the mass of TOI-2180 b and estimate a range of possibilities for its orbit.
Hoping to observe a second transit event, Dalba organized a campaign using 14 different telescopes across three continents in the northern hemisphere. Over the course of 11 days in August 2021, the effort resulted in 20,000 images of the TOI-2180 star, though none of them detected the planet with confidence.

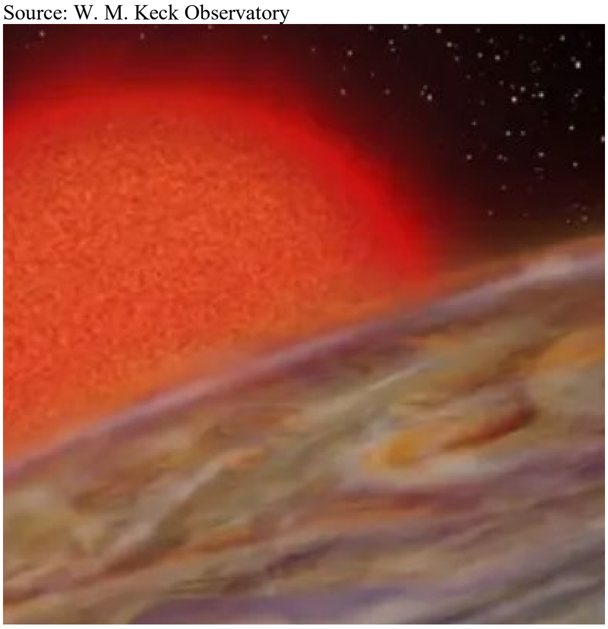
However, the campaign did lead the group to estimate that TESS will see the planet transit its star again in February, when they're planning a follow up study. Funding for Dalba's research is provided by the National Science Foundation's Astronomy and Astrophysics Postdoctoral Fellowship Program.

The citizen planet hunters' group takes publicly available data from NASA satellites like TESS and looks for single transit events. While professional astronomers use algorithms to scan a lot of data automatically, the Visual Survey Group uses a program they created to inspect telescope data by eye.

"The effort they put in is really important and impressive, because it's hard to write code that can identify single transit events reliably," Dalba said. "This is one area where humans are still beating code."

- Newly-found planets on the edge of destruction

Date: January 13, 2022
Source: W. M. Keck Observatory



Three newly-discovered planets have been orbiting dangerously close to stars nearing the end of their lives.

Out of the thousands of extrasolar planets found so far, these three gas giant planets first detected by the NASA TESS (Transiting Exoplanet Survey Satellite) Mission, have some of the shortest-period orbits around subgiant or giant stars. One of the planets, TOI-2337b, will be consumed by its host star in less than 1 million years, sooner than any other currently known planet.

"These discoveries are crucial to understanding a new frontier in exoplanet studies: how planetary systems evolve over time," explained lead author Samuel Grunblatt, a postdoctoral fellow at the American Museum of Natural History and the Flatiron Institute in New York City. Grunblatt, who earned his PhD from the University of Hawai?i Institute for Astronomy (UH IfA), added that "these observations offer new windows into planets nearing the end of their lives, before their host stars swallow them up."

Grunblatt announced the discovery and confirmation of these planets -- TOI-2337b, TOI-4329b, and TOI-2669b -- at an American Astronomical Society press conference today; the study has been accepted for publication in the *Astronomical Journal*.

The researchers estimate that the planets have masses between 0.5 and 1.7 times Jupiter's mass, and sizes that range from slightly smaller to more than 1.6 times the size of Jupiter. They also span a wide range of densities, from Styrofoam-like to three times denser than water, implying a wide variety of origins.

These three planets are believed to be just the tip of the iceberg. "We expect to find tens to hundreds of these evolved transiting planet systems with TESS, providing new details on how planets interact with each other, inflate, and migrate around stars, including those like our Sun," said Nick Saunders, a graduate student at UH IfA and co-author of the study.

The planets were first found in NASA TESS Mission full-frame image data taken in 2018 and 2019. Grunblatt and his collaborators identified the candidate planets in TESS data, and then used W. M. Keck Observatory's High-Resolution Echelle Spectrometer (HIRES) on Maunakea, Hawai?i to confirm the existence of the three planets.

"The Keck observations of these planetary systems are critical to understanding their origins, helping reveal the fate of solar systems like our own," said UH IfA Astronomer Daniel Huber, who co-authored the study.

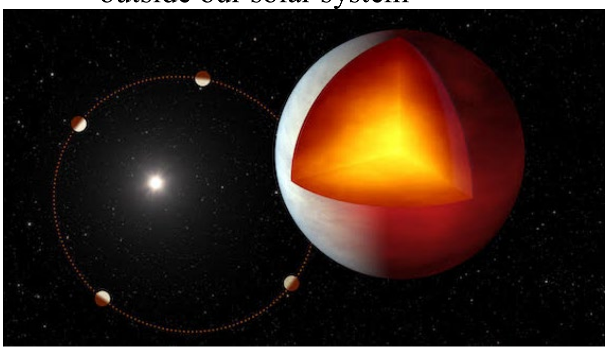
Current models of planet dynamics suggest that planets should spiral in toward their host stars as the stars evolve over time, particularly in the last 10 percent of the star's lifetime. This process also heats the planets, potentially causing their atmospheres to inflate. However, this stellar evolution will also cause the orbits of planets around the host star to come closer to one another, increasing the likelihood that some of them will collide, or even destabilize the entire planetary system.

The wide variety of planet densities found in the study suggests that these planetary systems have been shaped through chaotic planet-to-planet interactions. This could also have resulted in unpredictable heating rates and timescales for these planets, giving them the wide range in densities we observe today. Future observations of one of these systems, TOI-4329, with the recently-launched James Webb Space Telescope could reveal evidence for water or carbon dioxide in the planet's atmosphere. If these molecules are seen, the data would provide constraints on where these planets formed, and what sort of interactions had to occur to produce the planetary orbits we see today.

Continued monitoring of these systems with the NASA TESS telescope will constrain the rate at which these planets are spiralling into their host stars. So far, no clear signal of orbital decay has been observed in any of the systems, but a longer baseline of observations with the TESS Extended Missions will provide much tighter constraints on planet in-spiral than are currently possible, revealing how strongly planetary systems are affected by stellar evolution.

The team hopes that this 'planetary archaeology' will help us to understand the past, present, and future of planetary systems, moving us one step closer to answering the question: "Are we alone?"

- New insights into seasons on a planet outside our solar system



Observations of a hot Jupiter may also advance our understanding of planet origins and evolution

Date: January 13, 2022
Source: McGill University

Imagine being in a place where the winds are so strong that they move at the speed of sound. That's just one aspect of the atmosphere on XO-3b, one of a class of exoplanets (planets outside our solar system), known as hot Jupiter's. The eccentric orbit of the planet also leads to seasonal variations hundreds of times stronger than what we experience on Earth. In a recent paper, a McGill-led research team, provides new insight into what seasons looks like on a planet outside our solar system. The researchers also suggest that the oval orbit, extremely high surface temperatures (2,000 degrees C- hot enough to vaporize rock) and "puffiness" of XO-3b reveal traces of the planet's history. The findings will potentially advance both the scientific understanding of how exoplanets form and evolve and give some context for planets in our own solar system.

Hot Jupiter's are massive, gaseous worlds like Jupiter, that orbit closer to their parent stars than Mercury is to the Sun. Though not present in our own solar system, they appear to be common throughout the galaxy. Despite being the most studied type of exoplanet, major questions remain about how they form. Could there be subclasses of hot Jupiter's with different formation stories? For example, do these planets take shape far from their parent stars -- at a distance where it's cold enough for molecules such as water to become solid -- or closer. The first scenario fits better with theories about how planets in our own solar system are born, but what would drive these types of planets to migrate so close to their parent stars remains unclear.

To test those ideas, the authors of a recent McGill-led study used data from NASA's retired Spitzer Space Telescope to look at the atmosphere of exoplanet XO-3b. They observed eccentric seasons and measured wind speeds on the planet by obtaining a phase curve of the planet as it completed a full revolution about its host star.

Looking at atmospheric dynamics and interior evolution

"This planet is an extremely interesting case study for atmospheric dynamics and interior evolution, as it lies in an intermediate regime of planetary mass where processes normally neglected for less massive hot Jupiter's may come into play," says Lisa Dang, the first author of a paper published recently in *The Astronomical Journal*, a PhD student at McGill University's Department of Physics.

"XO-3b has an oval orbit rather than the circular orbit of almost all other known hot Jupiter's. This suggests that it recently migrated toward its parent star; if that's the case, it will eventually settle into a more circular orbit."

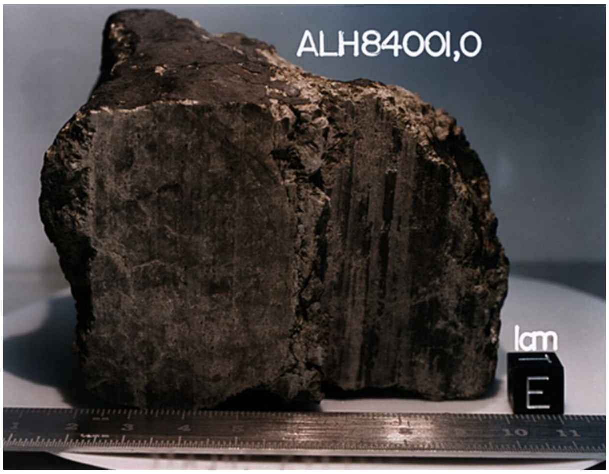
The eccentric orbit of the planet also leads to seasonal variations hundreds of times stronger than what we experience on Earth. Nicolas Cowan, a McGill professor explains: "The entire planet receives three times more energy when it is close to its star during a brief sort of summer, than when it is far from the star."
The researchers also re-estimated the planet's mass and radius and found that the planet was surprisingly puffier than expected. They suggest and that the possible source of this heating could be due to leftover nuclear fusion.

Excess warmth and puffiness due to tidal heating?

Observations by Gaia, an ESA (European Space Agency) mission, found that the planet is puffier than expected which indicate its interior may be particularly energetic. Spitzer observations also hints that the planet produces much of its own heat as XO-3b's excess thermal emission isn't seasonal -- it's observed throughout the year on XO-3b. It's possible that the excess warmth is coming from the planet's interior, through a process called tidal heating. The star's gravitational squeeze on the planet oscillates as the oblong orbit takes the planet farther and then closer to the star. The resulting changes in interior pressure produce heat.
For Dang, this unusual hot Jupiter provides an opportunity to test ideas about which formation processes may producer certain characteristics in these exoplanets. For example, could tidal heating in other hot Jupiter's also be a sign of recent migration? XO-3b alone won't unlock the mystery, but it serves as an important test for emerging ideas about these scorching giants.

- ❖ Martian meteorites organic materials origin not biological, formed by geochemical interactions between water and rock

The search for life on Mars can teach us about the reactions that led to the building blocks of life on early Earth
Date: January 13, 2022
Source: Carnegie Institution for Science



Organic molecules found in a meteorite that hurtled to Earth from Mars were synthesized during interactions between water and rocks that occurred on the Red Planet about 4 billion years ago, according to new analysis led by Carnegie's Andrew Steele and published by *Science*.
The meteorite, called Allan Hills (ALH) 84001, was discovered in the Antarctic in 1984 and is considered one of the oldest known projectiles to reach Earth from Mars.
"Analysing the origin of the meteorite's minerals can serve as a window to reveal both the geochemical processes occurring early in Earth's history and Mars' potential for habitability," explained Steele, who has done extensive research on organic material in Martian meteorites and is a member of both the Perseverance and Curiosity rovers' science teams.
Organic molecules contain carbon and hydrogen, and sometimes include oxygen, nitrogen, sulphur, and other elements. Organic compounds are commonly associated with life, although they can be created by non-biological processes as well, which are referred to as abiotic organic chemistry.
For years, scientists have debated the origin story for the organic carbon found in the Allan Hills 84001 meteorite, with possibilities including various abiotic process related to volcanic activity, impact events on Mars, or hydrological exposure, as well as potentially the remnants of ancient life forms on Mars or contamination from its crash landing on Earth.
The Steele-led team, which also included Carnegie's Larry Nittler, Jianhua Wang, Pamela Conrad, Suzy Vitale, and Vincent Riggi as well as researchers from GFZ German Research Centre for Geosciences, Free University of Berlin, NASA Johnson Space Centre, NASA Ames Research Centre, and Rensselaer Polytechnic Institute, used a

variety of sophisticated sample preparation and analysis techniques -- including co-located nanoscale imaging, isotopic analysis, and spectroscopy -- to reveal the origin of organic molecules in the Allan Hills 84001 meteorite. They found evidence of water-rock interactions similar to those that happen on Earth. The samples indicate that the Martian rocks experienced two important geochemical processes. One, called serpentinization, occurs when iron- or magnesium-rich igneous rocks chemically interact with circulating water, changing their mineralogy and producing hydrogen in the process. The other, called carbonization, involves interaction between rocks and slightly acidic water containing dissolved carbon dioxide and results in the formation of carbonate minerals.

It is unclear whether these processes were induced by surrounding aqueous conditions simultaneously or sequentially, but the evidence indicates that the interactions between water and rocks did not occur over a prolonged period. What is evident, however, is that the reactions produced organic material from the reduction of carbon dioxide.

These mineralogical features are rare in Martian meteorites, and while carbonation and serpentinization have been shown in orbital surveys of Mars and carbonation has been found in other, less-ancient, Martian meteorites, this is the first instance of these processes occurring in samples from ancient Mars. Organic molecules have been detected by Steele in other Martian meteorites and from his work with the Sample Analysis at Mars (SAM) team on the Curiosity rover, indicating that abiotic synthesis of organic molecules has been a part of Martian geochemistry for much of the planet's history.

