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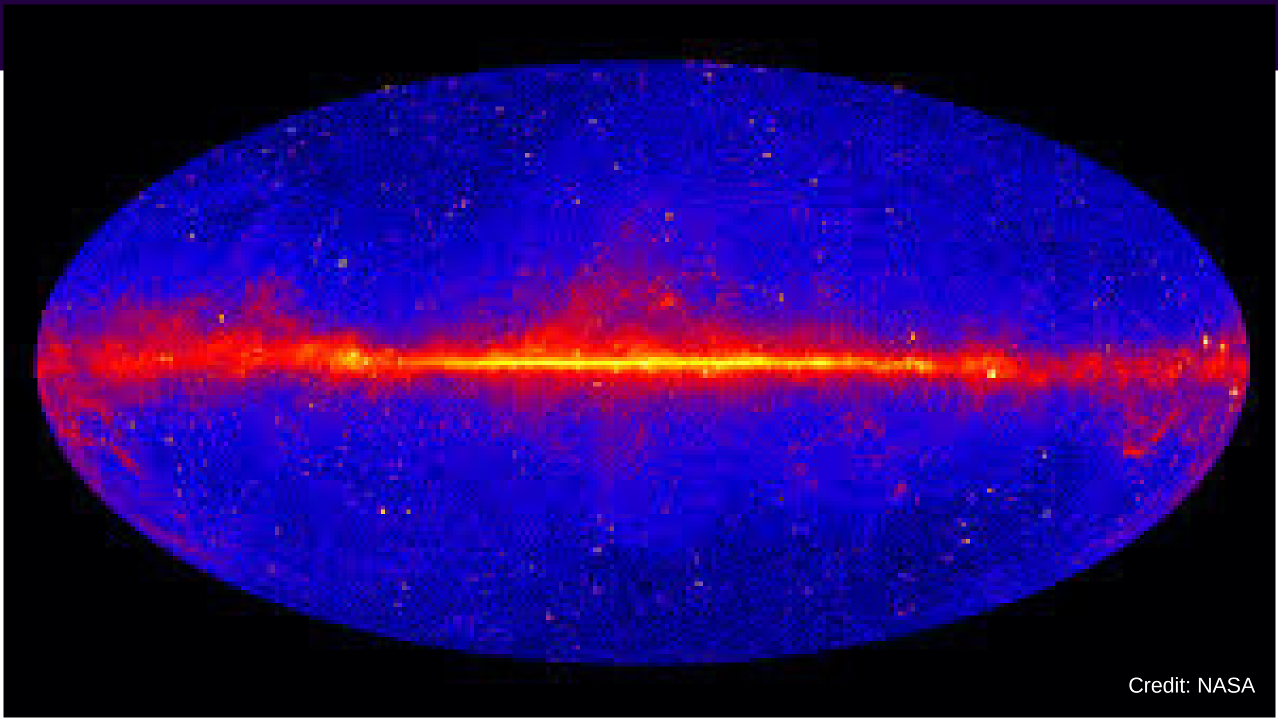
CENTRE FOR ASTRO-PARTICLE PHYSICS



