MARCH 2021 | VOL. 10

CENTRE FOR ASTRO-PARTICLE PHYSICS

THE OFFICIAL NEWSLETTER OF THE CENTRE FOR ASTRO-PARTICLE PHYSICS

A limited number of top-up bursaries are available for MSc and PhD students from the CAPP.

Interested students should contact Ms Anna Samara Larmuth (**aslarmuth@uj.ac.za**) with their academic transcripts.

Further Your Studies

CUTTING EDGE RESEARCH BY CAPP GROUP MEMBERS

Scientists and students at the Centre for Astro-Particle Physics focus on research in Gamma-ray Astrophysics, Neutrino Astrophysics, Neutrino Physics and Gravitational Wave Physics.

We perform theoretical studies as well as data analysis and modelling. All three experimental facilities that we are involved in, namely the Fermi Gamma-ray Space Telescope; the Cherenkov Telescope Array and the KM3NeT Neutrino Telescope, perform cutting edge research.

Thus, working at CAPP can provide students and postdoctoral fellows opportunities to get involved in the science of these state of the art experiments, learn the latest techniques and interpret data collected with various instruments.

Research in Astro-Particle Physics requires strong background in Physics, Mathematics and computer programming.

Although some theoretical studies are still done on papers with pencils, numerical computations and simulations on computers are the main tools to make theoretical predictions these days. Data analysis and modeling also require significant computer skills and learning specialised software.

Students who would like to pursue postgraduate studies in AstroParticle Physics should choose Physics and Mathematics for their BSc degree.

The BSc Honours programme at the Department of Physics offer a wide range of advanced courses, including Astrophysics courses, that can prepare students for future MSc and PhD research in Astro-Particle Physics.

Honours students also get a taste of research by doing a project that helps them to prepare for MSc and PhD studies.

Say Farewell to One of Our CAPP Members

JESSICA-SHEAY VERRALL

Miss Jessica-Sheay Verrall studied her undergraduate degree with majors Physics and Chemistry at the University of Johannesburg from 2015-2017.

She then studied her Honours degree with major in Astrophysics in 2018. During her honours year she started working at the Centre for Astro-particle Physics as a student assistant.

In 2019 she started working full-time for the centre as the Research Administrator. She was part of the local organising committee for the Ninth International Fermi Symposium which was supposed to take place March-April 2020.

After 2 and a half years of working at CAPP she will now be leaving to pursue her new career in Education.

A Warm Welcome to One of Our Newest CAPP Members

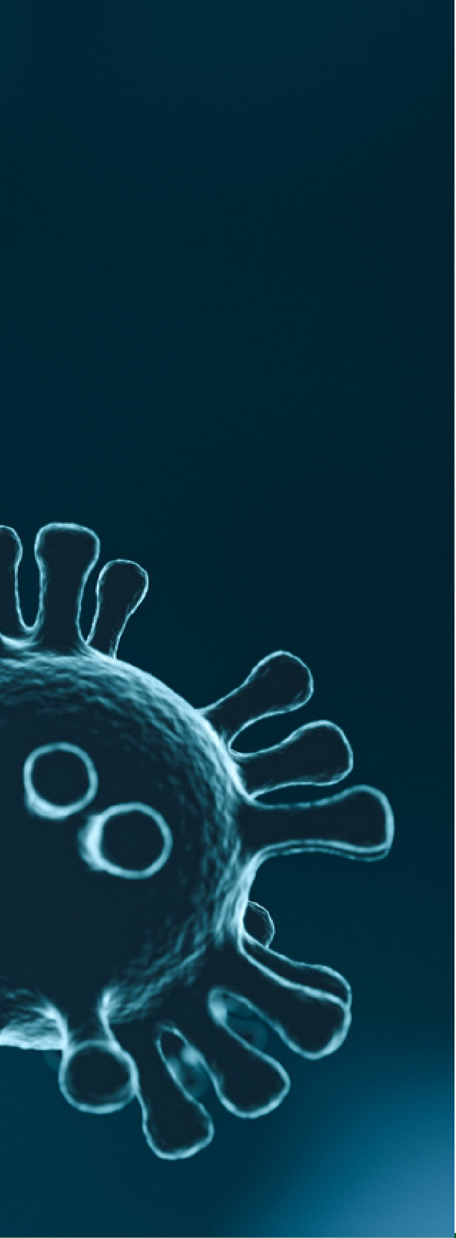
MONICA BARNARD

Dr. Monica Barnard started her undergraduate studies in the Department of Physical and Chemical Sciences at NWU (Potchefstroom campus).

Afterwards she continued her post graduate studies at the same institution under the supervision of both Prof. Christo Venter and Dr. Alice Harding (co-supervisor) in high-energy astrophysics, specifically pulsar science.

She completed her undergraduate BSc degree in Physics and Applied Mathematics, as well as my BSc Honours, MSc (cum laude) and PhD in pulsar astrophysics.

