South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 548 – January 2021 Editor: Roger Burgess
THE January MEETING IS CANCELLED DUE TO COVID-19

The Trustees understand that all the members of the South Downs Astronomical Society are well aware that the Covid 19 restriction problems have meant that our monthly meetings have had to be cancelled throughout this year. We now have to cancel the December AGM in January and all monthly meetings probably until the spring.
The members of the committee will remain the same during that period except for our Secretary, Anthony Van Bick who has recently resigned.
The good news for the members is that we will not have to pay any subscriptions until the Covid problems are dealt with and we are back to normal.

John Green

We have a virtual meeting 8th January at 19:30 Andrew Mowbray "The Astronomers' Guide to Strange Things in the Sky". Email me for joining instructions if you have not already received them

- Astronomers detect possible radio emission from exoplanet

Date: December 16, 2020
Source: Cornell University

Illustration of a 'hot Jupiter' exoplanet orbiting nearby star (stock image).
Credit: © dottedyeti / stock.adobe.com

By monitoring the cosmos with a radio telescope array, an international team of scientists has detected radio bursts emanating from the constellation Boötes -- that could be the first radio emission collected from a planet beyond our solar system.
The team, led by Cornell postdoctoral researcher Jake D. Turner, Philippe Zarka of the Observatoire de Paris -- Paris Sciences et Lettres University and Jean-Mathias Griessmeier of the Université d'Orléans will publish their findings in the forthcoming research section of *Astronomy & Astrophysics*, on Dec. 16.
"We present one of the first hints of detecting an exoplanet in the radio realm," Turner said. "The signal is from the Tau Boötes system, which contains a binary star and an exoplanet. We make the case for an emission by the planet itself. From the strength and polarization of the radio signal and the planet's magnetic field, it is compatible with theoretical predictions."
Among the co-authors is Turner's postdoctoral advisor Ray Jayawardhana, the Harold Tanner Dean of the College of Arts and Sciences, and a professor of astronomy.
"If confirmed through follow-up observations," Jayawardhana said, "this radio detection opens up a new window on exoplanets, giving us a novel way to examine alien worlds that are tens of light-years away."
Using the Low Frequency Array (LOFAR), a radio telescope in the Netherlands, Turner and his colleagues uncovered emission bursts from a star-system hosting a so-called hot Jupiter, a gaseous giant planet that is very close to its own sun. The group also observed other potential exoplanetary radio-emission candidates in the 55 Cancri (in the constellation Cancer) and Upsilon Andromeda systems. Only the Tau Boötes exoplanet system -- about 51 light-years away -- exhibited a significant radio signature, a unique potential window on the planet's magnetic field.
Observing an exoplanet's magnetic field helps astronomers decipher a planet's interior and atmospheric properties, as well as the physics

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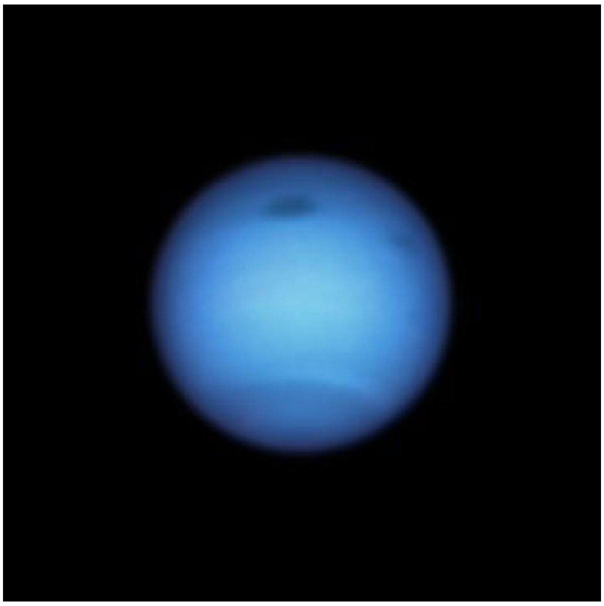
of star-planet interactions, said Turner, a member of Cornell's Carl Sagan Institute.
Earth's magnetic field protects it from solar wind dangers, keeping the planet habitable.
"The magnetic field of Earth-like exoplanets may contribute to their possible habitability," Turner said, "by shielding their own atmospheres from solar wind and cosmic rays, and protecting the planet from atmospheric loss."
Two years ago, Turner and his colleagues examined the radio emission signature of Jupiter and scaled those emissions to mimic the possible signatures from a distant Jupiter-like exoplanet. Those results became the template for searching radio emission from exoplanets 40 to 100 light-years away.
After poring over nearly 100-hours of radio observations, the researchers were able to find the expected hot Jupiter signature in Tau Boötes. "We learned from our own Jupiter what this kind of detection looks like. We went searching for it and we found it," Turner said.
The signature, though, is weak. "There remains some uncertainty that the detected radio signal is from the planet. The need for follow-up observations is critical," he said.
Turner and his team have already begun a campaign using multiple radio telescopes to follow up on the signal from Tau Boötes.
In addition to Turner, Jayawardhana, Griessmeier and Zarka, the co-authors are Laurent Lamy and Baptiste Cecconi of the Observatoire de Paris, France; Joseph Lazio from NASA's Jet Propulsion Laboratory; J. Emilio Enriquez and Imke de Pater from the University of California, Berkeley; Julien N. Girard from Rhodes University, Grahamstown, South Africa; and Jonathan D. Nichols from the University of Leicester, United Kingdom.
Turner, who laid the groundwork for this research while earning his doctorate at the University of Virginia, received funding from the National Science Foundation.

- ❖ Dark storm on Neptune reverses direction, possibly shedding a fragment

Date: December 16, 2020
Source: NASA/Goddard Space Flight Centre



This Hubble Space Telescope snapshot of the dynamic blue-green planet Neptune reveals a monstrous dark storm (top centre) and the emergence of a smaller dark spot nearby (top right). The giant vortex, which is wider than the Atlantic Ocean, was traveling south toward certain doom by atmospheric forces at the equator when it suddenly made a U-turn and began drifting back northward.
Credit: NASA, ESA, STScI, M.H. Wong (University of California, Berkeley), and L.A. Sromovsky and P.M. Fry (University of Wisconsin-Madison)

Astronomers using NASA's Hubble Space Telescope watched a mysterious dark vortex on Neptune abruptly steer away from a likely death on the giant blue planet.
The storm, which is wider than the Atlantic Ocean, was born in the planet's northern hemisphere and discovered by Hubble in 2018. Observations a year later showed that it began drifting southward toward the equator, where such storms are expected to vanish from sight. To the surprise of observers, Hubble spotted the vortex change direction by August 2020, doubling back to the north. Though Hubble has tracked similar dark spots over the past 30 years, this unpredictable atmospheric behaviour is something new to see.
Equally as puzzling, the storm was not alone. Hubble spotted another smaller dark spot in January this year that temporarily appeared near its larger cousin. It might possibly have been a piece of the giant vortex that broke off, drifted away, and then disappeared in subsequent observations.
"We are excited about these observations because this smaller dark fragment is potentially part of the dark spot's disruption

process," said Michael H. Wong of the University of California at Berkeley. "This is a process that's never been observed. We have seen some other dark spots fading away and they're gone, but we've never seen anything disrupt, even though it's predicted in computer simulations."

The large storm, which is 4,600 miles across, is the fourth dark spot Hubble has observed on Neptune since 1993. Two other dark storms were discovered by the Voyager 2 spacecraft in 1989 as it flew by the distant planet, but they had disappeared before Hubble could observe them. Since then, only Hubble has had the sharpness and sensitivity in visible light to track these elusive features, which have sequentially appeared and then faded away over a duration of about two years each. Hubble uncovered this latest storm in September 2018.

Wicked Weather

Neptune's dark vortices are high-pressure systems that can form at mid-latitudes and may then migrate toward the equator. They start out remaining stable due to Coriolis forces, which cause northern hemisphere storms to rotate clockwise, due to the planet's rotation. (These storms are unlike hurricanes on Earth, which rotate counter clockwise because they are low-pressure systems.) However, as a storm drifts toward the equator, the Coriolis effect weakens and the storm disintegrates. In computer simulations by several different teams, these storms follow a more-or-less straight path to the equator, until there is no Coriolis effect to hold them together. Unlike the simulations, the latest giant storm didn't migrate into the equatorial "kill zone."

"It was really exciting to see this one act like it's supposed to act and then all of a sudden it just stops and swings back," Wong said. "That was surprising."

Dark Spot Jr.

The Hubble observations also revealed that the dark vortex's puzzling path reversal occurred at the same time that a new spot, informally deemed "dark spot jr.," appeared. The newest spot was slightly smaller than its cousin, measuring about 3,900 miles across. It was near the side of the main dark spot that faces the equator -- the location that some simulations show a disruption would occur. However, the timing of the smaller spot's emergence was unusual. "When I first saw the small spot, I thought the bigger one was being disrupted," Wong said. "I didn't think another vortex was forming because the small one is farther towards the equator. So it's within this unstable region. But we can't prove the two are related. It remains a complete mystery.

"It was also in January that the dark vortex stopped its motion and started moving northward again," Wong added. "Maybe by shedding that fragment, that was enough to stop it from moving towards the equator."