Credit: NASA

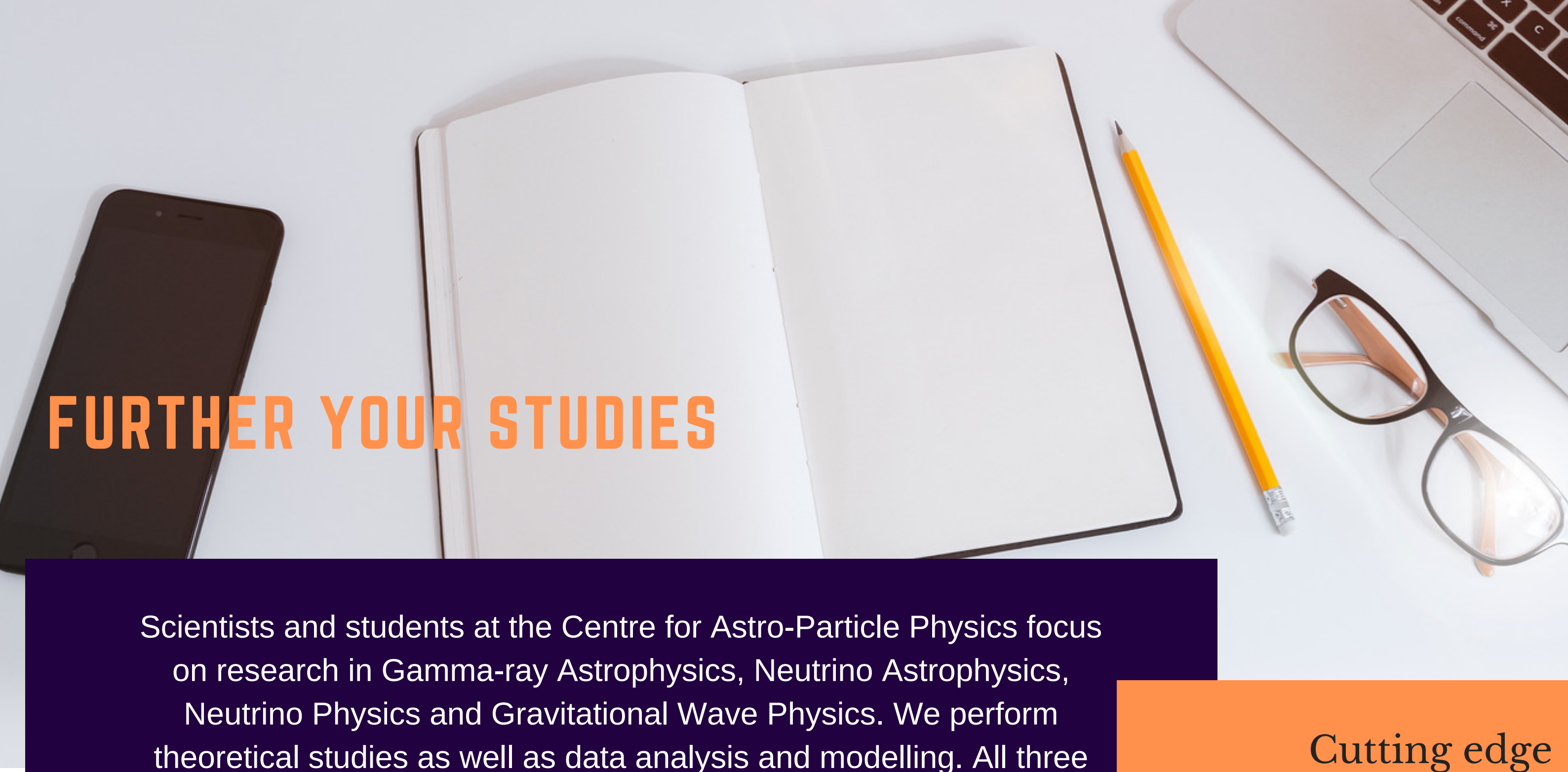
NEWSLETTER OF THE CENTRE FOR ASTRO-PARTICLE PHYSICS

UNIVERSITY OF JOHANNESBURG

FOURTH EDITION

DATE: 19-06-2019

Designed by Jessica-Sheay Verrall



FURTHER YOUR STUDIES

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..

Cutting edge research by CAPP group members.

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 Astro-Particle 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.

A limited number of top-up bursaries are available for Honours, MSc and PhD students from the CAPP. Interested students should contact Ms Jessica-Sheay Verrall (capp@uj.ac.za) with their academic transcripts.

