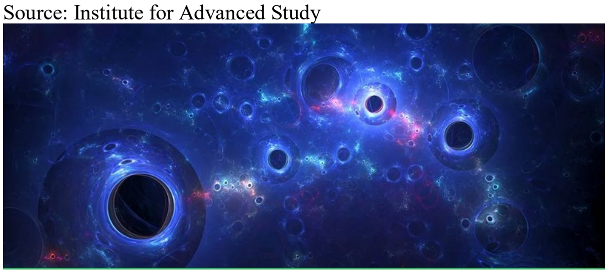
South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 554 – July 2nd 2021 Editor: Roger Burgess
THE MEETING IS CANCELLED DUE TO COVID-19

We have a virtual meeting Friday 2nd July Zoom Meeting 19:30 Ann Bonell Ladies of the Night.
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.

- Hubble data confirms galaxies lacking dark matter

Date: June 17, 2021
Source: Institute for Advanced Study



The most accurate distance measurement yet of ultra-diffuse galaxy (UDG) NGC1052-DF2 (DF2) confirms beyond any shadow of a doubt that it is lacking in dark matter. The newly measured distance of 22.1 +/-1.2 megaparsecs was obtained by an international team of researchers led by Zili Shen and Pieter van Dokkum of Yale University and Shany Danieli, a NASA Hubble Fellow at the Institute for Advanced Study.
"Determining an accurate distance to DF2 has been key in supporting our earlier results," stated Danieli. "The new measurement reported in this study has crucial implications for estimating the physical properties of the galaxy, thus confirming its lack of dark matter."
The results, published in *Astrophysical Journal Letters* on June 9, 2021, are based on 40 orbits of NASA's Hubble Space Telescope, with imaging by the Advanced Camera for Surveys and a "tip of the red giant branch" (TRGB) analysis, the gold standard for such refined measurements. In 2019, the team published results measuring the distance to neighbouring UDG NGC1052-DF4 (DF4) based on 12 Hubble orbits and TRGB analysis, which provided compelling evidence of missing dark matter. This preferred method expands on the team's 2018 studies that relied on "surface brightness fluctuations" to gauge distance. Both galaxies were discovered with the Dragonfly Telephoto Array at the New Mexico Skies observatory.
"We went out on a limb with our initial Hubble observations of this galaxy in 2018," van Dokkum said. "I think people were right to question it because it's such an unusual result. It would be nice if there were a simple explanation, like a wrong distance. But I think it's more fun and more interesting if it actually is a weird galaxy."
In addition to confirming earlier distance findings, the Hubble results indicated that the galaxies were located slightly farther away than previously thought, strengthening the case that they contain little to no dark matter. If DF2 were closer to Earth, as some astronomers claim, it would be intrinsically fainter and less massive, and the galaxy would need dark matter to account for the observed effects of the total mass.
Dark matter is widely considered to be an essential ingredient of galaxies, but this study lends further evidence that its presence may not be inevitable. While dark matter has yet to be directly observed, its gravitational influence is like a glue that holds galaxies together and governs the motion of visible matter. In the case of DF2 and DF4, researchers were able to account for the motion of stars based on stellar mass alone, suggesting a lack or absence of dark matter. Ironically, the detection of galaxies deficient in dark matter will likely help to reveal its puzzling nature and provide new insights into galactic evolution.
While DF2 and DF4 are both comparable in size to the Milky Way galaxy, their total

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masses are only about one percent of the Milky Way's mass. These ultra-diffuse galaxies were also found to have a large population of especially luminous globular clusters.
This research has generated a great deal of scholarly interest, as well as energetic debate among proponents of alternative theories to dark matter, such as Modified Newtonian dynamics (MOND). However, with the team's most recent findings -- including the relative distances of the two UDGs to NGC1052 -- such alternative theories seem less likely. Additionally, there is now little uncertainty in the team's distance measurements given the use of the TRGB method. Based on fundamental physics, this method depends on the observation of red giant stars that emit a flash after burning through their helium supply that always happens at the same brightness.
"There's a saying that extraordinary claims require extraordinary evidence, and the new distance measurement strongly supports our previous finding that DF2 is missing dark matter," stated Shen. "Now it's time to move beyond the distance debate and focus on how such galaxies came to exist."
Moving forward, researchers will continue to hunt for more of these oddball galaxies, while considering a number of questions such as: How are UDGs formed? What do they tell us about standard cosmological models? How common are these galaxies, and what other unique properties do they have? It will take uncovering many more dark matter-less galaxies to resolve these mysteries and the ultimate question of what dark matter really is.

- Mystery solved: Dust cloud led to Betelgeuse's 'Great Dimming'

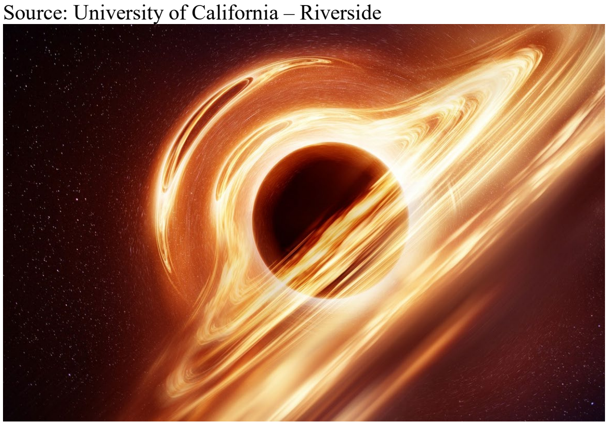
Date: June 16, 2021
Source: Harvard-Smithsonian Centre for Astrophysics

When Betelgeuse, a bright orange star in the constellation of Orion, lost more than two-thirds of its brightness in late 2019 and early 2020, astronomers were puzzled.
What could cause such an abrupt dimming? Now, in a new paper published Wednesday in *Nature*, an international team of astronomers reveal two never-before-seen images of the mysterious darkening -- and an explanation. The dimming was caused by a dusty veil shading the star, which resulted from a drop in temperature on Betelgeuse's stellar surface.
Led by Miguel Montargès at the Observatoire de Paris, the new images were taken in January and March of 2020 using the European Southern Observatory's Very Large Telescope. Combined with images previously taken in January and December 2019, the astronomers clearly capture how the stellar surface changed and darkened over time, especially in the southern region.
"For once, we were seeing the appearance of a star changing in real-time on a scale of weeks," Montargès says.
According to the astronomers, this abrupt dimming was caused by the formation of stardust.
Betelgeuse's surface regularly changes as giant bubbles of gas move, shrink and swell within the star. The team concludes that some time before the great dimming, the star ejected a large gas bubble that moved away from it, aided by the star's outward pulsation. When a patch of the surface cooled down shortly after, that temperature decrease was enough for the heavier elements (e.g. silicon) in the gas to condense into solid dust.
The new findings match Andrea Dupree's previous observations of Betelgeuse using the Hubble Space Telescope. Dupree, an astronomer at the Centre for Astrophysics | Harvard & Smithsonian and a co-author on the new paper, captured signs of dense, heated material moving through the star's atmosphere in the months leading up to the great dimming.
"With Hubble, we could see the material as it left the star's surface and moved out through the atmosphere, before the dust formed that caused the star to appear to dim," Dupree says.
Dupree found that the material moved about 200,000 miles per hour as it travelled from the star's surface to its outer atmosphere. Once the gas bubble was millions of miles from the hot star, it cooled and formed a dust cloud that temporarily blocked the star's light.
The star returned to its normal brightness by April 2020.
Dupree, who has been studying Betelgeuse since 1985, hopes to continue studying the star in hopes of catching it eject another gas bubble.
"Betelgeuse is a unique star; it is enormous and nearby and we are observing material directly leaving the surface of the supergiant," she says. "How and where material is ejected

affects our understanding of the evolution of all stars!"
Video 1:
https://www.youtube.com/watch?v=SK_A7fegeOw
Video 2:
https://www.youtube.com/watch?v=G6HEB6G4Ros

- How a supermassive black hole originates

Study points to a seed black hole produced by a dark matter halo collapse
Date: June 16, 2021
Source: University of California – Riverside