Monica's PhD will be awarded to her at the NWU Graduation ceremony in June this year. Currently she is appointed as a post-graduate student at the Physics department of UJ, and will resume her research in the high-energy astrophysics field (i.e., magnetar studies) under the supervision of Prof. Soebur Razzaque.



9TH INTERNATIONAL FERMI SYMPOSIUM

12 - 17 APRIL 2021

Due to the COVID-19 pandemic and current lock-down restrictions in South Africa, the Ninth International Fermi Symposium will now be held virtually for participants around the world.

This meeting will focus on the new scientific investigations and results enabled by Fermi, the mission and instrument characteristics, future opportunities, and coordinated observations and analyses.

Participants will be able to access the Ninth International Fermi Symposium programme on the following Indico page:

https://indico.cern.ch/event/1010947/

Contact Details:
Contact Person: Anna Samara Larmuth
Contact Email: capp@uj.ac.za

RESEARCH FROM OUR CENTRE

Rare Star's Giant Gamma-ray Burst GRB 2004015A Captured Close to Our Home Galaxy

RESEARCH BY PROFESSOR SOEBUR RAZZAQUE

On most days, our planet is blasted by slight and brief gamma-ray bursts (GRBs). But sometimes a gigantic flare like the GRB 200415A enters our galaxy, while sweeping along the energy that dwarfs our sun.

Scientists have now shown that GRB 200415A came from another potential source for short GRBS. It exploded out of a very rare, strong neutron star called a magnetar.

Previously observed GRBs originated relatively far away from our own galaxy, the Milky Way. Yet this one was a lot closer to home, in celestial terms.

BGRB blasts can interrupt the transmission of cell phones on Earth, but they can also be messengers from the very early history of the cosmos.

A different end game

"Our sun is a very ordinary star. When it dies, it will get bigger and become a red giant star. After that it will collapse into a small compact star called a white dwarf.

"But stars that are a lot more massive than the sun play a different end game," says Prof. Soebur Razzaque of the University of Johannesburg.

Razzaque headed a team forecasting GRB behavioUr for study published in Nature Astronomy on January 13, 2021.

"He says, "When these massive stars die, they explode into a supernova. What's left after that is a very small compact star, small enough to fit in a valley about 12 miles (about 20km) across.

This star is called a neutron star. It's so dense that just a spoonful of it would weigh tons on earth".

It's these huge stars, and what's left of them causes the largest explosions in the world.

A telling split second

Scientists have known for a while that GRB's long scooping supernovas are bursting for more than two seconds. In 2017, it was discovered that two neutron stars entwining into each other may also create a short GRB. The blast of 2017 came from a healthy 130 million light years away from us.

But it does not justify all of the other GRBs that researchers could find almost everyday in our sky.

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hat day, the GRB's massive flare swept past Mars. It has announced itself to the satellites, the astronauts and the International Space Station circling our earth.

It was the first known giant flare since the launch of NASA's Fermi Gamma-ray space telescope in 2008. And it only lasted 140 milliseconds, about a blink of an eye.

This time, however, the orbital telescopes and instruments captured even more data on the giant GRB flare than the previous one observed 16 years ago.

Bursts from another source

The enigmatic celestial tourist has been called GRB 200415A. The Inter Planetary Network (IPN), a group of physicists, pointed out where the giant flare originated from. GRB 200415A burst from a magnetar in a galaxy called NGC 253, in the Sculptor constellation, they say.

Many of the historically identified GRB's is traced to supernovae or two neutron stars entwining into each other.

Razzaque says, "In the Milky Way there are tens of thousands of neutron stars".

"Of those, only 30 are currently known to be magnetars.

"Magnetars are up to a thousand times more magnetic than ordinary neutron stars. Most emit X-rays every now and then. But so far, we know of only a handful of magnetars that produced giant flares. The brightest we could detect was in 2004. Then GRB 200415A arrived in 2020."

Galaxy NGC 253 is outside our home, the Milky Way, and it is only 11.4 million light years away from us.

This is relatively similar when it comes to nuclear frying strength of the GRB's giant flare.

A giant flare is so much more powerful than the solar flares of our sun, it's hard to conceive. Big solar flares from our sun often interrupt mobile phone coverage and power supplies.

The GRB's enormous flare even interrupted communication networks in 2004.

Second wave nabbed for the first time

Razzaque says, "No two gamma-ray bursts (GRBs) are ever the same, even if they happen in a similar way. And no two magnetars are the same either. We're still trying to understand how stars end their life and how these very energetic gamma rays are produced.

"It's only in the last 20 years or so, that we have all the instruments in place to detect these GRB events in many different ways - in gravitational waves, radio waves, visible light, X rays and gamma rays."

He goes on to say, "GRB 200415A was the first time ever that both the first and second explosions of a giant flare were detected."

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Understanding the second wave

In 2005 study, Razzaque expected the first and second explosions during a giant flare.