FOLLOW US

WEBSITE

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.
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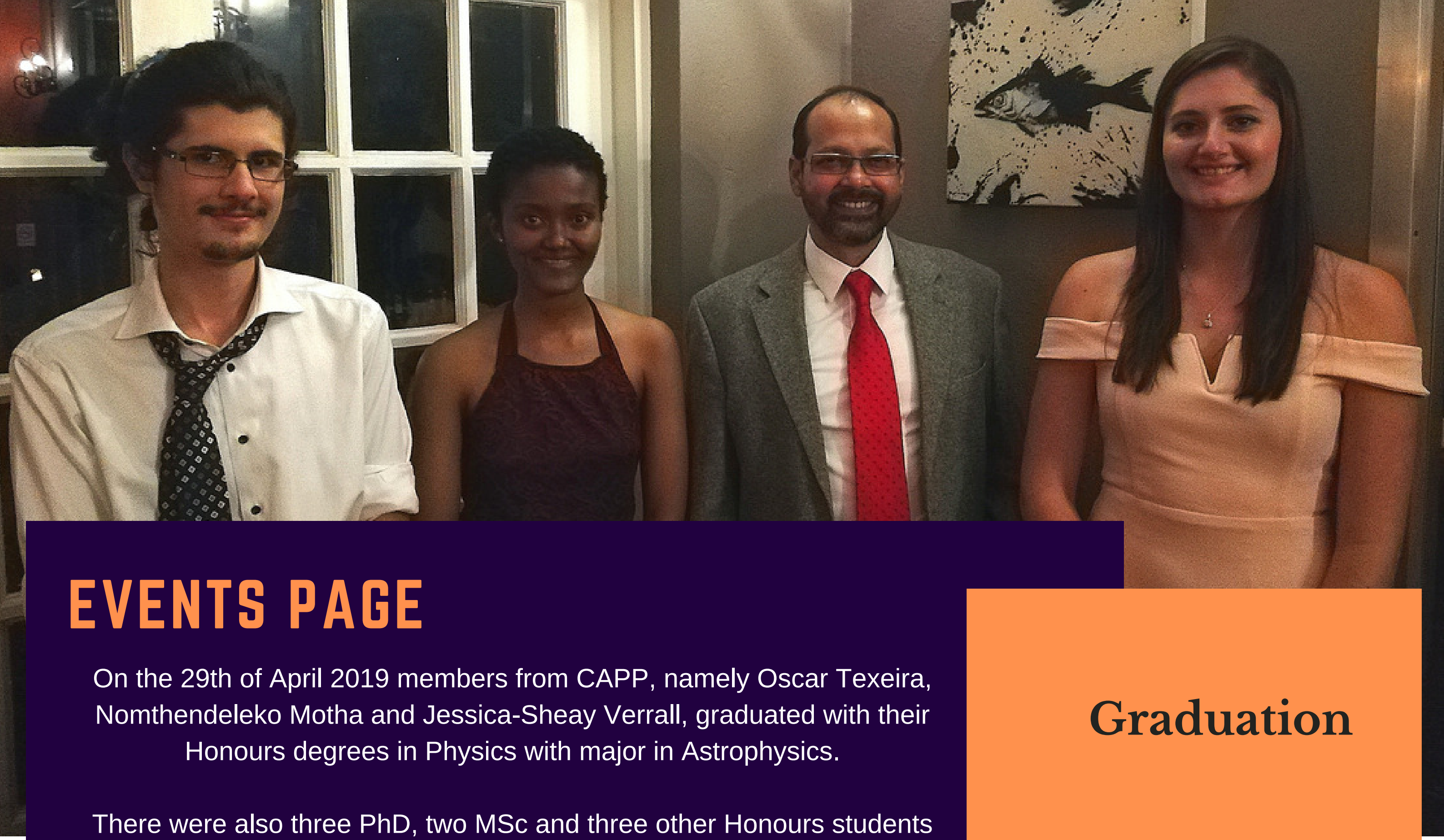
We now have a Facebook and Instagram page. Please help us grow by following us and sharing the news.