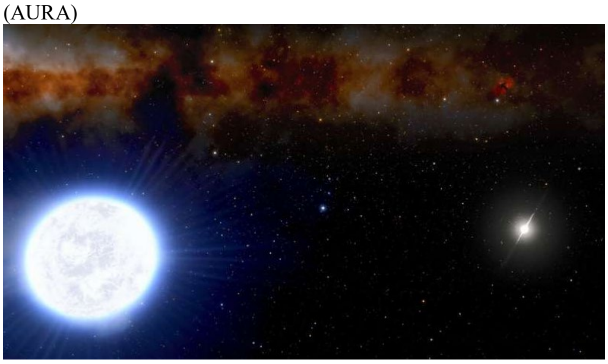
"These kinds of non-biological, geological reactions are responsible for a pool of organic carbon compounds from which life could have evolved and represent a background signal that must be taken into consideration when searching for evidence of past life on Mars," Steele concluded. "Furthermore, if these reactions happened on ancient Mars, they must have happened on ancient Earth, and could possibly explain the results from Saturn's moon Enceladus as well. All that is required for this type of organic synthesis is for a brine that contains dissolved carbon dioxide to percolate through igneous rocks. The search for life on Mars is not just an attempt to answer the question 'are we alone?' It also relates to early Earth environments and addresses the question of 'where did we come from?'"

The US Antarctic meteorite samples were recovered by the Antarctic Search for Meteorites (ANSMET) program, which has been funded by NSF and NASA and characterized and curated by the Department of Mineral Sciences of the Smithsonian Institution and the Astromaterials Acquisition and Curation Office at NASA Johnson Space Centre, respectively.

This work was funded by NASA, Carnegie's Earth and Planets Laboratory, and the Helmholtz Recruiting Initiative program.

- Cosmic 'spider' found to be source of powerful gamma-rays

Date: January 12, 2022
Source: Association of Universities for Research in Astronomy (AURA)



Artist’s impression of an evolving white dwarf (foreground) and millisecond pulsar (background) binary system. Using the 4.1-meter SOAR Telescope on Cerro Pachón in Chile, part of Cerro Tololo Inter-American Observatory, a Program of NSF’s NOIRLab, astronomers have discovered the first example of a binary system consisting of an evolving white dwarf orbiting a millisecond pulsar, in which the millisecond pulsar is in the final phase of the spin-up process. The source, originally detected by the Fermi Space Telescope, is a “missing link” in the evolution of such binary systems. Credit: NOIRLab / NSF / AURA / J. da Silva / Spaceengine

Acknowledgment: M. Zamani (NSF’s NOIRLab)

Using the 4.1-meter SOAR Telescope in Chile, astronomers have discovered the first example of a binary system where a star in the process of becoming a white dwarf is orbiting a neutron star that has just finished turning into a rapidly spinning pulsar. The pair, originally detected by the Fermi Gamma-ray Space Telescope, is a "missing link" in the evolution of such binary systems.

A bright, mysterious source of gamma rays has been found to be a rapidly spinning neutron star -- dubbed a millisecond pulsar -- that is orbiting a star in the process of evolving into an extremely-low-mass white dwarf. These types of binary systems are referred to by astronomers as "spiders" because the pulsar tends to "eat" the outer parts of the companion star as it turns into a white dwarf.

The duo was detected by astronomers using the 4.1-meter SOAR Telescope on Cerro Pachón in Chile, part of Cerro Tololo Inter-American Observatory (CTIO), a Program of NSF's NOIRLab.

NASA's Fermi Gamma-ray Space Telescope has been cataloguing objects in the Universe that produce copious gamma rays since its launch in 2008, but not all of the sources of gamma rays that it detects have been classified. One such source, called 4FGL J1120.0-2204 by astronomers, was the second brightest gamma-ray source in the entire sky that had gone unidentified, until now.

Astronomers from the United States and Canada, led by Samuel Swihart of the US Naval Research Laboratory in Washington, D.C., used the Goodman Spectrograph on the SOAR Telescope to determine the true identity of 4FGL J1120.0-2204. The gamma-ray source, which also emits X-rays, as observed by NASA's Swift and ESA's XMM-Newton space telescopes, has been shown to be a binary system consisting of a "millisecond pulsar" that spins hundreds of times per second, and the precursor to an extremely-low-mass white dwarf. The pair are located over 2600 light-years away.

"Michigan State University's dedicated time on the SOAR Telescope, its location in the southern hemisphere and the precision and stability of the Goodman spectrograph, were all important aspects of this discovery," says Swihart.

"This is a great example of how mid-sized telescopes in general, and SOAR in particular, can be used to help characterize unusual discoveries made with other ground and space-based facilities," notes Chris Davis, NOIRLab Program Director at US National Science Foundation. "We anticipate that SOAR will play a crucial role in the follow-up of many other time-variable and multi-messenger sources over the coming decade."

The optical spectrum of the binary system measured by the Goodman spectrograph showed that light from the proto-white dwarf companion is Doppler shifted -- alternately shifted to the red and the blue -- indicating that it orbits a compact, massive neutron star every 15 hours.

"The spectra also allowed us to constrain the approximate temperature and surface gravity of the companion star," says Swihart, whose team was able to take these properties and apply them to models describing how binary star systems evolve. This allowed them to determine that the companion is the precursor to an extremely-low-mass white dwarf, with a surface temperature of 8200 °C (15,000 °F), and a mass of just 17% that of the Sun.

When a star with a mass similar to that of the Sun or less reaches the end of its life, it will run out of the hydrogen used to fuel the nuclear fusion processes in its core. For a time, helium takes over and powers the star, causing it to contract and heat up, and prompting its expansion and evolution into a red giant that is hundreds of millions of kilometres in size. Eventually, the outer layers of this swollen star can be accreted onto a binary companion and nuclear fusion halts, leaving behind a white dwarf about the size of Earth and sizzling at temperatures exceeding 100,000 °C (180,000 °F).

The proto-white dwarf in the 4FGL J1120.0-2204 system hasn't finished evolving yet. "Currently it's bloated, and is about five times larger in radius than normal white dwarfs with similar masses," says Swihart. "It will continue cooling and contracting and, in about two billion years, it will look identical to many of the extremely low mass white dwarfs that we already know about."

Millisecond pulsars twirl hundreds of times every second. They are spun up by accreting matter from a companion, in this case from the star that became the white dwarf. Most millisecond pulsars emit gamma rays and X-rays, often when the pulsar wind, which is a stream of charged particles emanating from the rotating neutron star, collides with material emitted from a companion star.

About 80 extremely low-mass white dwarfs are known, but "this is the first precursor to an extremely low-mass white dwarf found that is likely orbiting a neutron star," says Swihart. Consequently, 4FGL J1120.0-2204 is a unique look at the tail-end of this spin-up process. All the other white dwarf-pulsar binaries that have been discovered are well past the spinning-up stage.

"Follow-up spectroscopy with the SOAR Telescope, targeting unassociated Fermi gamma-ray sources, allowed us to see that the companion was orbiting something," says Swihart. "Without those observations, we couldn't have found this exciting system."

- Oxygen ions in Jupiter's innermost radiation belts

Date: January 12, 2022
Source: Max Planck Institute for Solar System Research

Nearly 20 years after the end of NASA's Galileo mission to Jupiter, scientists led by the Max Planck Institute for Solar System Research (MPS) in Germany have unlocked a new secret from the mission's extensive data sets. For the first time, the research team was able to determine beyond doubt that the high-energy ions surrounding the gas giant as part of its inner radiation belt are primarily oxygen and sulphur ions. They are thought to have originated in volcanic eruptions on Jupiter's moon Io. Near the orbit of the moon Amalthea, which orbits Jupiter further inward, the team discovered an unexpectedly high concentration of high-energy oxygen ions that cannot be explained by Io's volcanic activity. A previously unknown ion source must be at work here. The results of the study were published today in the journal *Science Advances.*

Planets like Earth, Jupiter, and Saturn with global magnetic fields of their own are surrounded by so-called radiation belts: Trapped in the magnetic field, fast moving charged particles such as electrons, protons, and heavier ions whiz around thus forming the invisible, torus-shaped radiation belts. With their high velocities reaching almost the speed of light, the particles can ionize other molecules when they collide, creating a hazardous environment that can also be dangerous to space probes and their instruments. In this respect, the gas giant Jupiter sports the most extreme radiation belts in the Solar System. In their new publication, researchers from the MPS, the California Institute of Technology (USA), the Johns Hopkins Applied Physics Laboratory (USA), the Laboratory of Instrumentation and Experimental Particle Physics (Portugal), and the Academy of Athens (Greece) now present the most comprehensive study to date of the heavy ions in Jupiter's inner radiation belts. Like Jupiter's massive magnetic field, its radiation belts extend several million kilometres into space; however, the region within the moon's orbit of Europa, an area with a radius of about 670,000 kilometres around the gas giant, is the scene of the highest energetic particle densities and velocities. Viewed from Jupiter, Europa is the second of the four large Jovian satellites named "Galilean moons" after their 17th century discoverer. Io is the innermost Galilean moon. With the space probes Pioneer 11 in the mid-1970s, Galileo from 1995 to 2003, and currently Juno, three space missions have so far ventured into this innermost part of these radiation belts and performed in-situ measurements. "Unfortunately, the data from Pioneer 11 and Juno do not allow us to conclude beyond doubt what kind of ions the spacecraft encountered there," says MPS scientist Dr. Elias Roussos, lead author of the new study, describing the current state of research. "Therefore, their energies and origin were also unclear until now," he adds. Only the now rediscovered data from the last months of the Galileo mission is detailed enough to improve this situation.

Venturing into the inner radiation belts

NASA's Galileo spacecraft reached the Jupiter system in 1995. Equipped with the Heavy Ion Counter (HIC), contributed by the California Institute of Technology, and the Energetic Particle Detector (EPD), developed and built by Johns Hopkins Applied Physics Laboratory in collaboration with the MPS, the mission spent the following eight years providing fundamental insights into the distribution and dynamics of charged particles around the gas giant. However, to protect the spacecraft, it initially flew solely through the outer, less extreme regions of the radiation belts. Only in 2003, shortly before the end of the mission, when a greater risk was justifiable, Galileo ventured into the innermost region within the orbits of the moons Amalthea and Thebe. Viewed from Jupiter, Amalthea and Thebe are the third and fourth moons of the giant planet. The orbits of Io and Europa lie farther outward.

"Because of the exposure to strong radiation, it was to be expected that the measurement data from HIC and EPD from the inner region of the radiation belt would be heavily corrupted. After all, neither of these two instruments was specifically designed to operate in such a harsh environment," Roussos describes his expectations when he started working on the current study three years ago. Nevertheless, the researcher wanted to see for himself. As a member of NASA's Cassini mission, he had witnessed Cassini's final, similarly daring orbits at Saturn two years earlier and analysed the unique data from that final mission phase. "The thought of the long-completed Galileo mission kept coming to my mind," Roussos recalls. To his own surprise, among many unusable data sets there were also some that could be processed and analysed with much effort.

Enigmatic oxygen ions

With the help of this scientific treasure, the authors of the current study have now been able to determine for the first time the ion composition within the inner radiation belts, as well as the ions' velocities and spatial distribution. In contrast to the radiation belts of Earth and Saturn, which are dominated by protons, the region within the orbit of Io also contains large amounts of the much heavier oxygen and sulphur ions, with oxygen ions prevailing among the two. "The energy distribution of the heavy ions outside the orbit of Amalthea suggests that they are largely introduced from a more distant region of the radiations belts," Roussos says. The moon Io with its more than 400 active volcanoes, which repeatedly hurl large amounts of sulphur and sulphur dioxide into space, and to a lesser extent, Europa, are likely the main sources.

Further inward, within Amalthea's orbit, the ion composition changes drastically in favour of oxygen. "The concentration and the energy of oxygen ions there is much higher than expected," Roussos says. Actually, the concentration should be decreasing in this region, as the moons Amalthea and Thebe absorb incoming ions; the two small moons' orbits thus form a kind of natural ion barrier. This behaviour is, for example, known from radiation belts of the Saturnian system with its many moons.

The only explanation for the increased concentration of oxygen ions is therefore another, local source in the innermost region of the radiation belts. The release of oxygen following the collisions of sulphur ions with the fine dust particles of Jupiter's rings constitute one possibility, as the researchers' computer simulations show. The rings, which are much fainter than the Saturnian ones, extend approximately as far as the orbit of Thebe. However, it is also conceivable that low-frequency electromagnetic waves in the magnetospheric environment of the innermost radiation belts heat oxygen ions to the observed energies.

"Currently, it is not possible to distinguish in favour of either of these possible sources," Roussos says. Any of these two candidate mechanisms, nevertheless, have parallels to high energy particle production in stellar or extrasolar environments, further establishing that Jupiter's radiation belts extend into the astrophysical realm, a fact that the researcher hopes would justify their future exploration with a dedicated space mission.

- New evidence of a gravitational wave background

Date: January 12, 2022
Source: University of Birmingham


Visualization of the gravitational waves generated by two black holes. (Henze/NASA)

The results of a comprehensive search for a background of ultra-low frequency gravitational waves has been announced by an international team of astronomers including scientists from the Institute for Gravitational Wave Astronomy at the University of Birmingham.

These light-year-scale ripples, a consequence of Einstein's theory of general relativity, permeate all of spacetime and could originate from mergers of the most massive black holes in the Universe or from events occurring soon after the formation of the Universe in the Big Bang. Scientists have been searching for definitive evidence of these signals for several decades.