The researchers are continuing to analyse more data to determine whether remnants of dark spot jr. persisted through the rest of 2020.

Dark Storms Still Puzzling

It's still a mystery how these storms form, but this latest giant dark vortex is the best studied so far. The storm's dark appearance may be due to an elevated dark cloud layer and it could be telling astronomers about the storm's vertical structure.

Another unusual feature of the dark spot is the absence of bright companion clouds around it, which were present in Hubble images taken when the vortex was discovered in 2018. Apparently, the clouds disappeared when the vortex halted its southward journey. The bright clouds form when the flow of air is perturbed and diverted upward over the vortex, causing gases to likely freeze into methane ice crystals. The lack of clouds could be revealing information on how spots evolve, say researchers.

Weather Eye on the Outer Planets

Hubble snapped many of the images of the dark spots as part of the Outer Planet Atmospheres Legacy (OPAL) program, a long-term Hubble project, led by Amy Simon of NASA's Goddard Space Flight Centre in Greenbelt, Maryland, that annually captures global maps of our solar system's outer planets when they are closest to Earth in their orbits.

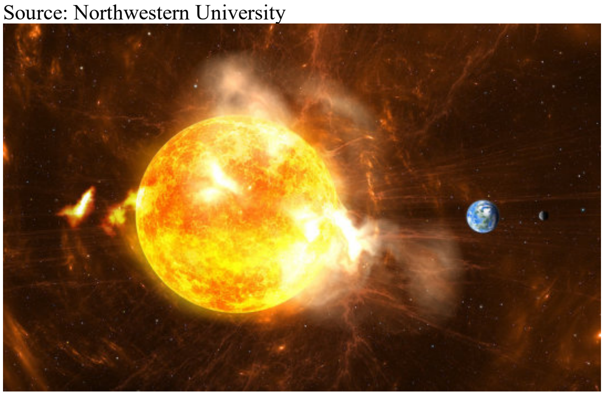
OPAL's key goals are to study long-term seasonal changes, as well as capture comparatively transitory events, such as the appearance of dark spots on Neptune or potentially Uranus. These dark storms may be so fleeting that in the past some of them may have appeared and faded during multi-year gaps in Hubble's observations of Neptune. The OPAL program ensures that astronomers won't miss another one.

"We wouldn't know anything about these latest dark spots if it wasn't for Hubble," Simon said. "We can now follow the large

storm for years and watch its complete life cycle. If we didn't have Hubble, then we might think the Great Dark Spot seen by Voyager in 1989 is still there on Neptune, just like Jupiter's Great Red Spot. And, we wouldn't have known about the four other spots Hubble discovered." Wong will present the team's findings Dec. 15 at the fall meeting of the American Geophysical Union.
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.

- The upside of volatile space weather

Robust stellar flares might not prevent life on exoplanets, could facilitate its detection
Date: December 21, 2020
Source: Northwestern University



Giant solar flare illustration (stock image).
Credit: © Peter Jurik / stock.adobe.com

Although violent and unpredictable, stellar flares emitted by a planet's host star do not necessarily prevent life from forming, according to a new Northwestern University study.
Emitted by stars, stellar flares are sudden flashes of magnetic imagery. On Earth, the sun's flares sometimes damage satellites and disrupt radio communications. Elsewhere in the universe, robust stellar flares also have the ability to deplete and destroy atmospheric gases, such as ozone. Without the ozone, harmful levels of ultraviolet (UV) radiation can penetrate a planet's atmosphere, thereby diminishing its chances of harbouring surface life.
By combining 3D atmospheric chemistry and climate modelling with observed flare data from distant stars, a Northwestern-led team discovered that stellar flares could play an important role in the long-term evolution of a planet's atmosphere and habitability.
"We compared the atmospheric chemistry of planets experiencing frequent flares with planets experiencing no flares. The long-term atmospheric chemistry is very different," said Northwestern's Howard Chen, the study's first author. "Continuous flares actually drive a planet's atmospheric composition into a new chemical equilibrium."
"We've found that stellar flares might not preclude the existence of life," added Daniel Horton, the study's senior author. "In some cases, flaring doesn't erode all of the atmospheric ozone. Surface life might still have a fighting chance."
The study will be published on Dec. 21 in the journal *Nature Astronomy*. It is a joint effort among researchers at Northwestern, University of Colorado at Boulder, University of Chicago, Massachusetts Institute of Technology and NASA Nexus for Exoplanet System Science (NExSS).
Horton is an assistant professor of Earth and planetary sciences in Northwestern's Weinberg College of Arts and Sciences. Chen is a Ph.D. candidate in Horton's Climate Change Research Group and a NASA future investigator.

Importance of flares

All stars -- including our very own sun -- flare, or randomly release stored energy. Fortunately for Earthlings, the sun's flares typically have a minimal impact on the planet. "Our sun is more of a gentle giant," said Allison Youngblood, an astronomer at the University of Colorado and co-author of the study. "It's older and not as active as younger and smaller stars. Earth also has a strong magnetic field, which deflects the sun's damaging winds."
Unfortunately, most potentially habitable exoplanets aren't as lucky. For planets to potentially harbour life, they must be close enough to a star that their water won't freeze -- but not so close that water vaporizes.
"We studied planets orbiting within the habitable zones of M and K dwarf stars -- the most common stars in the universe," Horton said. "Habitable zones around these stars are narrower because the stars are smaller and less powerful than stars like our sun. On the flip side, M and K dwarf stars are thought to have more frequent flaring activity than our sun, and their tidally locked planets are

unlikely to have magnetic fields helping deflect their stellar winds."

Chen and Horton previously conducted a study of M dwarf stellar systems' long-term climate averages. Flares, however, occur on an hours- or days-long timescales. Although these brief timescales can be difficult to simulate, incorporating the effects of flares is important to forming a more complete picture of exoplanet atmospheres. The researchers accomplished this by incorporating flare data from NASA's Transiting Exoplanet Satellite Survey, launched in 2018, into their model simulations.

Using flares to detect life

If there is life on these M and K dwarf exoplanets, previous work hypothesizes that stellar flares might make it easier to detect. For example, stellar flares can increase the abundance of life-indicating gasses (such as nitrogen dioxide, nitrous oxide and nitric acid) from imperceptible to detectable levels.

"Space weather events are typically viewed as a detriment to habitability," Chen said. "But our study quantitatively shows that some space weather can actually help us detect signatures of important gases that might signify biological processes."

This study involved researchers from a wide range of backgrounds and expertise, including climate scientists, exoplanet scientists, astronomers, theorists and observers.

"This project was a result of fantastic collective team effort," said Eric T. Wolf, a planetary scientist at CU Boulder and a co-author of the study. "Our work highlights the benefits of interdisciplinary efforts when investigating conditions on extrasolar planets."

The study was supported by the NASA Earth and Space Science and Technology Graduate Research Award (number 80NSSC19K1523).

- Key clues to understanding the death of stars

Date: December 22, 2020
Source: Northwestern University

Any Neapolitan ice cream lover knows three flavours are better than one. New research from Northwestern University has found that by studying all three "flavours" involved in a supernova, they've unlocked more clues as to how and why stars die.

Scientists look at neutrinos (subatomic particles) for critical information about supernova explosions. While previous research identified three "flavours" of neutrinos, many researchers continued to simplify studies on the topic by studying "vanilla" while ignoring "chocolate" and "strawberry."

By including all three flavours in the study, Northwestern researchers have developed a deeper knowledge of dying stars and begun to unravel existing hypotheses.

The study was published Wednesday, Dec. 16, in the journal *Physical Review Letters*.

In a supernova explosion, 99% of the dead star's energy is emitted through neutrinos. Traveling almost at the speed of light and interacting extremely weakly with matter, neutrinos are the first messengers to reach the earth and indicate a star has died.

Since their initial discovery in the 1950s, particle physicists and astrophysicists have made important strides in understanding, detecting and creating neutrinos. But to limit the complexity of models, many people studying subatomic particles make assumptions to simplify the research -- for example, that non-electron neutrinos behave identically when they are propelled from a supernova.

Part of what makes studying neutrinos so complicated is they come from compact objects (the inside of a star) and then interact with one another, said senior author Manibrata Sen, a postdoctoral researcher currently based at Northwestern under the Network for Neutrinos, Nuclear Astrophysics and Symmetries program at University of California -- Berkeley. That means when one flavour is impacted, much like a melting tub of Neapolitan ice cream, its evolution is affected by all others in the system.

"You can't create conditions to have neutrinos interacting with each other on Earth," Sen said. "But in compact objects, you have a very high density of neutrinos. So now each neutrino is interacting with each other because there are so many around."

As a result, when an enormous number of neutrinos are sent careening during the massive explosion of a core-collapse supernova, they begin to oscillate. Interactions between neutrinos change the properties and behaviours of the whole system, creating a coupled relationship.

