South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 552 – May 2021 Editor: Roger Burgess
THE MEETING IS CANCELLED DUE TO COVID-19

We have a virtual meeting Friday 7th May Zoom Meeting 19:30 Mark Woodland BSc will present An Introduction to Astronomy. Assuming some time this year we will be holding the delayed AGM, we are looking for a new secretary and committee members, it probably won't be until September so you have time to prepare.

- Astronomers release new all-sky map of Milky Way's outer reaches

Date: April 21, 2021
Source: NASA/Jet Propulsion Laboratory

Large Magellanic Cloud (stock image).

Credit: © Camille / stock.adobe.com

Astronomers using data from NASA and ESA (European Space Agency) telescopes have released a new all-sky map of the outermost region of our galaxy. *[Editor's note: See Related Multimedia link below.]* Known as the galactic halo, this area lies outside the swirling spiral arms that form the Milky Way's recognizable central disk and is sparsely populated with stars. Though the halo may appear mostly empty, it is also predicted to contain a massive reservoir of dark matter, a mysterious and invisible substance thought to make up the bulk of all the mass in the universe.

The data for the new map comes from ESA's Gaia mission and NASA's Near-Earth Object Wide Field Infrared Survey Explorer, or NEOWISE, which operated from 2009 to 2013 under the moniker WISE. The study makes use of data collected by the spacecraft between 2009 and 2018.

The new map reveals how a small galaxy called the Large Magellanic Cloud (LMC) -- so named because it is the larger of two dwarf galaxies orbiting the Milky Way -- has sailed through the Milky Way's galactic halo like a ship through water, its gravity creating a wake in the stars behind it. The LMC is located about 160,000 light-years from Earth and is less than one-quarter the mass of the Milky Way.

Though the inner portions of the halo have been mapped with a high level of accuracy, this is the first map to provide a similar picture of the halo's outer regions, where the wake is found -- about 200,000 light-years to 325,000 light-years from the galactic centre. Previous studies have hinted at the wake's existence, but the all-sky map confirms its presence and offers a detailed view of its shape, size, and location.

This disturbance in the halo also provides astronomers with an opportunity to study something they can't observe directly: dark matter. While it doesn't emit, reflect, or absorb light, the gravitational influence of dark matter has been observed across the universe. It is thought to create a scaffolding on which galaxies are built, such that without it, galaxies would fly apart as they spin. Dark matter is estimated to be five times more common in the universe than all the matter that emits and/or interacts with light, from stars to planets to gas clouds.

Although there are multiple theories about the nature of dark matter, all of them indicate that it should be present in the Milky Way's halo. If that's the case, then as the LMC sails through this region, it should leave a wake in the dark matter as well. The wake observed in the new star map is thought to be the outline

Contact us - by email at: roger@burgess.world Society - by email via: www.southdownsas.org.uk
Web Page http://www.southdownsas.org.uk/
Or by telephone 07776 302839 Fax 01243 785092

of this dark matter wake; the stars are like leaves on the surface of this invisible ocean, their position shifting with the dark matter. The interaction between the dark matter and the Large Magellanic Cloud has big implications for our galaxy. As the LMC orbits the Milky Way, the dark matter's gravity drags on the LMC and slows it down. This will cause the dwarf galaxy's orbit to get smaller and smaller, until the galaxy finally collides with the Milky Way in about 2 billion years. These types of mergers might be a key driver in the growth of massive galaxies across the universe. In fact, astronomers think the Milky Way merged with another small galaxy about 10 billion years ago.

"This robbing of a smaller galaxy's energy is not only why the LMC is merging with the Milky Way, but also why *all* galaxy mergers happen," said Rohan Naidu, a doctoral student in astronomy at Harvard University and a co-author of the new paper. "The wake in our map is a really neat confirmation that our basic picture for how galaxies merge is on point!"

A Rare Opportunity

The authors of the paper also think the new map -- along with additional data and theoretical analyses -- may provide a test for different theories about the nature of dark matter, such as whether it consists of particles, like regular matter, and what the properties of those particles are.

"You can imagine that the wake behind a boat will be different if the boat is sailing through water or through honey," said Charlie Conroy, a professor at Harvard University and an astronomer at the Centre for Astrophysics | Harvard & Smithsonian, who co-authored the study. "In this case, the properties of the wake are determined by which dark matter theory we apply."

Conroy led the team that mapped the positions of over 1,300 stars in the halo. The challenge arose in trying to measure the exact distance from Earth to a large portion of those stars: It's often impossible to figure out whether a star is faint and close by or bright and far away. The team used data from ESA's Gaia mission, which provides the location of many stars in the sky but cannot measure distances to the stars in the Milky Way's outer regions.

After identifying stars most likely located in the halo (because they were not obviously inside our galaxy or the LMC), the team looked for stars belonging to a class of giant stars with a specific light "signature" detectable by NEOWISE. Knowing the basic properties of the selected stars enabled the team to figure out their distance from Earth and create the new map. It charts a region starting about 200,000 light-years from the Milky Way's centre, or about where the LMC's wake was predicted to begin, and extends about 125,000 light-years beyond that.

Conroy and his colleagues were inspired to hunt for LMC's wake after learning about a team of astrophysicists at the University of Arizona in Tucson that makes computer models predicting what dark matter in the galactic halo should look like. The two groups worked together on the new study.

One model by the Arizona team, included in the new study, predicted the general structure and specific location of the star wake revealed in the new map. Once the data had confirmed that the model was correct, the team could confirm what other investigations have also hinted at: that the LMC is likely on its first orbit around the Milky Way. If the smaller galaxy had already made multiple orbits, the shape and location of the wake would be significantly different from what has been observed. Astronomers think the LMC formed in the same environment as the Milky Way and another nearby galaxy, M31, and that it is close to completing a long first orbit around our galaxy (about 13 billion years). Its next orbit will be much shorter due to its interaction with the Milky Way.

"Confirming our theoretical prediction with observational data tells us that our understanding of the interaction between these two galaxies, including the dark matter, is on the right track," said University of Arizona doctoral student in astronomy Nicolás Garavito-Camargo, who led work on the model used in the paper.

The new map also provides astronomers with a rare opportunity to test the properties of the dark matter (the notional water or honey) in our own galaxy. In the new study, Garavito-Camargo and colleagues used a popular dark matter theory called cold dark matter that fits the observed star map relatively well. Now the University of Arizona team is running simulations that use different dark matter theories to see which one best matches the wake observed in the stars.

"It's a really special set of circumstances that came together to create this scenario that lets us test our dark matter theories," said Gurtina

Besla, a co-author of the study and an associate professor at the University of Arizona. "But we can only realize that test with the combination of this new map and the dark matter simulations that we built." Launched in 2009, the WISE spacecraft was placed into hibernation in 2011 after completing its primary mission. In September 2013, NASA reactivated the spacecraft with the primary goal of scanning for near-Earth objects, or NEOs, and the mission and spacecraft were renamed NEOWISE. NASA's Jet Propulsion Laboratory in Southern California managed and operated WISE for NASA's Science Mission Directorate. The mission was selected competitively under NASA's Explorers Program managed by the agency's Goddard Space Flight Centre in Greenbelt, Maryland. NEOWISE is a project of JPL, a division of Caltech, and the University of Arizona, supported by NASA's Planetary Defense Coordination Office.

❖ Telescopes unite in unprecedented observations of famous black hole

Date: April 14, 2021
Source: Harvard-Smithsonian Centre for Astrophysics

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

In April 2019, scientists released the first image of a black hole in galaxy M87 using the Event Horizon Telescope (EHT). However, that remarkable achievement was just the beginning of the science story to be told.

Data from 19 observatories released today promise to give unparalleled insight into this black hole and the system it powers, and to improve tests of Einstein's General Theory of Relativity.