Supermassive black holes, or SMBHs, are black holes with masses that are several million to billion times the mass of our sun. The Milky Way hosts an SMBH with mass a few million times the solar mass. Surprisingly, astrophysical observations show that SMBHs already existed when the universe was very young. For example, a billion solar mass black holes are found when the universe was just 6% of its current age, 13.7 billion years. How do these SMBHs in the early universe originate?
A team led by a theoretical physicist at the University of California, Riverside, has come up with an explanation: a massive seed black hole that the collapse of a dark matter halo could produce.
Dark matter halo is the halo of invisible matter surrounding a galaxy or a cluster of galaxies. Although dark matter has never been detected in laboratories, physicists remain confident this mysterious matter that makes up 85% of the universe's matter exists. Were the visible matter of a galaxy not embedded in a dark matter halo, this matter would fly apart.
"Physicists are puzzled why SMBHs in the early universe, which are located in the central regions of dark matter halos, grow so massively in a short time," said Hai-Bo Yu, an associate professor of physics and astronomy at UC Riverside, who led the study that appears in *Astrophysical Journal Letters*. "It's like a 5-year-old child that weighs, say, 200 pounds. Such a child would astonish us all because we know the typical weight of a new born baby and how fast this baby can grow. Where it comes to black holes, physicists have general expectations about the mass of a seed black hole and its growth rate. The presence of SMBHs suggests these general expectations have been violated, requiring new knowledge. And that's exciting."
A seed black hole is a black hole at its initial stage -- akin to the baby stage in the life of a human.
"We can think of two reasons," Yu added. "The seed -- or 'baby' -- black hole is either much more massive or it grows much faster than we thought, or both. The question that then arises is what are the physical mechanisms for producing a massive enough seed black hole or achieving a fast enough growth rate?"
"It takes time for black holes to grow massive by accreting surrounding matter," said co-author Yi-Ming Zhong, a postdoctoral researcher at the Kavli Institute for Cosmological Physics at the University of Chicago. "Our paper shows that if dark matter has self-interactions then the gravothermal collapse of a halo can lead to a massive enough seed black hole. Its growth rate would be more consistent with general expectations."
In astrophysics, a popular mechanism used to explain SMBHs is the collapse of pristine gas in protogalaxies in the early universe.
"This mechanism, however, cannot produce a massive enough seed black hole to accommodate newly observed SMBHs -- unless the seed black hole experienced an extremely fast growth rate," Yu said. "Our work provides an alternative explanation: a self-interacting dark matter halo experiences gravothermal instability and its central region collapses into a seed black hole."
The explanation Yu and his colleagues propose works in the following way:
Dark matter particles first cluster together under the influence of gravity and form a dark matter halo. During the evolution of the halo, two competing forces -- gravity and pressure -- operate. While gravity pulls dark matter particles inward, pressure pushes them outward. If dark matter particles have no self-interactions, then, as gravity pulls them toward the central halo, they become hotter, that is, they move faster, the pressure increases

effectively, and they bounce back. However, in the case of self-interacting dark matter, dark matter self-interactions can transport the heat from those "hotter" particles to nearby colder ones. This makes it difficult for the dark matter particles to bounce back.
Yu explained that the central halo, which would collapse into a black hole, has angular momentum, meaning, it rotates. The self-interactions can induce viscosity, or "friction," that dissipates the angular momentum. During the collapse process, the central halo, which has a fixed mass, shrinks in radius and slows down in rotation due to viscosity. As the evolution continues, the central halo eventually collapses into a singular state: a seed black hole. This seed can grow more massive by accreting surrounding baryonic -- or visible -- matter such as gas and stars.
"The advantage of our scenario is that the mass of the seed black hole can be high since it is produced by the collapse of a dark matter halo," Yu said. "Thus, it can grow into a supermassive black hole in a relatively short timescale."
The new work is novel in that the researchers identify the importance of baryons -- ordinary atomic and molecular particles -- for this idea to work.
"First, we show the presence of baryons, such as gas and stars, can significantly speed up the onset of the gravothermal collapse of a halo and a seed black hole could be created early enough," said Wei-Xiang Feng, Yu's graduate student and a co-author on the paper. "Second, we show the self-interactions can induce viscosity that dissipates the angular momentum remnant of the central halo. Third, we develop a method to examine the condition for triggering general relativistic instability of the collapsed halo, which ensures a seed black hole could form if the condition is satisfied."
Over the past decade, Yu has explored novel predictions of dark matter self-interactions and their observational consequences. His work has shown that self-interacting dark matter can provide a good explanation for the observed motion of stars and gas in galaxies.
"In many galaxies, stars and gas dominate their central regions," he said. "Thus, it's natural to ask how the presence of this baryonic matter affects the collapse process. We show it will speed up the onset of the collapse. This feature is exactly what we need to explain the origin of supermassive black holes in the early universe. The self-interactions also lead to viscosity that can dissipate angular momentum of the central halo and further help the collapse process."

- EnVision will peer through Venus's thick clouds with radars and spectrometers.

ESA/VR2Planets/DamiaBouic

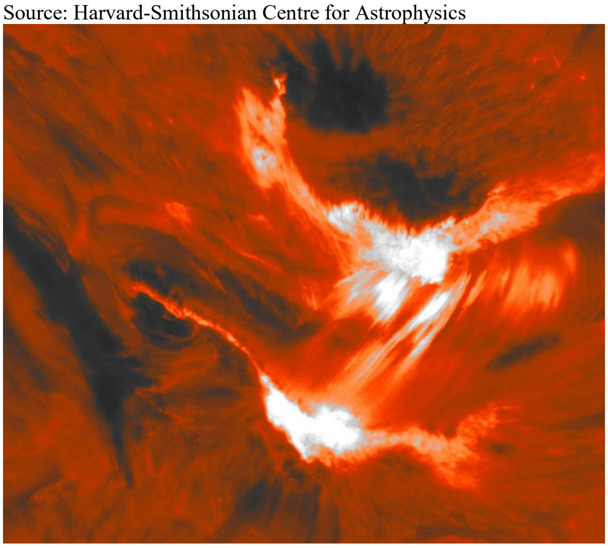
Mars is *so* last year. After NASA announced on 2 June that it will launch two probes to Venus before the end of the decade, the European Space Agency (ESA) today joined the party by selecting EnVision, another orbiter mission to our cloud-wrapped twin, for launch in 2031. The €610 million EnVision is the latest medium-class mission in ESA's science program.
Compared with Mars, Venus has seen fewer visits from robotic spacecraft, but increased interest in climate change and Earth-like exoplanets has prompted researchers to ask why Venus is now a scalding hot greenhouse oven with a sulfuric acid atmosphere, after starting out so similarly to Earth. ESA's Venus Express, which operated from 2006 to 2014, helped find hinds of ancient oceans and active volcanoes on the planet. Firming up that evidence is a key aim for EnVision, says lead scientist Richard Ghail of Royal Holloway, University of London. "The pattern of volcanoes tells us how the planet works," he says.
Although there is some overlap in the aims and instruments of the NASA and ESA missions, Ghail says, "They do all fit together and in a sense, they are in the right order." NASA's VERITAS will provide a detailed global map of the planet's topography, whereas DAVINCI+ will establish compositional "ground truth" by parachuting a probe through the atmosphere. EnVision will follow up by zooming in to understand how surface activity affects atmospheric dynamics, Ghail says.
Venus's thick cloud cover means optical cameras can't see much, but other

wavelengths can penetrate the murk. EnVision will use an infrared spectrometer to seek out hot spots on the surface that could indicate active volcanoes. It will use radar to map the surface, looking for signs of lava flows. Ultraviolet and high-resolution infrared spectrometers will then look for water vapor and sulphur dioxide emissions, to see whether smouldering volcanoes are driving cloud chemistry today.

Ghail thinks space agencies have recognized that Venus deserves the same layered approach used on Mars, where global mapping missions have been followed by more targeted observations. “The discovery by Venus Express that there may be volcanism,” he says, “has made it a more interesting place to be.”

- The give and take of mega-flares from stars

Date: June 16, 2021
Source: Harvard-Smithsonian Centre for Astrophysics



The long relationships between stars and the planets around them -- including the Sun and the Earth -- may be even more complex than previously thought. This is one conclusion of a new study involving thousands of stars using NASA's Chandra X-ray Observatory.

By conducting the largest survey ever of star-forming regions in X-rays, a team of researchers has helped outline the link between very powerful flares, or outbursts, from youthful stars, and the impact they could have on planets in orbit.

"Our work tells us how the Sun may have behaved and affected the young Earth billions of years ago," said Kostantin Getman of Pennsylvania State University in University Park, Pennsylvania who led the study. "In some ways, this is our ultimate origin story: how the Earth and Solar System came to be."

The scientists examined Chandra's X-ray data of more than 24,000 stars in 40 different regions where stars are forming. They captured over a thousand stars that gave off flares that are vastly more energetic than the most powerful flare ever observed by modern astronomers on the Sun, the "Solar Carrington Event" in 1859. "Super" flares are at least one hundred thousand times more energetic than the Carrington Event and "mega" flares up to 10 million times more energetic.