Therefore, when neutrino density is high, a fraction of neutrinos interchange flavours. When different flavours are emitted in different directions deep within a star, conversions occur rapidly and are called "fast

conversions." Interestingly, the research found that as the number of neutrinos grows, so do their conversion rates, regardless of mass.
In the study, the scientist created a non-linear simulation of a "fast conversion" when three neutrino flavours are present, where a fast conversion is marked by neutrinos interacting and changing flavours. The researchers removed the assumption that the three flavours of neutrinos -- muon, electron and tau neutrinos -- have the same angular distribution, giving them each a different distribution.
A two-flavour setup of the same concept looks at electron neutrinos and "x" neutrinos, in which x can be either muon or tau neutrinos and where differences between the two are insignificant.
"We've shown that they actually are all relevant, and ignoring the presence of muons is not a good strategy," Sen said. "By including them we show past results are incomplete, and results change drastically when you perform a three-flavour study."
While the research could have major implications in both particle and astrophysics, even models used in this research included simplifications. The team hopes to make their results more generic by including spatial dimensions in addition to components of momentum and time.
In the meantime, Sen said he hopes his team's research will help the community embrace more complexity in their studies.
"We are trying to convince the community that when you take these fast conversions into account, you have to use all three flavours to understand it," he said. "A proper understanding of fast oscillations can actually hold the key to why some stars explode from supernovas."

- ❖ Multi-messenger astronomy offers new estimates of neutron star size and universe expansion

Date: December 21, 2020
Source: DOE/Los Alamos National Laboratory

A combination of astrophysical measurements has allowed researchers to put new constraints on the radius of a typical neutron star and provide a novel calculation of the Hubble constant that indicates the rate at which the universe is expanding.
"We studied signals that came from various sources, for example recently observed mergers of neutron stars," said Ingo Tews, a theorist in Nuclear and Particle Physics, Astrophysics and Cosmology group at Los Alamos National Laboratory, who worked with an international collaboration of researchers on the analysis to appear in the journal *Science* on December 18. "We jointly analysed gravitational-wave signals and electromagnetic emissions from the mergers, and combined them with previous mass measurements of pulsars or recent results from NASA's Neutron Star Interior Composition Explorer. We find that the radius of a typical neutron star is about 11.75 kilometres and the Hubble constant is approximately 66.2 kilometres per second per megaparsec."
Combining signals to gain insight into distant astrophysical phenomena is known in the field as multi-messenger astronomy. In this case, the researchers' multi-messenger analysis allowed them to restrict the uncertainty of their estimate of neutron star radii to within 800 meters.
Their novel approach to measuring the Hubble constant contributes to a debate that has arisen from other, competing determinations of the universe's expansion. Measurements based on observations of exploding stars known as supernovae are currently at odds with those that come from looking at the Cosmic Microwave Background (CMB), which is essentially the left-over energy from the Big Bang. The uncertainties in the new multimessenger Hubble calculation are too large to definitively resolve the disagreement, but the measurement is slightly more supportive of the CMB approach.
Tews' primary scientific role in the study was to provide the input from nuclear theory calculations that are the starting point of the analysis. His seven collaborators on the paper comprise an international team of scientists from Germany, the Netherlands, Sweden, France, and the United States.

- ❖ A blazar in the early universe

Details revealed in galaxy's jet 12.8 billion light-years from Earth
Date: December 22, 2020
Source: National Radio Astronomy Observatory

The super sharp radio "vision" of the National Science Foundation's Very Long Baseline Array (VLBA) has revealed previously unseen details in a jet of material ejected at three-quarters the speed of light from the core of a galaxy some 12.8 billion light-years from Earth. The galaxy, dubbed PSO J0309+27, is a blazar, with its jet pointed toward Earth, and is the brightest radio-emitting blazar yet seen at such a distance. It also is the second-brightest X-ray emitting blazar at such a distance.

In this image, the brightest radio emission comes from the galaxy's core, at bottom right. The jet is propelled by the gravitational energy of a supermassive black hole at the core, and moves outward, toward the upper left. The jet seen here extends some 1,600 light-years, and shows structure within it.

At this distance, PSO J0309+27 is seen as it was when the universe was less than a billion years old, or just over 7 percent of its current age.

An international team of astronomers led by Cristiana Spingola of the University of Bologna in Italy, observed the galaxy in April and May of 2020. Their analysis of the object's properties provides support for some theoretical models for why blazars are rare in the early universe. The researchers reported their results in the journal *Astronomy & Astrophysics*.

- ❖ Powerful electrical events quickly alter surface chemistry on Mars, other planetary bodies

Date: December 15, 2020
Source: Washington University in St. Louis

Thinking like Earthlings may have caused scientists to overlook the electrochemical effects of Martian dust storms.

On Earth, dust particles are viewed mainly in terms of their physical effects, like erosion. But, in exotic locales from Mars to Venus to Jupiter's icy moon Europa, electrical effects can affect the chemical composition of a planetary body's surface and atmosphere in a relatively short time, according to new research from Washington University in St. Louis.

"This direction of scientific investigation has been largely overlooked in the past," said Alian Wang, research professor in the Department of Earth and Planetary Sciences in Arts & Sciences. "Researchers are used to thinking 'inside the box' based on terrestrial experience."

Wang's study in the *Journal of Geophysical Research: Planets* focuses on amorphous sulphur and chlorine salts found by the Curiosity rover at Gale crater on Mars. The chemical signature of these materials could have been induced by electrochemical processes during Martian dust activities in a relatively short geologic time frame: years to hundreds of years.

Low-strength electrostatic discharge causes electrochemical reactions that transform materials on the Martian surface, Wang explained, causing loss of crystallinity, removal of structural water and oxidation of certain elements like sulphur, chlorine and iron.

"The collective chemical effect of electrostatic discharge can be significant," Wang said. "This is the core idea of our new study."

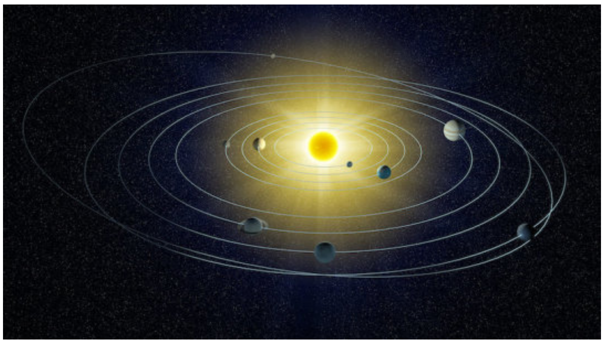
The findings could inform science priorities for the next phase of Mars exploration missions, including NASA's Perseverance rover, China National Space Administration's Tianwen-1 lander and rover, and the European Space Agency's ExoMars lander and rover.

"'Explore the subsurface' is the suggestion that we would give to the next phase of Mars exploration missions," said Bradley Jolliff, the Scott Rudolph Professor of Earth and Planetary Sciences and a co-author on the paper.

"These missions are all seeking evidence for geological and hydrological evolution at their selected landing sites, and they are especially looking for and hoping to collect samples that contain traces of past biological activity," Jolliff said. "Exploring the subsurface would enable sampling of ancient materials -- some of which might still be safekeeping precious biomarkers."

- ❖ New superhighway system discovered in the Solar System

Date: December 9, 2020
Source: University of California - San Diego



Stylized illustration of Solar System (stock image).
Credit: © Mopic / stock.adobe.com

Researchers have discovered a new superhighway network to travel through the Solar System much faster than was previously possible. Such routes can drive comets and asteroids near Jupiter to Neptune's distance in under a decade and to 100 astronomical units in less than a century. They could be used to

send spacecraft to the far reaches of our planetary system relatively fast, and to monitor and understand near-Earth objects that might collide with our planet.
In their paper, published in the Nov. 25 issue of *Science Advances*, the researchers observed the dynamical structure of these routes, forming a connected series of arches inside what's known as space manifolds that extend from the asteroid belt to Uranus and beyond. This newly discovered "celestial autobahn" or "celestial highway" acts over several decades, as opposed to the hundreds of thousands or millions of years that usually characterize Solar System dynamics.
The most conspicuous arch structures are linked to Jupiter and the strong gravitational forces it exerts. The population of Jupiter-family comets (comets having orbital periods of 20 years) as well as small-size solar system bodies known as Centaurs, are controlled by such manifolds on unprecedented time scales. Some of these bodies will end up colliding with Jupiter or being ejected from the Solar System.
The structures were resolved by gathering numerical data about millions of orbits in our Solar System and computing how these orbits fit within already-known space manifolds. The results need to be studied further, both to determine how they could be used by spacecraft, or how such manifolds behave in the vicinity of the Earth, controlling the asteroid and meteorite encounters, as well as the growing population of artificial human-made objects in the Earth-Moon system.

- How nearby galaxies form their stars

Date: December 21, 2020
Source: University of Zurich

Stars are born in dense clouds of molecular hydrogen gas that permeates interstellar space of most galaxies. While the physics of star formation is complex, recent years have seen substantial progress towards understanding how stars form in a galactic environment. What ultimately determines the level of star formation in galaxies, however, remains an open question.
In principle, two main factors influence the star formation activity: The amount of molecular gas that is present in galaxies and the timescale over which the gas reservoir is depleted by converting it into stars. While the gas mass of galaxies is regulated by a competition between gas inflows, outflows and consumption, the physics of the gas-to-star conversion is currently not well understood. Given its potentially critical role, many efforts have been undertaken to determine the gas depletion timescale observationally. However, these efforts resulted in conflicting findings partly because of the challenge in measuring gas masses reliably given current detection limits.