"We knew that the first direct image of a black hole would be ground-breaking," says Kazuhiro Hada of the National Astronomical Observatory of Japan, a co-author of a new study published in *The Astrophysical Journal Letters* that describes the large set of data. "But to get the most out of this remarkable image, we need to know everything we can about the black hole's behaviour at that time by observing over the entire electromagnetic spectrum."

The immense gravitational pull of a supermassive black hole can power jets of particles that travel at almost the speed of light across vast distances. M87's jets produce light spanning the entire electromagnetic spectrum, from radio waves to visible light to gamma rays. This pattern is different for each black hole. Identifying this pattern gives crucial insight into a black hole's properties -- for example, its spin and energy output -- but is a challenge because the pattern changes with time.

Scientists compensated for this variability by coordinating observations with many of the world's most powerful telescopes on the ground and in space, collecting light from across the spectrum. These 2017 observations were the largest simultaneous observing campaign ever undertaken on a supermassive black hole with jets.

Three observatories managed by the Centre for Astrophysics | Harvard & Smithsonian participated in the landmark campaign: the Submillimetre Array (SMA) in Hilo, Hawaii; the space-based Chandra X-ray Observatory; and the Very Energetic Radiation Imaging Telescope Array System (VERITAS) in southern Arizona.

Beginning with the EHT's now iconic image of M87, a new video takes viewers on a journey through the data from each telescope. Each consecutive frame shows data across many factors of ten in scale, both of wavelengths of light and physical size.

The sequence begins with the April 2019 image of the black hole. It then moves through images from other radio telescope arrays from around the globe (SMA), moving outward in the field of view during each step. Next, the view changes to telescopes that detect visible light, ultraviolet light, and X-rays (Chandra). The screen splits to show how these images, which cover the same amount of the sky at the same time, compare to one another. The sequence finishes by showing what gamma-ray telescopes on the ground (VERITAS), and

Fermi in space, detect from this black hole and its jet.

Each telescope delivers different information about the behaviour and impact of the 6.5-billion-solar-mass black hole at the centre of M87, which is located about 55 million light-years from Earth.

"There are multiple groups eager to see if their models are a match for these rich observations, and we're excited to see the whole community use this public data set to help us better understand the deep links between black holes and their jets," says co-author Daryl Haggard of McGill University in Montreal, Canada.

The data were collected by a team of 760 scientists and engineers from nearly 200 institutions, spanning 32 countries or regions, and using observatories funded by agencies and institutions around the globe. The observations were concentrated from the end of March to the middle of April 2017.

"This incredible set of observations includes many of the world's best telescopes," says co-author Juan Carlos Algaba of the University of Malaya in Kuala Lumpur, Malaysia. "This is a wonderful example of astronomers around the world working together in the pursuit of science."

The first results show that the intensity of the light produced by material around M87's supermassive black hole was the lowest that had ever been observed. This produced ideal conditions for viewing the 'shadow' of the black hole, as well as being able to isolate the light from regions close to the event horizon from those tens of thousands of light-years away from the black hole.

The combination of data from these telescopes, and current (and future) EHT observations, will allow scientists to conduct important lines of investigation into some of astrophysics' most significant and challenging fields of study. For example, scientists plan to use these data to improve tests of Einstein's Theory of General Relativity. Currently, uncertainties about the material rotating around the black hole and being blasted away in jets, in particular the properties that determine the emitted light, represent a major hurdle for these General Relativity tests.

A related question that is addressed by today's study concerns the origin of energetic particles called "cosmic rays," which continually bombard the Earth from outer space. Their energies can be a million times higher than what can be produced in the most powerful accelerator on Earth, the Large Hadron Collider. The huge jets launched from black holes, like the ones shown in today's images, are thought to be the most likely source of the highest energy cosmic rays, but there are many questions about the details, including the precise locations where the particles get accelerated. Because cosmic rays produce light via their collisions, the highest-energy gamma rays can pinpoint this location, and the new study indicates that these gamma-rays are likely not produced near the event horizon -- at least not in 2017. A key to settling this debate will be comparison to the observations from 2018, and the new data being collected this week.

"Understanding the particle acceleration is really central to our understanding of both the EHT image as well as the jets, in all their 'colours'," says co-author Sera Markoff from the University of Amsterdam. "These jets manage to transport energy released by the black hole out to scales larger than the host galaxy, like a huge power cord. Our results will help us calculate the amount of power carried, and the effect the black hole's jets have on its environment."

The release of this new treasure trove of data coincides with the EHT's 2021 observing run, which leverages a worldwide array of radio dishes, the first since 2018. Last year's campaign was cancelled because of the COVID-19 pandemic, and the previous year was suspended because of unforeseen technical problems. This very week, for six nights, EHT astronomers are targeting several supermassive black holes: the one in M87 again, the one in our Galaxy called Sagittarius A*, and several more distant black holes. Compared to 2017, the array has been improved by adding three more radio telescopes: the Greenland Telescope, the Kitt Peak 12-meter Telescope in Arizona, and the NOrthern Extended Millimetre Array (NOEMA) in France.

"With the release of these data, combined with the resumption of observing and an improved EHT, we know many exciting new results are on the horizon," says co-author Mislav Balokovi? of Yale University.

"I'm really excited to see these results come out, along with my fellow colleagues working on the SMA, some of whom were directly involved in collecting some of the data for this spectacular view into M87," says co-author Garrett Keating, a Submillimetre Array project scientist. "And with the results of Sagittarius A* -- the massive black hole at the centre of the Milky Way -- coming out soon, and the resumption of observing this year, we are looking forward to even more amazing results with the EHT for years to come."

- The science of spin: Asteroseismologists confirm older stars rotate faster than expected

Date: April 22, 2021
Source: University of Birmingham

Stars spin faster than expected as they age according to a new study led by scientists at the University of Birmingham which uses asteroseismology to shed new light on this emerging theory.
All stars, like the Sun, are born spinning. As they grow older, their spin slows down due to magnetic winds in a process called 'magnetic braking'. Research published in 2016 by scientists at Carnegie Observatories delivered the first hints that stars at a similar stage of life as the Sun were spinning faster than magnetic braking theories predicted. The results from this study were based on a method in which scientists pinpoint dark spots on the surface of stars and track them as they move with the stars' spin. While the method has proven robust for measuring spin in younger stars, however, older stars have fewer star spots, which has made the effects of this "weakened" magnetic braking on these stars hard to confirm.
In a new study, published in *Nature Astronomy,* researchers at the University of Birmingham used a different approach to confirm that older stars do, in fact, appear to rotate faster than expected. The team used asteroseismology to calculate how the star is rotating. This relatively new field of study enables scientists to measure the oscillations caused by sound waves trapped inside the star. By measuring the different characteristics of these waves, they can reveal different characteristics of stars, such as their size or age.
In this study, the team measured the modes, or the frequencies, of the sound waves produced by the star's oscillation. As the star spins, these modes split into different frequencies. This can be imagined, the author's say, as the sound of two ambulances stood still on a roundabout compared to when they are driving in circles. By measuring these frequencies, it is possible to calculate the rate of spin in a way that is possible for both young and old stars.
Lead author on the paper, Dr Oliver Hall, said: "Although we've suspected for some time that older stars rotate faster than magnetic braking theories predict, these new asteroseismic data are the most convincing yet to demonstrate that this 'weakened magnetic braking' is actually the case. Models based on young stars suggest that the change in a star's spin is consistent throughout their lifetime, which is different to what we see in these new data."
One aspect the researchers believe could be key to the change in momentum loss, is changes to the star's magnetic field. Understanding how the magnetic field interacts with rotation will be an important area of future study, and is being worked on by authors on the paper.
The results could also shed light on our own star's activity over the next several billion years, explains co-author Dr Guy Davies: "These new findings demonstrate that we still have a lot to learn about the future of our own Sun as well as other stars. This work helps place in perspective whether or not we can expect reduced solar activity and harmful space weather in the future. To answer these questions we need better models of solar rotation, and this work takes an important step towards improving the models and supplying the data needed to test them."