The International Pulsar Timing Array (IPTA), joining the work of several astrophysics collaborations from around the world, recently completed its search for gravitational waves in their most recent official data release, known as Data Release 2 (DR2).

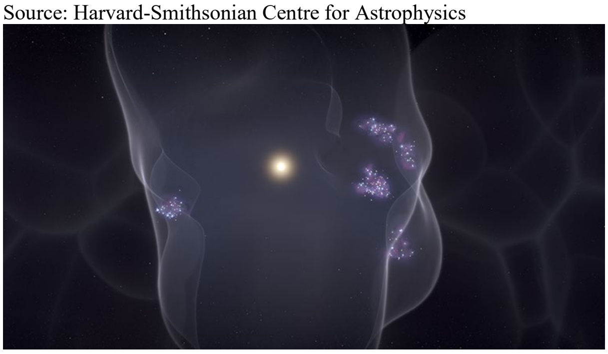
This data set consists of precision timing data from 65 millisecond pulsars -- stellar remnants which spin hundreds of times per second, sweeping narrow beams of radio waves that appear as pulses due to the spinning -- obtained by combining the independent data sets from the IPTA's three founding members: The European Pulsar Timing Array (EPTA), the North American Nanohertz Observatory for Gravitational Waves (NANOGrav), and

the Parkes Pulsar Timing Array in Australia (PPTA).
These combined data reveal strong evidence for an ultra-low frequency signal detected by many of the pulsars in the combined data. The characteristics of this common-among-pulsars signal are in broad agreement with those expected from a gravitational wave "background."
The gravitational wave background is formed by many different overlapping gravitational-wave signals emitted from the cosmic population of supermassive binary black holes (i.e. two supermassive black holes orbiting each other and eventually merging) -- similar to background noise from the many overlapping voices in a crowded hall.
This result further strengthens the gradual emergence of similar signals that have been found in the individual data sets of the participating pulsar timing collaborations over the past few years.
Professor Alberto Vecchio, Director of the Institute for Gravitational Wave Astronomy at the University of Birmingham, and member of the EPTA, says: "The detection of gravitational waves from a population of massive black hole binaries or from another cosmic source will give us unprecedented insights into how galaxy form and grow, or cosmological processes taking place in the infant universe. A major international effort of the scale of IPTA is needed to reach this goal, and the next few years could bring us a golden age for these explorations of the universe."
"This is a very exciting signal! Although we do not have definitive evidence yet, we may be beginning to detect a background of gravitational waves," says Dr Siyuan Chen, a member of the EPTA and NANOGrav, and the leader of the IPTA DR2 search and publication.
Dr Boris Goncharov from the PPTA cautions on the possible interpretations of such common signals: "We are also looking into what else this signal could be. For example, perhaps it could result from noise that is present in individual pulsars' data that may have been improperly modelled in our analyses."
To identify the gravitational-wave background as the origin of this ultra-low frequency signal, the IPTA must also detect spatial correlations between pulsars. This means that each pair of pulsars must respond in a very particular way to gravitational waves, depending on their separation on the sky.
These signature correlations between pulsar pairs are the "smoking gun" for a gravitational-wave background detection. Without them, it is difficult to prove that some other process is not responsible for the signal. Intriguingly, the first indication of a gravitational wave background would be a common signal like that seen in the IPTA DR2. Whether or not this spectrally similar ultra-low frequency signal is correlated between pulsars in accordance with the theoretical predictions will be resolved with further data collection, expanded arrays of monitored pulsars, and continued searches of the resulting longer and larger data sets.
Consistent signals like the one recovered with the IPTA analysis have also been published in individual data sets more recent than those used in the IPTA DR2, from each of the three founding collaborations. The IPTA DR2 analysis demonstrates the power of the international combination giving strong evidence for a gravitational wave background compared to the marginal or absent evidences from the constituent data sets. Additionally, new data from the MeerKAT telescope and from the Indian Pulsar Timing Array (InPTA), the newest member of the IPTA, will further expand future data sets.
"The first hint of a gravitational wave background would be a signal like that seen in the IPTA DR2. Then, with more data, the signal will become more significant and will show spatial correlations, at which point we will know it is a gravitational wave background. We are very much looking forward to contributing several years of new data to the IPTA for the first time, to help achieve a gravitational wave background detection," says Dr Bhal Chandra Joshi, a member of the InPTA.
Given the latest published results from the individual groups who now all can clearly recover the common signal, the IPTA is optimistic for what can be achieved once these are combined into the IPTA Data Release 3. Work is already ongoing on this new data release, which at a minimum will include updated data sets from the four constituent PTAs of the IPTA. The analysis of the DR3 data set is expected to finish within the next few years.
Dr Maura McLaughlin of the NANOGrav collaboration says, "If the signal we are

currently seeing is the first hint of a gravitational wave background, then based on our simulations, it is possible we will have more definite measurements of the spatial correlations necessary to conclusively identify the origin of the common signal in the near future."

- 1,000-light-year wide bubble surrounding Earth is source of all nearby, young stars

Date: January 12, 2022
Source: Harvard-Smithsonian Centre for Astrophysics



The Earth sits in a 1,000-light-year-wide void surrounded by thousands of young stars -- but how did those stars form?
In a paper appearing Wednesday in *Nature*, astronomers at the Centre for Astrophysics | Harvard & Smithsonian (CfA) and the Space Telescope Science Institute (STScI) reconstruct the evolutionary history of our galactic neighbourhood, showing how a chain of events beginning 14 million years ago led to the creation of a vast bubble that's responsible for the formation of all nearby, young stars.
"This is really an origin story; for the first time we can explain how all nearby star formation began," says astronomer and data visualization expert Catherine Zucker who completed the work during a fellowship at the CfA.
The paper's central figure, a 3D spacetime animation, reveals that all young stars and star-forming regions -- within 500 light years of Earth -- sit on the surface of a giant bubble known as the Local Bubble. While astronomers have known of its existence for decades, scientists can now see and understand the Local Bubble's beginnings and its impact on the gas around it.

The Source of Our Stars: The Local Bubble

Using a trove of new data and data science techniques, the spacetime animation shows how a series of supernovae that first went off 14 million years ago, pushed interstellar gas outwards, creating a bubble-like structure with a surface that's ripe for star formation. Today, seven well-known star-forming regions or molecular clouds -- dense regions in space where stars can form -- sit on the surface of the bubble.
"We've calculated that about 15 supernovae have gone off over millions of years to form the Local Bubble that we see today," says Zucker who is now a NASA Hubble Fellow at STScI.
The oddly-shaped bubble is not dormant and continues to slowly grow, the astronomers note.
"It's coasting along at about 4 miles per second," Zucker says. "It has lost most of its oomph though and has pretty much plateaued in terms of speed."
The expansion speed of the bubble, as well as the past and present trajectories of the young stars forming on its surface, were derived using data obtained by Gaia, a space-based observatory launched by the European Space Agency.
"This is an incredible detective story, driven by both data and theory," says Harvard professor and Centre for Astrophysics astronomer Alyssa Goodman, a study co-author and founder of glue, data visualization software that enabled the discovery. "We can piece together the history of star formation around us using a wide variety of independent clues: supernova models, stellar motions and exquisite new 3D maps of the material surrounding the Local Bubble."

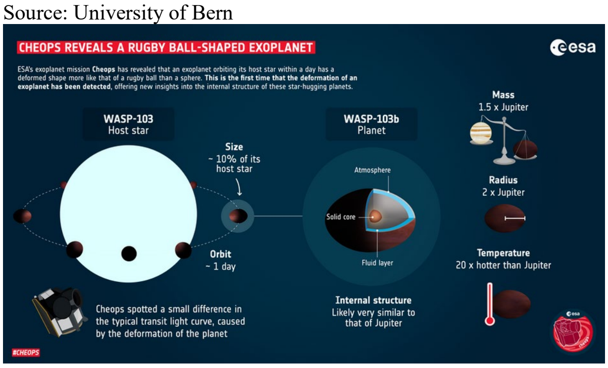
Bubbles Everywhere?

"When the first supernovae that created the Local Bubble went off, our Sun was far away from the action" says co-author João Alves, a professor at the University of Vienna. "But about five million years ago, the Sun's path through the galaxy took it right into the bubble, and now the Sun sits -- just by luck -- almost right in the bubble's centre."
Today, as humans peer out into space from near the Sun, they have a front row seat to the process of star formation occurring all around on the bubble's surface.
Astronomers first theorized that super bubbles were pervasive in the Milky Way nearly 50 years ago. "Now, we have proof -- and what are the chances that we are right smack in the middle of one of these things?" asks Goodman. Statistically, it is very unlikely that the Sun would be cantered in a giant bubble if such bubbles were rare in our Milky Way Galaxy, she explains.

Goodman likens the discovery to a Milky Way that resembles very hole-y swiss cheese, where holes in the cheese are blasted out by supernovae, and new stars can form in the cheese around the holes created by dying stars.
Next, the team, including co-author and Harvard doctoral student Michael Foley, plans to map out more interstellar bubbles to get a full 3D view of their locations, shapes and sizes. Charting out bubbles, and their relationship to each other, will ultimately allow astronomers to understand the role played by dying stars in giving birth to new ones, and in the structure and evolution of galaxies like the Milky Way.
Zucker wonders, "Where do these bubbles touch? How do they interact with each other? How do super bubbles drive the birth of stars like our Sun in the Milky Way?"
Additional co-authors on the paper are Douglas Finkbeiner and Diana Khimey of the CfA; Josefa Gro?schedland Cameren Swiggum of the University of Vienna; Shmuel Bialy of the University of Maryland; Joshua Speagle of the University of Toronto; and Andreas Burkert of the University Observatory Munich.

- ❖ Rugby ball-shaped exoplanet discovered

Date: January 12, 2022
Source: University of Bern



With the help of the CHEOPS space telescope, an international team including researchers from the Universities of Bern and Geneva as well as the National Centre of Competence in Research (NCCR) PlanetS, was able to detect the deformation of an exoplanet for the first time. Due to strong tidal forces, the appearance of the planet WASP-103b resembles a rugby ball rather than a sphere.
On coasts, the tides determine the rhythm of events. At low tide, boats remain on land; at high tide, the way out to sea is cleared for them again. On Earth, the tides are mainly generated by the moon. Its gravitational pull causes an accumulation of water in the ocean region below, which is then missing in surrounding regions and thus accounts for the low tide. Although this deformation of the ocean causes striking differences in level in many places, it is hardly recognisable from space.
On the planet WASP-103b, tides are much more extreme. The planet orbits its star in just one day and is deformed by the strong tidal forces so drastically, that its appearance resembles a rugby ball. This is shown by a new study involving researchers from the Universities of Bern and Geneva as well as the National Centre of Competence in Research (NCCR) PlanetS, published today in the scientific journal *Astronomy & Astrophysics*.
This finding was made possible thanks to observations with the CHEOPS space telescope. CHEOPS is a joint mission of the European Space Agency (ESA) and Switzerland, led by the University of Bern in collaboration with the University of Geneva.

A ground-breaking measurement

The planet WASP-103b is located in the constellation Hercules, is almost twice the size of Jupiter, has one and a half times its mass and is about fifty times closer to its star than Earth is to the Sun. "Because of its great proximity to its star, we had already suspected that very large tides are caused on the planet. But, we had not yet been able to verify this," explains study co-author Yann Alibert, professor of astrophysics at the University of Bern and member of the NCCR PlanetS.
The NASA/ESA Hubble Space Telescope and NASA's Spitzer Space Telescope had already observed the planet. In combination with the high precision and pointing flexibility of CHEOPS, these observations enabled the researchers to measure the tiny signal of the tidal deformation of the planet light years away. In doing so, they took advantage of the fact that the planet dims the light of the star slightly each time it passes in front of it.
"After observing several such so-called "transits," we were able to measure the deformation. It's incredible that we were able to do this -- it's the first time such an analysis has been done," reports Babatunde Akinsanmi, a researcher at the University of Geneva, co-author of the study and NCCR PlanetS associate.

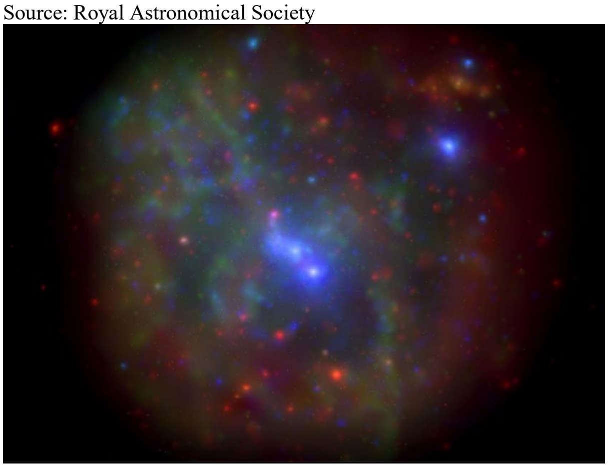
The planet is inflated

The researchers' results not only allow conclusions to be drawn about the shape of the planet, but also about its interior. This is because the team was also able to derive a

parameter called the "Love number" (named after the British mathematician Augustus E. H. Love) from the transit light curve of WASP-103b. It indicates how the mass is distributed within the planet and thus also gives clues about its inner structure. "The resistance of a material to deformation depends on its composition," explains Akinsanmi. "We can only see the tides on Earth in the oceans. The rocky part doesn't move that much. Therefore, by measuring how much the planet is deformed, we can determine how much of it is made up of rock, gas or water."
WASP-103b's Love number is like Jupiter's, our Solar System's biggest gas giant. It suggests that the internal structures of WASP-103b and Jupiter are similar -- even though WASP-103b is twice as large. "In principle, we would expect a planet with 1.5 times the mass of Jupiter to be about the same size. Therefore, WASP-103b must be highly inflated due to heating by its nearby star, and perhaps other mechanisms," says Monika Lendl, professor of astronomy at the University of Geneva and co-author of the study.
However, since the measurement uncertainty in the Love number is still quite high, future observations with CHEOPS and the James Webb Space Telescope will be needed to decipher the details of the tidal deformation and internal structure of WASP-103b and comparable exoplanets. "This would improve our understanding of these so-called 'hot Jupiter's' and allow a better comparison between them and giant planets in the Solar System," Lendl concludes.