Typical star formation is linked to the overall gas reservoir

The present study from the Institute for Computational Science of the University of Zurich uses a new statistical method based on Bayesian modelling to properly account for galaxies with undetected amounts of molecular or atomic hydrogen to minimize observational bias. This new analysis reveals that, in typical star-forming galaxies, molecular and atomic hydrogen are converted into stars over approximately constant timescales of 1 and 10 billion years, respectively. However, extremely active galaxies ("starbursts") are found to have much shorter gas depletion timescales. "These findings suggest that star formation is indeed directly linked to the overall gas reservoir and thus set by the rate at which gas enters or leaves a galaxy," says Robert Feldmann, professor at the Centre for Theoretical Astrophysics and Cosmology. In contrast, the dramatically higher star-formation activity of starbursts likely has a different physical origin, such as galaxy interactions or instabilities in galactic disks.
This analysis is based on observational data of nearby galaxies. Observations with the Atacama Large Millimetre/Submillimetre Array, the Square Kilometre Array and other observatories promise to probe the gas content of large numbers of galaxies across cosmic history. It will be paramount to continue the development of statistical and data-science methods to accurately extract the physical content from these new observations and to fully uncover the mysteries of star formation in galaxies.

- Longest intergalactic gas filament discovered

Study confirms models on the evolution of our universe
Date: December 17, 2020
Source: University of Bonn

More than half of the matter in our universe has so far remained hidden from us. However, astrophysicists had a hunch where it might be: In so-called filaments, unfathomably large thread-like structures of hot gas that surround and connect galaxies and galaxy clusters. A team led by the University of Bonn (Germany) has now for the first time observed a gas filament with a length of 50 million light years. Its structure is strikingly similar to the predictions of computer simulations. The observation therefore also confirms our ideas about the origin and evolution of our universe. The results are published in the journal *Astronomy & Astrophysics*.

We owe our existence to a tiny aberration. Pretty much exactly 13.8 billion years ago, the Big Bang occurred. It is the beginning of space and time, but also of all matter that makes up our universe today. Although it was initially concentrated at one point, it expanded at breakneck speed -- a gigantic gas cloud in which matter was almost uniformly distributed.

Almost, but not completely: In some parts the cloud was a bit denser than in others. And for this reason alone there are planets, stars and galaxies today. This is because the denser areas exerted slightly higher gravitational forces, which drew the gas from their surroundings towards them. More and more matter therefore concentrated at these regions over time. The space between them, however, became emptier and emptier. Over the course of a good 13 billion years, a kind of sponge structure developed: large "holes" without any matter, with areas in between where thousands of galaxies are gathered in a small space, so-called galaxy clusters.

Fine web of gas threads

If it really happened that way, the galaxies and clusters should still be connected by remnants of this gas, like the gossamer-thin threads of a spider web. "According to calculations, more than half of all baryonic matter in our universe is contained in these filaments -- this is the form of matter of which stars and planets are composed, as are we ourselves," explains Prof. Dr. Thomas Reiprich from the Argelander Institute for Astronomy at the University of Bonn. Yet it has so far escaped our gaze: Due to the enormous expansion of the filaments, the matter in them is extremely diluted: It contains just ten particles per cubic meter, which is much less than the best vacuum we can create on Earth.

However, with a new measuring instrument, the eROSITA space telescope, Reiprich and his colleagues were now able to make the gas fully visible for the first time. "eROSITA has very sensitive detectors for the type of X-ray radiation that emanates from the gas in filaments," explains Reiprich. "It also has a large field of view -- like a wide-angle lens, it captures a relatively large part of the sky in a single measurement, and at a very high resolution." This allows detailed images of such huge objects as filaments to be taken in a comparatively short time.

Confirmation of the standard model

In their study, the researchers examined a celestial object called Abell 3391/95. This is a system of three galaxy clusters, which is about 700 million light years away from us. The eROSITA images show not only the clusters and numerous individual galaxies, but also the gas filaments connecting these structures. The entire filament is 50 million light years long. But it may be even more enormous: The scientists assume that the images only show a section.

"We compared our observations with the results of a simulation that reconstructs the evolution of the universe," explains Reiprich. "The eROSITA images are strikingly similar to computer-generated graphics. This suggests that the widely accepted standard model for the evolution of the universe is correct." Most importantly, the data show that the missing matter is probably actually hidden in the filaments.

- ❖ Saturn moon, Enceladus, could support life in its subsurface ocean

Discovery provides more evidence that the

Date: December 16, 2020

Source: Southwest Research Institute

Using data from NASA's Cassini spacecraft, scientists at Southwest Research Institute (SwRI) modelled chemical processes in the subsurface ocean of Saturn's moon Enceladus. The studies indicate the possibility that a varied metabolic menu could support a potentially diverse microbial community in the liquid water ocean beneath the moon's icy facade.

Prior to its deorbit in September of 2017, Cassini sampled the plume of ice grains and water vapor erupting from cracks on the icy surface of Enceladus, discovering molecular hydrogen, a potential food source for microbes. A new paper published in the planetary science journal Icarus explores other potential energy sources.

"The detection of molecular hydrogen (H2) in the plume indicated that there is free energy available in the ocean of Enceladus," said lead author Christine Ray, who works part time at SwRI as she pursues a Ph.D. in physics from The University of Texas at San Antonio. "On Earth, aerobic, or oxygen-breathing, creatures consume energy in organic matter such as glucose and oxygen to create carbon dioxide and water. Anaerobic microbes can metabolize hydrogen to create methane. All life can be distilled to similar chemical reactions associated with a disequilibrium between oxidant and reductant compounds."

This disequilibrium creates a potential energy gradient, where redox chemistry transfers electrons between chemical species, most often with one species undergoing oxidation while another species undergoes reduction. These processes are vital to many basic functions of life, including photosynthesis and respiration. For example, hydrogen is a source of chemical energy supporting anaerobic microbes that live in the Earth's oceans near hydrothermal vents. At Earth's ocean floor, hydrothermal vents emit hot, energy-rich, mineral-laden fluids that allow unique ecosystems teeming with unusual creatures to thrive. Previous research found growing evidence of hydrothermal vents and chemical disequilibrium on Enceladus, which hints at habitable conditions in its subsurface ocean.

"We wondered if other types of metabolic pathways could also provide sources of energy in Enceladus' ocean," Ray said. "Because that would require a different set of oxidants that we have not yet detected in the plume of Enceladus, we performed chemical modelling to determine if the conditions in the ocean and the rocky core could support these chemical processes."

For example, the authors looked at how ionizing radiation from space could create the oxidants O2 and H2O2, and how abiotic geochemistry in the ocean and rocky core could contribute to chemical disequilibria that might support metabolic processes. The team considered whether these oxidants could accumulate over time if reductants are not present in appreciable amounts. They also considered how aqueous reductants or seafloor minerals could convert these oxidants into sulphates and iron oxides.

"We compared our free energy estimates to ecosystems on Earth and determined that, overall, our values for both aerobic and anaerobic metabolisms meet or exceed minimum requirements," Ray said. "These results indicate that oxidant production and oxidation chemistry could contribute to supporting possible life and a metabolically diverse microbial community on Enceladus."

"Now that we've identified potential food sources for microbes, the next question to ask is 'what is the nature of the complex organics that are coming out of the ocean?'" said SwRI Program Director Dr. Hunter Waite, a co-author of the new paper, referencing an online *Nature* paper authored by Postberg et al. in 2018. "This new paper is another step in understanding how a small moon can sustain life in ways that completely exceed our expectations!"

The paper's findings also have great significance for the next generation of exploration.

"A future spacecraft could fly through the plume of Enceladus to test this paper's predictions on the abundances of oxidized compounds in the ocean," said SwRI Senior Research Scientist Dr. Christopher Glein, another co-author. "We must be cautious, but I find it exhilarating to ponder whether there might be strange forms of life that take advantage of these sources of energy that appear to be fundamental to the workings of Enceladus."

- A pair of lonely planet-like objects born like stars

Date: December 16, 2020
Source: University of Bern

Star-forming processes sometimes create mysterious astronomical objects called brown dwarfs, which are smaller and colder than stars, and can have masses and temperatures down to those of exoplanets in the most extreme cases. Just like stars, brown dwarfs often wander alone through space, but can also be seen in binary systems, where two brown dwarfs orbit one another and travel together in the galaxy.

Researchers led by Clémence Fontanive from the Centre for Space and Habitability (CSH) and the NCCR PlanetS discovered a curious starless binary system of brown dwarfs. The system CFHTWIR-Oph 98 (or Oph 98 for short) consists of the two very low-mass objects Oph 98 A and Oph 98 B. It is located 450 light years away from Earth in the stellar association Ophiuchus. The researchers were surprised by the fact that Oph 98 A and B are orbiting each other from a strikingly large distance, about 5 times the distance between Pluto and the Sun, which corresponds to 200 times the distance between the Earth and the Sun. The study has just been published in *The Astrophysical Journal Letters*.

Extremely low masses and a very large separation

The pair is a rare example of two objects similar in many aspects to extra-solar giant planets, orbiting around each other with no parent star. The more massive component, Oph 98 A, is a young brown dwarf with a mass of 15 times that of Jupiter, which is almost exactly on the boundary separating brown dwarfs from planets. Its companion, Oph 98 B, is only 8 times heavier than Jupiter. Components of binary systems are tied by an invisible link called gravitational binding energy, and this bond gets stronger when objects are more massive or closer to one another. With extremely low masses and a very large separation, Oph 98 has the weakest binding energy of any binary system known to date.