- Using exoplanets as dark matter detectors

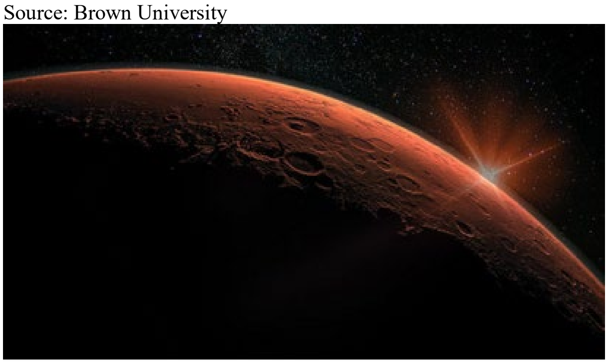
Temperature of planets reveal new details, scientists say
Date: April 22, 2021
Source: Ohio State University

In the continuing search for dark matter in our universe, scientists believe they have found a unique and powerful detector: exoplanets.
In a new paper, two astrophysicists suggest dark matter could be detected by measuring the effect it has on the temperature of exoplanets, which are planets outside our solar system.

This could provide new insights into dark matter, the mysterious substance that can't be directly observed, but which makes up roughly 80% of the mass of the universe.
"We believe there should be about 300 billion exoplanets that are waiting to be discovered," said Juri Smirnov, a fellow at The Ohio State University's Centre for Cosmology and Astroparticle Physics.
"Even finding and studying a small number of them could give us a great deal of information about dark matter that we don't know now."
Smirnov co-authored the paper with Rebecca Leane, a postdoctoral researcher at the SLAC National Accelerator Laboratory at Stanford University. It was published today (April 22, 2021) in the journal *Physical Review Letters*.
Smirnov said that when the gravity of exoplanets captures dark matter, the dark matter travels to the planetary core where it "annihilates" and releases its energy as heat. The more dark matter that is captured, the more it should heat up the exoplanet.
This heating could be measured by NASA's James Webb Space Telescope, an infrared telescope scheduled to launch in October that will be able to measure the temperature of distant exoplanets.
"If exoplanets have this anomalous heating associated with dark matter, we should be able to pick it up," Smirnov said.
Exoplanets may be particularly useful in detecting light dark matter, Smirnov said, which is dark matter with a lower mass. Researchers have not yet probed light dark matter by direct detection or other experiments.
Scientists believe that dark matter density increases toward the centre of our Milky Way galaxy. If that is true, researchers should find that the closer planets are to the galactic centre, the more their temperatures should rise.
"If we would find something like that, it would be amazing. Clearly, we would have found dark matter," Smirnov said.
Smirnov and Leane propose one type of search that would involve looking close to Earth at gas giants -- so called "Super Jupiters" -- and brown dwarfs for evidence of heating caused by dark matter. One advantage of using planets like this as dark matter detectors is that they don't have nuclear fusion, like stars do, so there is less "background heat" that would make it hard to find a dark matter signal.
In addition to this local search, the researchers suggest a search for distant rogue exoplanets that are no longer orbiting a star. The lack of radiation from a star would again cut down on interference that could obscure a signal from dark matter.
One of the best parts of using exoplanets as dark matter detectors is that it doesn't require any new types of instrumentation such as telescopes, or searches that aren't already being done, Smirnov said.
As of now, researchers have identified more than 4,300 confirmed exoplanets and an additional 5,695 candidates are currently under investigation. Gaia, a space observatory of the European Space Agency, is expected to identify tens of thousands more potential candidates in the next few years.
"With so many exoplanets being studied, we will have a tremendous opportunity to learn more than ever before about dark matter," Smirnov said.

- Mars has right ingredients for present-day microbial life beneath its surface, study finds

Date: April 22, 2021
Source: Brown University



Mars illustration (stock image; elements furnished by NASA).
Credit: © elen31 / stock.adobe.com

As NASA's Perseverance rover begins its search for ancient life on the surface of Mars, a new study suggests that the Martian subsurface might be a good place to look for possible present-day life on the Red Planet.
The study, published in the journal *Astrobiology*, looked at the chemical composition of Martian meteorites -- rocks blasted off of the surface of Mars that eventually landed on Earth. The analysis determined that those rocks, if in consistent contact with water, would produce the chemical energy needed to support microbial communities similar to those that survive in the unlit depths of the Earth. Because these meteorites may be representative of vast swaths of the Martian crust, the findings

suggest that much of the Mars subsurface could be habitable.

"The big implication here for subsurface exploration science is that wherever you have groundwater on Mars, there's a good chance that you have enough chemical energy to support subsurface microbial life," said Jesse Tarnas, a postdoctoral researcher at NASA's Jet Propulsion Laboratory who led the study while completing his Ph.D. at Brown University. "We don't know whether life ever got started beneath the surface of Mars, but if it did, we think there would be ample energy there to sustain it right up to today."

In recent decades, scientists have discovered that Earth's depths are home to a vast biome that exists largely separated from the world above. Lacking sunlight, these creatures survive using the by-products of chemical reactions produced when rocks come into contact with water.

One of those reactions is radiolysis, which occurs when radioactive elements within rocks react with water trapped in pore and fracture space. The reaction breaks water molecules into their constituent elements, hydrogen and oxygen. The liberated hydrogen is dissolved in the remaining groundwater, while minerals like pyrite (fool's gold) soak up free oxygen to form sulphate minerals. Microbes can ingest the dissolved hydrogen as fuel and use the oxygen preserved in the sulphates to "burn" that fuel.

In places like Canada's Kidd Creek Mine, these "sulphate-reducing" microbes have been found living more than a mile underground, in water that hasn't seen the light of day in more than a billion years. Tarnas has been working with a team co-led by Brown University professor Jack Mustard and Professor Barbara Sherwood Lollar of the University of Toronto to better understand these underground systems, with an eye toward looking for similar habitats on Mars and elsewhere in the solar system. The project, called Earth 4-D: Subsurface Science and Exploration, is supported by the Canadian Institute for Advances Research.

For this new study, the researchers wanted to see if the ingredients for radiolysis-driven habitats could exist on Mars. They drew on data from NASA's Curiosity rover and other orbiting spacecraft, as well as compositional data from a suite of Martian meteorites, which are representative of different parts of the planet's crust.

The researchers were looking for the ingredients for radiolysis: radioactive elements like thorium, uranium and potassium; sulphide minerals that could be converted to sulphate; and rock units with adequate pore space to trap water. The study found that in several different types of Martian meteorites, all the ingredients are present in adequate abundances to support Earth-like habitats. This was particularly true for regolith breccias -- meteorites sourced from crustal rocks more than 3.6 billion years old -- which were found to have the highest potential for life support.

Unlike Earth, Mars lacks a plate tectonics system that constantly recycle crustal rocks. So these ancient terrains remain largely undisturbed.

The researchers say the findings help make the case for an exploration program that looks for signs of present-day life in the Martian subsurface. Prior research has found evidence of an active groundwater system on Mars in the past, the researchers say, and there's reason to believe that groundwater exists today. One recent study, for example, raised the possibility of an underground lake lurking under the planet's southern ice cap. This new research suggests that wherever there's groundwater, there's energy for life.

Tarnas and Mustard say that while there are certainly technical challenges involved in subsurface exploration, they aren't as insurmountable as people may think. A drilling operation wouldn't require "a Texas-sized oil rig," Mustard said, and recent advances in small drill probes could soon put the Martian depths within reach.

"The subsurface is one of the frontiers in Mars exploration," Mustard said. "We've investigated the atmosphere, mapped the surface with different wavelengths of light and landed on the surface in half-a-dozen places, and that work continues to tell us so much about the planet's past. But if we want to think about the possibility of present-day life, the subsurface is absolutely going to be where the action is."