These powerful flares observed by Chandra in this work occur in all of the star-forming regions and among young stars of all different masses, including those similar to the Sun. They are also seen at all different stages in the evolution of young stars, ranging from early stages when the star is heavily embedded in dust and gas and surrounded by a large planet-forming disk, to later stages when planets would have formed and the disks are gone. The stars in the study have ages estimated to be less than 5 million years, compared to the Sun's age of 4.5 billion years.

The team found several super-flares occur per week for each young star, averaged over the whole sample, and about two mega-flares every year.

"We want to know what kinds of impact -- good and bad -- these flares have on the early lives of planets," said co-author Eric Feigelson, also of Penn State. "Flares this powerful can have major implications."

Over the past two decades, scientists have argued that these giant flares can help "give" planets to still-forming stars by driving gas away from disks of material that surround them. This can trigger the formation of pebbles and other small rocky material that is a crucial step for planets to form.

On the other hand, these flares may "take away" from planets that have already formed by blasting any atmospheres with powerful radiation, possibly resulting in their complete evaporation and destruction in less than 5 million years.

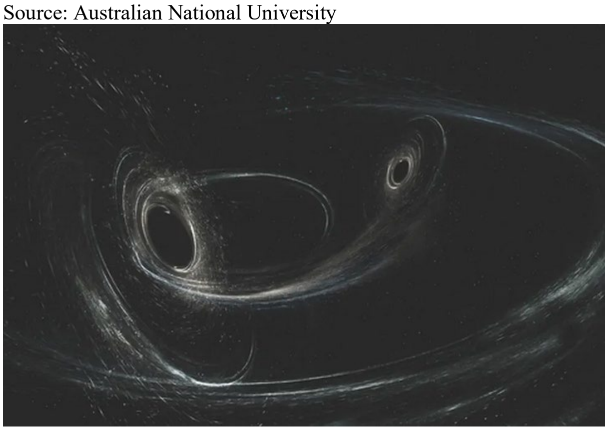
The researchers also performed detailed modelling of 55 bright super- and mega-flares and found that most of them resemble long-lasting flares seen on the Sun that produce "coronal mass ejections," powerful ejections of charged particles that can damage planetary atmospheres. The Solar Carrington Event involved such an ejection.

This work is also important for understanding the flares themselves. The team found that the properties of the flares, such as their brightness and frequency, are the same for

young stars with and without planet-forming disks. This implies that the flares are likely similar to those seen on the Sun, with loops of magnetic field having both footprints on the surface of the star, rather than one anchored to the disk and one to the star.
"We've found that these giant flares are like ones on the Sun but are just greatly magnified in energy and frequency, and the size of their magnetic loops," said co-author Gordon Garmire from the Huntingdon Institute for X-ray Astronomy in Huntingdon, Pennsylvania." Understanding these stellar outbursts may help us understand the most powerful flares and coronal mass ejections from the Sun."
Video:
https://www.youtube.com/watch?v=ydLScMtHD4I

- Gravitational wave search no hum drum hunt

Date: May 27, 2021
Source: Australian National University



The hunt for the never before heard "hum" of gravitational waves caused by mysterious neutron stars has just got a lot easier, thanks to an international team of researchers.
Gravitational waves have only been detected from black holes and neutron stars colliding, major cosmic events that cause huge bursts that ripple through space and time.
The research team, involving scientists from the LIGO Scientific Collaboration (LSC), Virgo Collaboration and the Centre for Gravitational Astrophysics (CGA) at The Australian National University (ANU), are now turning their eagle eye to spinning neutron stars to detect the waves.
Unlike the massive bursts caused by black holes or neutron stars colliding, the researchers say single spinning neutron stars have a bulge or "mountain" only a few millimetres high, which may produce a steady constant stream or "hum" of gravitational waves.
The researchers are using their methods that detected gravitational waves for the first time in 2015 to capture this steady soundtrack of the stars over the thunderous noise of massive black holes and dense neutron stars colliding. They say it's like trying to capture the squeak of a mouse in the middle of a stampeding herd of elephants.
If successful, it would be the first detection of a gravitational wave event that didn't involve the collision of massive objects like black holes or neutron stars.
ANU Distinguished Professor, Susan Scott from the ANU Research School of Physics, said the collision of dense neutron stars sent a "burst" of gravitational waves rippling through the Universe.
"Neutron stars are mystery objects," Professor Scott, also a Chief Investigator with the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav), said.
"We don't really understand what they are made up of, or how many types of them exist. But what we do know is that when they collide, they send incredible bursts of gravitational waves across the Universe.
"In contrast, the gentle hum of a spinning neutron star is very faint and almost impossible to detect."
Three new papers have just been published by the LSC and Virgo collaborations detailing the most sensitive searches to date for the faint hum of gravitational waves from spinning neutron stars.
Their work offers a "map to the potential El Dorado of gravitational waves."
"One of our searches targets young supernova remnants. These neutron stars, recently born, are more deformed, and should emit a stronger stream of gravitational waves," Dr Lilli Sun, from CGA and an Associate Investigator with OzGrav, said.
As these searches become more and more sensitive they are providing more detail than ever of the possible shape and make-up of neutron stars.
"If we can manage to detect this hum, we'll be able to look deep into the heart of a neutron star and unlock its secrets," Dr Karl Wette, a postdoctoral researcher with OzGrav and the CGA, said.
Professor Scott, who is also the leader of the General Relativity Theory and Data Analysis Group at ANU, added: "Neutron stars represent the densest form of matter in the Universe before a black hole will form."

"Searching for their gravitational waves allows us to probe nuclear matter states that simply can't be produced in laboratories on Earth."

- ALMA discovers earliest gigantic black hole storm

Date: June 16, 2021
Source: National Institutes of Natural Sciences

Researchers using the Atacama Large Millimetre/submillimetre Array (ALMA) discovered a titanic galactic wind driven by a supermassive black hole 13.1 billion years ago. This is the earliest-yet-observed example of such a wind to date and is a tell-tale sign that huge black holes have a profound effect on the growth of galaxies from the very early history of the Universe.
At the centre of many large galaxies hides a supermassive black hole that is millions to billions of times more massive than the Sun. Interestingly, the mass of the black hole is roughly proportional to the mass of the central region (bulge) of the galaxy in the nearby Universe. At first glance, this may seem obvious, but it is actually very strange. The reason is that the sizes of galaxies and black holes differ by about 10 orders of magnitude. Based on this proportional relationship between the masses of two objects that are so different in size, astronomers believe that galaxies and black holes grew and evolved together (coevolution) through some kind of physical interaction.
A galactic wind can provide this kind of physical interaction between black holes and galaxies. A supermassive black hole swallows a large amount of matter. As that matter begins to move at high speed due to the black hole's gravity it emits intense energy, which can push the surrounding matter outward. This is how the galactic wind is created.
"The question is when did galactic winds come into existence in the Universe?" says Takuma Izumi, the lead author of the research paper and a researcher at the National Astronomical Observatory of Japan (NAOJ). "This is an important question because it is related to an important problem in astronomy: how did galaxies and supermassive black holes coevolve?"
The research team first used NAOJ's Subaru Telescope to search for supermassive black holes. Thanks to its wide-field observation capability, they found more than 100 galaxies with supermassive black holes in the Universe more than 13 billion years ago.
Then, the research team utilized ALMA's high sensitivity to investigate the gas motion in the host galaxies of the black holes. ALMA observed a galaxy HSC J124353.93+010038.5 (hereafter J1243+0100), discovered by the Subaru Telescope, and captured radio waves emitted by the dust and carbon ions in the galaxy.
Detailed analysis of the ALMA data revealed that there is a high-speed gas flow moving at 500 km per second in J1243+0100. This gas flow has enough energy to push away the stellar material in the galaxy and stop the star formation activity. The gas flow found in this study is truly a galactic wind, and it is the oldest observed example of a galaxy with a huge wind of galactic size. The previous record holder was a galaxy about 13 billion years ago; so this observation pushes the start back another 100 million years.
The team also measured the motion of the quiet gas in J1243+0100, and estimated the mass of the galaxy's bulge, based on its gravitational balance, to be about 30 billion times that of the Sun. The mass of the galaxy's supermassive black hole, estimated by another method, was about 1% of that. The mass ratio of the bulge to the supermassive black hole in this galaxy is almost identical to the mass ratio of black holes to galaxies in the modern Universe. This implies that the coevolution of supermassive black holes and galaxies has been occurring since less than a billion years after the birth of the Universe.
"Our observations support recent high-precision computer simulations which have predicted that coevolutionary relationships were in place even at about 13 billion years ago," comments Izumi. "We are planning to observe a large number of such objects in the future, and hope to clarify whether or not the primordial coevolution seen in this object is an accurate picture of the general Universe at that time."