Discovery thanks to data from Hubble

Clémence Fontanive and her colleagues discovered the companion to Oph 98 A using images from the Hubble Space Telescope. Fontanive says: "Low-mass brown dwarfs are very cold and emit very little light, only through infrared thermal radiation. This heat glow is extremely faint and red, and brown dwarfs are hence only visible in infrared light." Furthermore, the stellar association in which the binary is located, Ophiuchus, is embedded in a dense, dusty cloud which scatters visible light. "Infrared observations are the only way to see through this dust," explains the lead researcher. "Detecting a system like Oph 98 also requires a camera with a very high resolution, as the angle separating Oph 98 A and B is a thousand times smaller than the size of the moon in the sky," she adds. The Hubble Space Telescope is among the few telescopes capable of observing objects as faint as these brown dwarfs, and able to resolve such tight angles. Because brown dwarfs are cold enough, water vapor forms in their atmospheres, creating prominent features in the infrared that are commonly used to identify brown dwarfs. However, these water signatures cannot be easily detected from the surface of the Earth. Located above the atmosphere in the vacuum of space, Hubble allows to probe the existence of water vapor in astronomical objects. Fontanive explains: "Both objects looked very red and showed clear signs of water molecules. This immediately confirmed that the faint source we saw next to Oph 98 A was very likely to also be a cold brown dwarf, rather than a random star that happened to be aligned with the brown dwarf in the sky."

The team also found images in which the binary was visible, collected 14 years ago with the Canada-France-Hawaii Telescope (CFHT) in Hawaii. "We observed the system again this summer from another Hawaiian observatory, the United Kingdom Infra-Red Telescope. Using these data, we were able to confirm that Oph 98 A and B are moving together across the sky over time, relative to other stars located behind them, which is evidence that they are bound to each other in a binary pair," explains Fontanive.

An atypical result of star formation

The Oph 98 binary system formed only 3 million years ago in the nearby Ophiuchus stellar nursery, making it a new born on astronomical timescales. The age of the system is much shorter than the typical time needed to build planets. Brown dwarfs like Oph 98 A are formed by the same mechanisms as stars. Despite Oph 98 B being the right size for a planet, the host Oph 98 A is too small to have a sufficiently large reservoir of material to build a planet that big. "This tells us that Oph 98 B, like its host, must have formed through the same mechanisms that produce stars and shows that the processes that create binary stars operate on scale-down versions all the way down to these planetary masses," comments Clémence Fontanive.

With the discovery of two planet-like worlds -- already uncommon products of star formation -- bound to each other in such an extreme configuration, "we are really witnessing an incredibly rare output of stellar formation processes," as Fontanive describes.

Bernese space exploration: With the world's elite since the first moon landing

When the second man, "Buzz" Aldrin, stepped out of the lunar module on July 21, 1969, the first task he did was to set up the Bernese Solar Wind Composition experiment (SWC) also known as the "solar wind sail" by planting it in the ground of the moon, even before the American flag. This experiment, which was planned and the results analysed by Prof. Dr. Johannes Geiss and his team from the Physics Institute of the University of Bern, was the first great highlight in the history of Bernese space exploration.

Ever since Bernese space exploration has been among the world's elite. The numbers are impressive: 25 times were instruments flown into the upper atmosphere and ionosphere using rockets (1967-1993), 9 times into the stratosphere with balloon flights (1991-2008), over 30 instruments were flown on space probes, and with CHEOPS the University of Bern shares responsibility with ESA for a whole mission.

- The farthest galaxy in the universe

Chemical signatures give away the distance to the most distant galaxy
Date: December 15, 2020
Source: University of Tokyo

A team of astronomers used the Keck I telescope to measure the distance to an ancient galaxy. They deduced the target galaxy GN-z11 is not only the oldest galaxy but also the most distant. It's so distant it defines the very boundary of the observable universe itself. The team hopes this study can shed light on a period of cosmological history when the universe was only a few hundred million years old.

We've all asked ourselves the big questions at times: "How big is the universe?" or "How and when did galaxies form?" Astronomers take these questions very seriously, and use fantastic tools that push the boundaries of technology to try and answer them. Professor Nobunari Kashikawa from the Department of Astronomy at the University of Tokyo is driven by his curiosity about galaxies. In particular, he sought the most distant one we can observe in order to find out how and when it came to be.

"From previous studies, the galaxy GN-z11 seems to be the farthest detectable galaxy from us, at 13.4 billion light years, or 134 nonillion kilometres (that's 134 followed by 30 zeros)," said Kashikawa. "But measuring and verifying such a distance is not an easy task."

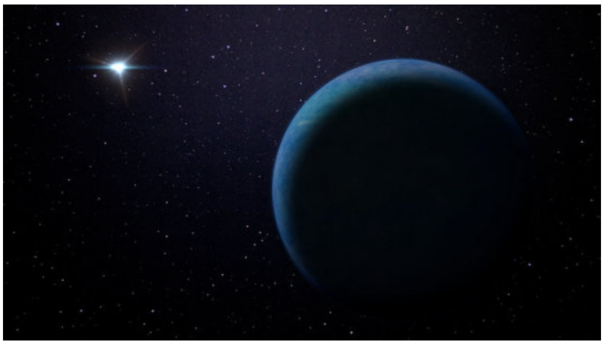
Kashikawa and his team measured what's known as the redshift of GN-z11; this refers to the way light stretches out, becomes redder, the farther it travels. Certain chemical signatures, called emission lines, imprint distinct patterns in the light from distant objects. By measuring how stretched these tell-tale signatures are, astronomers can deduce how far the light must have travelled, thus giving away the distance from the target galaxy.

"We looked at ultraviolet light specifically, as that is the area of the electromagnetic spectrum we expected to find the redshifted chemical signatures," said Kashikawa. "The Hubble Space Telescope detected the signature multiple times in the spectrum of GN-z11. However, even the Hubble cannot resolve ultraviolet emission lines to the degree we needed. So we turned to a more up-to-date ground-based spectrograph, an instrument to measure emission lines, called MOSFIRE, which is mounted to the Keck I telescope in Hawaii."

The MOSFIRE captured the emission lines from GN-z11 in detail, which allowed the team to make a much better estimation on its distance than was possible from previous data. When working with distances at these scales, it is not sensible to use our familiar units of kilometres or even multiples of them; instead, astronomers use a value known as the redshift number denoted by z. Kashikawa and his team improved the accuracy of the galaxy's z value by a factor of 100. If subsequent observations can confirm this, then the astronomers can confidently say GN-z11 is the farthest galaxy ever detected in the universe.

- Exoplanet around distant star resembles reputed 'Planet Nine' in our solar system

Astronomers confirm bound orbit for planet far from its star, showing that far-flung planets exist
Date: December 10, 2020
Source: University of California - Berkeley



Distant planet far from star, concept illustration (stock image).
Credit: © dottedyeti / stock.adobe.com

Astronomers are still searching for a hypothetical "Planet Nine" in the distant reaches of our solar system, but an exoplanet 336 light years from Earth is looking more and more like the Planet Nine of its star system .

Planet Nine, potentially 10 times the size of Earth and orbiting far beyond Neptune in a highly eccentric orbit about the sun, was proposed in 2012 to explain perturbations in the orbits of dwarf planets just beyond Neptune's orbit, so-called detached Kuiper Belt objects. It has yet to be found, if it exists.

A similarly weird extrasolar planet was discovered far from the star HD 106906 in 2013, the only such wide-separation planet known. While much heavier than the predicted mass of Planet Nine -- perhaps 11 times the mass of Jupiter, or 3,500 times the mass of Earth -- it, too, was sitting in a very unexpected location, far above the dust plane of the planetary system and tilted at an angle of about 21 degrees.

The big question, until now, has been whether the planet, called HD 106906 b, is in an orbit perpetually bound to the binary star -- which is a mere 15 million years old compared to the 4.5 billion-year age of our sun -- or whether it's on its way out of the planetary system, never to return.

In a paper appearing Dec. 10 in the *Astronomical Journal*, astronomers finally answer that question. By precisely tracking the planet's position over 14 years, they determined that it is likely bound to the star in a 15,000-year, highly eccentric orbit, making it a distant cousin of Planet Nine.

If it is in a highly eccentric orbit around the binary, "This raises the question of how did these planets get out there to such large separations," said Meiji Nguyen, a recent UC Berkeley graduate and first author of the paper. "Were they scattered from the inner solar system? Or, did they form out there?"

According to senior author Paul Kalas, University of California, Berkeley, adjunct professor of astronomy, the resemblance to the orbit of the proposed Planet Nine shows that such distant planets can really exist, and that they may form within the first tens of millions of years of a star's life. And based on the team's other recent discoveries about HD 106906, the planet seems to favour a scenario where passing stars also play a role.

"Something happens very early that starts kicking planets and comets outward, and then you have passing stars that stabilize their orbits," he said. "We are slowly accumulating the evidence needed to understand the diversity of extrasolar planets and how that relates to the puzzling aspects of our own solar system."

A young, dusty star with a weird planet

HD 106906 is a binary star system located in the direction of the constellation Crux. Astronomers have studied it extensively for the past 15 years because of its prominent disk of dust, which could be birthing planets. Our solar system may have looked like HD 106906 about 4.5 billion years ago as the planets formed in the swirling disk of debris left over from the formation of the sun.