EVENTS PAGE

Graduation

On the 29th of April 2019 members from CAPP, namely Oscar Texeira, Nomthendeleko Motha and Jessica-Sheay Verrall, graduated with their Honours degrees in Physics with major in Astrophysics.

There were also three PhD, two MSc and three other Honours students who graduated from the Physics Department. Two other students, Mr Daymore Makope and Isaac Magolego, also graduated Honours with major in Astrophysics.

Our new Postdoc

Ushak Rahaman is a postdoctorate fellow at CAPP. He did his PhD from IIT Bombay, India and his thesis title was "Mass hierarchy and CP violation determination in the long baseline neutrino oscillation experiments". His research interest so far is neutrino oscillation phenomenology in the long baseline neutrino oscillation experiments. He is also interested in neutrino mass models, charged lepton flavour violation and other beyond the standard model physics.

Outreach Activities: Interactive presentation at Marais Viljoen High School.

EVENTS PAGE

On the 14th of May 2019 Professor S Razzaque and Ms JS. Verrall went to Marais Viljoen High School to give a presentation to grade 10 -12 learner's having physical science and geography as subjects.

The presentation was designed to create awareness about the Centre as well as inform students about what is required to study physics at UJ at undergraduate level and ultimately a postgraduate degree in Astrophysics.

The presentation given was an interactive one, where the students could log onto Mentimeter on their phones, answer some of our questions and participate in the quiz all while receiving real time results. The top three learners from the quiz received prizes.

The latest news and discoveries

The first image of a black hole and how we got there

Francis, M. (2019). The incredible story behind the first image of a black hole. [online] Wired.co.uk. Available at: https://www.wired.co.uk/article/black-hole-photo-image [Accessed May 2019].

A glimpse into the universe

Guarino, B. (2018). Astrophysicists count all the starlight in the universe. [online] The Washington Post. Available at: https://www.washingtonpost.com/science/2018/11/29/astrophysicists-count-all-starlight-universe/?noredirect=on&utm_term=.11fee9e7c86e [Accessed Jun. 2019].

The possibility of a fourth neutrino

Siegel, E. (2019). Is There Really A Fourth Neutrino Out There In The Universe?. [online] Forbes. Available at: https://www.forbes.com/sites/startswithabang/2018/12/05/is-there-really-a-fourth-neutrino-out-there-in-the-universe/amp/ [Accessed May 2019].

A jet of compact radio emission was produced by a binary neutron star merger

Ghirlanda, G., Salafia, O., Paragi, Z., Giroletti, M., Yang, J., Marcote, B., Blanchard, J., Agudo, I., An, T., Bernardini, M., Beswick, R., Branchesi, M., Campana, S., Casadio, , L., Jonker, P., van Langevelde, H., Melandri, A., Moldon, J., Nava, L., Perego, A., Perez-Torres, M., Reynolds, C., Salvaterra, R., Tagliaferri, G., Venturi, T., Vergani, S. and Zhang, M. (2019). Compact radio emission indicates a structured jet was produced by a binary neutron star merger. Science, 363(6430), pp.968-971.

The first image of a black hole and how we got there

One of the predictions of Eistein's theory of general relativity is that black holes emit no radiation that we are yet able to detect, and nothing can escape it, not light nor matter.

The Event Horizon Telescope's (EHT) mission was to capture the first image of such a phenomenon. On April 10th 2019, history was made when EHT scientists released the very first direct image of a black hole.

This first image is from a black hole at the centre of the galaxy M87. The mission involved hundreds of astronomers, engineers, and data scientists from around the world.