These observation results are presented as Takuma Izumi et al. "Subaru High-z Exploration of Low-Luminosity Quasars (SHELLQs). XIII. Large-scale Feedback and Star Formation in a Low-Luminosity Quasar at z = 7.07," in the *Astrophysical Journal* on June 14, 2021.

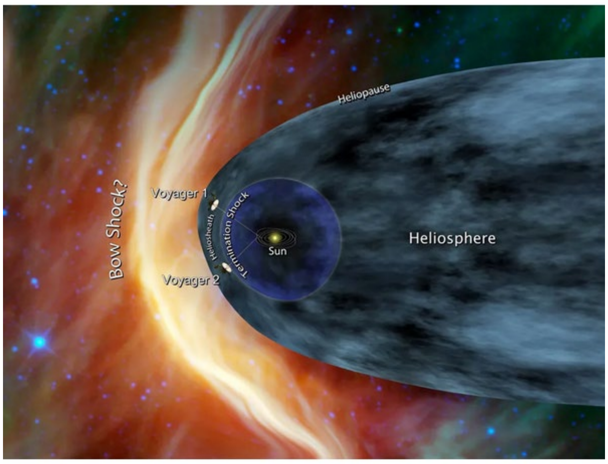
- ❖ Dark matter is slowing the spin of the Milky Way's galactic bar

Date: June 14, 2021
Source: University College London

The spin of the Milky Way's galactic bar, which is made up of billions of clustered stars, has slowed by about a quarter since its formation, according to a new study by researchers at University College London (UCL) and the University of Oxford.
For 30 years, astrophysicists have predicted such a slowdown, but this is the first time it has been measured.
The researchers say it gives a new type of insight into the nature of dark matter, which acts like a counterweight slowing the spin.
In the study, published in the *Monthly Notices of the Royal Astronomical Society*, researchers analysed Gaia space telescope observations of a large group of stars, the Hercules stream, which are in resonance with the bar -- that is, they revolve around the galaxy at the same rate as the bar's spin.
These stars are gravitationally trapped by the spinning bar. The same phenomenon occurs with Jupiter's Trojan and Greek asteroids, which orbit Jupiter's Lagrange points (ahead and behind Jupiter). If the bar's spin slows down, these stars would be expected to move further out in the galaxy, keeping their orbital period matched to that of the bar's spin.
The researchers found that the stars in the stream carry a chemical fingerprint -- they are richer in heavier elements (called metals in astronomy), proving that they have travelled away from the galactic centre, where stars and star-forming gas are about 10 times as rich in metals compared to the outer galaxy.
Using this data, the team inferred that the bar -- made up of billions of stars and trillions of solar masses -- had slowed down its spin by at least 24% since it first formed.
Co-author Dr Ralph Schoenrich (UCL Physics & Astronomy) said: "Astrophysicists have long suspected that the spinning bar at the centre of our galaxy is slowing down, but we have found the first evidence of this happening.
"The counterweight slowing this spin must be dark matter. Until now, we have only been able to infer dark matter by mapping the gravitational potential of galaxies and subtracting the contribution from visible matter.
"Our research provides a new type of measurement of dark matter -- not of its gravitational energy, but of its inertial mass (the dynamical response), which slows the bar's spin."
Co-author and PhD student Rimpei Chiba, of the University of Oxford, said: "Our finding offers a fascinating perspective for constraining the nature of dark matter, as different models will change this inertial pull on the galactic bar.
"Our finding also poses a major problem for alternative gravity theories -- as they lack dark matter in the halo, they predict no, or significantly too little slowing of the bar."
The Milky Way, like other galaxies, is thought to be embedded in a 'halo' of dark matter that extends well beyond its visible edge.
Dark matter is invisible and its nature is unknown, but its existence is inferred from galaxies behaving as if they were shrouded in significantly more mass than we can see.
There is thought to be about five times as much dark matter in the Universe as ordinary, visible matter.
Alternative gravity theories such as modified Newtonian dynamics reject the idea of dark matter, instead seeking to explain discrepancies by tweaking Einstein's theory of general relativity.
The Milky Way is a barred spiral galaxy, with a thick bar of stars in the middle and spiral arms extending through the disc outside the bar. The bar rotates in the same direction as the galaxy.
The research received support from the Royal Society, the Takenaka Scholarship Foundation, and the Science and Technology Facilities Council (STFC).

- ❖ Boundary of heliosphere mapped

Date: June 14, 2021
Source: DOE/Los Alamos National Laboratory



Scientists mapped the violent edge of the solar system (called the heliosphere) for the first time using an echolocation-like technique. (Image credit: NASA/JPL-Caltech)

For the first time, the boundary of the heliosphere has been mapped, giving scientists a better understanding of how solar and interstellar winds interact.

"Physics models have theorized this boundary for years," said Dan Reisenfeld, a scientist at Los Alamos National Laboratory and lead author on the paper, which was published in the *Astrophysical Journal* today. "But this is the first time we've actually been able to measure it and make a three-dimensional map of it."

The heliosphere is a bubble created by the solar wind, a stream of mostly protons, electrons, and alpha particles that extends from the Sun into interstellar space and protects the Earth from harmful interstellar radiation.

Reisenfeld and a team of other scientists used data from NASA's Earth-orbiting Interstellar Boundary Explorer (IBEX) satellite, which detects particles that come from the heliosheath, the boundary layer between the solar system and interstellar space. The team was able to map the edge of this zone -- a region called the heliopause. Here, the solar wind, which pushes out toward interstellar space, collides with the interstellar wind, which pushes in towards the Sun.

To do this measurement, they used a technique similar to how bats use sonar. "Just as bats send out sonar pulses in every direction and use the return signal to create a mental map of their surroundings, we used the Sun's solar wind, which goes out in all directions, to create a map of the heliosphere," said Reisenfeld.

They did this by using IBEX satellite's measurement of energetic neutral atoms (ENAs) that result from collisions between solar wind particles and those from the interstellar wind. The intensity of that signal depends on the intensity of the solar wind that strikes the heliosheath. When a wave hits the sheath, the ENA count goes up and IBEX can detect it.

"The solar wind 'signal' sent out by the Sun varies in strength, forming a unique pattern," explained Reisenfeld. "IBEX will see that same pattern in the returning ENA signal, two to six years later, depending on ENA energy and the direction IBEX is looking through the heliosphere. This time difference is how we found the distance to the ENA-source region in a particular direction."

They then applied this method to build the three-dimensional map, using data collected over a complete solar cycle, from 2009 through 2019.

"In doing this, we are able to see the boundary of the heliosphere in the same way a bat uses sonar to 'see' the walls of a cave," he added.

The reason it takes so long for the signal to return to IBEX is because of the vast distances involved. Distances in the solar system are measured in astronomical units (AU) where 1 AU is the distance from the Earth to the Sun. Reisenfeld's map shows that the minimum distance from the Sun to the heliopause is about 120 AU in the direction facing the interstellar wind, and in the opposite direction, it extends at least 350 AU, which is the distance limit of the sounding technique. For reference, the orbit of Neptune is about 60 AU across.

- Black holes help with star birth

The cosmic mass monsters clear the way for the formation of new suns in satellite galaxies

Date: June 14, 2021
Source: Max-Planck-Gesellschaft

Research combining systematic observations with cosmological simulations has found that, surprisingly, black holes can help certain galaxies form new stars. On scales of galaxies, the role of supermassive black holes for star formation had previously been seen as destructive -- active black holes can strip galaxies of the gas that galaxies need to form new stars. The new results, published in the journal *Nature*, showcase situations where active black holes can, instead, "clear the way" for galaxies that orbit inside galaxy groups or clusters, keeping those galaxies from having their star formation disrupted as they fly through the surrounding intergalactic gas.