Surprisingly, images of the star taken in 2013 by the Magellan Telescopes in Chile revealed a planet glowing from its own internal heat and sitting at an unusually large distance from the binary: 737 times farther from the binary than Earth is from the sun (737 astronomical units, or AU). That's 25 times farther from the star than Neptune is from the sun.

Kalas, who searches for planets and dust disks around young stars, co-led a team that used the Gemini Planet Imager on the Gemini South Telescope to obtain the first images of the star's debris disk. In 2015, these observations provided evidence that led theorists to propose that the planet formed close to the binary star and was kicked out because of gravitational interactions with the binary. The evidence: The stars' outer dust disk and inner comet belt are lopsided, suggesting that something -- the planet -- perturbed their symmetry.

"The idea is that every time the planet comes to its closest approach to the binary star, it stirs up the material in the disk," said team member Robert De Rosa of the European Southern Observatory in Santiago, Chile, who is a former UC Berkeley postdoctoral fellow. "So, every time the planet comes through, it truncates the disk and pushes it up on one side. This scenario has been tested with simulations of this system with the planet on a similar orbit -- this was before we knew what the orbit of the planet was."

The problem, as pointed out by those simulating such planet interactions, is that a planet would normally be kicked out of the system entirely, becoming a rogue planet. Some other interaction, perhaps with a passing star, would be necessary to stabilize the orbit of an eccentric planet like HD 106906 b.

A similar scenario has been proposed for the formation of Planet Nine: that its interaction with our giant planets early in our solar system's history kicked it out of the inner solar system, after which passing stars in our local cluster stabilized its orbit.

Kalas went looking for such a fly-by star for HD 106906 b, and last year he and De Rosa, then at Stanford University, reported finding

several nearby stars that would have zipped by the planetary system 3 million years earlier, perhaps providing the nudge needed to stabilize the planet's orbit.
Now, with precise measurements of the planet's orbit between 2004 and 2018, Nguyen, de Rosa and Kalas present evidence that the planet is most likely in a stable, but very elliptical, orbit around its binary star.
"Though it's only been 14 years of observations, we were still able to, surprisingly, get a constraint on the orbit for the first time, confirming our suspicion that it was very misaligned and also that the planet is on an approximately 15,000-year orbit." Nguyen said. "The fact that our results are consistent with predictions is, I think, a strong piece of evidence that this planet is, indeed, bound. In the future, a radial velocity measurement is needed to confirm our findings."
The science team's orbital measurements came from comparing astrometric data from the European Space Agency's Gaia observatory, which accurately maps the positions of billions of stars, and images from the Hubble Space Telescope. Because Hubble must obscure the glare from the binary star to see the dimmer debris disk, astronomers were unable to determine the exact position of the star relative to HD 106906 b. Gaia data allowed the team to determine the binary's position more precisely, and thus chart the movement of the planet relative to the binary between 2004 and 2018, less than one-thousandth of its orbital period.
"We can harness the extremely precise astrometry from Gaia to infer where the primary star should be in our Hubble images, and then measuring the position of the companion is rather trivial," Nguyen said.
In addition to confirming the planet's 15,000-year orbit, the team found that the orbit is actually tilted much more severely to the plane of the disk: between 36 and 44 degrees. At its closest approach to the binary, its elliptical orbit would take it no closer than about 500 AU from the stars, implying that it has no effect on inner planets also suspected to be part of the system. That is also the case with Planet Nine, which has no observed effect on any of the sun's eight planets.
"What I really think makes HD 106906 unique is that it is the only exoplanet that we know that is directly imaged, surrounded by a debris disk, misaligned relative to its system and is widely separated," Nguyen said. "This is what makes it the sole candidate we have found thus far whose orbit is analogous to the hypothetical Planet Nine."
The work was supported by the National Science Foundation (AST-1518332) and the National Aeronautics and Space Administration (NNX15AC89G, NNX15AD95G, HST-GO-14670/NAS5-26555). This work benefited from NASA's Nexus for Exoplanet System Science (NExSS) research coordination network sponsored by NASA's Science Mission Directorate.

- A look at the sun's dusty environment

Date: December 10, 2020
Source: University of Colorado at Boulder

Researchers from the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder are diving into the dusty environment that surrounds the sun -- a search that could help to reveal how planets like Earth come into being.
The pursuit comes by way of NASA's Parker Solar Probe, a pioneering mission that has taken scientists closer to Earth's home star than any spacecraft to date. Over two years, the probe has circled the sun six times, hitting maximum speeds of roughly 290,000 miles per hour.
In the process, the Parker team has learned a lot about the microscopic grains of dust that lie just beyond the sun's atmosphere, said David Malaspina, a space plasma physicist at LASP. In new research, for example, he and his colleagues discovered that the densities of these bits of rock and ice seem to vary wildly over the span of months -- not something scientists were expecting.
"Every time we go into a new orbit, and we think we understand what we're seeing around the sun, nature goes and surprises us," said Malaspina, also an assistant professor in the Department of Astrophysical and Planetary Sciences.
He will present the group's results Tuesday, Dec. 8 at the 2020 virtual fall meeting of the American Geophysical Union (AGU).
Malaspina said that dust can give researchers an unexpected, and tiny, window into the processes that formed Earth and its neighbouring planets more than 4.5 billion years ago.
"By learning how our star processes dust, we can extrapolate that to other solar systems to learn more about planet formation and how a

cloud of dust becomes a solar system," he said.

Solar Dyson

The area just around the sun, a hot and radiation-rich environment, is often dustier than you might imagine, Malaspina said. It contains more grains of dust by volume than most other open expanses of space in the solar system. That's because the star, through gravity and other forces, pulls dust toward it from millions to billions of miles away, a bit like a vacuum cleaner.

But this vacuum cleaner is imperfect. As dust particles get closer to the sun, its radiation pushes on them more and more -- some of those grains of dust will begin to blow in the other direction and can even fly out of the solar system entirely. The Wide-Field Imager for Parker Solar Probe (WISPR) instrument suite onboard the spacecraft found the first evidence for the existence of this dust-devoid region, known as the dust-free zone, more than 90 years after it was predicted.

"What you get is this really interesting environment where all of these particles are moving inward, but once they reach the near-sun environment, they can be blown away," Malaspina said.

Since launching in 2018, Parker Solar Probe -- built and operated by the Johns Hopkins Applied Physics Laboratory, which also leads the mission for NASA -- has flown to within about 11.6 million miles of the Sun's surface. On each of Parker's orbits around the sun, the spacecraft collided with thousands of grains of dust. Many of these particles vaporize on the spot, creating a small burst of charged particles that the probe can detect using the five antennae that are part of its FIELDS Experiment. LASP plays an important role in this experiment, which is led by the University of California, Berkeley. Think of it like studying insect populations by counting the splatters on your car's windshield.

"You get a small puff of plasma," Malaspina said. "By looking at these spikes, we can understand how many dust impacts we're getting hit by."

New mysteries

Malaspina and his colleagues were originally hoping to use those puffs to pinpoint where exactly the solar system's inward-flying dust becomes outward-flying dust. But they stumbled on something puzzling in the process: The concentrations of dust that the team recorded seemed to vary by as much as 50% between Parker's six orbits around the Sun.

"That's really interesting because the timescale that it takes for dust to move in toward the Sun is thousands to millions of years," Malaspina said. "So how do we get variation in just three or four months?"

This dusty environment, in other words, may be a lot more complicated and fast-shifting than scientists previously thought. Malaspina said that the team will need to wait for Parker to complete more orbits to know exactly what's happening. He's just excited to be part of this once-in-a-lifetime chance to run a finger along the Sun's dusty shelves.

"This is the only in-situ measurement we are going to get for a long time in the inner solar system," Malaspina said. "We're trying to make the best of it and learn as much as we can."

- Researchers uncover key clues about the solar system's history

New clues lead to a better understanding of the evolution of the solar system and the origin of Earth as a habitable planet

Date: December 4, 2020
Source: University of Rochester

Asteroid illustration (stock image).
Credit: © Mopic / stock.adobe.com

In a new paper published in the journal *Nature Communications Earth and Environment,* researchers at the University of Rochester were able to use magnetism to determine, for the first time, when carbonaceous chondrite asteroids -- asteroids that are rich in water and amino acids -- first arrived in the inner solar system. The research provides data that helps inform scientists about the early origins of the solar system and why some planets, such as Earth, became habitable and were able to sustain conditions conducive for life, while other planets, such as Mars, did not.

The research also gives scientists data that can be applied to the discovery of new exoplanets. "There is special interest in defining this history -- in reference to the huge number of exoplanet discoveries -- to deduce whether events might have been similar or different in exo-solar systems," says John Tarduno, the William R. Kenan, Jr., Professor in the Department of Earth and Environmental Sciences and dean of research for Arts, Sciences & Engineering at Rochester. "This is another component of the search for other habitable planets."

Solving a Paradox Using a Meteorite in Mexico

Some meteorites are pieces of debris from outer space objects such as asteroids. After breaking apart from their "parent bodies," these pieces are able to survive passing through the atmosphere and eventually hit the surface of a planet or moon.