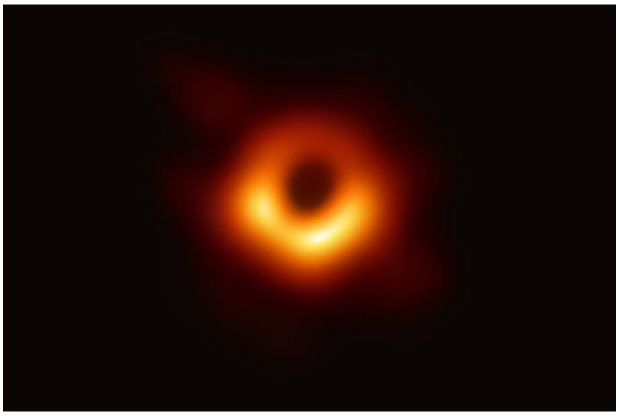
Astronomers believe that there is a black hole at the centre of every large galaxy (including our own). The mass of M87's black hole is 6.5 billion times the mass of the Sun. The image itself shows the glowing plasma (matter where electrons have been stripped from their atoms by the intense friction) surrounding the black hole, the shape and size of the event horizon itself being revealed with the shadow at the centre of the image.

The image shows the asymmetrical shape of the matter, both how the plasma swirls around the event horizon, and also how the path of the light emitted by material is affected by the gravitational distortion of spacetime. Precisely in agreement with Einstein's predictions of general relativity.

Not only does this image test general relativity, but its implications go beyond that. It was found that what happens at the event horizon can influence what atoms get distributed throughout an entire galaxy. This is because the pressures which build around the black hole can expel material in a wind before they get to the event horizon and that energy affects the galaxy as a whole.

Scientists had to purchase petabyte-size disks in order to store the large amounts of data from each telescope, and there were a very larger number of telescopes used to observe it (in the US, Europe, Chile, and Antarctica). The initial phase involved eight observatories, forming a worldwide array of telescopes with enough power in order to see light emitted right from the edge of a black hole.

The reason M87 was the focal point of this mission and not our own galaxies black hole is because our galaxy has a lot more "pollution" compared to M87. This means there is much more gas and dust in our galaxy which obscured the picture.



A jet of compact radio emission was produced by a binary neutron star merger

A binary neutron star merger was detected by gravitational waves and electromagnetic emission. The gravitational waves were detected first and a few seconds later the gamma ray burst was observed. Approximately eleven hours after the detection of the gamma ray burst, the electromagnetic observations from ultra-violet to near-infrared wavelengths allowed scientists to pinpoint the host galaxy of GW170817. The afterglow of the emission may have been produced by either a narrow relativistic jet or an isotropic outflow. High spatial resolution measurements of the source size and displacement was used to discriminate between these two scenarios.

Interpretation of the long-lasting radio, optical and X-ray emission, had besought the launch of a jet from the remnant of the merger. This jet will dig into the surrounding kilonova (a transient astronomical event that occurs in a compact binary system when two neutron stars or a neutron star and a black hole merge into each other) material ejected beforehand. The jet will either successfully breakthrough the ejecta, or it will fail to break through and deposit all its energy into the ejecta, therefore, forming a hot cocoon which will expand due to high pressure.

Observations performed 207 days after the merger, by the Very Long Baseline Interferometry, made use of 32 radio telescopes. The apparent source size was found to be constrained smaller than 2.5 milliarcseconds at the 90% confidence level. Excluding the isotropic outflow scenario, which would have indicated that the GW170817 produced a structured relativistic jet. The rate calculations made by scientists show that at least 10 % of neutron star mergers produce such a jet.

A glimpse into the universe

With the light of some billion trillion stars our universe shines. Scientists had recently undergone the task of summing up the universe's stars' light, or better known to scientists as photons. Scientists had approximated that stars have emitted 41084photons into the universe.