The research was supported by the Canadian Institute for Advanced Research.

- ❖ New research reveals secret to Jupiter's curious aurora activity

Date: April 10, 2021
Source: University of Alaska Fairbanks

Auroral displays continue to intrigue scientists, whether the bright lights shine over Earth or over another planet. The lights hold clues to the makeup of a planet's magnetic field and how that field operates.

New research about Jupiter proves that point -- and adds to the intrigue.

Peter Delamere, a professor of space physics at the University of Alaska Fairbanks Geophysical Institute, is among an international team of 13 researchers who have made a key discovery related to the aurora of our solar system's largest planet.

The team's work was published April 9, 2021, in the journal *Science Advances*. The research paper, titled "How Jupiter's unusual magnetospheric topology structures its aurora," was written by Binzheng Zhang of the Department of Earth Sciences at the University of Hong Kong; Delamere is the primary co-author.

Research done with a newly developed global magnetohydrodynamic model of Jupiter's magnetosphere provides evidence in support of a previously controversial and criticized idea that Delamere and researcher Fran Bagenal of the University of Colorado at Boulder put forward in a 2010 paper -- that Jupiter's polar cap is threaded in part with closed magnetic field lines rather than entirely with open magnetic field lines, as is the case with most other planets in our solar system.

"We as a community tend to polarize -- either open or closed -- and couldn't imagine a solution where it was a little of both," said Delamere, who has been studying Jupiter since 2000. "Yet in hindsight, that is exactly what the aurora was revealing to us."

Open lines are those that emanate from a planet but trail off into space away from the sun instead of reconnecting with a corresponding location in the opposite hemisphere.

On Earth, for example, the aurora appears on closed field lines around an area referred to as the auroral oval. It's the high latitude ring near -- but not at -- each end of Earth's magnetic axis.

Within that ring on Earth, however, and as with some other planets in our solar system, is an empty spot referred to as the polar cap. It's a place where magnetic field lines stream out unconnected -- and where the aurorae rarely appear because of it. Think of it like an incomplete electrical circuit in your home: No complete circuit, no lights.

Jupiter, however, has a polar cap in which the aurora dazzles. That puzzled scientists.

The problem, Delamere said, is that researchers were so Earth-centric in their thinking about Jupiter because of what they had learned about Earth's own magnetic fields.

The arrival at Jupiter of NASA's Juno spacecraft in July 2016 provided images of the polar cap and aurora. But those images, along with some captured by the Hubble Space Telescope, couldn't resolve the disagreement among scientists about open lines versus closed lines.

So Delamere and the rest of the research team used computer modelling for help. Their research revealed a largely closed polar region with a small crescent-shaped area of open flux, accounting for only about 9 percent of the polar cap region. The rest was active with aurora, signifying closed magnetic field lines.

Jupiter, it turns out, possesses a mix of open and closed lines in its polar caps.

"There was no model or no understanding to explain how you could have a crescent of open flux like this simulation is producing," he said. "It just never even entered my mind. I don't think anybody in the community could have imagined this solution. Yet this simulation has produced it."

"To me, this is a major paradigm shift for the way that we understand magnetospheres."

What else does this reveal? More work for researchers.

"It raises many questions about how the solar wind interacts with Jupiter's magnetosphere and influences the dynamics," Delamere said.

Jupiter's aurorally active polar cap could, for example, be due to the rapidity of the planet's rotation -- once every 10 hours compared to Earth's once every 24 hours -- and the enormity of its magnetosphere. Both reduce the impact of the solar wind, meaning the polar cap magnetic field lines are less likely to be torn apart to become open lines.

And to what extent does Jupiter's moon Io affect the magnetic lines within Jupiter's polar cap? Io is electrodynamically linked to Jupiter, something unique in our solar system, and as such is constantly stripped of heavy ions by its parent planet.

As the paper notes, "The jury is still out on the magnetic structure of Jupiter's magnetosphere and what exactly its aurora is telling us about its topology."

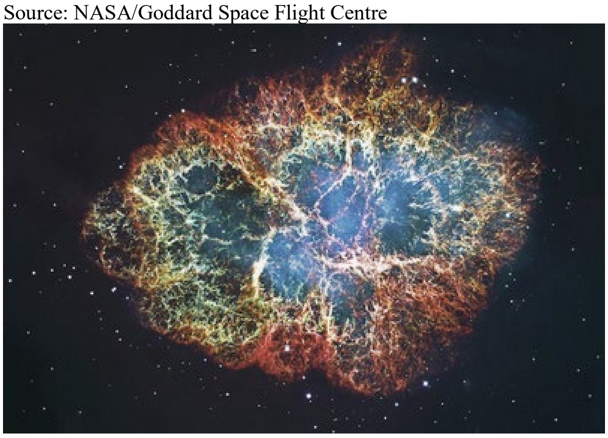
- Amounts of organic molecules in planetary systems differ from early on

Date: April 9, 2021
Source: RIKEN

An international group of scientists led by the RIKEN Cluster for Pioneering Research have studied the chemical composition of 50 protoplanetary-disk forming regions in the Perseus Molecular Cloud, and found that despite being in the same cloud, the amounts of complex organic molecules they contain are quite different. Interestingly, the chemically rich young disks have similar compositions of organic molecules. These findings raise an important question: do solar-like systems share a common chemistry at birth?
It was once believed that complex organic molecules were rare in the universe, and that this rarity might be a reason we have not found evidence of life outside the earth. However, in the last two decades it has become clear that these molecules are common. According to Yao-Lun Yang, who led the research as a member of the Star and Planet Formation Laboratory in the RIKEN Cluster for Pioneering Research, and is now at the University of Virginia as a VICO Origins postdoctoral fellow, "Today, scientists have begun to systematically survey protoplanetary disks -- disks where planets eventually form around a star -- in the hope of determining how these molecules form, how common they are, and what impact they have on planetary systems."
Though scientists have looked at individual systems, there is little comparative data to understand these young stars as a group. The RIKEN-led group decided to use observations from the ALMA observatory in Chile, which thanks to its high resolution allows scientists to study chemical compounds in protoplanetary disks. The observations required more than three years to complete. The group surveyed the emission from organic molecules at specific frequencies in very young disks. They looked at methanol and acetonitrile, as well as two larger molecules, methyl formate and dimethyl ether. They found that different regions had large variation in the abundance of methanol and acetonitrile, though intriguingly, the relative abundance between the two species was remarkably similar. According to Yang, "This implies that there is a common production mechanism of these two molecules, and this give us important hints on how they form in space." In addition, the abundances of methyl formate and dimethyl ether tended to be higher relative to methanol in denser regions, hinting that there is something about the denser conditions that allows them to be abundant. Their findings were published by the American Astronomical Society last week in The *Astrophysical Journal*.
According to Nami Sakai, leader of the Star and Planet Formation Laboratory, "This raises important questions regarding how special the chemical environment of the infant Solar system is. We will be able to answer this question in the future by examining the chemical evolution of the gas surrounding young protostars. We hope that such knowledge will be a base for understanding the origin of life on the Earth.

- NASA's NICER finds X-ray boosts in the Crab Pulsar's radio bursts

Date: April 8, 2021
Source: NASA/Goddard Space Flight Centre



Crab Nebula (stock image; elements furnished by NASA).
Credit: © allexxandarx / stock.adobe.com

A global science collaboration using data from NASA's Neutron star Interior Composition Explorer (NICER) telescope on the International Space Station has discovered X-ray surges accompanying radio bursts from the pulsar in the Crab Nebula. The finding shows that these bursts, called giant radio pulses, release far more energy than previously suspected.
A pulsar is a type of rapidly spinning neutron star, the crushed, city-sized core of a star that exploded as a supernova. A young, isolated neutron star can spin dozens of times each second, and its whirling magnetic field powers beams of radio waves, visible light, X-rays, and gamma rays. If these beams sweep past Earth, astronomers observe clock-like pulses of emission and classify the object as a pulsar. "Out of more than 2,800 pulsars catalogued, the Crab pulsar is one of only a few that emit giant radio pulses, which occur sporadically and can be hundreds to thousands of times brighter than the regular pulses," said lead scientist Teruaki Enoto at the RIKEN Cluster for Pioneering Research in Wako, Saitama

prefecture, Japan. "After decades of observations, only the Crab has been shown to enhance its giant radio pulses with emission from other parts of the spectrum."