Active black holes are primarily thought to have a destructive influence on their surroundings. As they blast energy into their

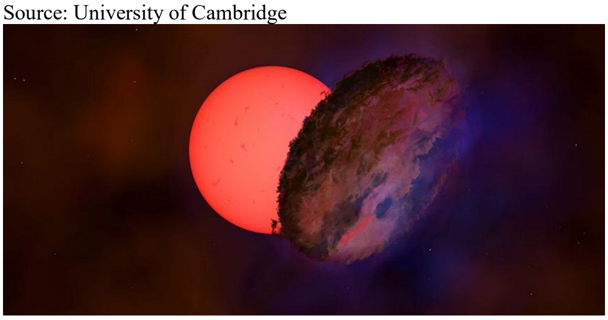
host galaxy, they heat up and eject that galaxy's gas, making it more difficult for the galaxy to produce new stars. But now, researchers have found that the same activity can actually help with star formation -- at least for the satellite galaxies that orbit the host galaxy.
The counter-intuitive result came out of a collaboration sparked by a lunchtime conversation between astronomers specializing in large-scale computer simulations and observers. As such, it is a good example for the kind of informal interaction that has become more difficult under pandemic conditions.
Astronomical observations that include taking a distant galaxy's spectrum -- the rainbow-like separation of a galaxy's light into different wavelengths -- allow for fairly direct measurements of the rate at which that galaxy is forming new stars.
Going by such measurements, some galaxies are forming stars at rather sedate rates. In our own Milky Way galaxy, only one or two new stars are born each year. Others undergo brief bursts of excessive star formation activity, called "star bursts," with hundreds of stars born per year. In yet other galaxies, star formation appears to be suppressed, or "quenched," as astronomers say: Such galaxies have virtually stopped forming new stars.
A special kind of galaxy, specimens of which are frequently -- almost half of the time -- found to be in such a quenched state, are so-called satellite galaxies. These are part of a group or cluster of galaxies, their mass is comparatively low, and they orbit a much more massive central galaxy similar to the way satellites orbit the Earth.
Such galaxies typically form very few new stars, if at all, and since the 1970s, astronomers have suspected that something very much akin to headwind might be to blame: Groups and clusters of galaxies not only contain galaxies, but also rather hot thin gas filling the intergalactic space.
As a satellite galaxy orbits through the cluster at a speed of hundreds of kilometres per second, the thin gas would make it feel the same kind of "headwind" that someone riding a fast bike, or motor-bike, will feel. The satellite galaxy's stars are much too compact to be affected by the steady stream of oncoming intergalactic gas.
But the satellite galaxy's own gas is not: It would be stripped away by the oncoming hot gas in a process known as "ram pressure stripping." On the other hand, a fast-moving galaxy has no chance of pulling in a sufficient amount of intergalactic gas, to replenish its gas reservoir. The upshot is that such satellite galaxies lose their gas almost completely -- and with it the raw material needed for star formation. As a result, star-formation activity would be quenched.
The processes in question take place over millions or even billions of years, so we cannot watch them happening directly. But even so, there are ways for astronomers to learn more. They can utilize computer simulations of virtual universes, programmed so as to follow the relevant laws of physics -- and compare the results with what we actually observe. And they can look for tell-tale clues in the comprehensive "snapshot" of cosmic evolution that is provided by astronomical observations.
Annalisa Pillepich, a group leader at the Max Planck Institute for Astronomy (MPIA), specializes in simulations of this kind. The IllustrisTNG suite of simulations, which Pillepich has co-led, provides the most detailed virtual universes to date -- universes in which researchers can follow the movement of gas around on comparatively small scales.
IllustrisTNG provides some extreme examples of satellite galaxies that have freshly been stripped by ram pressure: so-called "jellyfish galaxies," that are trailing the remnants of their gas like jellyfish are trailing their tentacles. In fact, identifying all the jellyfish in the simulations is a recently launched citizen science project on the Zooniverse platform, where volunteers can help with the research into that kind of freshly quenched galaxy.
But, while jellyfish galaxies are relevant, they are not where the present research project started. Over lunch in November 2019, Pillepich recounted a different one of her IllustrisTNG results to Ignacio Martín-Navarro, an astronomer specializing in observations, who was at MPIA on a Marie Curie fellowship. A result about the influence of supermassive black holes that reached beyond the host galaxy, into intergalactic space.
Such supermassive black holes can be found in the centre of all galaxies. Matter falling onto such a black hole typically becomes part of a rotating so-called accretion disk surrounding the black hole, before falling into the black hole itself. This fall onto the

accretion disk liberates an enormous amount of energy in the form of radiation, and oftentimes also in the form of two jets of quickly moving particles, which accelerate away from the black hole at right angles to the accretion disk. A supermassive black hole that is emitting energy in this way is called an Active Galactic Nucleus, AGN for short.
While IllustrisTNG is not detailed enough to include black hole jets, it does contain physical terms that simulate how an AGN is adding energy to the surrounding gas. And as the simulation showed, that energy injection will lead to gas outflows, which in turn will orient themselves along a path of least resistance: in the case of disk galaxies similar to our own Milky Way, perpendicular to the stellar disk; for so-called elliptical galaxies, perpendicular to a suitable preferred plane defined by the arrangement of the galaxy's stars.
Over time, the bipolar gas outflows, perpendicular to the disk or preferred plane, will go so far as to affect the intergalactic environment -- the thin gas surrounding the galaxy. They will push the intergalactic gas away, each outflow creating a gigantic bubble.
It was this account that got Pillepich and Martín-Navarro thinking: If a satellite galaxy were to pass through that bubble -- would it be affected by the outflow, and would its star formation activity be quenched even further?
Martín-Navarro took up this question within his own domain. He had extensive experience in working with data from one of the largest systematic surveys to date: the Sloan Digital Sky Survey (SDSS), which provides high-quality images of a large part of the Northern hemisphere. In the publicly available data from that survey's 10th data, he examined 30,000 galaxy groups and clusters, each containing a central galaxy and on average 4 satellite galaxies.
In a statistical analysis of those thousands of systems, he found a small, but marked difference between satellite galaxies that were close to the central galaxy's preferred plane and satellites that were markedly above and below. But the difference was in the opposite direction the researchers had expected: Satellites above and below the plane, within the thinner bubbles, were on average not more likely, but about 5% less likely to have had their star formation activity quenched.
With that surprising result, Martín-Navarro went back to Annalisa Pillepich, and the two performed the same kind of statistical analysis in the virtual universe of the IllustrisTNG simulations. In simulations of that kind, after all, cosmic evolution is not put in "by hand" by the researchers. Instead, the software includes rules that model the rules of physics for that virtual universe as naturally as possible, and which also include suitable initial conditions that correspond to the state of our own universe shortly after the Big Bang.
That is why simulations like that leave room for the unexpected -- in this particular case, for re-discovering the on-plane, off-plane distribution of quenched satellite galaxies: The virtual universe showed the same 5% deviation for the quenching of satellite galaxies! Evidently, the researchers were on to something.
In time, Pillepich, Martín-Navarro and their colleagues came up with a hypothesis for the physical mechanism behind the quenching variation. Consider a satellite galaxy travelling through one of the thinned-out bubbles the central black hole has blown into the surrounding intergalactic medium. Due to the lower density, that satellite galaxy experiences less headwind, less ram pressure, and is thus less likely to have its gas stripped away.
Then, it is down to statistics. For satellite galaxies that have orbited the same central galaxies several times already, traversing bubbles but also the higher-density regions in between, the effect will not be noticeable. Such galaxies will have lost their gas long ago. But for satellite galaxies that have joined the group, or cluster, rather recently, location will make a difference: If those satellites happen to land in a bubble first, they are less likely to lose their gas then if they happen to land outside a bubble. This effect could account for the statistical difference for the quenched satellite galaxies.
With the excellent agreement between the statistical analyses of both the SDSS observations and the IllustrisTNG simulations, and with a plausible hypothesis for a mechanism, this is a highly promising result. In the context of galaxy evolution, it is particularly interesting because it confirms, indirectly, the role of active galactic nuclei not only heating intergalactic gas up, but actively "pushing it away," to create lower-density regions. And as with all promising results, there are now a number of natural directions that either Martín-Navarro, Pillepich and their

colleagues or other scientists can take in order to explore further.

- Astronomers spot a 'blinking giant' near the centre of the Galaxy

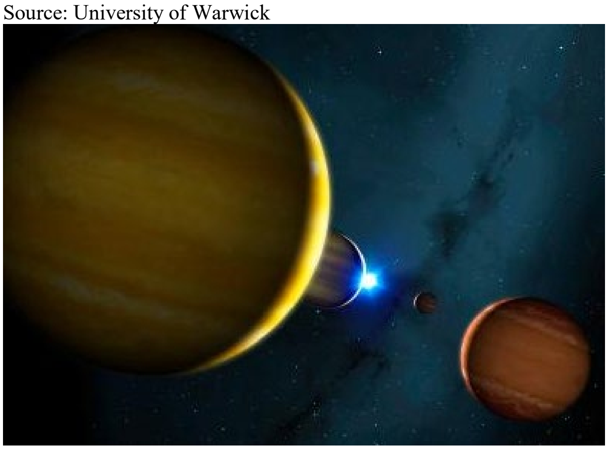
Date: June 11, 2021
Source: University of Cambridge