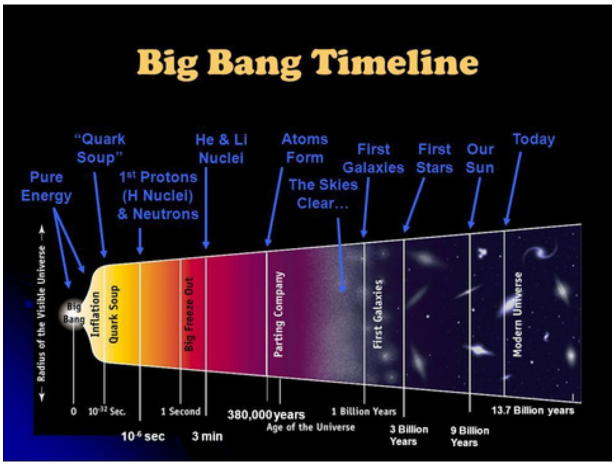
With this technique, not only were scientists able to count the number of photons emitted but they were also able to construct a history of star formation. They had found that star births peaked about 3 billion years after the big bang and this spurt has since slowed down in the past 10+ billion years.

For many years the goal of astronomers was to gather information from this distant starlight, but the extragalactic background light was very difficult to observe directly. The extragalactic background is basically the entire emission from all the stars in the universe.

The extragalactic background light has always been difficult to study because stars form in a cradle of gas and dust, this gas and dust then absorbs some of the light. But the rest of the light particles, the photons in the visible and ultraviolet wavelengths, escape to glow across the universe. Some of the light which does escape can be swamped out by nearby emissions from our solar system and the rest of our Milky Way galaxy's stars.

We also need to consider that even those which escape can possibly collide with gamma rays, for instance, and this results in an annihilation which creates new particles. Gamma rays are also made of photons, however, they are of much higher energies.

Gamma rays are emitted by blazars or by supermassive balck holes at the centers of galaxies, when matter near these black holes are shredded and flung away. Gamma ray photons will only interact with photons from starlight. Essentially the starlight absorbs the gamma rays. The gamma ray detector found on the Fermi observatory is able to observe how these rays lose energy when they annihilate starlight.



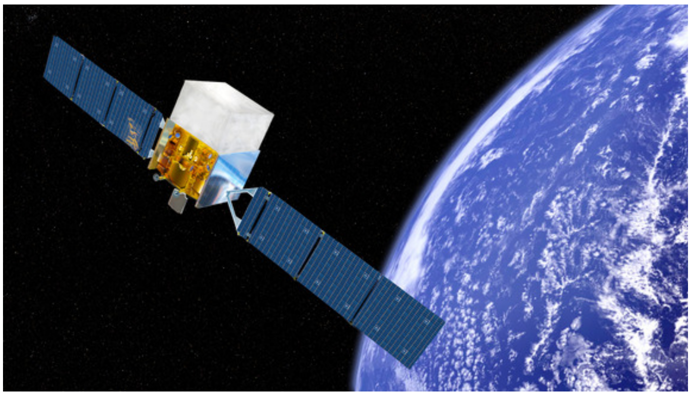
Kumar, K. (2019). Big Bang and the Age of the Universe.

The energy loss is a sign that the rays hit star photons, and this is how they counted the starlight. 739 blazars were used to survey starlight across history, where the closest blazar was created 200 million years ago. The most distant blazar was created 11.6 billion years.

It was found that The stars really began to bloom when the universe was only 2 billion years old, and our universe is now 13,77 billion years old. The star formation reached its peak a few billion years later and then began a slow decline as it aged.

Even though this technique offered a glimpse into the early ages of our universe,not enough is known about the first billion years. To understand the first billion years, astrophysicists are eagerly anticipating the long-delayed launch of the James Webb telescope, which will probe farther stars — and further back in time.

Prof S Razzaque of CAPP is a coauthor of this study published in the Science magazine. A model of the extra-galactic background light proposed by Prof Razzaque and his collaborators (Razzaque, Dermer and Finke 2009; Finke, Razzaque and Dermer 2010) is widely used in the gamma-ray astronomy and consistent with the results found in this study.



NASA (2019). Fermi Satellite.

