South Downs Mercury

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THE FEBRUARY MEETING IS CANCELLED DUE TO COVID-19

We have a virtual meeting Friday 2nd April Zoom Meeting 19:30 Gary Fildes (Ex CEO Kielder Observatory) The solar system. Email me for joining instructions if you have not already received them

- Astronomers get first measurements of Jupiter's stratospheric storms that show 'unique beast' dwarfing Earth's issues

Even though its Great Red Spot appears to be shrinking, the storm behind it will probably live on

Katyanna Quach Sat 20 Mar 2021 // 10:10 UTC

Terrifying winds rip across Jupiter's poles reaching speeds of up to 400 metres per second, or 900 miles an hour, three times faster than the most powerful tornadoes on Earth, according to the first direct measurements of the gas giant's turbulent stratosphere.

Astronomers refer to these particularly powerful bursts as jets. "Our detection indicates that these jets could behave like a giant vortex with a diameter of up to four times that of Earth, and some 900 kilometres in height," said Bilal Benmahi, a researcher at the University of Bordeaux and co-author of a paper [PDF] published in Astronomy & Astrophysics detailing the findings.

"A vortex of this size would be a unique meteorological beast in our Solar System," Thibault Cavalié, a research scientist at Bordeaux Observatory and co-author of the paper, added this week.

Volatile gusts of winds are a well-known feature on the gas giant; massive cyclones like its Great Red Spot are visible. Scientists have previously studied Jupiter's upper atmosphere, though the latest observations made using Atacama Large Millimetre/submillimetre Array focused on its middle atmosphere.

The polar bursts are faster at 400 metres per second, and the gales around its equator are slower at about 167 metres per second (600 kilometres per hour, 370 miles per hour.)

The wind speeds were measured by tracking hydrogen cyanide molecules generated by the impact of Comet Shoemaker–Levy 9 in 1994. Using the telescope's spectrometers, the team of researchers could detect tiny changes in the frequency of radiation the molecules emitted. These changes were the result of the winds. Just like how you can calculate how fast, say, an ambulance is speeding from the pitch of its siren, thanks to the Doppler effect, scientists can calculate the speed of Jupiter's gusts from the frequency of light emitted from hydrogen cyanide molecules.

Measuring Jupiter's winds accurately is important for understanding the planet and its moons as a whole, Vincent Hue, a research scientist at the Southwest Research Institute and co-author of the paper, explained to *The Register*. "Jupiter and its [satellites] constantly exchange materials, like dust, molecules, and charged particles. [It] has an important influence over the system because of its important magnetic field, it is important to characterize it as best as we can."

Studying its storms and cyclones also give astronomers a better idea of the planet's magnetic field. "The winds we detected near Jupiter's aurora are caused by the interaction between Jupiter's magnetosphere and its ionosphere through a complex coupling. Initially, Jupiter and its magnetosphere exchange angular momentum which creates these very high-altitude polar jets. At lower altitudes, in the stratosphere, the winds we have detected are actually a signature of these high-altitude polar jets," he added.

The next step is trying to figure out how these winds moderate the planet's overall climate and how they might impact the chemical composition of its atmosphere.

What has been happening to the Great Red Spot?

Jupiter's most famous storm, the Great Red Spot, has been shrinking, though a new study suggests it'll be around for a while yet.

Us Earthlings have been observing the Red Spot for more than 150 years, and it is certainly shrinking, down from 40,000 kilometres (24,850 miles) in 1879 to about 15,000 kilometres (9,320 miles) according to today's estimates. A study, published in the American Geophysical Union journal, however, reckons the storm will prevail.

The gas-giant sky watchers believe a series of smaller storms crashing into its most iconic feature has caused bits of its red clouds to disperse, making the spot look smaller. But although these opposing winds, or anticyclones, chip away at its clouds, the larger storm powering the spot swallows up these anticyclones and actually gains energy from them.

"The intense vorticity of the [Great Red Spot], together with its larger size and depth compared to the interacting vortices, guarantees its long lifetime," said Agustín Sánchez-Lavega, lead author of the paper and a professor of applied physics at the Basque Country University. The rotational power of the cyclone might drop, but the overall energy of the storm increases.

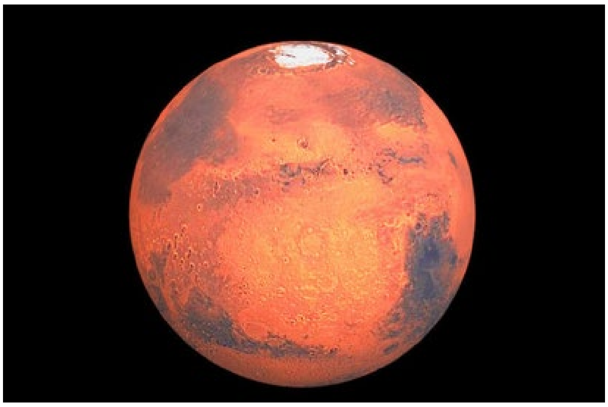
The disruptions in the Great Red Spot are superficial, the researchers argued. On the surface, the storm may appear to be getting weaker yet the depth of the winds hasn't decreased.

- What happened to Mars's water? It is still trapped there

New data challenges the long-held theory that all of Mars's water escaped into space

Date: March 16, 2021

Source: California Institute of Technolog



Mars (stock image).
Credit: © Peter Baxter / stock.adobe.com

Billions of years ago, the Red Planet was far bluer; according to evidence still found on the surface, abundant water flowed across Mars and forming pools, lakes, and deep oceans. The question, then, is where did all that water go?

The answer: nowhere. According to new research from Caltech and JPL, a significant portion of Mars's water -- between 30 and 99 percent -- is trapped within minerals in the planet's crust. The research challenges the current theory that the Red Planet's water escaped into space.

The Caltech/JPL team found that around four billion years ago, Mars was home to enough water to have covered the whole planet in an ocean about 100 to 1,500 meters deep; a volume roughly equivalent to half of Earth's Atlantic Ocean. But, by a billion years later, the planet was as dry as it is today. Previously, scientists seeking to explain what happened to the flowing water on Mars had suggested that it escaped into space, victim of Mars's low gravity. Though some water did indeed leave Mars this way, it now appears that such an escape cannot account for most of the water loss.

"Atmospheric escape doesn't fully explain the data that we have for how much water actually once existed on Mars," says Caltech PhD candidate Eva Scheller (MS '20), lead author of a paper on the research that was published by the journal *Science* on March 16 and presented the same day at the Lunar and Planetary Science Conference (LPSC).

Scheller's co-authors are Bethany Ehlmann, professor of planetary science and associate director for the Keck Institute for Space Studies; Yuk Yung, professor of planetary science and JPL senior research scientist; Caltech graduate student Danica Adams; and Renyu Hu, JPL research scientist. Caltech manages JPL for NASA.

The team studied the quantity of water on Mars over time in all its forms (vapor, liquid, and ice) and the chemical composition of the planet's current atmosphere and crust through the analysis of meteorites as well as using data provided by Mars rovers and orbiters, looking in particular at the ratio of deuterium to hydrogen (D/H).

Water is made up of hydrogen and oxygen: H2O. Not all hydrogen atoms are created equal, however. There are two stable isotopes of hydrogen. The vast majority of hydrogen atoms have just one proton within the atomic nucleus, while a tiny fraction (about 0.02 percent) exist as deuterium, or so-called "heavy" hydrogen, which has a proton and a neutron in the nucleus.

The lighter-weight hydrogen (also known as protium) has an easier time escaping the planet's gravity into space than its heavier counterpart. Because of this, the escape of a planet's water via the upper atmosphere would leave a tell-tale signature on the ratio of deuterium to hydrogen in the planet's atmosphere: there would be an outsized portion of deuterium left behind.

However, the loss of water solely through the atmosphere cannot explain both the observed deuterium to hydrogen signal in the Martian atmosphere and large amounts of water in the past. Instead, the study proposes that a combination of two mechanisms -- the trapping of water in minerals in the planet's crust and the loss of water to the atmosphere -- can explain the observed deuterium-to-hydrogen signal within the Martian atmosphere.