The new study, which will appear in the April 9 edition of *Science* and is now available online, analysed the largest amount of simultaneous X-ray and radio data ever collected from a pulsar. It extends the observed energy range associated with this enhancement phenomenon by thousands of times.

Located about 6,500 light-years away in the constellation Taurus, the Crab Nebula and its pulsar formed in a supernova whose light reached Earth in July 1054. The neutron star spins 30 times each second, and at X-ray and radio wavelengths it is among the brightest pulsars in the sky.

Between August 2017 and August 2019, Enoto and his colleagues used NICER to repeatedly observe the Crab pulsar in X-rays with energies up to 10,000 electron volts, or thousands of times that of visible light. While NICER was watching, the team also studied the object using at least one of two ground-based radio telescopes in Japan -- the 34-meter dish at the Kashima Space Technology Centre and the 64-meter dish at the Japan Aerospace Exploration Agency's Usuda Deep Space Centre, both operating at a frequency of 2 gigahertz.

he combined dataset effectively gave the researchers nearly a day and a half of simultaneous X-ray and radio coverage. All told, they captured activity across 3.7 million pulsar rotations and netted some 26,000 giant radio pulses.

Giant pulses erupt quickly, spiking in millionths of a second, and occur unpredictably. However, when they occur, they coincide with the regular clockwork pulsations.

NICER records the arrival time of every X-ray it detects to within 100 nanoseconds, but the telescope's timing precision isn't its only advantage for this study.

"NICER's capacity for observing bright X-ray sources is nearly four times greater than the combined brightness of both the pulsar and its nebula," said Zaven Arzoumanian, the project's science lead at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "So these observations were largely unaffected by pileup -- where a detector counts two or more X-rays as a single event -- and other issues that have complicated earlier analyses."

Enoto's team combined all of the X-ray data that coincided with giant radio pulses, revealing an X-ray boost of about 4% that occurred in synch with them. It's remarkably similar to the 3% rise in visible light also associated with the phenomenon, discovered in 2003. Compared to the brightness difference between the Crab's regular and giant pulses, these changes are remarkably small and provide a challenge for theoretical models to explain.

The enhancements suggest that giant pulses are a manifestation of underlying processes that produce emission spanning the electromagnetic spectrum, from radio to X-rays. And because X-rays pack millions of times the punch of radio waves, even a modest increase represents a large energy contribution. The researchers conclude that the total emitted energy associated with a giant pulse is dozens to hundreds of times higher than previously estimated from the radio and optical data alone.

"We still don't understand how or where pulsars produce their complex and wide-ranging emission, and it's gratifying to have contributed another piece to the multiwavelength puzzle of these fascinating objects," Enoto said.

NICER is an Astrophysics Mission of Opportunity within NASA's Explorers program, which provides frequent flight opportunities for world-class scientific investigations from space utilizing innovative, streamlined and efficient management approaches within the heliophysics and astrophysics science areas. NASA's Space Technology Mission Directorate supports the SEXTANT component of the mission, demonstrating pulsar-based spacecraft navigation.

- ❖ Discovery of rare 'quadruply imaged quasars' can help solve cosmological puzzles

Date: April 8, 2021
Source: California Institute of Technology

With the help of machine-learning techniques, a team of astronomers has discovered a dozen quasars that have been warped by a naturally occurring cosmic "lens" and split into four similar images. Quasars are extremely luminous cores of distant galaxies that are powered by supermassive black holes.

Over the past four decades, astronomers had found about 50 of these "quadruply imaged quasars," or quads for short, which occur when the gravity of a massive galaxy that happens to sit in front of a quasar splits its single image into four. The latest study, which spanned only a year and a half, increases the number of known quads by about 25 percent and demonstrates the power of machine learning to assist astronomers in their search for these cosmic oddities.

"The quads are gold mines for all sorts of questions. They can help determine the expansion rate of the universe, and help address other mysteries, such as dark matter and quasar 'central engines,'" says Daniel Stern, lead author of the new study and a research scientist at the Jet Propulsion Laboratory, which is managed by Caltech for NASA. "They are not just needles in a haystack but Swiss Army knives because they have so many uses."

The findings, to be published in *The Astrophysical Journal*, were made by combining machine-learning tools with data from several ground- and space-based telescopes, including the European Space Agency's Gaia mission; NASA's Wide-field Infrared Survey Explorer (or WISE); the W. M. Keck Observatory on Maunakea, Hawaii; Caltech's Palomar Observatory; the European Southern Observatory's New Technology Telescope in Chile; and the Gemini South telescope in Chile.

Cosmological Dilemma

In recent years, a discrepancy has emerged over the precise value of the universe's expansion rate, also known as Hubble's constant. Two primary means can be used to determine this number: one relies on measurements of the distance and speed of objects in our local universe, and the other extrapolates the rate from models based on distant radiation left over from the birth of our universe, called the cosmic microwave background. The problem is that the numbers do not match.

"There are potentially systematic errors in the measurements, but that is looking less and less likely," says Stern. "More enticingly, the discrepancy in the values could mean that something about our model of the universe is wrong and there is new physics to discover."

The new quasar quads, which the team gave nicknames such as Wolf's Paw and Dragon Kite, will help in future calculations of Hubble's constant and may illuminate why the two primary measurements are not in alignment. The quasars lie in between the local and distant targets used for the previous calculations, so they give astronomers a way to probe the intermediate range of the universe. A quasar-based determination of Hubble's constant could indicate which of the two values is correct, or, perhaps more interestingly, could show that the constant lies somewhere between the locally determined and distant value, a possible sign of previously unknown physics.

Gravitational Illusions

The multiplication of quasar images and other objects in the cosmos occurs when the gravity of a foreground object, such as a galaxy, bends and magnifies the light of objects behind it. The phenomenon, called gravitational lensing, has been seen many times before. Sometimes quasars are lensed into two similar images; less commonly, they are lensed into four.

"Quads are better than the doubly imaged quasars for cosmology studies, such as measuring the distance to objects, because they can be exquisitely well modelled," says co-author George Djorgovski, professor of astronomy and data science at Caltech. "They are relatively clean laboratories for making these cosmological measurements."

In the new study, the researchers used data from WISE, which has relatively coarse resolution, to find likely quasars, and then used the sharp resolution of Gaia to identify which of the WISE quasars were associated with possible quadruply imaged quasars. The researchers then applied machine-learning tools to pick out which candidates were most likely multiply imaged sources and not just different stars sitting close to each other in the sky. Follow-up observations by Keck, Palomar, the New Technology Telescope, and Gemini-South confirmed which of the objects were indeed quadruply imaged quasars lying billions of light-years away.

Humans and Machines Working Together

The first quad found with the help of machine learning, nicknamed Centaurus' Victory, was confirmed during an all-nighter the team spent at Caltech, with collaborators from Belgium, France, and Germany, while using a dedicated computer in Brazil, recalls co-author Alberto Krone-Martins of UC Irvine. The team had been remotely observing their objects using the Keck Observatory.

"Machine learning was key to our study but it is not meant to replace human decisions," explains Krone-Martins. "We continuously train and update the models in an ongoing learning loop, such that humans and the human expertise are an essential part of the loop. When we talk about 'AI' in reference to machine-learning tools like these, it stands for Augmented Intelligence not Artificial Intelligence."
"Alberto not only initially came up with the clever machine-learning algorithms for this project, but it was his idea to use the Gaia data, something that had not been done before for this type of project," says Djorgovski. "This story is not just about finding interesting gravitational lenses," he says, "but also about how a combination of big data and machine learning can lead to new discoveries."