A team led by Jonathan Granot of the Open University of Israel, Ramandeep Gill of George Washington University and Matthew Baring of the University of Rice are responsible for current study in the field of natural astronomy.

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They developed an improved theoretical model, or forecast, of what a second explosion would look like in a giant GRB flare. They were able to equate their model with the data measured from GRB 200415A after April 15, 2020.

Razzaque states, "The data from the Fermi Gamma-ray Burst Monitor (Fermi GBM) tells us about the first explosion. Data from the Fermi Large Area Telescope (Fermi LAT) tells us about the second."

"The second explosion occurred about 20 seconds after the first one, and has much higher gamma-ray energy than the first one. It also lasted longer. We still need to understand what happens after a few hundred seconds though."

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Messengers about deep time

If the next giant GRB flare comes closer to our home galaxy, the Milky Way, a strong radio telescope on the ground, such as MeerKAT in South Africa, might be able to detect it, he says.

"That would be an excellent opportunity to study the relationship between very high energy gamma-ray emissions and radio wave emissions in the second explosion. And that would tell us more about what works and doesn't work in our model."

The more we understand these transient fires, the more we can understand the universe in which we live.

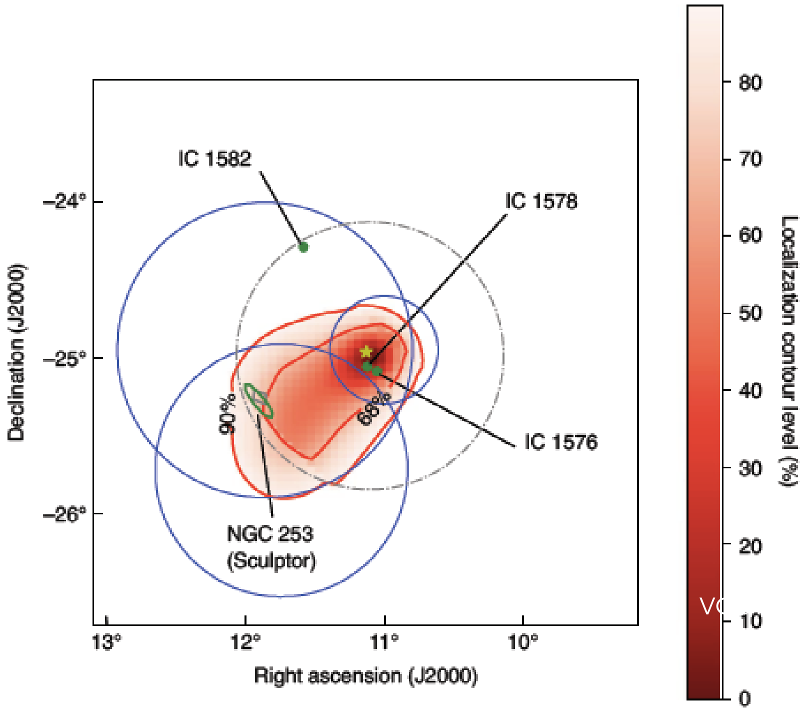
A star dying moments after the birth of the cosmos may be affecting mobile phone coverage today.

Razzaque says, "Even though gamma-ray bursts explode from a single star, we can detect them from very early in the history of the universe. Even going back to when the universe was a few hundred million years old."

"That is at an extremely early stage of the evolution of the universe. The stars that died at that time... we are only detecting their gamma-ray bursts now, because light takes time to travel.

"This means that gamma-ray bursts can tell us more about how the universe expands and evolves over time."

Rare star's giant gamma-ray burst GRB 200415A captured close to our home galaxy. (2021). Retrieved 11 February 2021, from https://www.eurekalert.org/pub_releases/2021-01/uoj-rsg011221.php



LATEST NEWS AND DISCOVERIES

Study of supergiant star Betelgeuse unveils the cause of its pulsations

RECALIBRATED ITS MASS, RADIUS, AND DISTANCE

The international team of physicists, including Ken'ichi Nomoto at the Kavli Center for Physics and Mathematics of the Universe (Kavli IPMU), performed a rigorous Betelgeuse analysis to find out more. They concluded that the star is in the early core helium-burning period (which is more than 100,000 years before the explosion occurs) and has a smaller mass which radius—and is closer to Earth than previously believed. They also showed that smaller changes in the brightness of Betelgeuse were driven by stellar pulsations, and indicated that the recent major dimming occurrence involved a cloud of dust.

The research team is headed by Dr. Meridith Joyce of the Australian National University (ANU), who was invited to talk at Kavli IPMU in January 2020 and includes Dr. Shing-Chi Leung, a former Kavli IPMU project researcher and new postdoctoral scholar at the California Institute of Technology, and Dr. Chiaki Kobayashi, associate professor at the University of Hertfordshire, who was a member of the Kavli IPMU affiliate.