- Black hole at centre of Milky Way unpredictable and chaotic

Date: January 12, 2022
Source: Royal Astronomical Society



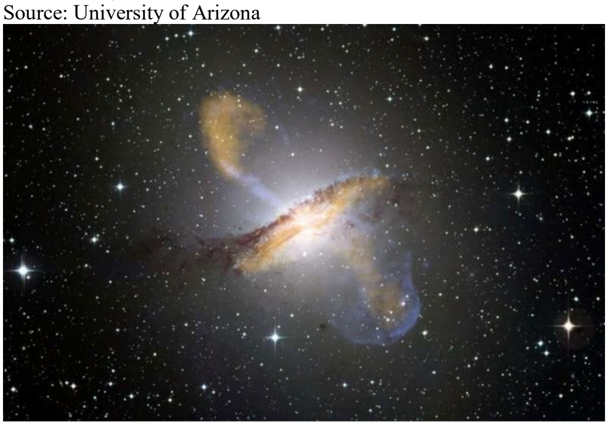
This X-ray image of the galactic centre merges all Swift observations from 2006 through 2013. Sagittarius A* is at the centre. Low-energy (300 to 1,500 electron volts) X-rays appear red. Green are medium-energy (1,500 to 3,000 eV). Blue are high-energy (3,000 to 10,000 eV).
Credit
NASA/Swift/N. Degenaar

An international team of researchers, led by postgraduate student Alexis Andrés, has found that the black hole at the centre of our galaxy, Sagittarius A*, not only flares irregularly from day to day but also in the long term. The team analysed 15 years' worth of data to come to this conclusion. The research was initiated by Andres in 2019 when he was a summer student at the University of Amsterdam. In the years that followed, he continued his research, which is now to be published in *Monthly Notices of the Royal Astronomical Society*.
Sagittarius A* is a strong source of radio, X-rays and gamma rays (visible light is blocked by intervening gas and dust). Astronomers have known for decades that Sagittarius A* flashes every day, emitting bursts of radiation that are ten to a hundred times brighter than normal signals observed from the black hole.
To find out more about these mysterious flares, the team of astronomers, led by Andrés, searched for patterns in 15 years of data made available by NASA's Neil Gehrels Swift Observatory, an Earth-orbiting satellite dedicated to the detection of gamma-ray bursts. The Swift Observatory has been observing gamma rays from black hole since 2006. Analysis of the data showed high levels of activity from 2006 to 2008, with a sharp decline in activity for the next four years. After 2012, the frequency of flares increased again -- the researchers had a difficult time distinguishing a pattern.
In the next few years, the team of astronomers expect to gather enough data to be able to rule out whether the variations in the flares from Sagittarius A* are due to passing gaseous clouds or stars, or whether something else can explain the irregular activity observed from our galaxy's central black hole.
"The long dataset of the Swift observatory did not just happen by accident," says co-author and previous supervisor to Andrés, Dr Nathalie Degenaar, also at the University of Amsterdam. Her request for these specific measurements from the Swift satellite was granted while she was a PhD student. "Since then, I've been applying for more observing time regularly. It's a very special observing programme that allows us to conduct a lot of research."

Co-author Dr Jakob van den Eijnden, of the University of Oxford, comments on the team's findings: "How the flares occur exactly remains unclear. It was previously thought that more flares follow after gaseous clouds or stars pass by the black hole, but there is no evidence for that yet. And we cannot yet confirm the hypothesis that the magnetic properties of the surrounding gas play a role either."

- New treasure trove of globular clusters holds clues about galaxy evolution

Date: January 11, 2022
Source: University of Arizona



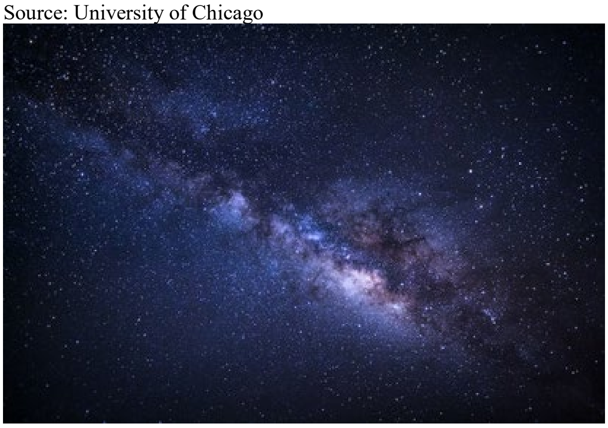
Centaurus A is an elliptical galaxy located about 13 million light-years from Earth. This colour composite image reveals the lobes and jets emanating from the active galaxy's central black hole. Credit: ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre); NASA/CXC/CfA/R.Kraft et al. (X-ray)

A survey completed using a combination of ground and space-based telescopes yielded a treasure trove of previously unknown globular clusters -- old, dense groups of thousands of stars that all formed at the same time -- in the outer regions of the elliptical galaxy Centaurus A. The work presents a significant advance in understanding the architecture and cosmological history of this galaxy and offers new insights into galaxy formation in general and the distribution of dark matter in the universe.
Allison Hughes, a doctoral student in the University of Arizona Department of Astronomy and Steward Observatory, is the first author of a peer-reviewed paper summarizing the findings that was published in the *Astrophysical Journal* in June. She will present the study during a virtual press briefing at the 239th Meeting of the Astronomical Society of America Tuesday.
Centaurus A, also known as NGC 5128, is a visually stunning, elliptical galaxy featuring a relativistic jet spewing from a supermassive black hole at its centre and spectacular streams of scattered stars left behind by past collisions and mergers with smaller galaxies orbiting Centaurus A. Located in the constellation Centaurus, 13 million light-years from Earth, Centaurus A is too far away to allow astronomers to see individual stars, but star clusters can be identified as such and used as "fossil evidence" of the galaxy's tumultuous evolution.
Hughes and her colleagues present a new catalogue of approximately 40,000 globular cluster candidates in Centaurus A, recommending follow-up observations focused on a set of 1,900 that are most likely to be true globular clusters. The researchers surveyed globular cluster candidates out to a projected radius of approximately 150 kiloparsecs, nearly half a million light-years from the galaxy's centre. The data combines observations from the following sources: the Panoramic Imaging Survey of Centaurus and Sculptor, or PISCeS; Gaia, a space observatory of the European Space Agency, and the NOAO Source Catalogue, which combines publicly accessible images from telescopes in both hemispheres covering nearly the entire sky.
.Centaurus A has been a leading target for extragalactic globular cluster studies due to its richness and proximity to Earth, but the majority of studies have focused on the inner 40 kiloparsecs (about 130,500 light-years) of the galaxy, Hughes explained, leaving the outer reaches of the galaxy largely unexplored.
Ranking the candidates based on the likelihood that they are true globular clusters, the team found that approximately 1,900 are highly likely to be confirmed as such and should be the highest priority for follow-up spectroscopic confirmation.
"We're using the Gaia satellite, which mostly focuses on surveys within our own galaxy, the Milky Way, in a new way in that we link up its observations with telescopes on the ground, in this case the Magellan Clay telescope in Chile and the Anglo-Australian Telescope in Australia."
Centaurus A's structure tells astronomers that it went through several major mergers with other galaxies, leading to its glob-like appearance with river-like regions that have many more stars than the surrounding areas, Hughes said. Providing the closest example of an elliptical galaxy, Centaurus A offers astronomers an opportunity to study up close a galaxy that is very unlike our own. The Milky Way, as well as its closest neighbour, the Andromeda Galaxy, are both spiral galaxies. With their familiar, pinwheel-like appearance,

spiral galaxies may seem like the "typical" galaxy, but it turns out that their less orderly elliptical cousins outnumber them in the cosmos.
"Centaurus A may look like an odd outlier, but that's only because we can get close enough to see its nitty gritty details," Hughes said. "More likely than not, both elliptical and spiral galaxies like the Milky Way are messier than we realize as soon as we look a little bit deeper than just on the surface."
Globular clusters serve as evidence of processes that happened a long time ago, Hughes said.
"For example, if you see a line of these globular clusters that all have similar metallicity (chemical composition) and move with similar radial velocity, we know they must have come from the same dwarf galaxy or some similar object that collided with Centaurus A and is now in the process of being assimilated."
Star clusters form from dense patches of gas in the interstellar medium. Almost every galaxy has globular clusters, including the Milky Way, which boasts around 150 of them, but most stars are not arranged in such clumps. By studying globular clusters, astronomers can gather clues about the galaxy hosting them, such as its mass, its history of interactions with nearby galaxies and even the distribution of dark matter within, according to Hughes.
"Globular clusters are interesting because they can be used as tracers of structures and processes in other galaxies where we can't resolve individual stars," Hughes said. "They hold on to chemical signatures, such as the elemental composition of their individual stars, so they tell us something about the environment in which they formed."
The researchers specifically looked for globular clusters far from the centre of the galaxy because Centaurus A's substructure hints at a large, undiscovered population of such clusters, Hughes explained. Previous observations had found just under 600 clusters in the more central regions, but the outer regions of the galaxy had remained largely uncharted.
"We looked farther out and discovered more than 100 new clusters already, and most likely there are more, because we haven't even finished processing the data," Hughes said.
"We can then use that data to reconstruct the architecture and movements in that galaxy, and also figure out its mass," Hughes said. "From that we can eventually subtract all its stars and see what's left -- that invisible mass must be its dark matter."

- Twelve for dinner: The Milky Way’s feeding habits shine a light on dark matter

Date: January 11, 2022
Source: University of Chicago



Milky Way (stock image).
Credit: © sripfoto / stock.adobe.com

Astronomers are one step closer to revealing the properties of dark matter enveloping our Milky Way galaxy, thanks to a new map of twelve streams of stars orbiting within our galactic halo.
Understanding these star streams is very important for astronomers. As well as revealing the dark matter that holds the stars in their orbits, they also tell us about the formation history of the Milky Way, revealing that the Milky Way has steadily grown over billions of years by shredding and consuming smaller stellar systems.
"We are seeing these streams being disrupted by the Milky Way's gravitational pull, and eventually becoming part of the Milky Way. This study gives us a snapshot of the Milky Way's feeding habits, such as what kinds of smaller stellar systems 'eats'. As our galaxy is getting older, it is getting fatter," said University of Toronto Professor Ting Li, the lead author of the paper.
Prof. Li and her international team of collaborators initiated a dedicated program -- the Southern Stellar Stream Spectroscopic Survey (S5) -- to measure the properties of stellar streams: the shredded remains of neighbouring small galaxies and star clusters that are being torn apart by our own Milky Way.
Li and her team are the first group of scientists to study such a rich collection of stellar streams, measuring the speeds of stars using the Anglo-Australian Telescope (AAT), a 4-meter optical telescope in Australia. Li and her team used the Doppler shift of light -- the

same property used by radar guns to catch speeding drivers -- to find out how fast individual stars are moving.
Unlike previous studies that have focused on one stream at a time, "S5 is dedicated to measuring as many streams as possible, which we can do very efficiently with the unique capabilities of the AAT," comments co-author Professor Daniel Zucker of Macquarie University.
The properties of stellar streams reveal the presence of the invisible dark matter of the Milky Way. "Think of a Christmas tree," says co-author Professor Geraint F. Lewis of the University of Sydney. "On a dark night, we see the Christmas lights, but not the tree they are wrapped around. But the shape of the lights reveals the shape of the tree," he said. "It is the same with stellar streams -- their orbits reveal the dark matter."
As well as measuring their speeds, the astronomers can use these observations to work out the chemical compositions of the stars, telling us where they were born. "Stellar streams can come either from disrupting galaxies or star clusters," says Professor Alex Ji at the University of Chicago, a co-author on the study. "These two types of streams provide different insights into the nature of dark matter."
According to Prof. Li, these new observations are essential for determining how our Milky Way arose from the featureless universe after the Big Bang. "For me, this is one of the most intriguing questions, a question about our ultimate origins," Li said. "It is the reason why we founded S5 and built an international collaboration to address this."
A crucial ingredient for the success of S5 were observations from the European Gaia space mission. "Gaia provided us with exquisite measurements of positions and motions of stars, essential for identifying members of the stellar streams," says Dr. Sergey Koposov, reader in observational astronomy in the University of Edinburgh and a co-author of the study.
Li's team plans to produce more measurements on stellar streams in the Milky Way. In the meantime, she is pleased with these results as a starting point. "Over the next decade, there will be a lot of dedicated studies looking at stellar streams," Li says. "We are trail-blazers and pathfinders on this journey. It is going to be very exciting!"