Studying the magnetization of meteorites can give researchers a better idea of when the objects formed and where they were located early in the solar system's history.

"We realized several years ago that we could use the magnetism of meteorites derived from asteroids to determine how far these meteorites were from the sun when their magnetic minerals formed," Tarduno says.

In order to learn more about the origin of meteorites and their parent bodies, Tarduno and the researchers studied magnetic data collected from the Allende meteorite, which fell to Earth and landed in Mexico in 1969. The Allende meteorite is the largest carbonaceous chondrite meteorite found on Earth and contains minerals -- calcium-aluminium inclusions -- that are thought to be the first solids formed in the solar system. It is one of the most studied meteorites and was considered for decades to be the classic example of a meteorite from a primitive asteroid parent body.

In order to determine when the objects formed and where they were located, the researchers first had to address a paradox about meteorites that was confounding the scientific community: how did the meteorites gain magnetization?

Recently, a controversy arose when some researchers proposed that carbonaceous chondrite meteorites like Allende had been magnetized by a core dynamo, like that of Earth. Earth is known as a differentiated body because it has a crust, mantle, and core that are separated by composition and density. Early in their history, planetary bodies can gain enough heat so that there is widespread melting and the dense material -- iron -- sinks to the centre.

New experiments by Rochester graduate student Tim O'Brien, the first author of the paper, found that magnetic signals interpreted by prior researchers was not actually from a core. Instead, O'Brien found, the magnetism is a property of Allende's unusual magnetic minerals.

Determining Jupiter's Role in Asteroid Migration

Having solved this paradox, O'Brien was able to identify meteorites with other minerals that could faithfully record early solar system magnetizations.

Tarduno's magnetics group then combined this work with theoretical work from Eric Blackman, a professor of physics and astronomy, and computer simulations led by graduate student Atma Anand and Jonathan Carroll-Nellenback, a computational scientist at Rochester's Laboratory for Laser Energetics. These simulations showed that solar winds draped around early solar system bodies and it was this solar wind that magnetized the bodies.

Using these simulations and data, the researchers determined that the parent asteroids from which carbonaceous chondrite meteorites broke off arrived in the Asteroid Belt from the outer solar system about 4,562 million years ago, within the first five million years of solar system history.

Tarduno says the analyses and modelling offers more support for the so-called grand tack theory of the motion of Jupiter. While scientists once thought planets and other planetary bodies formed from dust and gas in an orderly distance from the sun, today scientists realize that the gravitational forces associated with giant planets -- such as Jupiter and Saturn -- can drive the formation and migration of planetary bodies and asteroids. The grand tack theory suggests that asteroids were separated by the gravitational forces of the giant planet Jupiter, whose subsequent migration then mixed the two asteroid groups.

He adds, "This early motion of carbonaceous chondrite asteroids sets the stage for further scattering of water-rich bodies -- potentially to Earth -- later in the development of the solar system, and it may be a pattern common to exoplanet systems."

❖ Supercomputer simulations could unlock mystery of Moon's formation

Date: December 4, 2020
Source: Durham University

Astronomers have taken a step towards understanding how the Moon might have formed out of a giant collision between the early Earth and another massive object 4.5 billion years ago.

Scientists led by Durham University, UK, ran supercomputer simulations on the DiRAC High-Performance Computing facility to send a Mars-sized planet -- called Theia -- crashing into the early Earth.

Their simulations produced an orbiting body that could potentially evolve into a Moon-like object.

While the researchers are careful to say that this is not definitive proof of the Moon's origin, they add that it could be a promising stage in understanding how our nearest neighbour might have formed.

The findings are published in the journal *Monthly Notices of the Royal Astronomical Society*.

The Moon is thought to have formed in a collision between the early Earth and Theia, which scientists believe might have been an ancient planet in our solar system, about the size of Mars.

Researchers ran simulations to track material from the early Earth and Theia for four days after their collision, then ran other simulations after spinning Theia like a pool ball.

The simulated collision with the early Earth produced different results depending upon the size and direction of Theia's initial spin.

At one extreme the collision merged the two objects together while at the other there was a grazing hit-and-run impact.

Importantly, the simulation where no spin was added to Theia produced a self-gravitating clump of material with a mass of about 80 per cent of the Moon, while another Moon-like object was created when a small amount of spin was added.

The resulting clump, which settles into an orbit around the post-impact Earth, would grow by sweeping up the disc of debris surrounding our planet.

The simulated clump also has a small iron core, similar to that of the Moon, with an outer layer of materials made up from the early Earth and Theia.

Recent analysis of oxygen isotope ratios in the lunar samples collected by the Apollo space missions suggests that a mixture of early Earth and impactor material might have formed the Moon.

Lead author Sergio Ruiz-Bonilla, a PhD researcher in Durham University's Institute for Computational Cosmology, said: "By adding different amounts of spin to Theia in simulations, or by having no spin at all, it gives you a whole range of different outcomes for what might have happened when the early Earth was hit by a massive object all those billions of years ago.

"It's exciting that some of our simulations produced this orbiting clump of material that is relatively not much smaller than the Moon, with a disc of additional material around the post-impact Earth that would help the clump grow in mass over time.

"I wouldn't say that this is the Moon, but it's certainly a very interesting place to continue looking."

The Durham-led research team now plan to run further simulations altering the mass, speed and spinning rate of both the target and impactor to see what effect this has on the formation of a potential Moon.

Co-author Dr Vincent Eke, of Durham University's Institute for Computational Cosmology, said: "We get a number of different outcomes depending upon whether or not we introduce spin to Theia before it crashes into the early Earth.

"It's particularly fascinating that when no spin or very little spin is added to Theia that the impact with the early Earth leaves a trail of debris behind, which in some cases includes a body large enough to deserve being called a proto-Moon.

"There may well be a number of possible collisions that have yet to be investigated that could get us even closer to understanding just how the Moon formed in the first place."

❖ Leaving so soon? Unusual planetary nebula fades mere decades after it arrived

Date: December 3, 2020
Source: University of Washington

Stars are rather patient. They can live for billions of years, and they typically make slow transitions -- sometimes over many millions of years -- between the different stages of their lives.

So when a previously typical star's behaviour rapidly changes in a few decades, astronomers take note and get to work.

Such is the case with a star known as SAO 244567, which lies at the centre of Hen 3-1357, commonly known as the Stingray

Nebula. The Stingray Nebula is a planetary nebula -- an expanse of material sloughed off from a star as it enters a new phase of old age and then heated by that same star into colourful displays that can last for up to a million years.
The tiny Stingray Nebula unexpectedly appeared in the 1980s and was first imaged by scientists in the 1990s using NASA's Hubble Space Telescope. It is by far the youngest planetary nebula in our sky. A team of astronomers recently analysed a more recent image of the nebula, taken in 2016 by Hubble, and found something unexpected: As they report in a paper accepted to the Astrophysical Journal, the Stingray Nebula has faded significantly and changed shape over the course of just 20 years.
If dimming continues at current rates, in 20 or 30 years the Stingray Nebula will be barely perceptible, and was likely already fading when Hubble obtained the first clear images of it in 1996, according to lead author Bruce Balick, an emeritus professor of astronomy at UW.
"This is an unprecedented departure from typical behaviour for a planetary nebula," said Balick. "Over time, we would expect it to imperceptibly brighten and expand, which could easily go unnoticed in a century or more. But here we're seeing the Stingray nebula fade significantly in an incredibly compressed time frame of just 20 years. Moreover, its brightest inner structure has contracted -- not expanded -- as the nebula fades."
Planetary nebulae form after most stars, including stars like our own sun, swell into red giants as they exhaust hydrogen fuel. At the end of the red giant phase, the star then expels large amounts of its outer material as it gradually -- over the course of a million years -- transforms into a small, compact white dwarf. The sloughed-off material expands outward for several thousand years while the star heats the material, which eventually becomes ionized and glows.
Balick and his co-authors, Martín Guerrero at the Institute of Astrophysics of Andalusia in Spain and Gerardo Ramos-Larios at the University of Guadalajara in Mexico, compared Hubble images of the Stingray Nebula taken in 1996 and 2016. Hen 3-1357 changed shape markedly over 20 years, losing the sharp, sloping edges that gave the Stingray Nebula its name. Its colours have faded overall and once-prominent blue expanses of gas near its centre are largely gone.
"In a planetary nebula, the star is really the centre of all the activity," said Balick. "The material around it is directly responsive to the energy from its parent star."
The team analysed light spectra from Hen 3-1357 emitted by chemical elements in the nebula. Emission levels of hydrogen, nitrogen, sulphur and oxygen all dropped between 1996 and 2016, particularly oxygen, which dropped by a factor of 900. The resulting fade in colour and the nebula's change in shape are likely connected to the cooling of its parent star -- from a peak of about 107,500 degrees Fahrenheit in 2002 to just under 90,000 degrees Fahrenheit in 2015 -- which means it is giving off less ultraviolet ionizing radiation that heats the expelled gas and makes it glow.
"Like a doused forest fire, the smoke wanes more slowly than the flames that created it," said Balick. "Even so, we were amazed when the Hubble images revealed how quickly the nebula was fading. It took a month of work to believe it."
Astronomers have yet to understand why SAO 244567 made the Stingray Nebula light up and then fade almost as quickly. One theory, posited by a team led by Nicole Reindl at the University of Potsdam, is that the star underwent a brief burst of fresh helium fusion around its core, which stirred up its outer layers and caused its surface to both shrink and heat.
If so, then as its outer layers settle back down, the star may return to a more typical transition from red giant to white dwarf. Only future observations of the star and its nebula can confirm this.
"Unfortunately, the best tool to follow future changes in the Stingray Nebula, the Hubble Space Telescope, is near the end of its life as well," said Balick. "We can hope, but the odds aren't good for Hubble's survival as its three remaining gyroscopes start to fail. It's a good race to the finish."