The team studied Betelgeuse's difference in brightness using developmental, hydrodynamic and seismic modeling. They had a better understanding than ever that Betelgeuse is currently burning helium at its heart. They also revealed that stellar pulsations powered by the so-called kappa-mechanism caused the star to glow or fade continuously with two cycles of 185 (+-13.5) days and roughly 400 days. But the significant dip in brightness at the beginning of 2020 is unexpected and is likely

Betelgeuse is usually one of the brightest, most visible stars in the winter sky, defining the left shoulder of the Orion constellation. But it has been acting oddly lately: an unprecedentedly significant decrease in its brightness was detected at the beginning of 2020, which has led to rumors that Betelgeuse may be about to burst.

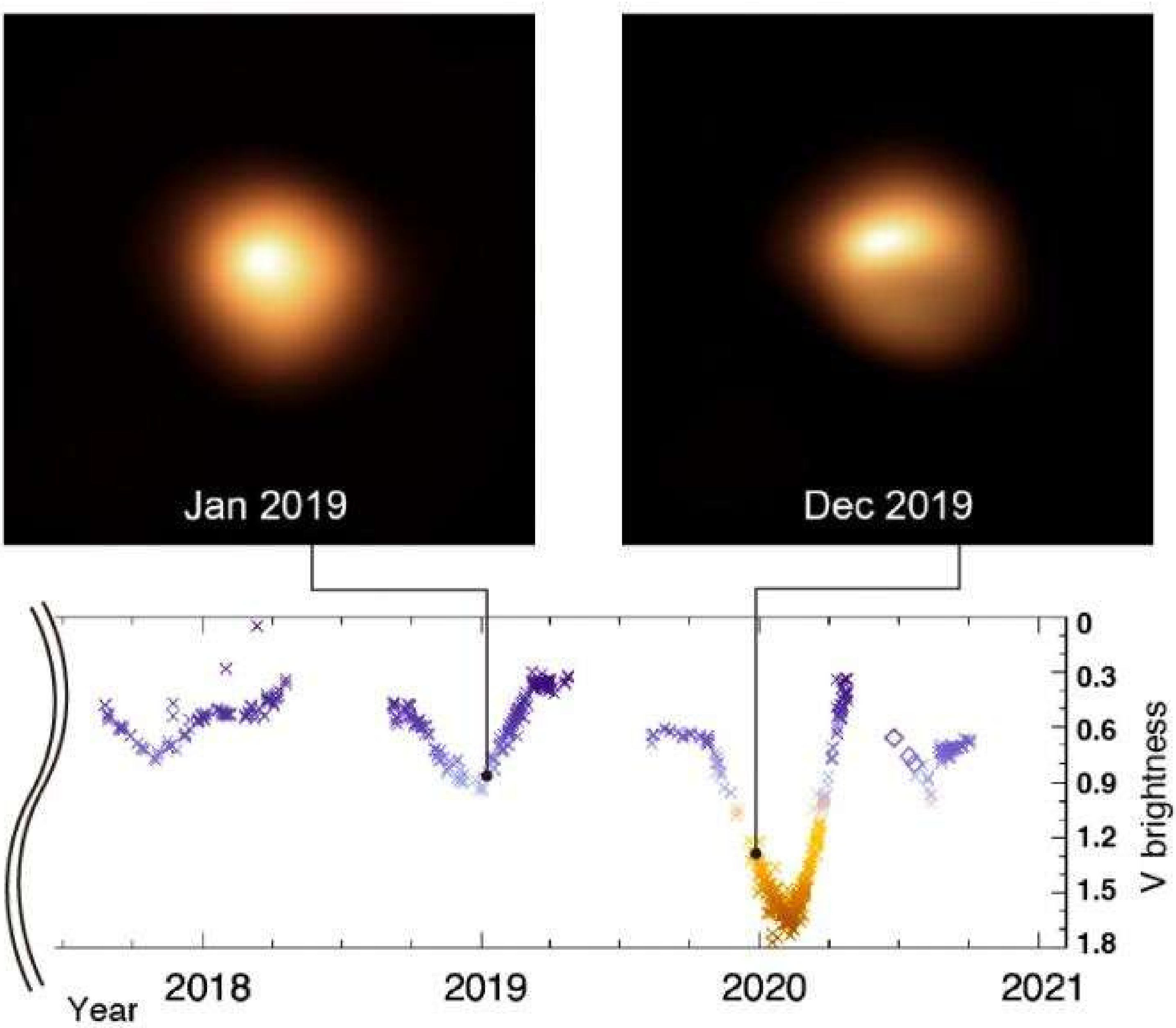
to be attributed to the dust cloud in front of Betelgeuse, as seen in the image.

Their study estimated a current mass of 16.5 to 19 solar masses—which is significantly smaller than the most recent figures. The research also showed how large the Betelgeuse is and how far it is from Earth.