- Astronomers identify potential clue to reinonization of universe

Date: January 10, 2022
Source: University of Iowa

About 400,000 years after the universe was created began a period called "The Epoch of Reionization."
During this time, the once hotter universe began to cool and matter clumped together, forming the first stars and galaxies. As these stars and galaxies emerged, their energy heated the surrounding environment, reionizing some of the remaining hydrogen in the universe.
The universe's reionization is well known, but determining how it happened has been tricky. To learn more, astronomers have peered beyond our Milky Way galaxy for clues. In a new study, astronomers at the University of Iowa identified a source in a suite of galaxies called Lyman continuum galaxies that may hold clues about how the universe was reionized.
In the study, the Iowa astronomers identified a black hole, a million times as bright as our sun, that may have been similar to the sources that powered the universe's reionization. That black hole, the astronomers report from observations made in February 2021 with NASA's flagship Chandra X-ray observatory, is powerful enough to punch channels in its respective galaxy, allowing ultraviolet photons to escape and be observed.
"The implication is that outflows from black holes may be important to enable escape of the ultraviolet radiation from galaxies that reionized the intergalactic medium," says Phil Kaaret, professor and chair in the Department of Physics and Astronomy and the study's corresponding author.
"We can't yet see the sources that actually powered the universe's reionization because they are too far away," Kaaret says. "We looked at a nearby galaxy with properties similar to the galaxies that formed in the early universe. One of the primary reasons that the James Webb Space Telescope was built was to

try to see the galaxies hosting the sources that actually powered the universe's reionization."
Jesse Bluem, a graduate research assistant at Iowa, and Andrea Prestwich, with the Harvard-Smithsonian Centre for Astrophysics, are co-authors of the *Monthly Notices of the Royal Astronomical Society: Letters* article.

- Ocean physics explain cyclones on Jupiter

Images from NASA satellite of polar cyclones on Jupiter allow scientists to study the forces that drive them
Date: January 10, 2022
Source: University of California - San Diego

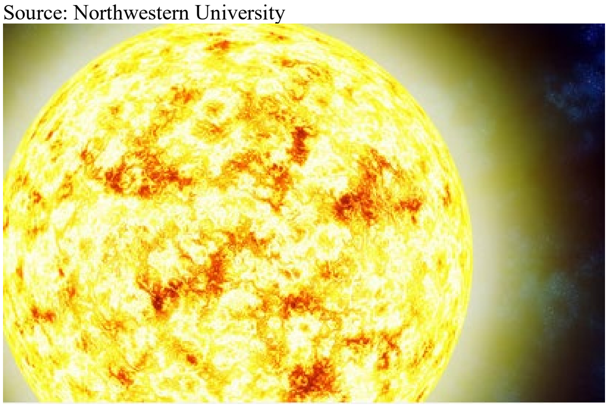

Jupiter’s swirling clouds captured by NASA’s Juno spacecraft. Image Credit: Enhanced Image by Gerald Eichstädt and Sean Doran (CC BY-NC-SA)/NASA/JPL-Caltech/SwRI/MSSS

Hurtling around Jupiter and its 79 moons is the Juno spacecraft, a NASA-funded satellite that sends images from the largest planet in our solar system back to researchers on Earth. These photographs have given oceanographers the raw materials for a new study published today in *Nature Physics* that describes the rich turbulence at Jupiter's poles and the physical forces that drive the large cyclones.
Lead author Lia Siegelman, a physical oceanographer and postdoctoral scholar at Scripps Institution of Oceanography at the University of California San Diego, decided to pursue the research after noticing that the cyclones at Jupiter's pole seem to share similarities with ocean vortices she studied during her time as a PhD student. Using an array of these images and principles used in geophysical fluid dynamics, Siegelman and colleagues provided evidence for a long time hypothesis that moist convection -- when hotter, less dense air rises -- drives these cyclones.
"When I saw the richness of the turbulence around the Jovian cyclones with all the filaments and smaller eddies, it reminded me of the turbulence you see in the ocean around eddies," said Siegelman. "These are especially evident on high-resolution satellite images of plankton blooms for example."
Siegelman says that understanding Jupiter's energy system, a scale much larger than Earth's one, could also help us understand the physical mechanisms at play on our own planet by highlighting some energy routes that could also exist on Earth.
"To be able to study a planet that is so far away and find physics that apply there is fascinating," she said. "It begs the question, do these processes also hold true for our own blue dot?"
Juno is the first spacecraft to capture images of Jupiter's poles; previous satellites orbited the equatorial region of the planet, providing views of the planet's famed Red Spot. Juno is equipped with two camera systems, one for visible light images and another that captures heat signatures using the Jovian Infrared Auroral Mapper (JIRAM), an instrument on the Juno spacecraft supported by the Italian Space Agency.
Siegelman and colleagues analysed an array of infrared images capturing Jupiter's north polar region, and in particular the polar vortex cluster. From the images, the researchers could calculate wind speed and direction by tracking the movement of the clouds between images. Next, the team interpreted infrared images in terms of cloud thickness. Hot regions correspond to thin clouds, where it is possible to see deeper into Jupiter's atmosphere. Cold regions represent thick cloud cover, blanketing Jupiter's atmosphere. These findings gave the researchers clues on the energy of the system. Since Jovian clouds are formed when hotter, less dense air rises, the researchers found that the rapidly rising air within clouds acts as an energy source that feeds larger scales up to the large circumpolar and polar cyclones.
Juno first arrived at the Jovian system in 2016, providing scientists with the first look at these large polar cyclones, which have a radius of about 1,000 kilometres or 620 miles. There are eight of these cyclones occurring at Jupiter's north pole, and five at its south pole. These storms have been present since that first view five years ago. Researchers are unsure how they originated or for how long they have been circulating, but they now know that moist convection is what sustains them. Researchers first hypothesized this energy transfer after observing lightning in storms on Jupiter.

Juno will continue orbiting Jupiter until 2025, providing researchers and the public alike with novel images of the planet and its extensive lunar system.
Seigelman is funded through the Scripps Institution of Oceanography Postdoctoral Program, working in the lab of physical oceanographer William Young, whose work is supported by the National Science Foundation.

- Astronomers capture red supergiant's death throes

'For the first time, we watched a red supergiant star explode,' researcher says
Date: January 6, 2022
Source: Northwestern University



Red giant star, illustration (stock image; elements furnished by NASA).
Credit: © Aaron Alien / stock.adobe.com

For the first time ever, astronomers have imaged in real time the dramatic end to a red supergiant's life -- watching the massive star's rapid self-destruction and final death throes before collapsing into a type II supernova.
Led by researchers at Northwestern University and the University of California, Berkeley (UC Berkeley), the team observed the red supergiant during its last 130 days leading up to its deadly detonation.
The discovery defies previous ideas of how red supergiant stars evolve right before exploding. Earlier observations showed that red super giants were relatively quiescent before their deaths -- with no evidence of violent eruptions or luminous emissions. The new observations, however, detected bright radiation from a red supergiant in the final year before exploding. This suggests at least some of these stars must undergo significant changes in their internal structure, which then result in the tumultuous ejection of gas moments before they collapse.
"This is a breakthrough in our understanding of what massive stars do moments before they die," said Wynn Jacobson-Galán, the study's lead author. "Direct detection of pre-supernova activity in a red supergiant star has never been observed before in an ordinary type II supernova. For the first time, we watched a red supergiant star explode."
The discovery was published today (Jan. 6) in *The Astrophysical Journal.*
Although the work was conducted at Northwestern, where Jacobson-Galán was a National Science Foundation (NSF) Graduate Research Fellow, he has since moved to UC Berkeley. Northwestern co-authors include Deanne Coppejans, Charlie Kilpatrick, Giacomo Terreran, Peter Blanchard and Lindsay DeMarchi, who are all members of Northwestern's Centre for Interdisciplinary and Exploratory Research in Astrophysics (CIERA).

'We've never confirmed such violent activity'

The University of Hawaii Institute for AstronomyPan-STARRS on Haleakal?, Maui, first detected the doomed massive star in summer 2020 via the huge amount of light radiating from the red supergiant. A few months later, in fall of 2020, a supernova lit the sky.
The team quickly captured the powerful flash and obtained the very first spectrum of the energetic explosion, named supernova 2020tlf (SN 2020tlf) using the W.M. Keck Observatory's Low Resolution Imaging Spectrometer on Maunakea, Hawai?i. The data showed direct evidence of dense circumstellar material surrounding the star at the time of explosion, likely the same gas that Pan-STARRS had imaged the red supergiant star violently ejecting earlier in the summer.
"It's like watching a ticking time bomb," said Raffaella Margutti, an adjunct associate professor at CIERA and the paper's senior author. "We've never confirmed such violent activity in a dying red supergiant star where we see it produce such a luminous emission, then collapse and combust, until now."
The team continued to monitor SN 2020tlf after the explosion. Based on data obtained from Keck Observatory's Deep Imaging and Multi-Object Spectrograph and Near Infrared Echellette Spectrograph, the researchers determined SN 2020tlf's progenitor red supergiant star -- located in the NGC 5731 galaxy about 120 million light-years away from Earth -- was 10 times more massive than the sun.

Remote possibilities

Margutti and Jacobson-Galán conducted most of the study during their time at Northwestern,

with Margutti serving as an associate professor of physics and astronomy and member of CIERA, and Jacobson-Galán as a graduate student in Margutti's research group. Margutti is now an associate professor of astronomy and astrophysics at UC Berkeley.
Northwestern's remote access to Keck Observatory's telescopes was integral to their research. From the University's Evanston campus, astronomers can connect with an on-site telescope operator in Hawai?iand choose where to position the telescope. By bypassing long-distance travel to Hawai?i, astronomers save precious observing time -- often catching transient events like supernovas, which can quickly flare up and then swiftly vanish.
"This significant discovery of a red supergiant supernova is yet one more strong indication of the importance of Northwestern's investment in access to top private telescope facilities, including the Keck Observatory," said Vicky Kalogera, the Daniel I. Linzer Distinguished University Professor of Physics and Astronomy at Northwestern's Weinberg College of Arts and Sciencesand director of CIERA. "The Keck telescopes, currently the best on our planet, uniquely enable scientific advances of this calibre as CIERA researchers have shown since our Keck partnership started just a few years ago."
Margutti, Jacobson-Galán and their Northwestern co-authors are members of the Young Supernova Experiment, which uses the Pan-STARRS telescope to catch supernovae right after they explode.
"I am most excited by all of the new 'unknowns' that have been unlocked by this discovery," Jacobson-Galán said. "Detecting more events like SN 2020tlf will dramatically impact how we define the final months of stellar evolution, uniting observers and theorists in the quest to solve the mystery on how massive stars spend the final moments of their lives."
The study was supported by NASA, the National Science Foundation, the Heising-Simons Foundation, the Canadian Institute for Advanced Research, the Alfred P. Sloan Foundation and VILLUM FONDEN.

- Sending life to the stars

Scientists contemplate launching tiny lifeforms into interstellar space

Date: January 6, 2022
Source: University of California - Santa Barbara

No longer solely in the realm of science fiction, the possibility of interstellar travel has appeared, tantalizingly, on the horizon. Although we may not see it in our lifetimes -- at least not some real version of the fictional warp-speeding, hyper driving, space-folding sort -- we are having early conversations of how life could escape the tether of our solar system, using technology that is within reach.
For UC Santa Barbara professors Philip Lubin and Joel Rothman, it's a great time to be alive. Born of a generation that saw breath taking advances in space exploration, they carry the unbridled optimism and creative spark of the early Space Age, when humans first found they could leave the Earth.
"The Apollo moon voyages were among the most momentous events in my life and contemplating them still blows my mind," said Rothman, a distinguished professor in the Department of Molecular, Cellular and Developmental Biology, and a self-admitted "space geek."
A mere 50 years have passed since that pivotal era, but humanity's knowledge of space and the technology to explore it have improved immensely, enough for Rothman to join experimental cosmologist Lubin in considering what it would take for living beings to embark on a journey across the vast distance separating us from our nearest neighbour in the galaxy. The result of their collaboration was published in the journal *Acta Astronautica*.
"I think it's our destiny to keep exploring," Rothman said. "Look at the history of the human species. We explore at smaller and smaller levels down to subatomic levels and we also explore at increasingly larger scales. Such drive toward ceaseless exploration lies at the core of who we are as a species."

Thinking Big, Starting Small

The biggest challenge to human-scale interstellar travel is the enormous distance between Earth and the nearest stars. The Voyager missions have proven that we can send objects across the 12 billion miles it takes to exit the bubble surrounding our solar system, the heliosphere. But the car-sized probes, traveling at speeds of more than 35,000 miles per hour, took 40 years to reach there and their distance from Earth is only a tiny fraction of that to the next star. If they were headed to the closest star, it would take them over 80,000 years to reach it.

That challenge is a major focus of Lubin's work, in which he reimagines the technology it would take to reach the next solar system in human terms. Traditional onboard chemical propulsion (a.k.a. rocket fuel) is out; it can't provide enough energy to move the craft fast enough, and the weight of it and current systems needed to propel it are not viable for the relativistic speeds the craft needs to achieve. New propulsion technologies are required -- and this is where the UCSB directed energy research program of using light as the "propellant" comes in.

"This has never been done before, to push macroscopic objects at speeds approaching the speed of light," said Lubin, a professor in the Department of Physics. Mass is such a huge barrier, in fact, that it rules out any human missions for the foreseeable future.

As a result, his team turned to robots and photonics. Small probes with onboard instrumentation that sense, collect and transmit data back to Earth will be propelled up to 20-30% of the speed of light by light itself using a laser array stationed on Earth, or possibly the moon. "We don't leave home with it," as Lubin explained, meaning the primary propulsion system stays "at home" while spacecraft are "shot out" at relativistic speeds. The main propulsion laser is turned on for a short period of time and then the next probe is readied to be launched.

"It would probably look like a semiconductor wafer with an edge to protect it from the radiation and dust bombardment as it goes through the interstellar medium," Lubin said. "It would probably be the size of your hand to start with." As the program evolves the spacecraft become larger with enhanced capability. The core technology can also be used in a modified mode to propel much larger spacecraft within our solar system at slower speeds, potentially enabling human missions to Mars in as little as one month, stopping included. This is another way of spreading life, but in our solar system.