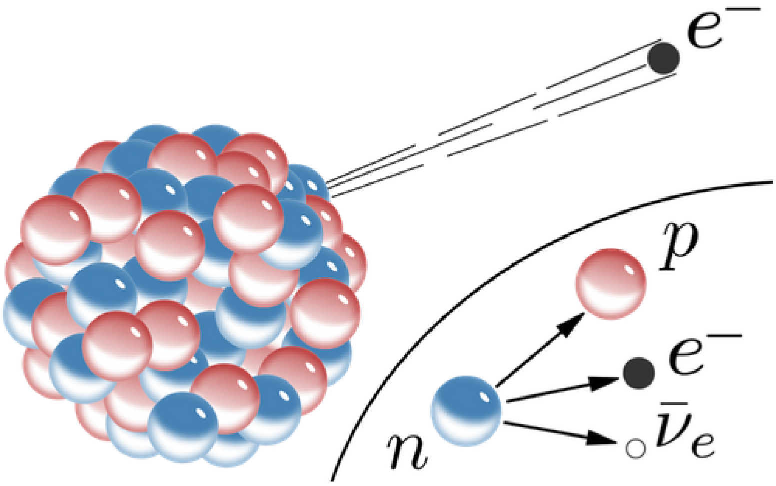
The possibility of a fourth neutrino

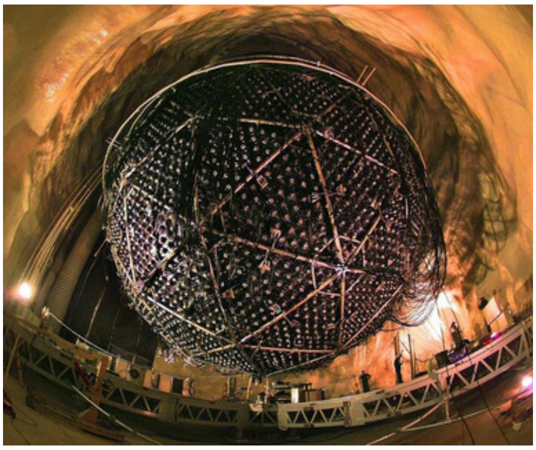
According to the Standard model of particle physics: There are three types of neutrino, the electron neutrino (νe), the muon neutrino (νμ), and the tau neutrino (ντ). These also have their antimatter counterparts. We also know that they have very tiny (non-zero) mass. They transform from one type into another while they travel through space, and they are generated when particles decay.

This Standard model was consistent until the Liquid Scintillator Neutrino Detector (LSND) experiment yielded results that could not be explained. In the physical models used, the relationships between the distance a neutrino travels, the neutrino energy, and the differences in mass between the different types of neutrinos, are simple. The ratio of distance-to-energy corresponds to a mass difference, and from solar and atmospheric neutrinos, the differences of mass were of the scale of milli-electron-volt, however, with small distances from the LSND experiment, it implied mass differences that were about 1000 times greater (electron-volt).

The solar neutrino measurements, the atmospheric neutrino measurements and the LSND results are mutually incompatible with the three Standard Model neutrinos. The MiniBooNe experiment at Fermilab wanted to try and reproduce these results to either prove or disprove it. They produced neutrinos, to collide, from the booster ring in the old Tevatron at Fermilab. After 16 years of data-taking, the MiniBooNe experimental results were not only consistent with the results of LSND but extended them.

This could mean many different things; could there be a more complicated type of mixing between neutrinos than presently known? Could neutrinos couple with dark matter or dark energy? Could they couple to themselves in a way that the Standard model cannot explain? Could the density of their material make a difference? Etc. There are ongoing experiments to gather more information about what exactly is at play with this phenomenon.





For more information on this subject you can read the following article: L.S. Miranda and S. Razzaque, titled "Revisiting constraints on 3+1 active-sterile neutrino mixing IceCube data," published in Journal of High Energy Physics, 1903 (2019) 203.