The exact size of the star was a bit of a mystery: older research, for example, indicated that it may be larger than the orbit of Jupiter. However, the findings of the team shows that Betelgeuse only stretches to two-thirds of that, with a radius of 750 times the radius of the sun. Once the physical size of the star is known, it is possible to calculate its distance from Earth. So far, the team's measurements reveal that it's just 530 light years away from us, or 25 percent closer than previously believed.

Their findings show that Betelgeuse is not at all close to bursting, and that it is too far from Earth for an eventual explosion to have a major effect here, even though it is also a very big deal when a supernova goes off. And because Betelgeuse is the closest contender for such an eruption, it gives us a rare chance to research what happens to stars like this before they explode.

Kavli Institute for the Physics and Mathematics of the Universe. (2021, February 8). Study of supergiant star Betelgeuse unveils the cause of its pulsations: Recalibrated its mass, radius, and distance. ScienceDaily. Retrieved February 9, 2021 from www.sciencedaily.com/releases/2021/02/210208100536.htm



The images were taken by the European Southern Observatory's (ESO's) Very Large Telescope. Credit: ESO/M. Montargès et al

LATEST NEWS AND DISCOVERIES

True identity of mysterious gamma-ray source revealed

UNIVERSITY OF MANCHESTER

An international research group, with members from Manchester University, has demonstrated that a rapidly spinning neutron star is at the centre of a celestial object now known as PSR J2039-5617.

The international partnership used innovative data processing techniques and the immense computational capacity of the citizen science project Einstein@Home to monitor the faint gamma-ray pulsation of neutron stars in the data of the NASA Fermi Space Telescope. Their measurements indicate that the pulsar is about a sixth of the mass of our Sun in space with a stellar companion. The pulsar is steadily but gradually evaporating the star. The team have observed that the orbit of the companion differs slightly and unpredictably over time. Using their search process, they hope to discover more of these networks with Einstein@Home in the future.

Searching for the so-called 'Spider' pulsar systems—quickly spinning neutron stars whose high-energy outflows are killing their binary companion star, took 10 years of accurate results.

Pulsars have been given the arachnid names of 'Black Widows' or 'Redbacks,' after spider species, where females have been known to kill smaller males after mating.

A new study published in the Monthly Notes of the Royal Astronomical Society details how researchers find a neutron star spinning 377 times a second in an exotic binary system using data from the Fermi Space Telescope of NASA.

The observations of the astronomer were uniquely strengthened by the Einstein@Home initiative, a network of thousands of civilian volunteers contributing their home computing power to the work of the Fermi Telescope.

The hunt for the party involved a very fine combing of the data in order not to lose any potential signals. The amount of computational power needed is immense. The quest will take 500 years to complete on a single data core. It was achieved in 2 months by using part of the tools of Einstein@Home.

With the computational resources donated by the volunteers of Einstein@Home, the team discovered gamma-ray pulsations from the quickly spinning neutron star. This pulsar gamma-ray, now known as J2039-5617, rotates roughly 377 times a second.

According to Lars Nieder, a PhD student at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute; AEI) in Hannover, "It had been suspected for years that there is a pulsar, a rapidly rotating neutron star, at the heart of the source we now know as PSR J2039-5617". He adds, "But it was only possible to lift the veil and discover the gamma-ray pulsations with the computing power donated by tens of thousands of volunteers to Einstein@Home."

Since 2014, the celestial phenomenon has been regarded as a source of X-rays, gamma rays and illumination. Every piece of evidence so far pointed to a rapidly spinning neutron star in orbit with a light star at the center of the source. But there was no clear evidence.

Emerging observations of the stellar companion with optical telescopes were the first step in solving this mystery. They offered detailed knowledge of the binary system without which a gamma-ray pulsar search (even with Einstein@Home's immense computational power) would be unfeasible.

The system's luminosity varies over an orbital period, depending on the side of the neutron star's companion is facing the planet.

"For J2039-5617, there are two main processes at work," states Dr. Colin Clark of the Jodrell Bank Centre for Astrophysics, lead author of the report. "The pulsar heats up one side of the light-weight companion, which appears brighter and more bluish.