At these relativistic speeds -- roughly 100 million miles per hour -- the wafercraft would reach the next solar system, Proxima Centauri, in roughly 20 years. Getting to that level of technology will require continuous innovation and improvement of both the space wafer, as well the photonics, where Lubin sees "exponential growth" in the field. The basic project to develop a roadmap to achieve relativistic flight via directed energy propulsion is supported by NASA and private foundations such as the Starlight program and by the Breakthrough Initiatives as the Starshot program.

"When I learned that the mass of these craft could reach gram levels or larger, it became clear that they could accommodate living animals," said Rothman, who realized that the creatures he'd been studying for decades, called C. elegans, could be the first Earthlings to travel between the stars. These intensively studied roundworms may be small and plain, but they are experimentally accomplished creatures, Rothman said.

"Research on this little animal has led to Nobel prizes to six researchers thus far," he noted.

C. elegans are already veterans of space travel, as the subject of experiments conducted on the International Space Station and aboard the space shuttle, even surviving the tragic disintegration of the Columbia shuttle. Among their special powers, which they share with other potential interstellar travellers that Rothman studies, tardigrades (or, more affectionately, water bears) can be placed in suspended animation in which virtually all metabolic function is arrested. Thousands of these tiny creatures could be placed on a wafer, put in suspended animation, and flown in that state until reaching the desired destination. They could then be wakened in their tiny StarChip and precisely monitored for any detectable effects of interstellar travel on their biology, with the observations relayed to Earth by photonic communication.

"We can ask how well they remember trained behaviour when they're flying away from their earthly origin at near the speed of light, and examine their metabolism, physiology, neurological function, reproduction and aging," Rothman added. "Most experiments that can be conducted on these animals in a lab can be performed onboard the StarChips as

they whiz through the cosmos." The effects of such long odysseys on animal biology could allow the scientists to extrapolate to potential effects on humans.
"We could start thinking about the design of interstellar transporters, whatever they may be, in a way that could ameliorate the issues that are detected in these diminutive animals," Rothman said.
Of course, being able to send humans to interstellar space is great for movies, but in reality is still a faraway dream. By the time we get to that point we may have created more suitable life forms or hybrid human-machines that are more resilient.
"This is a generational program," Lubin said. Scientists of coming generations ideally will contribute to our knowledge of interstellar space and its challenges, and enhance the design of the craft as technology improves. With the primary propulsion system being light, the underlying technology is on an exponential growth curve, much like electronics with a "Moore's Law" like expanding capability.

Planetary Protection and Extra-terrestrial Propagation

We're bound to our solar system for the foreseeable future; humans are fragile and delicate away from our home planet. But that hasn't stopped Lubin, Rothman, their research teams and their diverse collaborators, which include a radiation specialist and a science-trained theologian, to contemplate both the physiological and ethical aspects of sending life to space -- and perhaps even propagating life in space.
"There are the ethics," Lubin explained, "of planetary protection," in which serious thought is given to the possibility of contamination, either from our planet to others or vice versa.
"I think if you started talking about directed propagation of life, which is sometimes called panspermia -- this idea that life came from elsewhere and ended up on the earth by comets and other debris, or even intentionally from another civilization -- the idea that we would purposefully send out life does bring up big questions."
So far, the authors contend, there is no risk of forward contamination, as the probes nearing any other planet would burn up in their atmosphere or be obliterated in the collision with the surface. Because the wafercraft are on a one-way trip, there's no risk that any extra-terrestrial microbes will return to Earth.
While still somewhat on the fringe, the theory of panspermia seems to be getting some serious, if limited, attention, given how easy it is to propagate life when conditions are right and the discovery of several exoplanets and other celestial bodies that may have been, or could be, supportive of life as we know it.
"Some people have mused and published on ideas such as 'is the universe a lab experiment from some advanced civilization,'" Lubin said. "So people are certainly willing to think about advanced civilizations. Questions are good but answers are better. Right now we simply ponder these questions without the answers yet."
Another issue currently being contemplated in the wider space exploration community: What are the ethics of sending humans to Mars and other distant places knowing they may never come home? What about sending out small micro-organisms or human DNA? These existential inquiries are as old as the first human migrations and seafaring voyages, the answers to which will likely come the moment we're ready to take these journeys.
"I think we shouldn't, and won't, suppress the exploratory yearning that is intrinsic to our nature," Rothman said.

- How many black holes are out there in the universe?

Date: January 19, 2022
Source: Scuola Internazionale Superiore di Studi Avanzati

How many black holes are out there in the Universe? This is one of the most relevant and pressing questions in modern astrophysics and cosmology. The intriguing issue has recently been addressed by the SISSA Ph.D. student Alex Sicilia, supervised by Prof. Andrea Lapi and Dr. Lumen Boco, together with other collaborators from SISSA and from other national and international institutions. In a first paper of a series just published in *The Astrophysical Journal,* the authors have investigated the demographics of stellar mass black holes, which are black holes with masses between a few to some hundred solar masses, that originated at the end of the life of massive stars. According to the new research, a remarkable amount around 1% of the overall ordinary (baryonic) matter of the Universe is locked up in stellar mass black holes. Astonishingly, the researchers have found that the number of black holes within the observable Universe (a sphere of diameter around 90 billion light years) at present time is about 40 trillion, 40 billion billion (i.e., about 40 x 10^{18}, i.e. 4 followed by 19 zeros!).

A new method to calculate the number of black holes

As the authors of the research explain: "This important result has been obtained thanks to an original approach which combines the state-of-the-art stellar and binary evolution code SEVN developed by SISSA researcher Dr. Mario Spera to empirical prescriptions for relevant physical properties of galaxies, especially the rate of star formation, the amount of stellar mass and the metallicity of the interstellar medium (which are all important elements to define the number and the masses of stellar black holes). Exploiting these crucial ingredients in a self-consistent approach, thanks to their new computation approach, the researchers have then derived the number of stellar black holes and their mass distribution across the whole history of the Universe. Alex Sicilia, first author of the study, comments: "The innovative character of this work is in the coupling of a detailed model of stellar and binary evolution with advanced recipes for star formation and metal enrichment in individual galaxies. This is one of the first, and one of the most robust, ab initio computation of the stellar black hole mass function across cosmic history."

Origin of most massive stellar black holes

The estimate of the number of black holes in the observable Universe is not the only issue investigated by the scientists in this piece of research. In collaboration with Dr. Ugo Di Carlo and Prof. Michela Mapelli from University of Padova, they have also explored the various formation channels for black holes of different masses, like isolated stars, binary systems and stellar clusters. According to their work, the most massive stellar black holes originate mainly from dynamical events in stellar clusters. Specifically, the researchers have shown that such events are required to explain the mass function of coalescing black holes as estimated from gravitational wave observations by the LIGO/Virgo collaboration.

Lumen Boco, co-author of the paper, comments: "Our work provides a robust theory for the generation of light seeds for (super)massive black holes at high redshift, and can constitute a starting point to investigate the origin of 'heavy seeds', that we will pursue in a forthcoming paper.

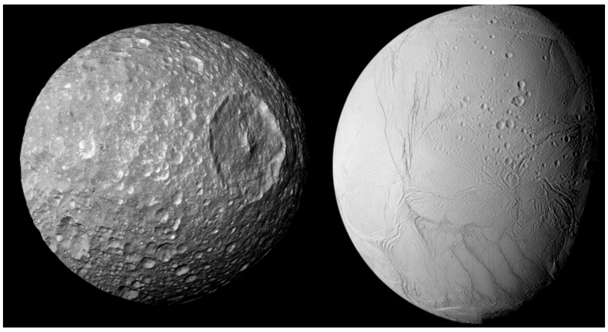
Prof. Andrea Lapi, Sicilia's supervisor and coordinator of the Ph.D. in Astrophysics and Cosmology at SISSA, adds: "This research is really multidisciplinary, covering aspects of, and requiring expertise in stellar astrophysics, galaxy formation and evolution, gravitational wave and multi-messenger astrophysics; as such it needs collaborative efforts from various members of the SISSA Astrophysics and Cosmology group, and a strong networking with external collaborators."

Alex Sicilia's work occurs in the context of an Innovative Training Network Project "BiD4BESt -- Big Data Application for Black Hole Evolution Studies" co-PIed by Prof. Andrea Lapi from SISSA (H2020-MSCAITN-2019 Project 860744), that has been funded by the European Union with about 3.5 million Euros overall; it involves several academic and industrial partners, to provide Ph.D. training to 13 early stage researchers in the area of black hole formation and evolution, by exploiting advanced data science techniques.

- Internal ocean in small Saturn moon uncovered

Discovery could point to a new class of 'stealth' ocean worlds

Date: January 19, 2022
Source: Southwest Research Institute



A Southwest Research Institute scientist set out to prove that the tiny, innermost moon of Saturn was a frozen inert satellite and instead discovered compelling evidence that Mimas has a liquid internal ocean. In the waning days of NASA's Cassini mission, the spacecraft identified a curious libration, or oscillation, in the moon's rotation, which often points to a geologically active body able to support an internal ocean.

"If Mimas has an ocean, it represents a new class of small, 'stealth' ocean worlds with surfaces that do not betray the ocean's existence," said SwRI's Dr. Alyssa Rhoden, a specialist in the geophysics of icy satellites, particularly those containing oceans, and the evolution of giant planet satellites systems.
One of the most profound discoveries in planetary science over the past 25 years is that worlds with oceans beneath layers of rock and ice are common in our solar system. Such worlds include the icy satellites of the giant planets, such as Europa, Titan and Enceladus, as well as distant planets like Pluto. Worlds like Earth with surface oceans must reside within a narrow range of distances from their stars to maintain the temperatures that support liquid oceans. Interior water ocean worlds (IWOWs), however, are found over a much wider range of distances, greatly expanding the number of habitable worlds likely to exist across the galaxy.
"Because the surface of Mimas is heavily cratered, we thought it was just a frozen block of ice," Rhoden said. "IWOWs, such as Enceladus and Europa, tend to be fractured and show other signs of geologic activity. Turns out, Mimas' surface was tricking us, and our new understanding has greatly expanded the definition of a potentially habitable world in our solar system and beyond."
Tidal processes dissipate orbital and rotational energy as heat in a satellite. To match the interior structure inferred from Mimas' libration, tidal heating within the moon must be large enough to keep the ocean from freezing out but small enough to maintain a thick icy shell. Using tidal heating models, the team developed numerical methods to create the most plausible explanation for a steady-state ice shell between 14 to 20 miles thick over a liquid ocean.
"Most of the time when we create these models, we have to fine tune them to produce what we observe," Rhoden said. "This time evidence for an internal ocean just popped out of the most realistic ice shell stability scenarios and observed librations."
The team also found that the heat flow from the surface was very sensitive to the thickness of the ice shell, something a spacecraft could verify. For instance, the Juno spacecraft is scheduled to fly by Europa and use its microwave radiometer to measure heat flows in this Jovian moon. This data will allow scientists to understand how heat flow affects the icy shells of ocean worlds such as Mimas, which are particularly interesting as NASA's Europa Clipper approaches its 2024 launch.
"Although our results support a present-day ocean within Mimas, it is challenging to reconcile the moon's orbital and geologic characteristics with our current understanding of its thermal-orbital evolution," Rhoden said. "Evaluating Mimas' status as an ocean moon would benchmark models of its formation and evolution. This would help us better understand Saturn's rings and mid-sized moons as well as the prevalence of potentially habitable ocean moons, particularly at Uranus. Mimas is a compelling target for continued investigation."
Rhoden is co-leader of NASA's Network for Ocean Worlds Research Coordination Network and previously served on the National Academies' Committee on Astrobiology and Planetary Science.

- Newly discovered carbon may yield clues to ancient Mars

Date: January 17, 2022
Source: Penn State


Mars Curiosity Rover exploring surface of the Red Planet (stock image; elements furnished by NASA).
Credit: © Paopano / stock.adobe.com

NASA's Curiosity rover landed on Mars on Aug. 6, 2012, and since then has roamed Gale Crater taking samples and sending the results back home for researchers to interpret.
Analysis of carbon isotopes in sediment samples taken from half a dozen exposed locations, including an exposed cliff, leave researchers with three plausible explanations for the carbon's origin -- cosmic dust, ultraviolet degradation of carbon dioxide, or ultraviolet degradation of biologically produced methane.
The researchers note today (Jan.17) in *Proceedings of the National Academy of Sciences* that "All three of these scenarios are unconventional, unlike processes common on Earth."