When water interacts with rock, chemical weathering forms clays and other hydrous minerals that contain water as part of their mineral structure. This process occurs on Earth as well as on Mars. Because Earth is tectonically active, old crust continually melts into the mantle and forms new crust at plate boundaries, recycling water and other molecules back into the atmosphere through volcanism. Mars, however, is mostly tectonically inactive, and so the "drying" of the surface, once it occurs, is permanent.

"Atmospheric escape clearly had a role in water loss, but findings from the last decade of Mars missions have pointed to the fact that there was this huge reservoir of ancient hydrated minerals whose formation certainly decreased water availability over time," says Ehlmann.

"All of this water was sequestered fairly early on, and then never cycled back out," Scheller says. The research, which relied on data from meteorites, telescopes, satellite observations, and samples analysed by rovers on Mars, illustrates the importance of having multiple ways of probing the Red Planet, she says.

Ehlmann, Hu, and Yung previously collaborated on research that seeks to understand the habitability of Mars by tracing the history of carbon, since carbon dioxide is the principal constituent of the atmosphere.

Next, the team plans to continue to use isotopic and mineral composition data to determine the fate of nitrogen and sulphur-bearing minerals. In addition, Scheller plans to continue examining the processes by which Mars's surface water was lost to the crust using laboratory experiments that simulate Martian weathering processes, as well as through observations of ancient crust by the Perseverance rover. Scheller and Ehlmann will also aid in Mars 2020 operations to collect rock samples for return to Earth that will allow the researchers and their colleagues to test these hypotheses about the drivers of climate change on Mars.

- A giant, sizzling planet may be orbiting the star Vega

Date: March 8, 2021
Source: University of Colorado at Boulder

The star Vega (stock image).
Credit: © infinitalavita / stock.adobe.com

Astronomers have discovered new hints of a giant, scorching-hot planet orbiting Vega, one of the brightest stars in the night sky.

The research, published this month in *The Astrophysical Journal*, was led by University of Colorado Boulder student Spencer Hurt, an undergraduate in the Department of Astrophysical and Planetary Sciences.

It focuses on an iconic and relatively young star, Vega, which is part of the constellation Lyra and has a mass twice that of our own sun.

This celestial body sits just 25 light-years, or about 150 trillion miles, from Earth -- pretty close, astronomically speaking.
Scientists can also see Vega with telescopes even when it's light out, which makes it a prime candidate for research, said study co-author Samuel Quinn.
"It's bright enough that you can observe it at twilight when other stars are getting washed out by sunlight," said Quinn, an astronomer at the Harvard and Smithsonian Centre for Astrophysics (CfA).
Despite the star's fame, researchers have yet to find a single planet in orbit around Vega. That might be about to change: Drawing on a decade of observations from the ground, Hurt, Quinn and their colleagues unearthed a curious signal that could be the star's first-known world.
If the team's findings bear out, the alien planet would orbit so close to Vega that its years would last less than two-and-a-half Earth days. (Mercury, in contrast, takes 88 days to circle the sun). This candidate planet could also rank as the second hottest world known to science -- with surface temperatures averaging a searing 5,390 degrees Fahrenheit.
Hurt said the group's research also helps to narrow down where other, exotic worlds might be hiding in Vega's neighbourhood.
"This is a massive system, much larger than our own solar system," Hurt said. "There could be other planets throughout that system. It's just a matter of whether we can detect them."

Youthful energy

Quinn would like to try. Scientists have discovered more than 4,000 exoplanets, or planets beyond Earth's solar system, to date. Few of those, however, circle stars that are as bright or as close to Earth as Vega. That means that, if there are planets around the star, scientists could get a really detailed look at them.
"It would be really exciting to find a planet around Vega because it offers possibilities for future characterization in ways that planets around fainter stars wouldn't," Quinn said.
There's just one catch: Vega is what scientists call an A-type star, the name for objects that tend to be bigger, younger and much faster-spinning than our own sun. Vega, for example, rotates around its axis once every 16 hours -- much faster than the sun with a rotational period that clocks in at 27 Earth days. Such a lightning-fast pace, Quinn said, can make it difficult for scientists to collect precise data on the star's motion and, by extension, any planets in orbit around it.
To take on that game of celestial hide-and-seek, he and colleagues pored through roughly 10 years of data on Vega collected by the Fred Lawrence Whipple Observatory in Arizona. In particular, the team was looking for a tell-tale signal of an alien planet -- a slight jiggle in the star's velocity.
"If you have a planet around a star, it can tug on the star, causing it to wobble back and forth," Quinn said.

Hot and puffy

The search may have paid off, said Hurt, who began the study as a summer research fellow working for Quinn at the CfA. The team discovered a signal that indicates that Vega might host what astronomers call a "hot Neptune" or maybe a "hot Jupiter."
"It would be at least the size of Neptune, potentially as big as Jupiter and would be closer to Vega than Mercury is to the sun," Hurt said.
That close to Vega, he added, the candidate world might puff up like a balloon, and even iron would melt into gas in its atmosphere.
The researchers have a lot more work to do before they can definitively say that they've discovered this sizzling planet. Hurt noted that the easiest way to look for it might be to scan the stellar system directly to look for light emitted from the hot, bright planet.
For now, the student is excited to see his hard work reflected in the constellations:
"Whenever I get to go outside and look at the night sky and see Vega, I say 'Hey, I know that star."
Other co-authors on the new study include David Latham, Gilbert Esquerdo, Michael Calkins, Perry Berlind, Christian Latham and George Zhou at the CfA; Andrew Vandeburg at the University of Wisconsin-Madison; and Ruth Angus at the American Museum of Natural History.

- ❖ Most distant quasar with powerful radio jets discovered

Date: March 8, 2021
Source: ESO

Quasar illustration (stock image).
Credit: © IgorZh / stock.adobe.com

With the help of the European Southern Observatory's Very Large Telescope (ESO's VLT), astronomers have discovered and studied in detail the most distant source of radio emission known to date. The source is a "radio-loud" quasar -- a bright object with powerful jets emitting at radio wavelengths -- that is so far away its light has taken 13 billion years to reach us. The discovery could provide important clues to help astronomers understand the early Universe.

Quasars are very bright objects that lie at the centre of some galaxies and are powered by supermassive black holes. As the black hole consumes the surrounding gas, energy is released, allowing astronomers to spot them even when they are very far away.

The newly discovered quasar, nicknamed P172+18, is so distant that light from it has travelled for about 13 billion years to reach us: we see it as it was when the Universe was just around 780 million years old. While more distant quasars have been discovered, this is the first-time astronomers have been able to identify the tell-tale signatures of radio jets in a quasar this early on in the history of the Universe. Only about 10% of quasars -- which astronomers classify as "radio-loud" -- have jets, which shine brightly at radio frequencies [1].

P172+18 is powered by a black hole about 300 million times more massive than our Sun that is consuming gas at a stunning rate. "The black hole is eating up matter very rapidly, growing in mass at one of the highest rates ever observed," explains astronomer Chiara Mazzucchelli, Fellow at ESO in Chile, who led the discovery together with Eduardo Bañados of the Max Planck Institute for Astronomy in Germany.

The astronomers think that there's a link between the rapid growth of supermassive black holes and the powerful radio jets spotted in quasars like P172+18. The jets are thought to be capable of disturbing the gas around the black hole, increasing the rate at which gas falls in. Therefore, studying radio-loud quasars can provide important insights into how black holes in the early Universe grew to their supermassive sizes so quickly after the Big Bang.

"I find it very exciting to discover 'new' black holes for the first time, and to provide one more building block to understand the primordial Universe, where we come from, and ultimately ourselves," says Mazzucchelli.

P172+18 was first recognised as a far-away quasar, after having been previously identified as a radio source, at the Magellan Telescope at Las Campanas Observatory in Chile by Bañados and Mazzucchelli. "As soon as we got the data, we inspected it by eye, and we knew immediately that we had discovered the most distant radio-loud quasar known so far," says Bañados.