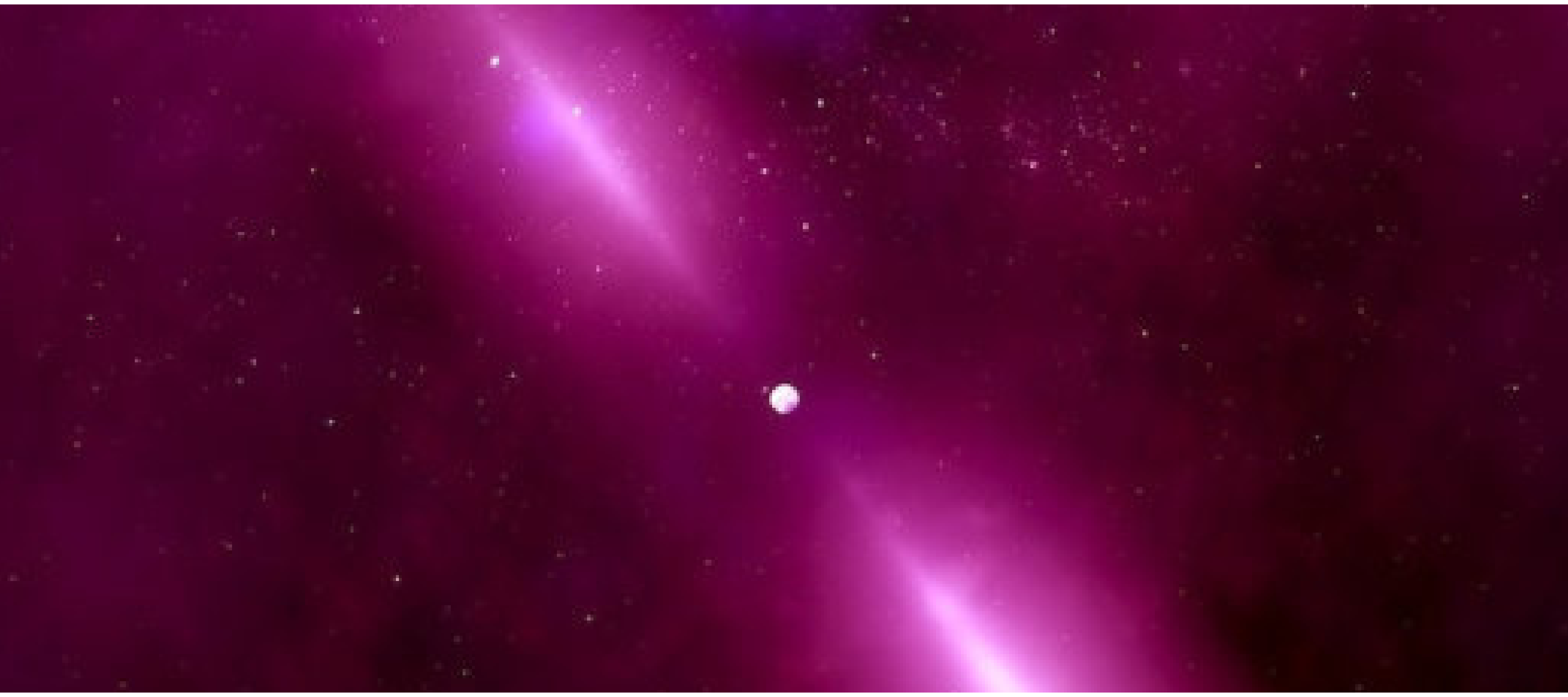
Additionally, the companion is distorted by the pulsar's gravitational pull causing the apparent size of the star to vary over the orbit. These observations allowed the team to get the most precise measurement possible of the binary star's 5.5-hour orbital period, as well as other properties of the system."

With this knowledge and the exact location of the Gaia data sky, the team used the aggregated computational resources of the distributed volunteer project Einstein@Hometo retrieve roughly 10 years of archival observations of the Fermi Gamma-ray Space Telescope of NASA.

Improving the earlier methods they had developed for this purpose, they enlisted the aid of tens of thousands of volunteers to scan the Fermi data for intermittent pulsations in gamma-ray photons detected by the Wide Area Telescope on board the space telescope. Volunteers contributed idle compute cycles to Einstein@Home on their machine CPUs and GPUs.

New knowledge of the frequency of gamma-ray pulsations has helped collaborators to detect radio pulsations in the Parkes radio telescope archival records. Their observations, also published in the Monthly Notices of the Royal Astronomical Society, indicate that the radio emission of the pulsar is always overshadowed by dust that has been blown off the companion star by its neighbouring Redback pulsar.

University of Manchester. (2021, February 3). True identity of mysterious gamma-ray source revealed. ScienceDaily. Retrieved February 9, 2021 from www.sciencedaily.com/releases/2021/02/210203123346.htm



Neutron star illustration (stock image; elements furnished by NASA).Credit: © Artsiom P / stock.adobe.com

LATEST NEWS AND DISCOVERIES

Galaxies hit single, doubles, and triple (growing black holes)

HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

If three galaxies collide, what happens to the massive black holes in the middle of each galaxy? Recent research using NASA's Chandra X-ray Observatory and many other telescopes provides new knowledge on how many black holes expand furiously since the celestial break-ups.

Astronomers want to understand more about interstellar collisions because resulting mergers are a crucial way for galaxies and giant black holes in their cores to evolve over cosmic time.

"There have been many studies of what happens to supermassive black holes when two galaxies merge," said Adi Foord of Stanford University, who led the study. "Ours is one of the first to systematically look at what happens to black holes when three galaxies come together."