- More than 5,000 tons of extra-terrestrial dust fall to Earth each year

Date: April 8, 2021
Source: CNRS

Meteor shower illustration (stock image).
Credit: © Paulista / stock.adobe.com

Every year, our planet encounters dust from comets and asteroids. These interplanetary dust particles pass through our atmosphere and give rise to shooting stars. Some of them reach the ground in the form of micrometeorites. An international program conducted for nearly 20 years by scientists from the CNRS, the Université Paris-Saclay and the National museum of natural history with the support of the French polar institute, has determined that 5,200 tons per year of these micrometeorites reach the ground. The study will be available in the journal *Earth & Planetary Science Letters* from April 15.
Micrometeorites have always fallen on our planet. These interplanetary dust particles from comets or asteroids are particles of a few tenths to hundredths of a millimetre that have passed through the atmosphere and reached the Earth's surface.
To collect and analyse these micrometeorites, six expeditions led by CNRS researcher Jean Duprat have taken place over the last two decades near the Franco-Italian Concordia station (Dome C), which is located 1,100 kilometres off the coast of Adélie Land, in the heart of Antarctica. Dome C is an ideal collection spot due to the low accumulation rate of snow and the near absence of terrestrial dust.
These expeditions have collected enough extra-terrestrial particles (ranging from 30 to 200 micrometres in size), to measure their annual flux, which corresponds to the mass accreted on Earth per square metre per year. If these results are applied to the whole planet, the total annual flux of micrometeorites represents 5,200 tons per year. This is the main source of extra-terrestrial matter on our planet, far ahead of larger objects such as meteorites, for which the flux is less than ten tons per year.
A comparison of the flux of micrometeorites with theoretical predictions confirms that most micrometeorites probably come from comets (80%) and the rest from asteroids.
This is valuable information to better understand the role played by these interplanetary dust particles in supplying water and carbonaceous molecules on the young Earth.

Notes

1. Comets are made of dust and ice. They come from far distances, from the Kuiper belt to the outer reaches of the Solar System. As they approach the Sun, comets become active through the sublimation of their ices and release cometary dust.
2. An asteroid is a mainly rocky celestial body of between a few hundred metres to several kilometres in size. The majority of these bodies are located in the asteroid belt between Mars and Jupiter.
3. This program has received funding from the IPEV, the CNRS, the CNES, the ANR, the Domaine d'intérêt majeur ACAV+, which supports research in the Ile-de-France region in the fields of astrophysics and the conditions of the appearance of life, as well as from LabEx P2IO. The French Polar Institute (IPEV) and its Italian counterpart (PNRA) provided the

logistical support needed to carry out the field collection program.

4. The French laboratories involved are: the Laboratoire de physique des deux infinis -- Irène Joliot-Curie (CNRS / Université Paris-Saclay / Université de Paris), the Institut de minéralogie, de physique des matériaux et de cosmochimie (CNRS / National museum of natural history / Université Sorbonne) and the Institut des sciences moléculaires d'Orsay (CNRS / Université Paris-Saclay). Three foreign laboratories are also involved: the Catholic University of America and NASA's Goddard Space Flight Centre in the United States, and the University of Leeds in the United Kingdom.
5. 1 micrometre (µm) is equal to 0.001 millimetres, or one thousandth of a millimetre.

- First transiting exoplanet's 'chemical fingerprint' reveals its distant birthplace

Date: April 7, 2021
Source: University of Warwick

Astronomers have found evidence that the first exoplanet that was identified transiting its star could have migrated to a close orbit with its star from its original birthplace further away.

Analysis of the planet's atmosphere by a team including University of Warwick scientists has identified the chemical fingerprint of a planet that formed much further away from its sun than it currently resides. It confirms previous thinking that the planet has moved to its current position after forming, a mere 7 million km from its sun or the equivalent of 1/20th the distance from the Earth to our Sun.

The conclusions are published today (7 April) in the journal *Nature* by an international team of astronomers. The University of Warwick led the modelling and interpretation of the results which mark the first time that as many as six molecules in the atmosphere of an exoplanet have been measured to determine its composition.

It is also the first time that astronomers have used these six molecules to definitively pinpoint the location at which these hot, giant planets form thanks to the composition of their atmospheres.

With new, more powerful telescopes coming online soon, their technique could also be used to study the chemistry of exoplanets that could potentially host life.

This latest research used the Telescopio Nazionale Galileo in La Palma, Spain, to acquire high-resolution spectra of the atmosphere of the exoplanet HD 209458b as it passed in front of its host star on four separate occasions. The light from the star is altered as it passes through the planet's atmosphere and by analysing the differences in the resulting spectrum astronomers can determine what chemicals are present and their abundances.

For the first time, astronomers were able to detect hydrogen cyanide, methane, ammonia, acetylene, carbon monoxide and low amounts of water vapour in the atmosphere of HD 209458b. The unexpected abundance of carbon-based molecules (hydrogen cyanide, methane, acetylene and carbon monoxide) suggests that there are approximately as many carbon atoms as oxygen atoms in the atmosphere, double the carbon expected. This suggests that the planet has preferentially accreted gas rich in carbon during formation, which is only possible if it orbited much further out from its star when it originally formed, most likely at a similar distance to Jupiter or Saturn in our own solar system.

Dr Siddharth Gandhi of the University of Warwick Department of Physics said: "The key chemicals are carbon-bearing and nitrogen-bearing species. If these species are at the level we've detected them, this is indicative of an atmosphere that is enriched in carbon compared to oxygen. We've used these six-chemical species for the first time to narrow down where in its protoplanetary disc it would have originally formed.

"There is no way that a planet would form with an atmosphere so rich in carbon if it is within the condensation line of water vapour. At the very hot temperature of this planet (1,500K), if the atmosphere contains all the elements in the same proportion as in the parent star, oxygen should be twice more abundant than carbon and mostly bonded with hydrogen to form water or to carbon to form carbon monoxide. Our very different finding agrees with the current understanding that hot Jupiters like HD 209458b formed far away from their current location."

Using models of planetary formation, the astronomers compared HD 209458b's chemical fingerprint with what they would expect to see for a planet of that type.

A solar system begins life as a disc of material surrounding the star which gathers together to form the solid cores of planets, which then accrete gaseous material to form an atmosphere. Close to the star where it is hotter, a large proportion of oxygen remains in the atmosphere in water vapour. Further out, as it gets cooler, that water condenses to become ice and is locked into a planet's core, leaving an atmosphere more heavily comprised of carbon- and nitrogen-based molecules. Therefore, planets orbiting close to the sun are expected to have atmospheres rich in oxygen, rather than carbon.

HD 209458b was the first exoplanet to be identified using the transit method, by observing it as it passed in front of its star. It has been the subject of many studies, but this is the first time that six individual molecules have been measured in its atmosphere to create a detailed 'chemical fingerprint'.

Dr Matteo Brogi from the University of Warwick team adds: "By scaling up these observations, we'll be able to tell what classes of planet we have out there in terms of their formation location and early evolution. It's really important that we don't work under the assumptions that there is only a couple of molecular species that are important to determine the spectra of these planets, as has frequently been done before. Detecting as many molecules as possible is useful when we move on to testing this technique on planets with conditions that are amenable for hosting life, because we will need to have a full portfolio of chemical species we can detect."

Paolo Giacobbe, researcher at the Italian National Institute for Astrophysics (INAF) and lead author of the paper, said: "If this discovery were a novel it would begin with 'In the beginning there was only water...' because the vast majority of the inference on exoplanet atmospheres from near-infrared observations was based on the presence (or absence) of water vapour, which dominates this region of the spectrum. We asked ourselves: is it really possible that all the other species expected from theory do not leave any measurable trace? Discovering that it is possible to detect them, thanks to our efforts in improving analysis techniques, opens new horizons to be explored."