However, owing to a short observation time, the team did not have enough data to study the object in detail. A flurry of observations with other telescopes followed, including with the X-shooter instrument on ESO's VLT, which allowed them to dig deeper into the characteristics of this quasar, including determining key properties such as the mass of the black hole and how fast it's eating up matter from its surroundings. Other telescopes that contributed to the study include the National Radio Astronomy Observatory's Very Large Array and the Keck Telescope in the US.

While the team are excited about their discovery, to appear in *The Astrophysical Journal*, they believe this radio-loud quasar could be the first of many to be found, perhaps at even larger cosmological distances. "This discovery makes me optimistic and I believe -- and hope -- that the distance record will be broken soon," says Bañados.

Observations with facilities such as ALMA, in which ESO is a partner, and with ESO's upcoming Extremely Large Telescope (ELT) could help uncover and study more of these early-Universe objects in detail.

Note

[1] Radio waves that are used in astronomy have frequencies between about 300 MHz and 300 GHz.

- Hubble shows torrential outflows from infant stars may not stop them from growing

Date: March 18, 2021
Source: NASA/Goddard Space Flight Centre

Though our galaxy is an immense city of at least 200 billion stars, the details of how they formed remain largely cloaked in mystery. Scientists know that stars form from the collapse of huge hydrogen clouds that are squeezed under gravity to the point where nuclear fusion ignites. But only about 30 percent of the cloud's initial mass winds up as a new-born star. Where does the rest of the hydrogen go during such a terribly inefficient process?

It has been assumed that a newly forming star blows off a lot of hot gas through lightsabre-shaped outflowing jets and hurricane-like winds launched from the encircling disk by powerful magnetic fields. These fireworks should squelch further growth of the central star. But a new, comprehensive Hubble survey shows that this most common explanation doesn't seem to work, leaving astronomers puzzled.

Researchers used data previously collected from NASA's Hubble and Spitzer space telescopes and the European Space Agency's Herschel Space Telescope to analyse 304 developing stars, called protostars, in the Orion Complex, the nearest major star-forming region to Earth. (Spitzer and Herschel are no longer operational).

In this largest-ever survey of nascent stars to date, researchers are finding that gas-clearing by a star's outflow may not be as important in determining its final mass as conventional theories suggest. The researchers' goal was to determine whether stellar outflows halt the in fall of gas onto a star and stop it from growing.

Instead, they found that the cavities in the surrounding gas cloud sculpted by a forming star's outflow did not grow regularly as they matured, as theories propose.

"In one stellar formation model, if you start out with a small cavity, as the protostar rapidly becomes more evolved, its outflow creates an ever-larger cavity until the surrounding gas is eventually blown away, leaving an isolated star," explained lead researcher Nolan Habel of the University of Toledo in Ohio.

"Our observations indicate there is no progressive growth that we can find, so the cavities are not growing until they push out all of the mass in the cloud. So, there must be some other process going on that gets rid of the gas that doesn't end up in the star."

The team's results will appear in an upcoming issue of *The Astrophysical Journal*.

A Star is Born

During a star's relatively brief birthing stage, lasting only about 500,000 years, the star quickly bulks up on mass. What gets messy is that, as the star grows, it launches a wind, as well as a pair of spinning, lawn-sprinkler-style jets shooting off in opposite directions. These outflows begin to eat away at the surrounding cloud, creating cavities in the gas.

Popular theories predict that as the young star evolves and the outflows continue, the cavities grow wider until the entire gas cloud around the star is completely pushed away. With its gas tank empty, the star stops accreting mass -- in other words, it stops growing.

To look for cavity growth, the researchers first sorted the protostars by age by analysing Herschel and Spitzer data of each star's light output. The protostars in the Hubble observations were also observed as part of the Herschel telescope's Herschel Orion Protostar Survey.

Then the astronomers observed the cavities in near-infrared light with Hubble's Near-infrared Camera and Multi-object Spectrometer and Wide Field Camera 3. The observations were taken between 2008 and 2017. Although the stars themselves are shrouded in dust, they emit powerful radiation which strikes the cavity walls and scatters off dust grains, illuminating the gaps in the gaseous envelopes in infrared light.

The Hubble images reveal the details of the cavities produced by protostars at various stages of evolution. Habel's team used the images to measure the structures' shapes and estimate the volumes of gas cleared out to form the cavities. From this analysis, they could estimate the amount of mass that had been cleared out by the stars' outbursts.

"We find that at the end of the protostellar phase, where most of the gas has fallen from the surrounding cloud onto the star, a number of young stars still have fairly narrow cavities," said team member Tom Megeath of the University of Toledo. "So, this picture that is still commonly held of what determines the mass of a star and what halts the in fall of gas is that this growing outflow cavity scoops up all of the gas. This has been pretty fundamental to our idea of how star formation

proceeds, but it just doesn't seem to fit the data here."
Future telescopes such as NASA's upcoming James Webb Space Telescope will probe deeper into a protostar's formation process. Webb spectroscopic observations will observe the inner regions of disks surrounding protostars in infrared light, looking for jets in the youngest sources. Webb also will help astronomers measure the accretion rate of material from the disk onto the star, and study how the inner disk is interacting with the outflow.

- Astronomers see a 'space jellyfish'

Date: March 18, 2021
Source: International Centre for Radio Astronomy Research

A radio telescope located in outback Western Australia has observed a cosmic phenomenon with a striking resemblance to a jellyfish.
Published today in *The Astrophysical Journal*, an Australian-Italian team used the Murchison Widefield Array (MWA) telescope to observe a cluster of galaxies known as Abell 2877.
Lead author and PhD candidate Torrance Hodgson, from the Curtin University node of the International Centre for Radio Astronomy Research (ICRAR) in Perth, said the team observed the cluster for 12 hours at five radio frequencies between 87.5 and 215.5 megahertz.
"We looked at the data, and as we turned down the frequency, we saw a ghostly jellyfish-like structure begin to emerge," he said.
"This radio jellyfish holds a world record of sorts. Whilst it's bright at regular FM radio frequencies, at 200 MHz the emission all but disappears.
"No other extragalactic emission like this has been observed to disappear anywhere near so rapidly."
This uniquely steep spectrum has been challenging to explain. "We've had to undertake some cosmic archaeology to understand the ancient background story of the jellyfish," said Hodgson.
"Our working theory is that around 2 billion years ago, a handful of supermassive black holes from multiple galaxies spewed out powerful jets of plasma. This plasma faded, went quiet, and lay dormant.
"Then quite recently, two things happened -- the plasma started mixing at the same time as very gentle shock waves passed through the system.
"This has briefly reignited the plasma, lighting up the jellyfish and its tentacles for us to see."
The jellyfish is over a third of the Moon's diameter when observed from Earth, but can only be seen with low-frequency radio telescopes.
"Most radio telescopes can't achieve observations this low due to their design or location," said Hodgson.
The MWA -- a precursor to the Square Kilometre Array (SKA) -- is located at CSIRO's Murchison Radio-astronomy Observatory in remote Western Australia.
The site has been chosen to host the low-frequency antennas for the SKA, with construction scheduled to begin in less than a year.
Professor Johnston-Hollitt, Mr Hodgson's supervisor and co-author, said the SKA will give us an unparalleled view of the low-frequency Universe.
"The SKA will be thousands of times more sensitive and have much better resolution than the MWA, so there may be many other mysterious radio jellyfish waiting to be discovered once it's operational.
"We're about to build an instrument to make a high resolution, fast frame-rate movie of the evolving radio Universe. It will show us from the first stars and galaxies through to the present day," she said.
"Discoveries like the jellyfish only hint at what's to come, it's an exciting time for anyone seeking answers to fundamental questions about the cosmos."

- First images of the cosmic web reveal a myriad of unsuspected dwarf galaxies

Date: March 18, 2021
Source: CNRS

Although the filaments of gas in which galaxies are born have long been predicted by cosmological models, we have so far had no real images of such objects. Now for the first time, several filaments of the 'cosmic web' have been directly observed using the MUSE (1) instrument installed on ESO's Very Large Telescope in Chile. These observations of the early Universe, 1 to 2 billion years after the Big Bang, point to the existence of a multitude of hitherto unsuspected dwarf galaxies.
Carried out by an international collaboration led by the Centre de Recherche Astrophysique de Lyon (CNRS/Université Lyon 1/ENS de Lyon), also involving the Lagrange laboratory (CNRS/Université Côte d'Azur/Observatoire

de la Côte d'Azur) (2), the study is published on 18 March 2021 in the journal *Astronomy & Astrophysics*.