Carbon has two stable isotopes, 12 and 13. By looking at the amounts of each in a substance, researchers can determine specifics about the carbon cycle that occurred, even if it happened a very long time ago.
"The amounts of carbon 12 and carbon 13 in our solar system are the amounts that existed at the formation of the solar system," said Christopher H. House, professor of geosciences, Penn State. "Both exist in everything, but because carbon 12 reacts more quickly than carbon 13, looking at the relative amounts of each in samples can reveal the carbon cycle."
Curiosity, which is led by NASA's Jet Propulsion Laboratory in Southern California, has spent the last nine years exploring an area of Gale Crater that has exposed layers of ancient rock. The rover drilled into the surface of these layers and recovered samples from buried sedimentary layers. Curiosity heated the samples in the absence of oxygen to separate any chemicals. Spectrographic analysis of a portion of the reduced carbon produced by this pyrolysis showed a wide range of carbon 12 and carbon 13 amounts depending on where or when the original sample formed. Some carbon was exceptionally depleted in carbon 13 while other carbon samples where enriched.
"The samples extremely depleted in carbon 13 are a little like samples from Australia taken from sediment that was 2.7 billion years old," said House. "Those samples were caused by biological activity when methane was consumed by ancient microbial mats, but we can't necessarily say that on Mars because it's a planet that may have formed out of different materials and processes than Earth."
To explain the exceptionally depleted samples, the researchers suggest three possibilities -- a cosmic dust cloud, ultraviolet radiation breaking down carbon dioxide, or ultraviolet degradation of biologically created methane.
According to House, every couple of hundred million years the solar system passes through a galactic molecular cloud.
"It doesn't deposit a lot of dust," said House. "It is hard to see any of these deposition events in the Earth record."
To create a layer that Curiosity could sample, the galactic dust cloud would have first lowered the temperature on a Mars that still contained water and created glaciers. The dust would have deposited on top of the ice and would then need to remain in place once the glacier melted, leaving behind a layer of dirt that included the carbon.
So far, there is limited evidence of past glaciers at Gale Crater on Mars. According to the researchers, "this explanation is plausible, but it requires additional research."
A second possible explanation for lower amounts of carbon 13 is the ultraviolet conversion of carbon dioxide to organic compounds like formaldehyde.
"There are papers that predict that UV could cause this type of fractionation," said House. "However, we need more experimental results showing this size fractionation so we can rule in or rule out this explanation."
The third possible method of producing carbon 13 depleted samples has a biological basis.
On Earth, a strongly carbon 13 depleted signature from a paleo surface would indicate past microbes consumed microbially produced methane. Ancient Mars may have had large plumes of methane being released from the subsurface where methane production would have been energetically favourable. Then, the released methane would either be consumed by surface microbes or react with ultraviolet light and be deposited directly on the surface. However, according to the researchers, there is currently no sedimentary evidence of surface microbes on the past Mars landscape, and so the biological explanation highlighted in the paper relies on ultraviolet light to place the carbon 13 signal onto the ground.
"All three possibilities point to an unusual carbon cycle unlike anything on Earth today," said House. "But we need more data to figure out which of these is the correct explanation. It would be nice if the rover would detect a large methane plume and measure the carbon isotopes from that, but while there are methane plumes, most are small, and no rover has sampled one large enough for the isotopes to be measured."
House also notes that finding the remains of microbial mats or evidence of glacial deposits could also clear things up, a bit.
"We are being cautious with our interpretation, which is the best course when studying another world," said House.
Curiosity is still collecting and analysing samples and will be returning to the pediment where it found some of the samples in this study in about a month.
"This research accomplished a long-standing goal for Mars exploration," said House. "To

measure different carbon isotopes -- one of the most important geology tools -- from sediment on another habitable world, and it does so by looking at 9 years of exploration."

Also working on the project from Penn State was Gregory M. Wong, recent doctoral recipient in geosciences.

Other participants in the research were, at NASA Jet Propulsion Laboratory: Christopher R. Webster, fellow and senior research scientist; Gregory J. Flesch, scientific applications software engineer; and Amy E. Hofmann, research scientist; at Solar System Exploration Division, NASA Goddard Space Flight Centre: Heather B. Franz, research scientist; Jennifer C. Stern, research assistant; Alex Pavlov, space scientist; Jennifer L. Eigenbrode, research assistant; Daniel P. Glavin, associate director for strategic science; Charles A. Malespin, chief, Planetary Environments Laboratory; and Paul R. Mahaffy, Retired Solar System Exploration Division Director; at University of Michigan: Sushil K. Atreya, professor of climate and space sciences and engineering and director of the Planetary Science Laboratory; at Carnegie Institution for Science: Andrew Steele, scientist; and at Georgetown University and NASA Goddard Space Flight Centre: Maëva Milan, postdoctoral fellow.

NASA supported this project.

- Highly eccentric black hole merger discovered

Date: January 20, 2022
Source: Rochester Institute of Technology


Artist's impression of binary black holes about to collide.

For the first time, scientists believe they have detected a merger of two black holes with eccentric orbits. According to a paper published in *Nature Astronomy* by researchers from Rochester Institute of Technology's Centre for Computational Relativity and Gravitation and the University of Florida, this can help explain how some of the black hole mergers detected by LIGO Scientific Collaboration and the Virgo Collaboration are much heavier than previously thought possible.

Eccentric orbits are a sign that black holes could be repeatedly gobbling up others during chance encounters in areas densely populated with black holes such as galactic nuclei. The scientists studied the most massive gravitational wave binary observed to date, GW190521, to determine if the merger had eccentric orbits.

"The estimated masses of the black holes are more than 70 times the size of our sun each, placing them well above the estimated maximum mass predicted currently by stellar evolution theory," said Carlos Lousto, a professor in the School of Mathematical Sciences and a member of the CCRG. "This makes an interesting case to study as a second generation binary black hole system and opens up to new possibilities of formation scenarios of black holes in dense star clusters."

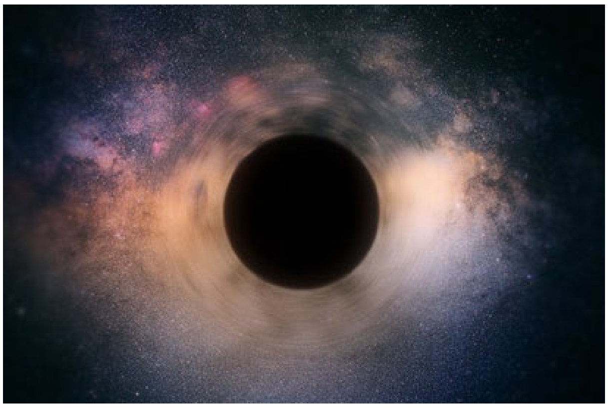
A team of RIT researchers including Lousto, Research Associate James Healy, Jacob Lange '20 Ph.D. (astrophysical sciences and technology), Professor and CCRG Director Manuela Campanelli, Associate Professor Richard O'Shaughnessy, and collaborators from the University of Florida formed to give a fresh look at the data to see if the black holes had highly eccentric orbits before they merged. They found the merger is best explained by a high-eccentricity, precessing model. To achieve this, the team performed hundreds of new full numerical simulations in local and national lab supercomputers, taking nearly a year to complete.

"This represents a major advancement in our understanding of how black holes merge," said Campanelli. "Through our sophisticated supercomputer simulations and the wealth of new data provided by LIGO and Virgo's rapidly advancing detectors, we are making new discoveries about the universe at astonishing rates."

An extension of this analysis by the same RIT and UFL team used a possible electromagnetic counterpart observed by the Zwicky Transient Facility to compute independently the cosmological Hubble constant with GW150521 as an eccentric binary black hole merger. They found excellent agreement with the expected values and recently published the work in the *Astrophysical Journal*.

- ❖ Hubble finds a black hole igniting star formation in a dwarf galaxy

Date: January 19, 2022
Source: NASA/Goddard Space Flight Centre



Black hole illustration (stock image).
Credit: © astrosystem / stock.adobe.com

Often portrayed as destructive monsters that hold light captive, black holes take on a less villainous role in the latest research from NASA's Hubble Space Telescope. A black hole at the heart of the dwarf galaxy Henize 2-10 is creating stars rather than gobbling them up. The black hole is apparently contributing to the firestorm of new star formation taking place in the galaxy. The dwarf galaxy lies 30 million light-years away, in the southern constellation Pyxis.

A decade ago this small galaxy set off debate among astronomers as to whether dwarf galaxies were home to black holes proportional to the supermassive behemoths found in the hearts of larger galaxies. This new discovery has little Henize 2-10, containing only one-tenth the number of stars found in our Milky Way, poised to play a big part in solving the mystery of where supermassive black holes came from in the first place.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

"Ten years ago, as a graduate student thinking I would spend my career on star formation, I looked at the data from Henize 2-10 and everything changed," said Amy Reines, who published the first evidence for a black hole in the galaxy in 2011 and is the principal investigator on the new Hubble observations, published in the January 19 issue of *Nature.*

"From the beginning I knew something unusual and special was happening in Henize 2-10, and now Hubble has provided a very clear picture of the connection between the black hole and a neighbouring star forming region located 230 light-years from the black hole," Reines said.

That connection is an outflow of gas stretching across space like an umbilical cord to a bright stellar nursery. The region was already home to a dense cocoon of gas when the low-velocity outflow arrived. Hubble spectroscopy shows the outflow was moving about 1 million miles per hour, slamming into the dense gas like a garden hose hitting a pile of dirt and spreading out. New born star clusters dot the path of the outflow's spread, their ages also calculated by Hubble.

This is the opposite effect of what's seen in larger galaxies, where material falling toward the black hole is whisked away by surrounding magnetic fields, forming blazing jets of plasma moving at close to the speed of light. Gas clouds caught in the jets' path would be heated far beyond their ability to cool back down and form stars. But with the less-massive black hole in Henize 2-10, and its gentler outflow, gas was compressed just enough to precipitate new star formation.

"At only 30 million light-years away, Henize 2-10 is close enough that Hubble was able to capture both images and spectroscopic evidence of a black hole outflow very clearly. The additional surprise was that, rather than suppressing star formation, the outflow was triggering the birth of new stars," said Zachary Schutte, Reines' graduate student and lead author of the new study.

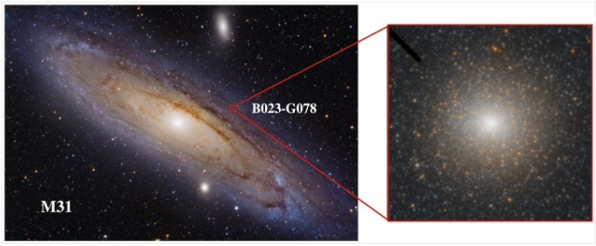
Ever since her first discovery of distinctive radio and X-ray emissions in Henize 2-10, Reines has thought they likely came from a massive black hole, but not as supermassive as those seen in larger galaxies. Other astronomers, however, thought that the radiation was more likely being emitted by a supernova remnant, which would be a familiar occurrence in a galaxy that is rapidly pumping out massive stars that quickly explode.

"Hubble's amazing resolution clearly shows a corkscrew-like pattern in the velocities of the gas, which we can fit to the model of a processing, or wobbling, outflow from a black hole. A supernova remnant would not have that pattern, and so it is effectively our

smoking-gun proof that this is a black hole," Reines said.
Reines expects that even more research will be directed at dwarf galaxy black holes in the future, with the aim of using them as clues to the mystery of how supermassive black holes came to be in the early universe. It's a persistent puzzle for astronomers. The relationship between the mass of the galaxy and its black hole can provide clues. The black hole in Henize 2-10 is around 1 million solar masses. In larger galaxies, black holes can be more than 1 billion times our Sun's mass. The more massive the host galaxy, the more massive the central black hole.
Current theories on the origin of supermassive black holes break down into three categories: 1) they formed just like smaller stellar-mass black holes, from the implosion of stars, and somehow gathered enough material to grow supermassive, 2) special conditions in the early universe allowed for the formation of supermassive stars, which collapsed to form massive black hole "seeds" right off the bat, or 3) the seeds of future supermassive black holes were born in dense star clusters, where the cluster's overall mass would have been enough to somehow create them from gravitational collapse.
So far, none of these black hole seeding theories has taken the lead. Dwarf galaxies like Henize 2-10 offer promising potential clues, because they have remained small over cosmic time, rather than undergoing the growth and mergers of large galaxies like the Milky Way. Astronomers think that dwarf galaxy black holes could serve as an analogue for black holes in the early universe, when they were just beginning to form and grow.
"The era of the first black holes is not something that we have been able to see, so it really has become the big question: where did they come from? Dwarf galaxies may retain some memory of the black hole seeding scenario that has otherwise been lost to time and space," Reines said.

- Extraordinary black hole found in neighbouring galaxy

Date: January 24, 2022
Source: University of Utah



The left panel shows a wide-field image of Messier 31 [Andromeda] with the red box and inset showing the location and image of B023-G78 where the black hole was found.
PHOTO CREDIT: Iván Éder/ NASA/ESA Hubble Space Telescope/NASA Hubble Advanced Camera for Surveys/HRC.

Astronomers discovered a black hole unlike any other. At one hundred thousand solar masses, it is smaller than the black holes we have found at the centres of galaxies, but bigger than the black holes that are born when stars explode. This makes it one of the only confirmed intermediate-mass black holes, an object that has long been sought by astronomers.
"We have very good detections of the biggest, stellar-mass black holes up to 100 times the size of our sun, and supermassive black holes at the centres of galaxies that are millions of times the size of our sun, but there aren't any measurements of black between these. That's a large gap," said senior author Anil Seth, associate professor of astronomy at the University of Utah and co-author of the study. "This discovery fills the gap."
The black hole was hidden within B023-G078, an enormous star cluster in our closest neighbouring galaxy Andromeda. Long thought to be a globular star cluster, the researchers argue that B023-G078 is instead a stripped nucleus. Stripped nuclei are remnants of small galaxies that fell into bigger ones and had their outer stars stripped away by gravitational forces. What's left behind is a tiny, dense nucleus orbiting the bigger galaxy and at the centre of that nucleus, a black hole.
"Previously, we've found big black holes within massive, stripped nuclei that are much bigger than B023-G078. We knew that there must be smaller black holes in lower mass stripped nuclei, but there's never been direct evidence," said lead author Renuka Pechetti of Liverpool John Moores University, who started the research while at the University of Utah. "I think this is a pretty clear case that we have finally found one of these objects."
The study published on Jan. 11, 2022, in *The Astrophysical Journal.*

A decades-long hunch

B023-G078 was known as a massive globular star cluster -- a spherical collection of stars bound tightly by gravity. However, there had only been a single observation of the object that determined its overall mass, about 6.2 million solar masses. For years, Seth had a feeling it was something else.

"I knew that the B023-G078 object was one of the most massive objects in Andromeda and thought it could be a candidate for a stripped nucleus. But we needed data to prove it. We'd been applying to various telescopes to get more observations for many, many years and my proposals always failed," said Seth. "When we discovered a supermassive black hole within a stripped nucleus in 2014, the Gemini Observatory gave us the chance to explore the idea."