- ❖ Caught speeding: Clocking the fastest-spinning brown dwarfs

Gemini North observations help set rotational speed limit for brown dwarfs

Date: April 8, 2021
Source: Association of Universities for Research in Astronomy (AURA)

Astronomers at Western University have discovered the most rapidly rotating brown dwarfs known. They found three brown dwarfs that each complete a full rotation roughly once every hour. That rate is so extreme that if these "failed stars" rotated any faster, they could come close to tearing themselves apart. Identified by NASA's Spitzer Space Telescope, the brown dwarfs were then studied by ground-based telescopes including Gemini North, which confirmed their surprisingly speedy rotation.

Three brown dwarfs have been discovered spinning faster than any other found before. Astronomers at Western University in Canada first measured the rotation speeds of these brown dwarfs using NASA's Spitzer Space Telescope and confirmed them with follow-up observations with the Gemini North telescope on Maunakea in Hawai'i and the Carnegie Institution for Science's Magellan Baade telescope in Chile. Gemini North is one of the pair of telescopes that make up the international Gemini Observatory, a Program of NSF's NOIRLab.

"We seem to have come across a speed limit on the rotation of brown dwarfs," said Megan Tannock, the Western University physics and astronomy graduate student who led the discovery. "Despite extensive searches, by our own team and others, no brown dwarfs have been found to rotate any faster. In fact, faster spins may lead to a brown dwarf tearing itself apart."

Brown dwarfs are, simply put, failed stars. They form like stars but are less massive and more like giant planets [1].

Tannock and Western University astronomer Stanimir Metchev worked with international collaborators to find three rapidly rotating brown dwarfs spinning around their axes once every hour. This is approximately 10 times faster than normal [2], and about 30 percent faster than the most rapid rotations previously measured in such objects.

The astronomers used large ground-based telescopes, Gemini North in Hawai'i and Magellan Baade in Chile, to confirm the rapid rotations. They did this by measuring alterations in the brown dwarfs' light caused by the Doppler effect and using a computer model to match those alterations to spin rates [3]. The researchers found that these brown dwarfs spin with speeds of about 350,000 kilometres per hour (around 220,000 miles per

hour) at their equator, which is 10 times faster than Jupiter.
"These unusual brown dwarfs are spinning at dizzying speeds," said Sandy Leggett, an astronomer at Gemini North who studies brown dwarfs. "At about 350,000 kilometres per hour, the relatively weak gravity of the brown dwarfs is barely holding them together. This exciting discovery by the Tannock team has identified rotational limits beyond which these objects may not exist."
The team first identified the rapid rotation rates by using NASA's Spitzer Space Telescope to measure how quickly the brightness of the objects varied. "Brown dwarfs, like planets with atmospheres, can have large weather storms that affect their visible brightness," explained Metchev. "The observed brightness variations show how frequently the same storms are seen as the object spins, which reveals the brown dwarf's spin period."
The team's results will appear in an upcoming issue of *The Astronomical Journal*.
Notes
[1] There are four known giant planets in the Solar System: Jupiter, Saturn, Uranus, and Neptune.
[2] Stars, brown dwarfs, and planets generally spin around their axis once every 10 hours or more slowly. For example, Earth spins around its axis once every 24 hours while Jupiter and Saturn take about 10 hours. The Sun spins around its axis on average every 27 days. The Sun's rotation rate varies with latitude, with its equatorial regions completing a rotation in about 25 days and the polar regions rotating once in approximately 35 days.
[3] As each brown dwarf rotates, light from the hemisphere turning toward us appears blue shifted while light from the hemisphere turning away from us appears redshifted because of the Doppler effect. This causes absorption lines in the brown dwarf's spectrum to appear broadened (stretched both toward the red end of the spectrum and the blue end of the spectrum). By matching this broadening to a computer model, the astronomers determined how fast each brown dwarf is spinning.

- First X-rays from Uranus discovered

Date: March 31, 2021
Source: Harvard-Smithsonian Centre for Astrophysics

Uranus illustration (stock image).
Credit: © revers_jr / stock.adobe.com

Astronomers have detected X-rays from Uranus for the first time, using NASA's Chandra X-ray Observatory. This result may help scientists learn more about this enigmatic ice giant planet in our solar system.
Uranus is the seventh planet from the Sun and has two sets of rings around its equator. The planet, which has four times the diameter of Earth, rotates on its side, making it different from all other planets in the solar system. Since Voyager 2 was the only spacecraft to ever fly by Uranus, astronomers currently rely on telescopes much closer to Earth, like Chandra and the Hubble Space Telescope, to learn about this distant and cold planet that is made up almost entirely of hydrogen and helium.
In the new study, researchers used Chandra observations taken in Uranus in 2002 and then again in 2017. They saw a clear detection of X-rays from the first observation, just analysed recently, and a possible flare of X-rays in those obtained fifteen years later. The main graphic shows a Chandra X-ray image of Uranus from 2002 (in pink) superimposed on an optical image from the Keck-I Telescope obtained in a separate study in 2004. The latter shows the planet at approximately the same orientation as it was during the 2002 Chandra observations.
What could cause Uranus to emit X-rays? The answer: mainly the Sun. Astronomers have observed that both Jupiter and Saturn scatter X-ray light given off by the Sun, similar to how Earth's atmosphere scatters the Sun's light. While the authors of the new Uranus study initially expected that most of the X-rays detected would also be from scattering, there are tantalizing hints that at least one other source of X-rays is present. If further observations confirm this, it could have intriguing implications for understanding Uranus.
One possibility is that the rings of Uranus are producing X-rays themselves, which is the

case for Saturn's rings. Uranus is surrounded by charged particles such as electrons and protons in its nearby space environment. If these energetic particles collide with the rings, they could cause the rings to glow in X-rays. Another possibility is that at least some of the X-rays come from auroras on Uranus, a phenomenon that has previously been observed on this planet at other wavelengths. On Earth, we can see colourful light shows in the sky called auroras, which happen when high-energy particles interact with the atmosphere. X-rays are emitted in Earth's auroras, produced by energetic electrons after they travel down the planet's magnetic field lines to its poles and are slowed down by the atmosphere. Jupiter has auroras, too. The X-rays from auroras on Jupiter come from two sources: electrons traveling down magnetic field lines, as on Earth, and positively charged atoms and molecules raining down at Jupiter's polar regions. However, scientists are less certain about what causes auroras on Uranus. Chandra's observations may help figure out this mystery.

Uranus is an especially interesting target for X-ray observations because of the unusual orientations of its spin axis and its magnetic field. While the rotation and magnetic field axes of the other planets of the solar system are almost perpendicular to the plane of their orbit, the rotation axis of Uranus is nearly parallel to its path around the Sun. Furthermore, while Uranus is tilted on its side, its magnetic field is tilted by a different amount, and offset from the planet's centre. This may cause its auroras to be unusually complex and variable. Determining the sources of the X-rays from Uranus could help astronomers better understand how more exotic objects in space, such as growing black holes and neutron stars, emit X-rays.

A paper describing these results appears in the most recent issue of the *Journal of Geophysical Research*. The authors are William Dunn (University College London, United Kingdom), Jan-Uwe Ness (University of Marseille, France), Laurent Lamy (Paris Observatory, France), Grant Tremblay (Centre for Astrophysics | Harvard & Smithsonian), Graziella Branduardi-Raymont (University College London), Bradford Snios (CfA), Ralph Kraft (CfA), Z. Yao (Chinese Academy of Sciences, Beijing), Affelia Wibisono (University College London).

NASA's Marshall Space Flight Centre manages the Chandra program. The Smithsonian Astrophysical Observatory's Chandra X-ray Centre controls science from Cambridge Massachusetts and flight operations from Burlington, Massachusetts.