The filamentary structure of hydrogen gas in which galaxies form, known as the cosmic web, is one of the major predictions of the model of the Big Bang and of galaxy formation. Until now, all that was known about the web was limited to a few specific regions, particularly in the direction of quasars, whose powerful radiation acts like car headlights, revealing gas clouds along the line of sight. However, these regions are poorly representative of the whole network of filaments where most galaxies, including our own, were born. Direct observation of the faint light emitted by the gas making up the filaments was a holy grail which has now been attained by an international team headed by Roland Bacon, CNRS researcher at the Centre de Recherche Astrophysique de Lyon (CNRS/Université Lyon 1/ENS de Lyon).

The team took the bold step of pointing ESO's Very Large Telescope, equipped with the MUSE instrument coupled to the telescope's adaptive optics system, at a single region of the sky for over 140 hours. Together, the two instruments form one of the most powerful systems in the world. The region selected forms part of the Hubble Ultra-Deep Field, which was until now the deepest image of the cosmos ever obtained. However, Hubble has now been surpassed, since 40% of the galaxies discovered by MUSE have no counterpart in the Hubble images.

After meticulous planning, it took eight months to carry out this exceptional observing campaign. This was followed by a year of data processing and analysis, which for the first-time revealed light from the hydrogen filaments, as well as images of several filaments as they were one to two billion years after the Big Bang, a key period for understanding how galaxies formed from the gas in the cosmic web. However, the biggest surprise for the team was when simulations showed that the light from the gas came from a hitherto invisible population of billions of dwarf galaxies spawning a host of stars (3). Although these galaxies are too faint to be detected individually with current instruments, their existence will have major consequences for galaxy formation models, with implications that scientists are only just beginning to explore.

Notes:

(1) MUSE, which stands for Multi-Unit Spectroscopic Explorer, is a 3D spectrograph designed to explore the distant Universe. The construction of the instrument was led by the Centre de Recherche Astrophysique de Lyon (CNRS/Université Claude Bernard-Lyon 1/ENS de Lyon).

(2) Other French laboratories involved: Laboratoire d'Astrophysique de Marseille (CNRS/Aix-Marseille Université/CNES), Institut de Recherche en Astrophysique et Planétologie (CNRS/Université Toulouse III -- Paul Sabatier/CNES).

(3) Until now, theory predicted that the light came from the diffuse cosmic ultraviolet background radiation (very weak background radiation produced by all the galaxies and stars) which, by heating the gas in the filaments, causes them to glow.

- ❖ Cosmic lens reveals faint radio galaxy

Natural magnification enables discovery

Date: March 16, 2021
Source: National Radio Astronomy Observatory

Radio telescopes are the world's most sensitive radio receivers, capable of finding extremely faint wisps of radio emission coming from objects at the farthest reaches of the universe. Recently, a team of astronomers used the National Science Foundation's Karl G. Jansky Very Large Array (VLA) to take advantage of a helping hand from nature to detect a distant galaxy that likely is the faintest radio-emitting object yet found.

The discovery was part of the VLA Frontier Fields Legacy Survey, led by NRAO Astronomer Eric Murphy, which used distant clusters of galaxies as natural lenses to study objects even farther away. The clusters served as gravitational lenses, using the gravitational pull of the galaxies in the clusters to bend and magnify light and radio waves coming from the more-distant objects.

In this composite, a VLA radio image is superimposed on a visible-light image from the Hubble Space Telescope. The prominent red-orange objects are radio relics -- large structures possibly caused by shock waves -- inside the foreground galaxy cluster, called MACSJ0717.5+3745, which is more than 5 billion light-years from Earth.

Detailed VLA observations showed that many of the galaxies in this image are emitting radio waves in addition to visible light. The VLA data revealed that one of these galaxies, shown in the pull out, is more than 8 billion light-years distant. Its light and radio waves have

been bent by the intervening cluster's gravitational-lensing effect.
The radio image of this distant galaxy, called VLAHFF-J071736.66+374506.4, has been magnified more than 6 times by the gravitational lens, the astronomers said. That magnification is what allowed the VLA to detect it.
"This probably is the faintest radio-emitting object ever detected," said Ian Heywood, of Oxford University in the UK. "This is exactly why we want to use these galaxy clusters as powerful cosmic lenses to learn more about the objects behind them."
"The magnification provided by the gravitational lens, combined with extremely sensitive VLA imaging, gave us an unprecedented look at the structure of a galaxy 300 times less massive than our Milky Way at a time when the universe was less than half its current age. This is giving us valuable insights on star formation in such low-mass galaxies at that time and how they eventually assembled into more massive galaxies," said Eric Jimenez-Andrade, of NRAO.
The scientists are reporting their work in a pair of papers that are accepted into publication in the *Astrophysical Journal*.

- How fast is the universe expanding? Galaxies provide one answer

New measure of Hubble constant highlights discrepancy between estimates of our cosmic fate
Date: March 8, 2021
Source: University of California – Berkeley

Expanding universe abstract concept (stock image).
Credit: © flashmovie / stock.adobe.com
Determining how rapidly the universe is expanding is key to understanding our cosmic fate, but with more precise data has come a conundrum: Estimates based on measurements within our local universe don't agree with extrapolations from the era shortly after the Big Bang 13.8 billion years ago.
A new estimate of the local expansion rate -- the Hubble constant, or H0 (H-naught) -- reinforces that discrepancy.
Using a relatively new and potentially more precise technique for measuring cosmic distances, which employs the average stellar brightness within giant elliptical galaxies as a rung on the distance ladder, astronomers calculate a rate -- 73.3 kilometres per second per megaparsec, give or take 2.5 km/sec/Mpc -- that lies in the middle of three other good estimates, including the gold standard estimate from Type Ia supernovae. This means that for every megaparsec -- 3.3 million light years, or 3 billion trillion kilometres -- from Earth, the universe is expanding an extra 73.3 ±2.5 kilometres per second. The average from the three other techniques is 73.5 ±1.4 km/sec/Mpc.
Perplexingly, estimates of the local expansion rate based on measured fluctuations in the cosmic microwave background and, independently, fluctuations in the density of normal matter in the early universe (baryon acoustic oscillations), give a very different answer: 67.4 ±0.5 km/sec/Mpc.
Astronomers are understandably concerned about this mismatch, because the expansion rate is a critical parameter in understanding the physics and evolution of the universe and is key to understanding dark energy -- which accelerates the rate of expansion of the universe and thus causes the Hubble constant to change more rapidly than expected with increasing distance from Earth. Dark energy comprises about two-thirds of the mass and energy in the universe, but is still a mystery.
For the new estimate, astronomers measured fluctuations in the surface brightness of 63 giant elliptical galaxies to determine the distance and plotted distance against velocity for each to obtain H0. The surface brightness fluctuation (SBF) technique is independent of other techniques and has the potential to provide more precise distance estimates than other methods within about 100 Mpc of Earth, or 330 million light years. The 63 galaxies in the sample are at distances ranging from 15 to 99 Mpc, looking back in time a mere fraction of the age of the universe.
"For measuring distances to galaxies out to 100 megaparsecs, this is a fantastic method," said cosmologist Chung-Pei Ma, the Judy Chandler Webb Professor in the Physical Sciences at the University of California, Berkeley, and professor of astronomy and

physics. "This is the first paper that assembles a large, homogeneous set of data, on 63 galaxies, for the goal of studying H-naught using the SBF method."
Ma leads the MASSIVE survey of local galaxies, which provided data for 43 of the galaxies -- two-thirds of those employed in the new analysis.
The data on these 63 galaxies was assembled and analysed by John Blakeslee, an astronomer with the National Science Foundation's NOIRLab. He is first author of a paper now accepted for publication in *The Astrophysical Journal* that he co-authored with colleague Joseph Jensen of Utah Valley University in Orem. Blakeslee, who heads the science staff that support NSF's optical and infrared observatories, is a pioneer in using SBF to measure distances to galaxies, and Jensen was one of the first to apply the method at infrared wavelengths. The two worked closely with Ma on the analysis.
"The whole story of astronomy is, in a sense, the effort to understand the absolute scale of the universe, which then tells us about the physics," Blakeslee said, harkening back to James Cook's voyage to Tahiti in 1769 to measure a transit of Venus so that scientists could calculate the true size of the solar system. "The SBF method is more broadly applicable to the general population of evolved galaxies in the local universe, and certainly if we get enough galaxies with the James Webb Space Telescope, this method has the potential to give the best local measurement of the Hubble constant."
The James Webb Space Telescope, 100 times more powerful than the Hubble Space Telescope, is scheduled for launch in October.