Astronomers have spotted a giant 'blinking' star towards the centre of the Milky Way, more than 25,000 light years away.
An international team of astronomers observed the star, VVV-WIT-08, decreasing in brightness by a factor of 30, so that it nearly disappeared from the sky. While many stars change in brightness because they pulsate or are eclipsed by another star in a binary system, it's exceptionally rare for a star to become fainter over a period of several months and then brighten again.
The researchers believe that VVV-WIT-08 may belong to a new class of 'blinking giant' binary star system, where a giant star -- 100 times larger than the Sun -- is eclipsed once every few decades by an as-yet unseen orbital companion. The companion, which may be another star or a planet, is surrounded by an opaque disc, which covers the giant star, causing it to disappear and reappear in the sky. The study is published in *Monthly Notices of the Royal Astronomical Society*.
The discovery was led by Dr Leigh Smith from Cambridge's Institute of Astronomy, working with scientists at the University of Edinburgh, the University of Hertfordshire, the University of Warsaw in Poland and Universidad Andres Bello in Chile.
"It's amazing that we just observed a dark, large and elongated object pass between us and the distant star and we can only speculate what its origin is," said co-author Dr Sergey Koposov from the University of Edinburgh.
Since the star is located in a dense region of the Milky Way, the researchers considered whether some unknown dark object could have simply drifted in front of the giant star by chance. However, simulations showed that there would have to be an implausibly large number of dark bodies floating around the Galaxy for this scenario to be likely.
One other star system of this sort has been known for a long time. The giant star Epsilon Aurigae is partly eclipsed by a huge disc of dust every 27 years, but only dims by about 50%. A second example, TYC 2505-672-1, was found a few years ago, and holds the current record for the eclipsing binary star system with the longest orbital period -- 69 years -- a record for which VVV-WIT-08 is currently a contender.
The UK-based team has also found two more of these peculiar giant stars in addition to VVV-WIT-08, suggesting that these may be a new class of 'blinking giant' stars for astronomers to investigate.
VVV-WIT-08 was found by the VISTA Variables in the Via Lactea survey (VVV), a project using the British-built VISTA telescope in Chile and operated by the European Southern Observatory, that has been observing the same one billion stars for nearly a decade to search for examples with varying brightness in the infrared part of the spectrum.
Project co-leader Professor Philip Lucas from the University of Hertfordshire said, "Occasionally we find variable stars that don't fit into any established category, which we call 'what-is-this?', or 'WIT' objects. We really don't know how these blinking giants came to be. It's exciting to see such discoveries from VVV after so many years planning and gathering the data."
While VVV-WIT-08 was discovered using VVV data, the dimming of the star was also observed by the Optical Gravitational Lensing Experiment (OGLE), a long-running observation campaign run by the University of Warsaw. OGLE makes more frequent observations, but closer to the visible part of the spectrum. These frequent observations were key for modelling VVV-WIT-08, and they showed that the giant star dimmed by the same amount in both the visible and infrared light.
There now appear to be around half a dozen potential known star systems of this type, containing giant stars and large opaque discs. "There are certainly more to be found, but the challenge now is in figuring out what the hidden companions are, and how they came to be surrounded by discs, despite orbiting so far from the giant star," said Smith. "In doing so, we might learn something new about how these kinds of systems evolve."

- Star's death will play a mean pinball with rhythmic planets

Date: June 11, 2021
Source: University of Warwick



Four planets locked in a perfect rhythm around a nearby star are destined to be pinballed around their solar system when their sun eventually dies, according to a study led by the University of Warwick that peers into its future.
Astronomers have modelled how the change in gravitational forces in the system as a result of the star becoming a white dwarf will cause its planets to fly loose from their orbits and bounce off each other's gravity, like balls bouncing off a bumper in a game of pinball. In the process, they will knock nearby debris into their dying sun, offering scientists new insight into how the white dwarfs with polluted atmospheres that we see today originally evolved. The conclusions by astronomers from the University of Warwick and the University of Exeter are published in the *Monthly Notices of the Royal Astronomical Society*.
The HR 8799 system is 135 light years away and comprises a 30-40 million year-old A type star and four unusually massive planets, all over five times the mass of Jupiter, orbiting very close to each other. The system also contains two debris discs, inside the orbit of the innermost planet and another outside the outermost. Recent research has shown that the four planets are locked in a perfect rhythm that sees each one completing double the orbit of its neighbour: so for every orbit the furthest completes, the next closest completes two, the next completes four, while the closest completes eight.
The team from Warwick and Exeter decided to learn the ultimate fate of the system by creating a model that allowed them to play 'planetary pinball' with the planets, investigating what may cause the perfect rhythm to destabilise.
They determined that the resonance that locks the four planets is likely to hold firm for the next 3 billion years, despite the effects of Galactic tides and close flybys of other stars. However, it always breaks once the star enters the phase in which it becomes a red giant, when it will expand to several hundred times its current size and eject nearly half its mass, ending up as a white dwarf.
The planets will then start to pinball and become a highly chaotic system where their movements become very uncertain. Even changing a planet's position by a centimetre at the start of the process can dramatically change the outcome.
Lead author Dr Dimitri Veras from the University of Warwick Department of Physics said: "The planets will gravitationally scatter off of one another. In one case, the innermost planet could be ejected from the system. Or, in another case, the third planet may be ejected. Or the second and fourth planets could switch positions. Any combination is possible just with little tweaks.
"They are so big and so close to each other the only thing that's keeping them in this perfect rhythm right now is the locations of their orbits. All four are connected in this chain. As soon as the star loses mass their locations will deviate, then two of them will scatter off one another, causing a chain reaction amongst all four."
Dr Veras was supported by an Ernest Rutherford Fellowship from the Science and Technology Facilities Council, part of UK Research and Innovation.
Regardless of the precise movements of the planets, one thing that the team is certain of is that the planets will move around enough to dislodge material from the system's debris discs into the atmosphere of the star. It is this type of debris that astronomers are analysing today to discover the histories of other white dwarf systems.
Dr Veras adds: "These planets move around the white dwarf at different locations and can easily kick whatever debris is still there into the white dwarf, polluting it.
"The HR 8799 planetary system represents a foretaste of the polluted white dwarf systems that we see today. It's a demonstration of the value of computing the fates of planetary systems, rather than just looking at their formation."
Co-author Professor Sasha Hinkley of the University of Exeter said: "The HR 8799

system has been so iconic for exoplanetary science since its discovery nearly 13 years ago, and so it is fascinating to see into the future, and watch it evolve from a harmonious collection of planets into a chaotic scene."

- Asteroid 16 Psyche might not be what scientists expected

Date: June 10, 2021
Source: University of Arizona

An artist's concept of asteroid 16 Psyche. Credit: Maxar/ASU/P.Rubin/NASA/JPL-Caltech

The widely studied metallic asteroid known as 16 Psyche was long thought to be the exposed iron core of a small planet that failed to form during the earliest days of the solar system. But new University of Arizona-led research suggests that the asteroid might not be as metallic or dense as once thought, and hints at a much different origin story.
Scientists are interested in 16 Psyche because if its presumed origins are true, it would provide an opportunity to study an exposed planetary core up close. NASA is scheduled to launch its Psyche mission in 2022 and arrive at the asteroid in 2026.
UArizona undergraduate student David Cantillo is lead author of a new paper published in *The Planetary Science Journal* that proposes 16 Psyche is 82.5% metal, 7% low-iron pyroxene and 10.5% carbonaceous chondrite that was likely delivered by impacts from other asteroids. Cantillo and his collaborators estimate that 16 Psyche's bulk density -- also known as porosity, which refers to how much empty space is found within its body -- is around 35%.
These estimates differ from past analyses of 16 Psyche's composition that led researchers to estimate it could contain as much as 95% metal and be much denser.
"That drop in metallic content and bulk density is interesting because it shows that 16 Psyche is more modified than previously thought," Cantillo said.
Rather than being an intact exposed core of an early planet, it might actually be closer to a rubble pile, similar to another thoroughly studied asteroid -- Bennu. UArizona leads the science mission team for NASA's OSIRIS-REx mission, which retrieved a sample from Bennu's surface that is now making its way back to Earth.
"Psyche as a rubble pile would be very unexpected, but our data continues to show low-density estimates despite its high metallic content," Cantillo said.
Asteroid 16 Psyche is about the size of Massachusetts, and scientists estimate it contains about 1% of all asteroid belt material. First spotted by an Italian astronomer in 1852, it was the 16th asteroid ever discovered.
"Having a lower metallic content than once thought means that the asteroid could have been exposed to collisions with asteroids containing the more common carbonaceous chondrites, which deposited a surface layer that we are observing," Cantillo said. This was also observed on asteroid Vesta by the NASA Dawn spacecraft.
Asteroid 16 Psyche has been estimated to been worth $10,000 quadrillion (that's $10,000 followed by 15 more zeroes), but the new findings could slightly devalue the iron-rich asteroid.
"This is the first paper to set some specific constraints on its surface content. Earlier estimates were a good start, but this refines those numbers a bit more," Cantillo said.
The other well-studied asteroid, Bennu, contains a lot of carbonaceous chondrite material and has porosity of over 50%, which is a classic characteristic of a rubble pile. Such high porosity is common for relatively small and low-mass objects such as Bennu -- which is only as large as the Empire State Building -- because a weak gravitational field prevents the object's rocks and boulders from being packed together too tightly. But for an object the size of 16 Psyche to be so porous is unexpected.
"The opportunity to study an exposed core of a planetesimal is extremely rare, which is why they're sending the spacecraft mission there," Cantillo said, "but our work shows that 16 Psyche is a lot more interesting than expected."
Past estimates of 16 Psyche's composition were done by analysing the sunlight reflected off its surface. The pattern of light matched that of other metallic objects. Cantillo and his

collaborators instead recreated 16 Psyche's regolith -- or loose rocky surface material -- by mixing different materials in a lab and analysing light patterns until they matched telescope observations of the asteroid. There are only a few labs in the world practicing this technique, including the UArizona Lunar and Planetary Laboratory and the Johns Hopkins Applied Physics Laboratory in Maryland, where Cantillo worked while in high school.