She and her colleagues identified triple galaxy fusion structures by connecting the NASA WISE project and the Sloan Digital Sky Survey (SDSS) to the Chandra archive-containing data that is now publicly accessible. Using this approach, they discovered seven triple galaxy mergers located between 370 million and 1 billion light years away from Earth.

Using advanced tools Foord developed for her Ph.D. at the University of Michigan, Ann Arbor, the team used Chandra data targeting these devices to identify X-ray sources marking the location of growing supermassive black holes. If the substance sinks into a black hole, it is heated to millions of degrees and creates x-rays.

With its sharp X-ray vision, Chandra is perfect for detecting growing supermassive black holes in mergers. The related X-ray sources are difficult to locate because they are usually clustered together in pictures and are sometimes faint. Foord's program has been developed primarily for the purpose of locating those sources. Data from other instruments were also used to null out other potential sources of X-ray emissions that were not related to supermassive black holes.

The findings of Foord and the team reveal that out of seven triple galaxy mergers, there is one with a single expanding supermassive black hole, four with double-growing supermassive black holes, and one with a triple one. The final triple fusion they were investigating appears to have struck out with no X-ray radiation observed from the supermassive black holes. In systems with many black holes, the separations between them vary from around 10,000 to 30,000 light years.

"Why do we care about the hitting percentage of these black holes?" said co-author Jessie Runnoe of Vanderbilt University in Nashville, Tenn. "Because these statistics can tell us more about how black holes and the galaxies they inhabit grow."

After discovering evidence for bright X-ray sources as candidates for growing supermassive black holes in Chandra data, researchers integrated archival data from other telescopes. Like a second arbiter conferring on the initial call, these evidence backed up the theory that several black holes were found in the merged galaxies.
To make these calls, the authors analyzed infrared data from the WISE mission, the Infrared Astronomical Spacecraft, and the Two Micron All Sky Telescopes to see how rapidly stars shape in the various galaxies in their survey. This helped them to predict how many of the observed X-rays are likely to originate from X-ray emitting structures containing large stars, rather than from a growing supermassive black hole. Since these star systems are new, they are more likely as the stars develop sooner. Foord and her collaborators have used this method to infer that one of the X-ray sources they have established is likely to originate from a series of X-ray emitting star systems.

The data from Chandra and WISE reveal that the system of growing supermassive black holes has the greatest volume of dust and methane. This correlates to theoretical computer models of mergers that indicate higher amounts of gas near black holes are more likely to cause the accelerated growth of black holes.

Triple merger experiments will help physicists consider whether pairs of supermassive black holes can be reached so close to each other that spacetime ripples are considered gravitational waves.

The energy lost by such waves would eventually cause the black holes to merge.

The Laser Interferometer Gravitational Wave Observatory (LIGO) and the Virgo array in Europe have shown astronomers that stellar black holes produce gravitational waves and combine, but it is not clear whether supermassive black holes do.

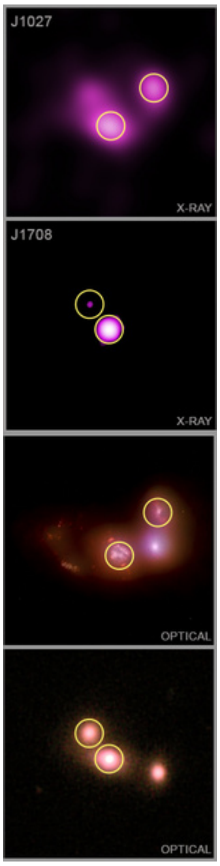
"There is a "nightmare scenario" where supermassive black holes cannot lose enough energy to come close together and make gravitational waves" said co-author Michael Koss of Eureka Scientific in Oakland, California. "If this is the case then projects like LISA and pulsar timing arrays won't have any supermassive black hole mergers to detect."

However, the gravitational interactions of the third supermassive black hole can prevent this stalling process. Studies of supermassive black holes in systems where three galaxies combine are therefore important for understanding whether the nightmare scenario could apply.

The system of three growing supermassive black holes had previously been stated by Ryan Pfeifle of George Mason University in Fairfax, Virginia, in a Chandra press release, and an October 2019 paper in The Astrophysical Journal, and a team led by Xin Lui of the University of Illinois at Urbana-Champaign, in a December 2019 paper in The Astrophysical Journal. This latest observation aims to bring this finding into the context of other triple galaxy mergers.

Foord discussed the new thesis at the 237th conference of the American Astronomical Society, which will be held from 11 to 15 January 2021. Two articles detailing this work have recently been published in The Astrophysical Journal. The Infrared Astronomy Satellite is a joint partnership between NASA and its partners in the Netherlands and the United Kingdom, and the Two Micron All Sky Telescope is a cooperation between the University of Massachusetts and the NASA Infrared Processing and Analysis Centre.

The Marshall Space Flight Center of NASA operates the Chandra program. The Smithsonian Astrophysical Observatory, Chandra X-ray Centre, manages research from Cambridge, Massachusetts, and flight operations from Burlington, Massachusetts.