Giant elliptical galaxies

The Hubble constant has been a bone of contention for decades, ever since Edwin Hubble first measured the local expansion rate and came up with an answer seven times too big, implying that the universe was actually younger than its oldest stars. The problem, then and now, lies in pinning down the location of objects in space that give few clues about how far away they are.
Astronomers over the years have laddered up to greater distances, starting with calculating the distance to objects close enough that they seem to move slightly, because of parallax, as the Earth orbits the sun. Variable stars called Cepheids get you farther, because their brightness is linked to their period of variability, and Type Ia supernovae get you even farther, because they are extremely powerful explosions that, at their peak, shine as bright as a whole galaxy. For both Cepheids and Type Ia supernovae, it's possible to figure out the absolute brightness from the way they change over time, and then the distance can be calculated from their apparent brightness as seen from Earth.
The best current estimate of H0 comes from distances determined by Type Ia supernova explosions in distant galaxies, though newer methods -- time delays caused by gravitational lensing of distant quasars and the brightness of water masers orbiting black holes -- all give around the same number.
The technique using surface brightness fluctuations is one of the newest and relies on the fact that giant elliptical galaxies are old and have a consistent population of old stars -- mostly red giant stars -- that can be modelled to give an average infrared brightness across their surface. The researchers obtained high-resolution infrared images of each galaxy with the Wide Field Camera 3 on the Hubble Space Telescope and determined how much each pixel in the image differed from the "average" -- the smoother the fluctuations over the entire image, the farther the galaxy, once corrections are made for blemishes like bright star-forming regions, which the authors exclude from the analysis.
Neither Blakeslee nor Ma was surprised that the expansion rate came out close to that of the other local measurements. But they are equally confounded by the glaring conflict with estimates from the early universe -- a conflict that many astronomers say means that our current cosmological theories are wrong, or at least incomplete.
The extrapolations from the early universe are based on the simplest cosmological theory -- called lambda cold dark matter, or ?CDM -- which employs just a few parameters to describe the evolution of the universe. Does the new estimate drive a stake into the heart of ?CDM?
"I think it pushes that stake in a bit more," Blakeslee said. "But it (?CDM) is still alive. Some people think, regarding all these local measurements, (that) the observers are wrong. But it is getting harder and harder to make that claim -- it would require there to be systematic errors in the same direction for several different methods: supernovae, SBF, gravitational lensing, water masers. So, as we

get more independent measurements, that stake goes a little deeper."

Ma wonders whether the uncertainties astronomers ascribe to their measurements, which reflect both systematic errors and statistical errors, are too optimistic, and that perhaps the two ranges of estimates can still be reconciled.

"The jury is out," she said. "I think it really is in the error bars. But assuming everyone's error bars are not underestimated, the tension is getting uncomfortable."

In fact, one of the giants of the field, astronomer Wendy Freedman, recently published a study pegging the Hubble constant at 69.8 ±1.9 km/sec/Mpc, roiling the waters even further. The latest result from Adam Riess, an astronomer who shared the 2011 Nobel Prize in Physics for discovering dark energy, reports 73.2 ±1.3 km/sec/Mpc. Riess was a Miller Postdoctoral Fellow at UC Berkeley when he performed this research, and he shared the prize with UC Berkeley and Berkeley Lab physicist Saul Perlmutter.

MASSIVE galaxies

The new value of H0 is a by-product of two other surveys of nearby galaxies -- in particular, Ma's MASSIVE survey, which uses space and ground-based telescopes to exhaustively study the 100 most massive galaxies within about 100 Mpc of Earth. A major goal is to weigh the supermassive black holes at the centres of each one.

To do that, precise distances are needed, and the SBF method is the best to date, she said. The MASSIVE survey team used this method last year to determine the distance to a giant elliptical galaxy, NGC 1453, in the southern sky constellation of Eridanus. Combining that distance, 166 million light years, with extensive spectroscopic data from the Gemini and McDonald telescopes -- which allowed Ma's graduate students Chris Liepold and Matthew Quenneville to measure the velocities of the stars near the centre of the galaxy -- they concluded that NGC 1453 has a central black hole with a mass nearly 3 billion times that of the sun.

To determine H0, Blakeslee calculated SBF distances to 43 of the galaxies in the MASSIVE survey, based on 45 to 90 minutes of HST observing time for each galaxy. The other 20 came from another survey that employed HST to image large galaxies, specifically ones in which Type Ia supernovae have been detected.

Most of the 63 galaxies are between 8 and 12 billion years old, which means that they contain a large population of old red stars, which are key to the SBF method and can also be used to improve the precision of distance calculations. In the paper, Blakeslee employed both Cepheid variable stars and a technique that uses the brightest red giant stars in a galaxy -- referred to as the tip of the red giant branch, or TRGB technique -- to ladder up to galaxies at large distances. They produced consistent results. The TRGB technique takes account of the fact that the brightest red giants in galaxies have about the same absolute brightness.

"The goal is to make this SBF method completely independent of the Cepheid-calibrated Type Ia supernova method by using the James Webb Space Telescope to get a red giant branch calibration for SBFs," he said.

"The James Webb telescope has the potential to really decrease the error bars for SBF," Ma added. But for now, the two discordant measures of the Hubble constant will have to learn to live with one another.

"I was not setting out to measure H0; it was a great product of our survey," she said. "But I am a cosmologist and am watching this with great interest."

Co-authors of the paper with Blakeslee, Ma and Jensen are Jenny Greene of Princeton University, who is a leader of the MASSIVE team, and Peter Milne of the University of Arizona in Tucson, who leads the team studying Type Ia supernovae. The work was supported by the National Aeronautics and Space Administration (HST-GO-14219, HST-GO-14654, HST GO-15265) and the National Science Foundation (AST-1815417, AST-1817100).

- Astronomers have detected a moving supermassive black hole

Date: March 12, 2021
Source: Harvard-Smithsonian Centre for Astrophysics

Scientists have long theorized that supermassive black holes can wander through space -- but catching them in the act has proven difficult.

Now, researchers at the Centre for Astrophysics | Harvard & Smithsonian have identified the clearest case to date of a supermassive black hole in motion. Their results are published today in the *Astrophysical Journal*.