- New study sows doubt about the composition of 70 percent of our universe

Date: March 31, 2021
Source: University of Copenhagen - Faculty of Science

Until now, researchers have believed that dark energy accounted for nearly 70 percent of the ever-accelerating, expanding universe.

For many years, this mechanism has been associated with the so-called cosmological constant, developed by Einstein in 1917, that refers to an unknown repellent cosmic power. But because the cosmological constant -- known as dark energy -- cannot be measured directly, numerous researchers, including Einstein, have doubted its existence -- without being able to suggest a viable alternative. Until now. In a new study by researchers at the University of Copenhagen, a model was tested that replaces dark energy with a dark matter in the form of magnetic forces.

"If what we discovered is accurate, it would upend our belief that what we thought made up 70 percent of the universe does not actually exist. We have removed dark energy from the equation and added in a few more properties for dark matter. This appears to have the same effect upon the universe's expansion as dark energy," explains Steen Harle Hansen, an associate professor at the Niels Bohr Institute's DARK Cosmology Centre.

The universe expands no differently without dark energy

The usual understanding of how the universe's energy is distributed is that it consists of five percent normal matter, 25 percent dark matter and 70 percent dark energy.

In the UCPH researchers' new model, the 25 percent share of dark matter is accorded special qualities that make the 70 percent of dark energy redundant.

"We don't know much about dark matter other than that it is a heavy and slow particle. But then we wondered -- what if dark matter had some quality that was analogous to magnetism in it? We know that as normal particles move around, they create magnetism. And, magnets attract or repel other magnets -- so what if that's what's going on in the universe? That this constant expansion of dark matter is occurring thanks to some sort of magnetic force?" asks Steen Hansen.

Computer model tests dark matter with a type of magnetic energy

Hansen's question served as the foundation for the new computer model, where researchers included everything that they know about the universe -- including gravity, the speed of the universe's expansion and X, the unknown force that expands the universe.

"We developed a model that worked from the assumption that dark matter particles have a type of magnetic force and investigated what effect this force would have on the universe. It turns out that it would have exactly the same effect on the speed of the university's expansion as we know from dark energy," explains Steen Hansen.

However, there remains much about this mechanism that has yet to be understood by the researchers.

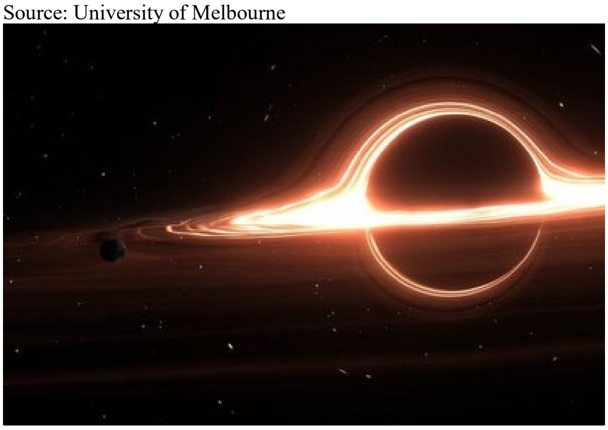
And it all needs to be checked in better models that take more factors into consideration. As Hansen puts it:

"Honestly, our discovery may just be a coincidence. But if it isn't, it is truly incredible. It would change our understanding of the universe's composition and why it is expanding. As far as our current knowledge, our ideas about dark matter with a type of magnetic force and the idea about dark energy are equally wild. Only more detailed observations will determine which of these models is the more realistic. So, it will be incredibly exciting to retest our result.

- Black hole key to galaxies' behemoths

Early universe explosion sheds light on elusive black hole

Date: March 29, 2021
Source: University of Melbourne



Black hole illustration (stock image; elements furnished by NASA). *Credit: © PatinyaS. / stock.adobe.com*

A new black hole breaks the record -- not for being the smallest or the biggest -- but for being right in the middle. The recently discovered 'Goldilocks' black hole is part of a missing link between two populations of black holes: small black holes made from stars and supermassive giants in the nucleus of most galaxies.

In a joint effort, researchers from the University of Melbourne and Monash University have uncovered a black hole approximately 55,000 times the mass of the sun, a fabled "intermediate-mass" black hole.

The discovery was published today in the paper "Evidence for an intermediate mass black hole from a gravitationally lensed gamma-ray burst" in the journal *Nature Astronomy*.

Lead author and University of Melbourne PhD student, James Paynter, said the latest discovery sheds new light on how supermassive black holes form. "While we know that these supermassive black holes lurk in the cores of most, if not all galaxies, we don't understand how these behemoths are able to grow so large within the age of the Universe," he said.

The new black hole was found through the detection of a gravitationally lensed gamma-ray burst. The gamma-ray burst, a half-second flash of high-energy light emitted by a pair of merging stars, was observed to have a tell-tale 'echo'. This echo is caused by the intervening intermediate-mass black hole, which bends the path of the light on its way to Earth, so that astronomers see the same flash twice.

Powerful software developed to detect black holes from gravitational waves was adapted to establish that the two flashes are images of the same object.

"This newly discovered black hole could be an ancient relic -- a primordial black hole -- created in the early Universe before the first stars and galaxies formed," said study co-author, Professor Eric Thrane from the Monash University School of Physics and Astronomy and Chief Investigator for the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav).

"These early black holes may be the seeds of the supermassive black holes that live in the hearts of galaxies today." Paper co-author, gravitational lensing pioneer, Professor Rachel Webster from the University of Melbourne, said the findings have the potential to help scientists make even greater strides.

"Using this new black hole candidate, we can estimate the total number of these objects in the Universe. We predicted that this might be

possible 30 years ago, and it is exciting to have discovered a strong example."
The researchers estimate that some 46,000 intermediate mass black holes are in the vicinity of our Milky Way galaxy.

- String theory solves mystery about how particles behave outside a black hole photon sphere

Date: March 29, 2021
Source: Kavli Institute for the Physics and Mathematics of the Universe
A paper by the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) Director Ooguri Hirosi and Project Researcher Matthew Dodelson on the string theoretical effects outside the black hole photon sphere has been selected for the "Editors' Suggestion" of the journal *Physical Review D.* Their paper was published on March 24, 2021.
In a quantum theory of point particles, a fundamental quantity is the correlation function, which measures the probability for a particle to propagate from one point to another. The correlation function develops singularities when the two points are connected by light-like trajectories. In a flat spacetime, there is such a unique trajectory, but when spacetime is curved, there can be many light-like trajectories connecting two points. This is a result of gravitational lensing, which describes the effect of curved geometry on the propagation of light.
In the case of a black hole spacetime, there are light-like trajectories winding around the black hole several times, resulting in a black hole photon sphere, as seen in the recent images by the Event Horizon Telescope (EHT) of the supermassive black hole at the centre of the galaxy M87.
Released on April 10, 2019, the EHT Collaboration's images captured the shadow of a black hole and its photon sphere, the ring of light surrounding it. A photon sphere can occur in a region of a black hole where light entering in a horizontal direction can be forced by gravity to travel in various orbits. These orbits lead to singularities in the aforementioned correlation function.
However, there are cases when the singularities generated by trajectories winding around a black hole multiple times contradict with physical expectations. Dodelson and Ooguri have shown that such singularities are resolved in string theory.
In string theory, every particle is considered as a particular excited state of a string. When the particle travels along a nearly light-like trajectory around a black hole, the spacetime curvature leads to tidal effects, which stretch the string.
Dodelson and Ooguri showed that, if one takes these effects into account, the singularities disappear consistently with physical expectations. Their result provides evidence that a consistent quantum gravity must contain extended objects such as strings as its degrees of freedom.
Ooguri says, "Our results show how string theoretical effects are enhanced near a black hole. Though the effects we found are not strong enough to have an observable consequence on ETH's black hole image, further research may show us a way to test string theory using black holes."