- Gaia space telescope measured the acceleration of the Solar System

Date: December 3, 2020
Source: University of Helsinki

The Gaia space telescope has measured the acceleration of the Solar System when it orbits the centre of our Milky Way galaxy. The Solar System motion relative to the stars

agrees with the results by Finnish astronomers in the 19th century.
Moreover, the observational data by Gaia improves satellite navigation. Finnish researchers are participating in this massive endeavour, that results in three-dimensional mapping of our galaxy, to be completed in 2024.
Today, Dec. 3, 2020, the European Space Agency (ESA) released observational data from the Gaia telescope (Gaia Early Data Release 3 or EDR3), in continuation to the DR1 and DR2 releases of the years 2016 and 2018. Gaia accrues accurate knowledge about, for example, the Milky Way stars, distant extragalactic quasars, and the asteroids of our Solar System.
Quasars are bright, star-like objects that allow for the determination of planet Earth's orientation in space. With the help of their precise positions measured by Gaia, a new high-precision reference system can be constructed for defining the positions of stars, Solar System objects, and also satellites.
"The knowledge accrued by Gaia affects the precision of satellite navigation in the future. The satellite positions and Earth orientation in space are determined in a reference frame tied to the directions of quasars. The precision and state of the art of the reference frame are critical for the precision in navigation," says Professor Markku Poutanen at the Finnish Geospatial Research Institute FGI, National Land Survey of Finland.
The precise observations of quasars resulted, for the first time, in a successful computation of the acceleration of the Solar System.
"The acceleration of the Solar System towards the centre of the Milky Way, as measured by Gaia, is (2.32±0.16) x 10-10 m/s2 or, roughly, two one-hundred-billionth parts of the gravitational acceleration caused by the Earth on its surface, " summarizes Astronomy Professor Karri Muinonen at the Department of Physics, University of Helsinki, also Research Professor at the Finnish Geospatial Research Institute FGI.

Gaia in the research of asteroids

Gaia's data processing is carried out within the European DPAC network (Data Processing and Analysis Consortium) with more than 300 researchers. Solar System researchers at the University of Helsinki take part in the Gaia data processing in several different ways.
"We are responsible for the daily computation of orbits for asteroids discovered by Gaia. Based on these computations, ground-based follow-up observations are organized," describes Muinonen.
"Before data releases, we take part in the validation of Gaia observations of asteroid positions, brightness’s, and spectra. Our research with Gaia data focuses on asteroid orbits, rotation periods and pole orientations, masses, shapes, and surface structural and compositional properties. In the computation of collision probabilities for near-Earth asteroids, the precision of reference frames is completely central," continues Muinonen.
Asteroid observations by Gaia were published in DR2 in spring 2018 (14 099 asteroids). In the forthcoming DR3 release in spring 2022, there will be position and brightness data for tens of thousands of asteroids and, for the first time, asteroid spectra will also be released.

Years of work and billions of stars

The EDR3 data has been collected by Gaia from the end of July 2014. The data includes, for example, position and brightness data of 1,81 billion stars and colour data of 1,55 billion stars from the time period of 34 months. Furthermore, the data more than triples the number of quasars observed for precise reference frames to 1,61 million.
EDR3 is a remarkable improvement, in terms of both numbers and precisions, as compared to the earlier releases. The newest release gives hints about the gigantic nature of the forthcoming DR3 release in spring 2022 and the final DR4 release after 2024.
Gaia observes astronomical objects systematically in the so-called L2 Lagrange point some 1,5 million kilometres from the Earth in the anti-sun direction. Gaia observes about two billion stars with a precision, at best, of one hundred millionths of a degree. The result will be a three-dimensional map of our galaxy.

Stellar motion in the future

Based on the Gaia data, researchers' have modelled the motion of stars in the Milky Way. They have produced an animation for the motion of 40 000 randomly selected stars on the sky 1.6 million years into the future.
"In the animation, short and long trails describe changes in stellar positions with 80 000 years. The former are mostly related to distant stars, whereas the latter are solely due to the nearby stars. Every now and then, short trails expand into long ones, and long trails shrink into short ones. This is also related to

the changing distances of the stars," says Muinonen.
In the end of the animation, stars appear to be removed from the left and collected to the right. This is due to the Solar System's motion relative to the stars. A similar phenomenon can be seen when moving from a centre of a forest islet to its boundary: the trees in the front gradually disappear whereas they seem to be collected in the back.
"This shows the average motion of the Solar System with respect to the surrounding stars. From the Finnish point of view, it is intriguing that the motion documented by Gaia agrees with the pioneering research about the Solar System's motion by Friedrich Wilhelm August Argelander (1799-1875) in the 19th century at the Helsinki Observatory," concludes Muinonen.
Argelander was the first astronomer, who unequivocally calculated the direction of Solar System motion in space. He worked at the Observatory, University of Helsinki, then the Imperial Alexander University. He had made the observations at the Turku Observatory in 1827-1831 before the observatory moved to Helsinki. In Helsinki, he compiled the stellar catalogue entitled "DLX stellarum fixarum positiones mediae ineunte anno 1830" that, as the title says, included the precise positions of 560 stars.

Movement of quasars is actually the movement of Solar System

More accurately, the apparent stellar streams include the information about the motion of the stars and the Solar System about the centre of the Milky Way. The Gaia quasar observations allow for the determination of the acceleration related to this orbital motion. Gaia has measured the apparent motions of quasars on the sky. These motions are tiny, about one thousandth part of the motion of stars 3000 light years from us. The apparent stream of quasars is directed toward the centre of the Milky Way, that is, in the direction where the acceleration of the Solar System is pointing. Gaia has, in essence, measured the absolute motion of the Solar System relative to the distant universe. This motion derives from the gravitational forces by the Milky Way and all other objects in the universe.

- ❖ Astronomers to release most accurate data ever for nearly two billion stars

Date: December 3, 2020
Source: Royal Astronomical Society

On 3 December an international team of astronomers will announce the most detailed ever catalogue of the stars in a huge swathe of our Milky Way galaxy. The measurements of stellar positions, movement, brightness and colours are in the third early data release from the European Space Agency's Gaia space observatory and will be publicly available. Initial findings include the first optical measurement of the acceleration of the Solar system. The data set, and early scientific discoveries, will be presented at a special briefing hosted by the Royal Astronomical Society.
Launched in 2013, Gaia operates in an orbit around the so-called Lagrange 2 (L2) point, located 1.5 million kilometres behind the Earth in the direction away from the Sun. At L2 the gravitational forces between the Earth and Sun are balanced, so the spacecraft stays in a stable position, allowing long-term essentially unobstructed views of the sky.
The primary objective of Gaia is measure stellar distances using the parallax method. In this case astronomers use the observatory to continuously scan the sky, measuring the apparent change in the positions of stars over time, resulting from the Earth's movement around the Sun.
Knowing that tiny shift in the positions of stars allows their distances to be calculated. On Earth this is made more difficult by the blurring of the Earth's atmosphere, but in space the measurements are only limited by the optics of the telescope.
Two previous releases included the positions of 1.6 billion stars. This release brings the total to just under 2 billion stars, whose positions are significantly more accurate than in the earlier data. Gaia also tracks the changing brightness and positions of the stars over time across the line of sight (their so-called proper motion), and by splitting their light into spectra, measures how fast they are moving towards or away from the Sun and assesses their chemical composition.
The new data include exceptionally accurate measurements of the 300,000 stars within the closest 326 light years to the Sun. The researchers use these data to predict how the star background will change in the next 1.6 million years. They also confirm that the Solar system is accelerating in its orbit around the Galaxy.
This acceleration is gentle, and is what would be expected from a system in a circular orbit.

Over a year the Sun accelerates towards the centre of the Galaxy by 7 mm per second, compared with its speed along its orbit of about 230 kilometres a second.

Gaia data additionally deconstruct the two largest companion galaxies to the Milky Way, the Small and Large Magellanic Clouds, allowing researchers to see their different stellar populations. A dramatic visualisation shows these subsets, and the bridge of stars between the two systems.

Dr Floor van Leeuwen of the Institute of Astronomy at the University of Cambridge, and UK Gaia DPAC Project Manager, comments: "Gaia is measuring the distances of hundreds of millions of objects that are many thousands of light years away, at an accuracy equivalent to measuring the thickness of hair at a distance of more than 2000 kilometres. These data are one of the backbones of astrophysics, allowing us to forensically analyse our stellar neighbourhood, and tackle crucial questions about the origin and future of our Galaxy."

Gaia will continue gathering data until at least 2022, with a possible mission extension until 2025. The final data releases are expected to yield stellar positions 1.9 times as accurate as those released so far, and proper motions more than 7 times more accurate, in a catalogue of more than 2 billion objects.