"We don't expect the majority of supermassive black holes to be moving; they're usually

content to just sit around," says Dominic Pesce, an astronomer at the Centre for Astrophysics who led the study. "They're just so heavy that it's tough to get them going. Consider how much more difficult it is to kick a bowling ball into motion than it is to kick a soccer ball -- realizing that in this case, the 'bowling ball' is several million times the mass of our Sun. That's going to require a pretty mighty kick."
Pesce and his collaborators have been working to observe this rare occurrence for the last five years by comparing the velocities of supermassive black holes and galaxies.
"We asked: Are the velocities of the black holes the same as the velocities of the galaxies they reside in?" he explains. "We expect them to have the same velocity. If they don't, that implies the black hole has been disturbed."
For their search, the team initially surveyed 10 distant galaxies and the supermassive black holes at their cores. They specifically studied black holes that contained water within their accretion disks -- the spiral structures that spin inward towards the black hole.
As the water orbits around the black hole, it produces a laser-like beam of radio light known as a maser. When studied with a combined network of radio antennas using a technique known as very long baseline interferometry (VLBI), masers can help measure a black hole's velocity very precisely, Pesce says.
The technique helped the team determine that nine of the 10 supermassive black holes were at rest -- but one stood out and seemed to be in motion.
Located 230 million light-years away from Earth, the black hole sits at the centre of a galaxy named J0437+2456. Its mass is about three million times that of our Sun.
Using follow-up observations with the Arecibo and Gemini Observatories, the team has now confirmed their initial findings. The supermassive black hole is moving with a speed of about 110,000 miles per hour inside the galaxy J0437+2456.
But what's causing the motion is not known. The team suspects there are two possibilities.
"We may be observing the aftermath of two supermassive black holes merging," says Jim Condon, a radio astronomer at the National Radio Astronomy Observatory who was involved in the study. "The result of such a merger can cause the new-born black hole to recoil, and we may be watching it in the act of recoiling or as it settles down again."
But there's another, perhaps even more exciting possibility: the black hole may be part of a binary system.
"Despite every expectation that they really ought to be out there in some abundance, scientists have had a hard time identifying clear examples of binary supermassive black holes," Pesce says. "What we could be seeing in the galaxy J0437+2456 is one of the black holes in such a pair, with the other remaining hidden to our radio observations because of its lack of maser emission."
Further observations, however, will ultimately be needed to pin down the true cause of this supermassive black hole's unusual motion.

- Not so fast, supernova: Highest-energy cosmic rays detected in star clusters

Date: March 11, 2021
Source: Michigan Technological University

Cocoon Nebula (stock image).
Credit: © fnendzig / stock.adobe.com

The highest-energy cosmic rays come from subatomic interactions within star clusters, not supernovae, say Michigan Tech physicists and collaborators.
For decades, researchers assumed the cosmic rays that regularly bombard Earth from the far reaches of the galaxy are born when stars go supernova -- when they grow too massive to support the fusion occurring at their cores and explode.
Those gigantic explosions do indeed propel atomic particles at the speed of light great distances. However, new research suggests even supernovae -- capable of devouring entire solar systems -- are not strong enough to imbue particles with the sustained energies needed to reach petaelectronvolts (PeVs), the amount of kinetic energy attained by very high-energy cosmic rays.
And yet cosmic rays have been observed striking Earth's atmosphere at exactly those

velocities, their passage marked, for example, by the detection tanks at the High-Altitude Water Cherenkov (HAWC) observatory near Puebla, Mexico. Instead of supernovae, the researchers posit that star clusters like the Cygnus Cocoon serve as PeVatrons -- PeV accelerators -- capable of moving particles across the galaxy at such high energy rates. Their paradigm-shifting research provides compelling evidence for star forming regions to be PeVatrons and is published in two recent papers in *Nature Astronomy* and *Astrophysical Journal Letters*.

A characteristic of physics research is how collaborative it is. The research was conducted by Petra Huentemeyer, professor of physics at Michigan Technological University, along with recent graduate Binita Hona '20, doctoral student Dezhi Huang, former MTU postdoc Henrike Fleischhack (now at Catholic University/NASA GSFC/CRESST II), Sabrina Casanova at the Institute of Nuclear Physics Polish Academy of Sciences in Krakow, Ke Fang at the University of Wisconsin and Roger Blanford at Stanford, along with numerous other collaborators of the HAWC Observatory.

Huentemeyer noted that HAWC and physicists from other institutions have measured cosmic rays from all directions and across many decades of energy. It's in tracking the cosmic rays with the highest known energy, PeVs, that their origin becomes so important.

"Cosmic rays below PeV energy are believed to come from our galaxy, but the question is what are the accelerators that can produce them," Huentemeyer said.

Fleischhack said the paradigm shift the researchers have uncovered is that before, scientists thought supernova remnants were the main accelerators of cosmic rays.

"They do accelerate cosmic rays, but they are not able to get to highest energies," she said.

So, what is driving cosmic rays' acceleration to PeV energy?

"There have been several other hints that star clusters could be part of the story," Fleischhack said. "Now we are getting confirmation that they are able to go to highest energies."

Star clusters are formed from the remnants of a supernova event. Known as star cradles, they contain violent winds and clouds of swirling debris -- such as those noted by the researchers in Cygnus OB2 and cluster [BDS2003]8. Inside, several types of massive stars known as spectral type O and type B stars are gathered by the hundreds in an area about 30 parsecs (108 light-years) across.

"Spectral type O stars are the most massive," Hona said. "When their winds interact with each other, shock waves form, which is where acceleration happens."

The researchers' theoretical models suggest that the energetic gamma-ray photons seen by HAWC are more likely produced by protons than by electrons.

"We will use NASA telescopes to search for the counterpart emission by these relativistic particles at lower energies," Fang said.

The extremely high energy at which cosmic rays reach our planet is notable. Specific conditions are required to accelerate particles to such velocities.

The higher the energy, the more difficult it is to confine the particles -- knowledge gleaned from particle accelerators here on Earth in Chicago and Switzerland. To keep particles from whizzing away, magnetism is required. Stellar clusters -- with their mixture of wind and nascent but powerful stars -- are turbulent regions with different magnetic fields that can provide the confinement necessary for particles to continue to accelerate.

"Supernova remnants have very fast shocks where the cosmic ray can be accelerated; however, they don't have the type of long confinement regions," Casanova said. "This is what star clusters are useful for. They're an association of stars that can create disturbances that confine the cosmic rays and make it possible for the shocks to accelerate them."

But how is it possible to measure atomic interactions on a galactic scale 5,000 light-years from Earth? The researchers used 1,343 days of measurements from HAWC detection tanks.

Huang explained how the physicists at HAWC trace cosmic rays by measuring the gamma rays these cosmic rays produce at galactic acceleration sites: "We didn't measure gamma rays directly; we measured the secondary rays generated. When gamma rays interact with the atmosphere, they generate secondary particles in particle showers."

"When particle showers are detected at HAWC, we can measure the shower and the charge of secondary particles," Huang said. "We use the particle charge and time information to reconstruct information from the primary gamma."

In addition to HAWC, the researchers plan to work with the Southern Wide-field Gamma-ray Observatory (SWGO), an observatory currently in the planning stages that will feature Cherenkov light detectors like HAWC but will be located in the southern hemisphere. "It would be interesting to see what we can see in the southern hemisphere," Huentemeyer said. "We will have a good view of the galactic centre that we don't have in the northern hemisphere. SWGO could give us many more candidates in terms of star clusters."
Future collaborations across hemispheres promise to help scientists around the world continue to explore the origins of cosmic rays and learn more about the galaxy itself.

- How the habitability of exoplanets is influenced by their rocks

Date: March 11, 2021
Source: University of Bern

The conditions on Earth are ideal for life. Most places on our planet are neither too hot nor too cold and offer liquid water. These and other requirements for life, however, delicately depend on the right composition of the atmosphere. Too little or too much of certain gases -- like carbon dioxide -- and Earth could become a ball of ice or turn into a pressure cooker. When scientists look for potentially habitable planets, a key component is therefore their atmosphere.
Sometimes, that atmosphere is primitive and largely consists of the gases that were around when the planet formed -- as is the case for Jupiter and Saturn. On terrestrial planets like Mars, Venus or Earth, however, such primitive atmospheres are lost. Instead, their remaining atmospheres are strongly influenced by surface geochemistry. Processes like the weathering of rocks alter the composition the atmosphere and thereby influence the habitability of the planet.
How exactly this works, especially under conditions very different from those on Earth, is what a team of scientists, led by Kaustubh Hakim of the Centre for Space and Habitability (CSH) at the University of Bern and the NCCR PlanetS, investigated. Their results were published today in *The Planetary Science Journal*.