"I've always been interested in space," said Cantillo, who is also president of the UArizona Astronomy Club. "I knew that astronomy studies would be heavy on computers and observation, but I like to do more hands-on kind of work, so I wanted to connect my studies to geology somehow. I'm majoring geology and minoring in planetary science and math."

"David's paper is an example of the cutting-edge research work done by our undergraduate students," said study co-author Vishnu Reddy, an associate professor of planetary sciences who heads up the lab in which Cantillo works. "It is also a fine example of the collaborative effort between undergraduates, graduate students, postdoctoral fellows and staff in my lab."

The researchers also believe the carbonaceous material on 16 Psyche's surfaces is rich in water, so they will next work to merge data from ground-based telescopes and spacecraft missions to other asteroids to help determine the amount of water present

- Astronomers discover a 'changing-look' blazar

Date: June 9, 2021
Source: University of Oklahoma

A University of Oklahoma doctoral student, graduate and undergraduate research assistants, and an associate professor in the Homer L. Dodge Department of Physics and Astronomy in the University of Oklahoma College of Arts and Sciences are lead authors on a paper describing a "changing-look" blazar -- a powerful active galactic nucleus powered by supermassive blackhole at the centre of a galaxy. The paper is published in *The Astrophysical Journal*.

Hora D. Mishra, a Ph.D. student, and faculty member Xinyu Dai are lead authors of the paper, along with Christopher Kochanek and Kris Stanek at the Ohio State University and Ben Shappee at the University of Hawaii. The paper represents the findings of researchers from 12 different institutions who participated in a two-year collaborative project involving the collection of spectra or imaging data in different electromagnetic bands. The OU team led the effort in analysing all the data collected from the collaboration and contributed primarily on the interpretation of the analysis results, assisted by OU graduate student Saloni Bhatiani and undergraduate students Cora DeFrancesco and John Cox who performed ancillary analyses to the project.

Blazars, explains Mishra, who also serves as president of Lunar Sooners, appear as parallel rays of light or particles, or jets, pointing to observers and radiating across all wavelengths of the electromagnetic spectrum. These jets span distances on the million light-year scales and are known to impact the evolution of the galaxy and galaxy cluster in which they reside via the radiation. These features make blazars ideal environments in which to study the physics of jets and their role in galaxy evolution.

"Blazars are a unique kind of AGN with very powerful jets," she said. "Jets are a radio mode of feedback and because of their scales, they penetrate the galaxy into their large-scale environment. The origin of these jets and processes driving the radiation are not well-known. Thus, studying blazars allows us to understand these jets better and how they are connected to other components of the AGN, like the accretion disk. These jets can heat up and displace gas in their environment affecting, for example, the star formation in the galaxy."

The team's paper highlights the results of a campaign to investigate the evolution of a blazar known as B2 1420+32. At the end of 2017, this blazar exhibited a huge optical flare, a phenomenon captured by the All Sky Automated Survey for SuperNovae telescope network.

"We followed this up by observing the evolution of its spectrum and light curve over the next two years and also retrieved archival data available for this object," Mishra said. "The campaign, with data spanning over a decade, has yielded some most exciting results. We see dramatic variability in the spectrum and multiple transformations between the two blazar sub-classes for the first time for a blazar, thus giving it the name 'changing-look' blazar."

The team concluded that this behaviour is caused by the dramatic continuum flux changes, which confirm a long-proposed

theory that separates blazars into two major categories.
"In addition, we see several very large multiband flares in the optical and gamma-ray bands on different timescales and new spectral features," Mishra said. "Such extreme variability and the spectral features demand dedicated searches for more such blazars, which will allow us to utilize the dramatic spectral changes observed to reveal AGN/jet physics, including how dust particles around supermassive black holes are destructed by the tremendous radiation from the central engine and how energy from a relativistic jet is transferred into the dust clouds, providing a new channel linking the evolution of the supermassive black hole with its host galaxy."
"We are very excited by the results of discovering a changing-look blazar that transforms itself not once, but three times, between its two sub-classes, from the dramatic changes in its continuum emission," she added. "In addition, we see new spectral features and optical variability that is unprecedented. These results open the door to more such studies of highly variable blazars and their importance in understanding AGN physics."
"It is really interesting to see the emergence of a forest of Iron emission lines, suggesting that nearby dust particles were evaporated by the strong radiation from the jet and released free Iron ions into the emitting clouds, a phenomenon predicted by theoretical models and confirmed in this blazar outburst," Dai said.

- CHIME telescope detects more than 500 mysterious fast radio bursts in its first year of operation

Observations quadruple the number of known radio bursts and reveal two types: One-offs and repeaters
Date: June 9, 2021
Source: Massachusetts Institute of Technology


The CHIME radio telescope has detected 535 fast radio bursts in its first year of operation. Credit: Andre Renard/CHIME Collaboration

To catch sight of a fast radio burst is to be extremely lucky in where and when you point your radio dish. Fast radio bursts, or FRBs, are oddly bright flashes of light, registering in the radio band of the electromagnetic spectrum, that blaze for a few milliseconds before vanishing without a trace.
These brief and mysterious beacons have been spotted in various and distant parts of the universe, as well as in our own galaxy. Their origins are unknown, and their appearance is unpredictable. Since the first was discovered in 2007, radio astronomers have only caught sight of around 140 bursts in their scopes.
Now, a large stationary radio telescope in British Columbia has nearly quadrupled the number of fast radio bursts discovered to date. The telescope, known as CHIME, for the Canadian Hydrogen Intensity Mapping Experiment, has detected 535 new fast radio bursts during its first year of operation, between 2018 and 2019.
Scientists with the CHIME Collaboration, including researchers at MIT, have assembled the new signals in the telescope's first FRB catalogue, which they will present this week at the American Astronomical Society Meeting.
The new catalogue significantly expands the current library of known FRBs, and is already yielding clues as to their properties. For instance, the newly discovered bursts appear to fall in two distinct classes: those that repeat, and those that don't. Scientists identified 18 FRB sources that burst repeatedly, while the rest appear to be one-offs. The repeaters also look different, with each burst lasting slightly longer and emitting more focused radio frequencies than bursts from single, nonrepeating FRBs.
These observations strongly suggest that repeaters and one-offs arise from separate mechanisms and astrophysical sources. With more observations, astronomers hope soon to pin down the extreme origins of these curiously bright signals.
"Before CHIME, there were less than 100 total discovered FRBs; now, after one year of observation, we've discovered hundreds more," says CHIME member Kaitlyn Shin, a graduate student in MIT's Department of Physics. "With all these sources, we can really start getting a picture of what FRBs look like as a whole, what astrophysics might be driving these events, and how they can be used to study the universe going forward."
Seeing flashes

CHIME comprises four massive parabolic radio antennas, roughly the size and shape of snowboarding half-pipes, located at the Dominion Radio Astrophysical Observatory in British Columbia, Canada. CHIME is a stationary array, with no moving parts. The telescope receives radio signals each day from half of the sky as the Earth rotates. While most radio astronomy is done by swivelling a large dish to focus light from different parts of the sky, CHIME stares, motionless, at the sky, and focuses incoming signals using a correlator -- a powerful digital signalling processor that can work through huge amounts of data, at a rate of about 7 terabits per second, equivalent to a few percent of the world's internet traffic.

"Digital signal processing is what makes CHIME able to reconstruct and 'look' in thousands of directions simultaneously," says Kiyoshi Masui, assistant professor of physics at MIT, who will lead the group's conference presentation. "That's what helps us detect FRBs a thousand times more often than a traditional telescope."