Harvard-Smithsonian Center for Astrophysics. (2021, January 14). Galaxies hit single, doubles, and triple (growing black holes). ScienceDaily. Retrieved February 10, 2021 from www.sciencedaily.com/releases/2021/01/210114130142.htm

You can view our website to see events, the latest news, images, and info regarding the research of our group members as they happen and when they happen.

www.uj.ac.za/capp

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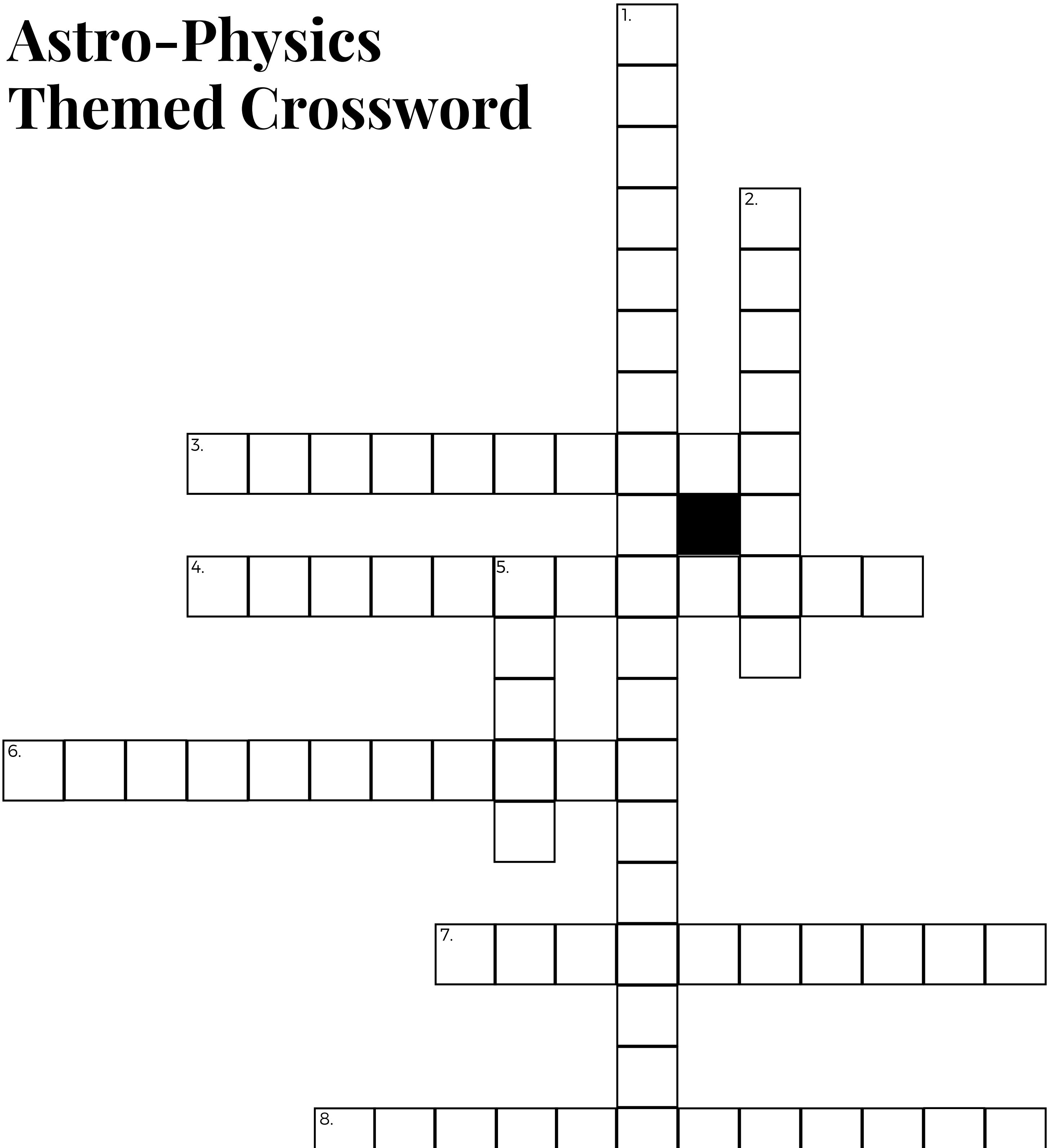
Instagram

Astro-Physics Themed Crossword



Crossword Clues

Across

3. The tenth- brightest star in the night sky.
4. Formed when a massive star runs out of fuel and collapses.
6. An arachnid name for pulsars.
7. A small very dense star that is typically the size of a planet
8. Occurring or situated between stars.

Down

1. A quickly spinning neutron stars whose high-energy outflows are killing their binary companion star.
2. A neutron star with a much stronger magnetic field than ordinary neutron stars.
5. A prominent constellation located on the celestial equator and visible throughout the world.