Conditions are decisive

"We want to understand how the chemical reactions between the atmosphere and the surface of planets change the composition of the atmosphere. On Earth, this process -- the weathering of silicate rocks assisted by water -- helps to maintain a temperate climate over long periods of time," Hakim explains. "When the concentration of CO_2 increases, temperatures also rise because of its greenhouse effect. Higher temperatures lead to more intense rainfall. Silicate weathering rates increase, which in turn reduce the CO_2 concentration and subsequently lower the temperature," says the researcher.
However, it need not necessarily work the same way on other planets. Using computer simulations, the team tested how different conditions affect the weathering process. For example, they found that even in very arid climates, weathering can be more intense than on Earth if the chemical reactions occur sufficiently quickly. Rock types, too, influence the process and can lead to very different weathering rates according to Hakim. The team also found that at temperatures of around 70°C, contrary to popular theory, silicate weathering rates can decrease with rising temperatures. "This shows that for planets with very different conditions than on Earth, weathering could play very different roles," Hakim says.

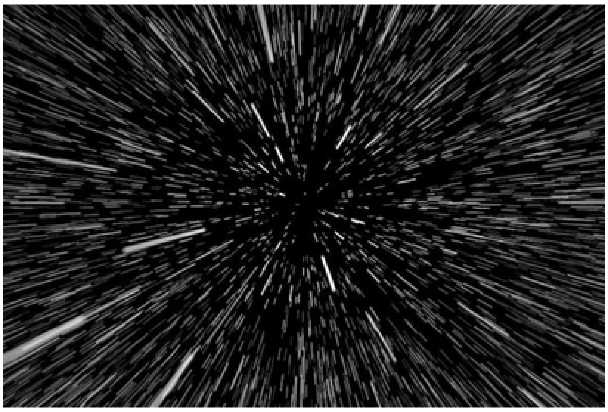
Implications for habitability and life detection

If astronomers ever find a habitable world, it will likely be in what they call the habitable zone. This zone is the area around a star, where the dose of radiation would allow water to be liquid. In the solar system, this zone roughly lies between Mars and Venus.
"Geochemistry has a profound impact on the habitability of planets in the habitable zone," study co-author and professor of astronomy and planetary sciences at the University of Bern and member of the NCCR PlanetS, Kevin Heng, points out. As the team's results indicate, increasing temperatures could reduce weathering and its balancing effect on other planets. What would potentially be a habitable world could turn out to be a hellish greenhouse instead.
As Heng further explains, understanding geochemical processes under different conditions is not only important to estimate the potential for life, but also for its detection. "Unless we have some idea of the results of geochemical processes under varying conditions, we will not be able to tell whether bio-signatures -- possible hints of life like the Phosphine that was found on Venus last year -

- indeed come from biological activity," the researcher concludes.

- Breaking the warp barrier for faster-than-light travel

New theoretical hyper-fast soliton solutions
Date: March 9, 2021
Source: University of Göttingen



Space travel abstract concept illustration (stock image).
Credit: © ikonacolor / stock.adobe.com

If travel to distant stars within an individual's lifetime is going to be possible, a means of faster-than-light propulsion will have to be found. To date, even recent research about superluminal (faster-than-light) transport based on Einstein's theory of general relativity would require vast amounts of hypothetical particles and states of matter that have "exotic" physical properties such as negative energy density. This type of matter either cannot currently be found or cannot be manufactured in viable quantities. In contrast, new research carried out at the University of Göttingen gets around this problem by constructing a new class of hyper-fast 'solitons' using sources with only positive energies that can enable travel at any speed. This reignites debate about the possibility of faster-than-light travel based on conventional physics. The research is published in the journal *Classical and Quantum Gravity*.

The author of the paper, Dr Erik Lentz, analysed existing research and discovered gaps in previous 'warp drive' studies. Lentz noticed that there existed yet-to-be explored configurations of space-time curvature organized into 'solitons' that have the potential to solve the puzzle while being physically viable. A soliton -- in this context also informally referred to as a 'warp bubble' -- is a compact wave that maintains its shape and moves at constant velocity. Lentz derived the Einstein equations for unexplored soliton configurations (where the space-time metric's shift vector components obey a hyperbolic relation), finding that the altered space-time geometries could be formed in a way that worked even with conventional energy sources. In essence, the new method uses the very structure of space and time arranged in a soliton to provide a solution to faster-than-light travel, which -- unlike other research -- would only need sources with positive energy densities. No "exotic" negative energy densities needed.

If sufficient energy could be generated, the equations used in this research would allow space travel to Proxima Centauri, our nearest star, and back to Earth in years instead of decades or millennia. That means an individual could travel there and back within their lifetime. In comparison, the current rocket technology would take more than 50,000 years for a one-way journey. In addition, the solitons (warp bubbles) were configured to contain a region with minimal tidal forces such that the passing of time inside the soliton matches the time outside: an ideal environment for a spacecraft. This means there would not be the complications of the so-called "twin paradox" whereby one twin travelling near the speed of light would age much more slowly than the other twin who stayed on Earth: in fact, according to the recent equations both twins would be the same age when reunited.

"This work has moved the problem of faster-than-light travel one step away from theoretical research in fundamental physics and closer to engineering. The next step is to figure out how to bring down the astronomical amount of energy needed to within the range of today's technologies, such as a large modern nuclear fission power plant. Then we can talk about building the first prototypes," says Lentz.

Currently, the amount of energy required for this new type of space propulsion drive is still immense. Lentz explains, "The energy required for this drive travelling at light speed encompassing a spacecraft of 100 meters in radius is on the order of hundreds of times of the mass of the planet Jupiter. The energy savings would need to be drastic, of approximately 30 orders of magnitude to be in range of modern nuclear fission reactors." He goes on to say: "Fortunately, several energy-saving mechanisms have been proposed in earlier research that can potentially lower the energy required by nearly 60 orders of magnitude." Lentz is currently in the early-stages of determining if these methods can be modified, or if new mechanisms are needed to bring the energy required down to what is currently possible.

- Distant planet may be on its second atmosphere

Date: March 11, 2021
Source: NASA/Goddard Space Flight Centre

Scientists using NASA's Hubble Space Telescope have found evidence that a planet orbiting a distant star may have lost its atmosphere but gained a second one through volcanic activity.

The planet, GJ 1132 b, is hypothesized to have begun as a gaseous world with a thick hydrogen blanket of atmosphere. Starting out at several times the diameter of Earth, this so-called "sub-Neptune" is believed to have quickly lost its primordial hydrogen and helium atmosphere due to the intense radiation of the hot, young star it orbits. In a short period of time, such a planet would be stripped down to a bare core about the size of Earth. That's when things got interesting.

To the surprise of astronomers, Hubble observed an atmosphere which, according to their theory, is a "secondary atmosphere" that is present now. Based on a combination of direct observational evidence and inference through computer modelling, the team reports that the atmosphere consists of molecular hydrogen, hydrogen cyanide, methane and also contains an aerosol haze. Modelling suggests the aerosol haze is based on photochemically produced hydrocarbons, similar to smog on Earth.

Scientists interpret the current atmospheric hydrogen in GJ 1132 b as hydrogen from the original atmosphere which was absorbed into the planet's molten magma mantle and is now being slowly released through volcanic processes to form a new atmosphere. The atmosphere we see today is believed to be continually replenished to balance the hydrogen escaping into space.

"It's super exciting because we believe the atmosphere that we see now was regenerated, so it could be a secondary atmosphere," said study co-author Raissa Estrela of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. "We first thought that these highly irradiated planets could be pretty boring because we believed that they lost their atmospheres. But we looked at existing observations of this planet with Hubble and said, 'Oh no, there is an atmosphere there.'"

The findings could have implications for other exoplanets, planets beyond our solar system.

"How many terrestrial planets don't begin as terrestrials? Some may start as sub-Neptunes, and they become terrestrials through a mechanism that photo-evaporates the primordial atmosphere. This process works early in a planet's life, when the star is hotter," said lead author Mark Swain of JPL. "Then the star cools down and the planet's just sitting there. So you've got this mechanism where you can cook off the atmosphere in the first 100 million years, and then things settle down. And if you can regenerate the atmosphere, maybe you can keep it."

In some ways GJ 1132 b, located about 41 light-years from Earth, has tantalizing parallels to Earth, but in some ways, it is very different. Both have similar densities, similar sizes, and similar ages, being about 4.5 billion years old. Both started with a hydrogen-dominated atmosphere, and both were hot before they cooled down. The team's work even suggests that GJ 1132 b and Earth have similar atmospheric pressure at the surface.