Over the first year of operation, CHIME detected 535 new fast radio bursts. When the scientists mapped their locations, they found the bursts were evenly distributed in space, seeming to arise from any and all parts of the sky. From the FRBs that CHIME was able to detect, the scientists calculated that fast radio bursts, bright enough to be seen by a telescope like CHIME, occur at a rate of about 9,000 per day across the entire sky -- the most precise estimate of FRBs overall rate to date.

"That's kind of the beautiful thing about this field -- FRBs are really hard to see, but they're not uncommon," says Masui, who is a member of MIT's Kavli Institute for Astrophysics and Space Research. "If your eyes could see radio flashes the way you can see camera flashes, you would see them all the time if you just looked up."

Mapping the universe

As radio waves travel across space, any interstellar gas, or plasma, along the way can distort or disperse the wave's properties and trajectory. The degree to which a radio wave is dispersed can give clues to how much gas it passed through, and possibly how much distance it has travelled from its source. For each of the 535 FRBs that CHIME detected, Masui and his colleagues measured its dispersion, and found that most bursts likely originated from far-off sources within distant galaxies. The fact that the bursts were bright enough to be detected by CHIME suggests that they must have been produced by extremely energetic sources. As the telescope detects more FRBs, scientists hope to pin down exactly what kind of exotic phenomena could generate such ultrabright, ultrafast signals.

Scientists also plan to use the bursts, and their dispersion estimates, to map the distribution of gas throughout the universe.

"Each FRB gives us some information of how far they've propagated and how much gas they've propagated through," Shin says. "With large numbers of FRBs, we can hopefully figure out how gas and matter are distributed on very large scales in the universe. So, alongside the mystery of what FRBs are themselves, there's also the exciting potential for FRBs as powerful cosmological probes in the future."

This research was supported by various institutions including the Canada Foundation for Innovation, the Dunlap Institute for Astronomy and Astrophysics at the University of Toronto, the Canadian Institute for Advanced Research, McGill University and the McGill Space Institute via the Trottier Family Foundation, and the University of British Columbia.

- Scientists discover new exoplanet with an atmosphere ripe for study

Date: June 9, 2021
Source: University of New Mexico

An international group of collaborators, including scientists from NASA's Jet Propulsion Laboratory and The University of New Mexico, have discovered a new, temperate sub-Neptune sized exoplanet with a 24-day orbital period orbiting a nearby M dwarf star. The recent discovery offers exciting research opportunities thanks to the planet's substantial atmosphere, small star, and how fast the system is moving away from the Earth.

The research, titled TOI-1231 b: A Temperate, Neptune-Sized Planet Transiting the Nearby M3 Dwarf NLTT 24399, will be published in a future issue of *The Astronomical Journal.*

The exoplanet, TOI-1231 b, was detected using photometric data from the Transiting Exoplanet Survey Satellite (TESS) and followed up with observations using the Planet Finder Spectrograph (PFS) on the Magellan Clay telescope at Las Campanas Observatory in Chile. The PFS is a sophisticated instrument that detects exoplanets through their gravitational influence on their host stars. As the planets orbit their hosts, the measured stellar velocities vary periodically, revealing the planetary presence and information about their mass and orbit.

The observing strategy adopted by NASA's TESS, which divides each hemisphere into 13 sectors that are surveyed for roughly 28 days, is producing the most comprehensive all-sky search for transiting planets. This approach has already proven its capability to detect both large and small planets around stars ranging from sun-like down to low-mass M dwarf stars. M dwarf stars, also known as a red dwarf, are the most common type of star in the Milky Way making up some 70 percent of all stars in the galaxy.

M dwarfs are smaller and possess a fraction of the sun's mass and have low luminosity. Because an M dwarf is smaller, when a planet of a given size transits the star, the amount of light that is blocked out by the planet is larger, making the transit more easily detectable. Imagine an Earth-like planet passing in front of a star the size of the sun, it's going to block out a tiny bit of light; but if it's passing in front of a star that's a lot smaller, the proportion of light that's blocked out will be larger. In a sense, this creates a larger shadow on the surface of the star, making planets around M dwarfs more easily detectable and easier to study.

Although it enables the detection of exoplanets across the sky, TESS's survey strategy also produces significant observational biases based on orbital period. Exoplanets must transit their host stars at least twice within TESS 's observing span to be detected with the correct period by the Science Processing Operations Centre (SPOC) pipeline and the Quick Look Pipeline (QLP), which search the 2-minute and 30-minute cadence TESS data, respectively. Because 74 percent of TESS' total sky coverage is only observed for 28 days, the majority of TESS exoplanets detected have periods less than 14 days. TOI-1231b's 24-day period, therefore, makes its discovery even more valuable.

NASA JPL scientist Jennifer Burt, the lead author of the paper, along with her collaborators including Diana Dragomir, an assistant professor in UNM's Department of Physics and Astronomy, measured both the radius and mass of the planet.

"Working with a group of excellent astronomers spread across the globe, we were able to assemble the data necessary to characterize the host star and measure both the radius and mass of the planet," said Burt. "Those values in turn allowed us to calculate the planet's bulk density and hypothesize about what the planet is made out of. TOI-1231 b is pretty similar in size and density to Neptune, so we think it has a similarly large, gaseous atmosphere."

"Another advantage of exoplanets orbiting M dwarf hosts is that we can measure their masses easier because the ratio of the planet mass to the stellar mass is also larger. When the star is smaller and less massive, it makes detection methods work better because the planet suddenly plays a bigger role as it stands out more easily in relation to the star," explained Dragomir. "Like the shadow cast on the star. The smaller the star, the less massive the star, the more the effect of the planet can be detected.

"Even though TOI 1231b is eight times closer to its star than the Earth is to the Sun, its temperature is similar to that of Earth, thanks to its cooler and less bright host star," says Dragomir. "However, the planet itself is actually larger than earth and a little bit smaller than Neptune -- we could call it a sub-Neptune."

Burt and Dragomir, who actually initiated this research while they were Fellows at MIT's Kavli Institute, worked with scientists specializing in observing and characterizing the atmospheres of small planets to figure out which current and future space-based missions might be able to peer into TOI-1231 b's outer layers to inform researchers exactly what kinds of gases are swirling around the planet. With a temperature around 330 Kelvin or 140 degrees Fahrenheit, TOI-1231b is one of the coolest, small exoplanets accessible for atmospheric studies discovered thus far.

Past research suggests planets this cool may have clouds high in their atmospheres, which makes it hard to determine what types of gases surround them. But new observations of another small, cool planet called K2-18 b broke this trend and showed evidence of water in its atmosphere, surprising many astronomers.

"TOI-1231 b is one of the only other planets we know of in a similar size and temperature range, so future observations of this new planet will let us determine just how common (or rare) it is for water clouds to form around these temperate worlds," said Burt.

Additionally, with its host star's high Near-Infrared (NIR) brightness, it makes an exciting target for future missions with the Hubble Space Telescope (HST) and the James Webb Space Telescope (JWST). The first set of these observations, led by one of the paper's co-authors, should take place later this month using the Hubble Space Telescope.

"The low density of TOI 1231b indicates that it is surrounded by a substantial atmosphere rather than being a rocky planet. But the composition and extent of this atmosphere are unknown!" said Dragomir. "TOI1231b could have a large hydrogen or hydrogen-helium atmosphere, or a denser water vapor atmosphere. Each of these would point to a different origin, allowing astronomers to understand whether and how planets form differently around M dwarfs when compared to the planets around our Sun, for example. Our upcoming HST observations will begin to answer these questions, and JWST promises an even more thorough look into the planet's atmosphere."

Another way to study the planet's atmosphere is to investigate whether gas is being blown away, by looking for evidence of atoms like hydrogen and helium surrounding the planet as it transits across the face of its host star. Generally, hydrogen atoms are almost impossible to detect because their presence is masked by interstellar gas. But this planet-star system offers a unique opportunity to apply this method because of how fast it's moving away from the Earth.

"One of the most intriguing results of the last two decades of exoplanet science is that, thus far, none of the new planetary systems we've discovered look anything like our own solar system," said Burt. "They're full of planets between the size of Earth and Neptune on orbits much shorter than Mercury's, so we don't have any local examples to compare them to. This new planet we've discovered is still weird -- but it's one step closer to being somewhat like our neighbourhood planets. Compared to most transiting planets detected thus far, which often have scorching temperatures in the many hundreds or thousands of degrees, TOI-1231 b is positively frigid."

In closing, Dragomir reflects that "this planet joins the ranks of just two or three other nearby small exoplanets that will be scrutinized with every chance we get and using a wide range of telescopes, for years to come so keep an eye out for new TOI1231b developments!"