With their new observational data from the Gemini Observatory and images from the Hubble Space Telescope, Pechetti, Seth and their team calculated how mass was distributed within the object by modelling its light profile. A globular cluster has a signature light profile that has the same shape near the centre as it does in the outer regions. B023-G078 is different. The light at the centre is round and then gets flatter moving outwards. The chemical makeup of the stars changes too, with more heavy elements in the stars at the centre than those near the object's edge.

"Globular star clusters basically form at the same time. In contrast, these stripped nuclei can have repeated formation episodes, where gas falls into the centre of the galaxy, and forms stars. And other star clusters can get dragged into the centre by the gravitational forces of the galaxy," said Seth. "It's kind of the dumping ground for a bunch of different stuff. So, stars in stripped nuclei will be more complicated than in globular clusters. And that's what we saw in B023-G078."

The researchers used the object's mass distribution to predict how fast the stars should be moving at any given location within the cluster and compared it to their data. The highest velocity stars were orbiting around the centre. When they built a model without including a black hole, the stars at the centre were too slow compared their observations. When they added the black hole, they got speeds that matched the data. The black hole adds to the evidence that this object is a stripped nucleus.

"The stellar velocities we are getting gives us direct evidence that there's some kind of dark mass right at the centre," said Pechetti. "It's very hard for globular clusters to form big black holes. But if it's in a stripped nucleus, then there must already be a black hole present, left as a remnant from the smaller galaxy that fell into the bigger one."

The researchers are hoping to observe more stripped nuclei that may hold more intermediate mass black holes. These are an opportunity to learn more about the black hole population at the centres of low-mass galaxies, and to learn about how galaxies are built up from smaller building blocks.

"We know big galaxies form generally from the merging of smaller galaxies, but these stripped nuclei allow us to decipher the details of those past interactions," said Seth.

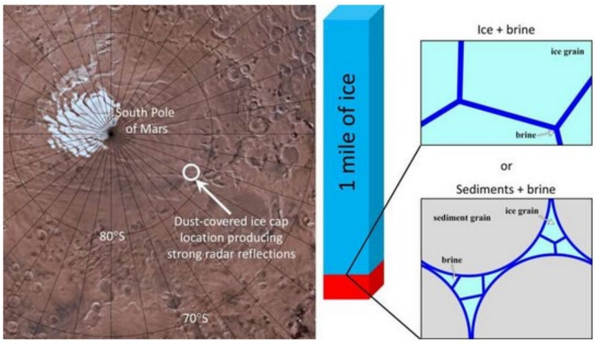
Other authors include Sebastian Kamann of the Liverpool John Moores University; Nelson Caldwell, Harvard-Smithsonian Centre for Astrophysics; Jay Strader, Michigan State University; Mark den Brok, Leibniz-Institut für Astrophysik Potsdam; Nora Luetzgendorf, European Space Agency; Nadine Neumayer, Max Planck Institüt für Astronomie; and Karina Voggel, Observatoire astronomique de Strasbourg.

- Liquid water beneath Martian south polar cap?

Geophysical radar reflections, laboratory experiments point to slushy brines

Date: January 25, 2022

Source: Southwest Research Institute



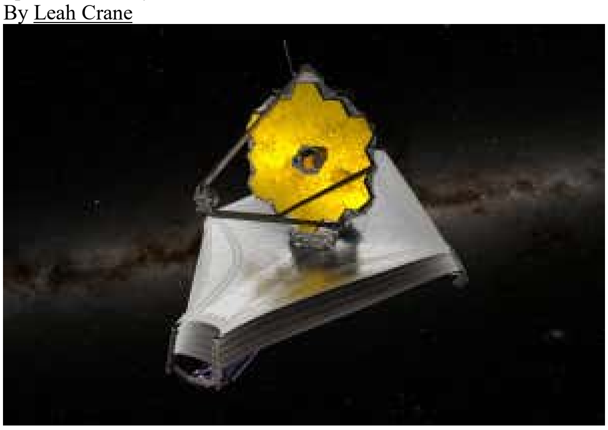
An SwRI scientist studied the antifreeze properties of exotic salts that exist ...

A Southwest Research Institute scientist measured the properties of ice-brine mixtures as cold as -145 degrees Fahrenheit to help confirm that salty water likely exists between grains of ice or sediment under the ice cap at Mars' south pole. Laboratory measurements conducted by SwRI geophysicist Dr. David Stillman support oddly bright reflections detected by the MARSIS subsurface sounding radar aboard ESA's Mars Express orbiter.

With a 130-foot antenna, MARSIS flies over the planet, bouncing radio waves over a selected area and then receiving and analysing the echoes or reflections. Any near-surface liquid water should send a strong bright signal, whereas the radar signal for ice and rock would be much smaller.
Because conventional models assume the Mars south polar cap experiences temperatures much lower than the melting point of water, many scientists have questioned the presence of liquid water. Clay, hydrated salts and saline ices have been proposed as potential explanations for the source of the bright basal reflections. The Italian-led team investigating the proposed phenomena used previously published data, simulations and new laboratory measurements.
"Lakes of liquid water actually exist beneath glaciers in Arctic and Antarctic regions, so we have Earth analogues for finding liquid water below ice," said Stillman, a specialist in detecting water in any format -- liquid, ice or absorbed -- on planetary bodies and co-author of a paper describing these findings. "The exotic salts that we know exist on Mars have amazing 'antifreeze' properties allowing brines to remain liquid down to -103 degrees Fahrenheit. We studied these salts in our lab to understand how they would respond to radar."
Stillman has over a decade of experience measuring the properties of materials at cold temperatures to detect and characterize subsurface ice, unfrozen water and the potential for life throughout the solar system. For this project, Stillman measured the properties of perchlorate brines in an SwRI environmental chamber that produces near-liquid-nitrogen temperatures at Mars-like pressures.
"My Italian colleagues reached out to see if my laboratory experiment data would support the presence of liquid water beneath the Martian ice cap," Stillman said. "The research showed that we don't have to have lakes of perchlorate and chloride brines, but that these brines could exist between the grains of ice or sediments and are enough to exhibit a strong dielectric response. This is similar to how seawater saturates grains of sand at the shoreline or how flavouring permeates a slushy, but at -103 degrees Fahrenheit below a mile of ice near the South Pole of Mars."
The search for water in the cosmos is rooted in searching for potential habitability, because all known life requires water.
"In this case 'following the water' has led us to place so cold that life as we know it couldn't flourish," Stillman said. "But it's still interesting, and who knows what evolutionary paths extra-terrestrial life may have taken?"

- The James Webb Space Telescope has arrived at its final destination

Space 25 January 2022
By Leah Crane



An artist's impression of the James Webb Space Telescope
ESA/ATG medialab

One month after its launch, the James Webb Space Telescope (JWST) has arrived at its new home. On 24 January, the spacecraft fired its thrusters for about 5 minutes to place it into its final orbit, and now it is ready to calibrate its mirrors and scientific instruments before peering out into the universe.
The telescope is at a gravitationally stable spot called a Lagrange point, where all the forces on the spacecraft balance out to keep it in place, orbiting the sun along with Earth. This particular Lagrange point, called L2, is about 1.5 million kilometres away from the planet in the direction opposite to the sun. It won't stay parked directly at the Lagrange point, but will wobble back and forth around it in what is called a halo orbit, which requires a small burn of the thrusters about every three weeks but is more stable in the long run.
Aside from the fact that parking near a Lagrange point will save fuel, L2 is a particularly good spot for observing the sky without worrying about heat or light from the sun, Earth or the moon. JWST faces away from all of those objects, with its huge sunshield blocking out their light to protect the telescope's sensitive observations.
The telescope requires extreme cold to function, which the sunshield will also provide. While the sun-facing side of the shield will be at a temperature of about 85°C, the other side will be kept at about -233°C, nearly as cold as the average temperature in deep space. Now that JWST has reached its parking spot, it will take about a week for

everything to cool down before the telescope's engineers can begin the final necessary steps before observations can begin.
Those final steps have two parts. First, the 18 hexagonal segments that make up the telescope's primary mirror have to be aligned with incredible precision – they have to line up to within one five-thousandth the width of a human hair, said JWST team member Lee Feinberg at NASA's Goddard Space Flight Centre in Maryland in a 24 January press conference. That process is expected to take about three months, followed by a month of calibrating the scientific instruments before the first detailed images can be taken.
"Everything we're doing is about getting the observatory ready to do transformative science," said JWST scientist Jane Rigby, also at NASA Goddard, in the press conference. "We're a month in, and the baby hasn't even opened its eyes yet." If all goes well, the science mission will begin around the end of June.
The first year of science is already mapped out, with more than 300 observing programmes planned, said Rigby. Many of them will be dedicated to examining exoplanets, peering into their atmospheres to learn more about their composition and potential habitability. Others will look for the most distant galaxies in the observable universe, studying how they formed and evolved over time. Some observing programmes will seek to understand dark matter and dark energy in an attempt to unravel the greatest mysteries of the cosmos.
Because every part of the launch and the trip to L2 has gone so smoothly, JWST has enough fuel to keep doing these observations for well beyond 10 years.

- ❖ How the James Webb telescope will rewrite the story of the universe

The most anticipated space telescope ever is about to launch. It will give us a clear picture of the first stars and reveal the atmospheres of exoplanets too – if it unfolds without a hitch
By Colin Stuart

NASA, ESA, V. Ksoll and D. Gouliermis (Universität Heidelberg), et al.; Processing: Gladys Kober (NASA/Catholic University of America)

IN EARLY October, a cargo ship steered to starboard, leaving the Atlantic Ocean off the east coast of South America and entering the muddy waters of the Korou river. It was the final phase of the voyage and no effort had been spared to protect the prized item on board. It was housed inside a specially designed case to keep it safe from the pitch and roll of the waves. The river had been dredged to ensure the ship didn't get stuck in the shallows. Even the exact date of the voyage had been kept secret, to avoid the attention of pirates.
The precious cargo was the James Webb Space Telescope, perhaps the most hotly anticipated scientific instrument ever. Known as the JWST, the telescope has been more than 25 years in the making and its launch has been delayed countless times. But it has now completed its voyage to the launch site in French Guiana and, if all goes smoothly, it will finally leave Earth in late December. "I still haven't wrapped my head around it," says Torsten Böker, deputy project scientist for the JWST at the European Space Agency (ESA). "It seems a little bit unreal."

Removing covers from the mirrors of the James Webb Space Telescope

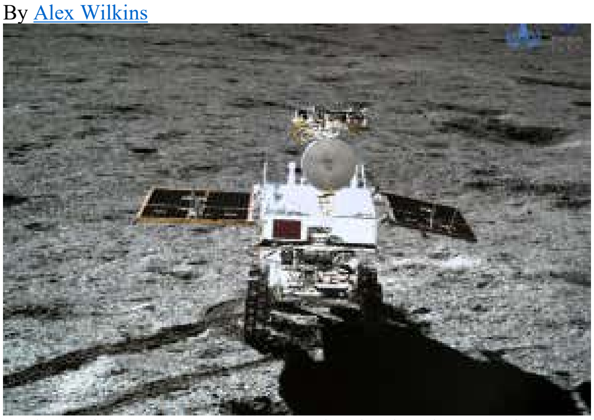
NASA/Chris Gunn

Unreal not only because it has often looked like the telescope might never take off, but also because this device is designed to be a time machine that will help us see back to the enigmatic era of the universe's first stars, which we know precious little about. Unreal, too, …

- ❖ Yutu-2 lunar rover finds sticky soil on the far side of the moon

We haven't been able to take a close-up look at the far side of the moon until now, and the discoveries being made by the Yutu-2 rover might prove important for future missions

By Alex Wilkins



A photo of the Yutu-2 moon rover, taken by the Chang'e-4 lunar probe
AFP

The first rover to visit the far side of the moon, China's Yutu-2, has found stark differences between there and the near side. These include stickier, more supportive soil on the far side and a greater abundance of small rocks and impact craters.

Despite several exploratory missions to the moon, crewed and un-crewed, the moon's far side has remained unexplored because of difficulties communicating with Earth from there. But in 2019, China's Chang'e 4 mission deposited the Yutu-2 rover to roam the far side's surface.

Now, Liang Ding at the Harbin Institute of Technology, China, and his colleagues have deduced something of the make-up and features of the far-side soil based on the way Yutu-2 has trundled around and on the observations it made using radar and spectrometry.

The researchers, who declined to be interviewed for this article, found that the rover didn't slip and skid as much as it would have been expected to do on the moon's near side, indicating that the far side was relatively flat. The soil also appeared to readily stick to the rover's six wheels, which means it is probably more consolidated and supportive.

As well as being useful for designing future lunar rovers, understanding the soil make-up and rock distribution can tell us about the history of the lunar surface itself.

"Finding a larger proportion of small rocks is probably linked with the age of the surface," says Lionel Wilson at Lancaster University, UK. "You've worn down the larger rocks. If you wait long enough, you'll reduce a rock just to several millimetre-sized particles."

The Yutu-2 rover also found a dark greenish, glistening material at the bottom of one crater, similar to glassy materials found in Apollo mission samples. This is the first time that one of these minerals, probably a remnant of a previous impact, has been found in-situ on the moon.

"Any information on the history of bombardment, at all scales, from large impactors all the way down to the atomic scale, is really important and valuable," says Wilson.

The lunar far side is also relatively electromagnetically quiet because it blocks out Earth's transmissions, making it well suited for astronomy. Building any observatories there will require a deep knowledge of the soil make-up and surface of the lunar far side, which could be explored in future missions.

"The exploration of the far side is really in its infancy," says Sara Russell at the Natural History Museum in London. "It's like this whole new world to explore. We really have a lot to find out about the far side of the moon; it's really exciting."