But the planets have profoundly different formation histories. Earth is not believed to be the surviving core of a sub-Neptune. And Earth orbits at a comfortable distance from our Sun. GJ 1132 b is so close to its red dwarf star that it completes an orbit around its host star once every day and a half. This extremely close proximity keeps GJ 1132 b tidally locked, showing the same face to its star at all times -- just as our Moon keeps one hemisphere permanently facing Earth.

"The question is, what is keeping the mantle hot enough to remain liquid and power volcanism?" asked Swain. "This system is special because it has the opportunity for quite a lot of tidal heating."

Tidal heating is a phenomenon that occurs through friction, when energy from a planet's orbit and rotation is dispersed as heat inside the planet. GJ 1132 b is in an elliptical orbit, and the tidal forces acting on it are strongest when it is closest to or farthest from its host star. At least one other planet in the host star's system also gravitationally pulls on the planet. The consequences are that the planet is squeezed or stretched through this gravitational "pumping." That tidal heating keeps the mantle liquid for a long time. A nearby example in our own solar system is

Jupiter's moon Io, which has continuous volcanic activity due to a tidal tug-of-war from Jupiter and the neighbouring Jovian moons. Given GJ 1132 b's hot interior, the team believes the planet's cooler, overlying crust is extremely thin, perhaps only hundreds of feet thick. That's much too feeble to support anything resembling volcanic mountains. Its flat terrain may also be cracked like an eggshell due to tidal flexing. Hydrogen and other gases could be released through such cracks.

NASA's upcoming James Webb Space Telescope has the ability to observe this exoplanet. Webb's infrared vision may allow scientists to see down to the planet's surface. "If there are magma pools or volcanism going on, those areas will be hotter," explained Swain. "That will generate more emission, and so they'll be looking potentially at the actual geologic activity -- which is exciting!"

Video:
https://www.youtube.com/watch?v=9VuNmjXfmXE&t=1s

- ❖ Scientists uncover warehouse-full of complex molecules never before seen in space

Radio observations of a cold, dense cloud of molecular gas reveal more than a dozen unexpected molecules

Date: March 18, 2021
Source: Harvard-Smithsonian Centre for Astrophysics

Scientists have discovered a vast, previously unknown reservoir of new aromatic material in a cold, dark molecular cloud by detecting individual polycyclic aromatic hydrocarbon molecules in the interstellar medium for the first time, and in doing so are beginning to answer a three-decades-old scientific mystery: how and where are these molecules formed in space?

"We had always thought polycyclic aromatic hydrocarbons were primarily formed in the atmospheres of dying stars," said Brett McGuire, Assistant Professor of Chemistry at the Massachusetts Institute of Technology, and the Project Principal Investigator for GOTHAM, or Green Bank Telescope (GBT) Observations of TMC-1: Hunting Aromatic Molecules. "In this study, we found them in cold, dark clouds where stars haven't even started forming yet."

Aromatic molecules, and PAHs -- shorthand for polycyclic aromatic hydrocarbons -- are well known to scientists. Aromatic molecules exist in the chemical makeup of human beings and other animals, and are found in food and medicines. As well, PAHs are pollutants formed from the burning of many fossil fuels and are even amongst the carcinogens formed when vegetables and meat are charred at high temperatures. "Polycyclic aromatic hydrocarbons are thought to contain as much as 25-percent of the carbon in the universe," said McGuire, who is also a research associate at the Centre for Astrophysics | Harvard & Smithsonian (CfA). "Now, for the first time, we have a direct window into their chemistry that will let us study in detail how this massive reservoir of carbon reacts and evolves through the process of forming stars and planets."

Scientists have suspected the presence of PAHs in space since the 1980s but the new research, detailed in nine papers published over the past seven months, provides the first definitive proof of their existence in molecular clouds. To search out the elusive molecules, the team focused the 100m behemoth radio astronomy GBT on the Taurus Molecular Cloud, or TMC-1 -- a large, pre-stellar cloud of dust and gas located roughly 450 light-years from Earth that will someday collapse in on itself to form stars -- and what they found was astonishing: not only were the accepted scientific models incorrect, but there was a lot more going on in TMC-1 than the team could have imagined.

"From decades of previous modelling, we believed that we had a fairly good understanding of the chemistry of molecular clouds," said Michael McCarthy, an astrochemist and Acting Deputy Director of CfA, whose research group made the precise laboratory measurements that enabled many of these astronomical detections to be established with confidence. "What these new astronomical observations show is these molecules are not only present in molecular clouds, but at quantities which are orders of magnitude higher than standard models predict."

McGuire added that previous studies revealed only that there were PAH molecules out there, but not which specific ones. "For the last 30 years or so, scientists have been observing the bulk signature of these molecules in our galaxy and other galaxies in the infrared, but we couldn't see which individual molecules made up that mass. With the addition of radio astronomy, instead of seeing this large mass that we can't distinguish, we're seeing individual molecules."

Much to their surprise, the team didn't discover just one new molecule hiding out in TMC-1. Detailed in multiple papers, the team observed 1-cyanonaphthalene, 1-cyano-cyclopentadiene, HC11N, 2-cyanonaphthalene, vinylcyanoacetylene, 2-cyano-cyclopentadiene, benzonitrile, trans-(E)-cyanovinylacetylene, HC4NC, and propargylcyanide, among others. "It's like going into a boutique shop and just browsing the inventory on the front-end without ever knowing there was a back room. We've been collecting little molecules for 50 years or so and now we have discovered there's a back door. When we opened that door and looked in, we found this giant warehouse of molecules and chemistry that we did not expect," said McGuire. "There it was, all the time, lurking just beyond where we had looked before."

McGuire and other scientists at the GOTHAM project have been "hunting" for molecules in TMC-1 for more than two years, following McGuire's initial detection of benzonitrile in 2018. The results of the project's latest observations may have ramifications in astrophysics for years to come. "We've stumbled onto a whole new set of molecules unlike anything we've previously been able to detect, and that is going to completely change our understanding of how these molecules interact with each other. It has downstream ramifications," said McGuire, adding that eventually these molecules grow large enough that they begin to aggregate into the seeds of interstellar dust. "When these molecules get big enough that they're the seeds of interstellar dust, these have the possibility then to affect the composition of asteroids, comets, and planets, the surfaces on which ices form, and perhaps in turn even the locations where planets form within star systems."

The discovery of new molecules in TMC-1 also has implications for astrochemistry, and while the team doesn't yet have all of the answers, the ramifications here, too, will last for decades. "We've gone from one-dimensional carbon chemistry, which is very easy to detect, to real organic chemistry in space in the sense that the newly discovered molecules are ones that a chemist knows and recognizes, and can produce on Earth," said McCarthy. "And this is just the tip of the iceberg. Whether these organic molecules were synthesized there or transported there, they exist, and that knowledge alone is a fundamental advance in the field."

Before the launch of GOTHAM in 2018, scientists had catalogued roughly 200 individual molecules in the Milky Way's interstellar medium. These new discoveries have prompted the team to wonder, and rightly so, what's out there. "The amazing thing about these observations, about this discovery, and about these molecules, is that no one had looked, or looked hard enough," said McCarthy. "It makes you wonder what else is out there that we just haven't looked for."

This new aromatic chemistry that scientists are finding isn't isolated to TMC-1. A companion survey to GOTHAM, known as ARKHAM -- A Rigorous K/Ka-Band Survey Hunting for Aromatic Molecules -- recently found benzonitrile in multiple additional objects. "Incredibly, we found benzonitrile in every single one of the first four objects observed by ARKHAM," said Andrew Burkhardt, a Submillimetre Array Postdoctoral Fellow at the CfA and a co-principal investigator for GOTHAM. "This is important because while GOTHAM is pushing the limit of what chemistry we thought is possible in space, these discoveries imply that the things we learn in TMC-1 about aromatic molecules could be applied broadly to dark clouds anywhere. These dark clouds are the initial birthplaces of stars and planets. So, these previously invisible aromatic molecules will also need to be thought about at each later step along the way to the creation of stars, planets, and solar systems like our own."