Volume 14
The Official Newsletter of the
Centre for Astro-Particle Physics (CAPP)
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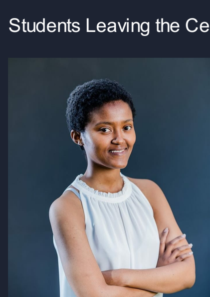
LATEST NEWS

Students Leaving the Centre



Ms. Nomthendeleko Motha

A warm farewell to one of our very own, Nomthendeleko Motha (Thendi), who graduated in 2021 with her Master's under the supervision of Professor Soebur Razzaque. Thendi will be pursuing her PhD studies at the University of the Western Cape (UWC). Your CAPP family are seriously going to miss you here. Best of luck for your new endeavor and the never-ending adventures.

We hope to see you soon!

New Students to the Centre

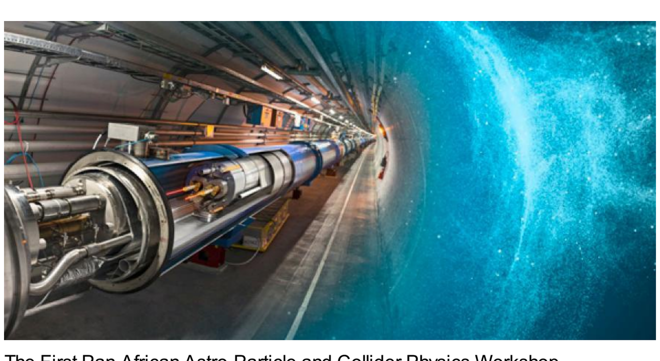
Ms. Dimakatso Maheso

A warm welcome to Ms. Dimakatso Maheso (DJ) who graduated in 2021 with her Honours degree in Physics at the University of Johannesburg, South Africa. DJ will be pursuing her Master's studies under the supervision of Professor Soebur Razzaque. Your CAPP family welcomes you with open arms, and wishes you the best of luck towards pursuing your studies of astro-particle physics.

We look forward to working with you!

UP-AND-COMING CONFERENCES

20	01	25	25
DAYS	HOURS	MIN	SEC

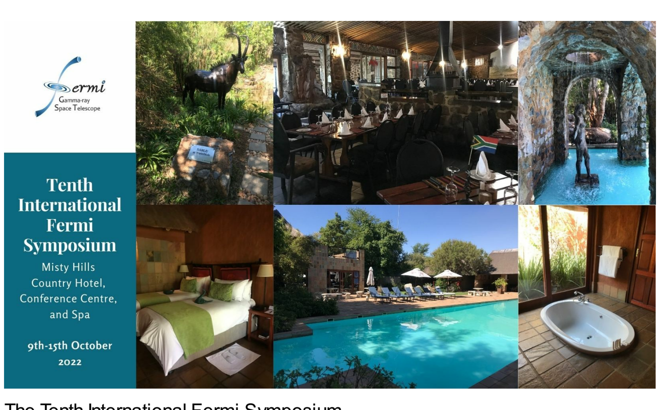


The First Pan-African Astro-Particle and Collider Physics Workshop

The intent of the workshop is to provide a forum for the exchange of information among African researchers in the fields of Astro-Particle and Collider Particle Physics. Prominent members of the International community will be invited to give overview presentations. Students and junior researchers will be given an opportunity to present. The workshop will take place between the 21-23 March 2022.

Visit the First Pan-African Astro-Particle and Collider Physics Workshop Indico page here.

07	07	23	48	38
MONTHS	DAYS	HOURS	MIN	SEC



The Tenth International Fermi Symposium

Due to the COVID-19 pandemic, the Ninth International Fermi Symposium was meant to take place in 2020 at Misty Hills, however, it had to be postponed to 2021, and was held virtually. The lifting of bans and easing of restrictions has allowed for the Tenth International Fermi Symposium to be held in person for participants from around the world at Misty Hills Country Hotel, Conference Centre, and Spa from the 9th-15th October 2022.

Visit the Tenth International Fermi Symposiun's Indico Page here.

LATEST OPPORTUNITIES

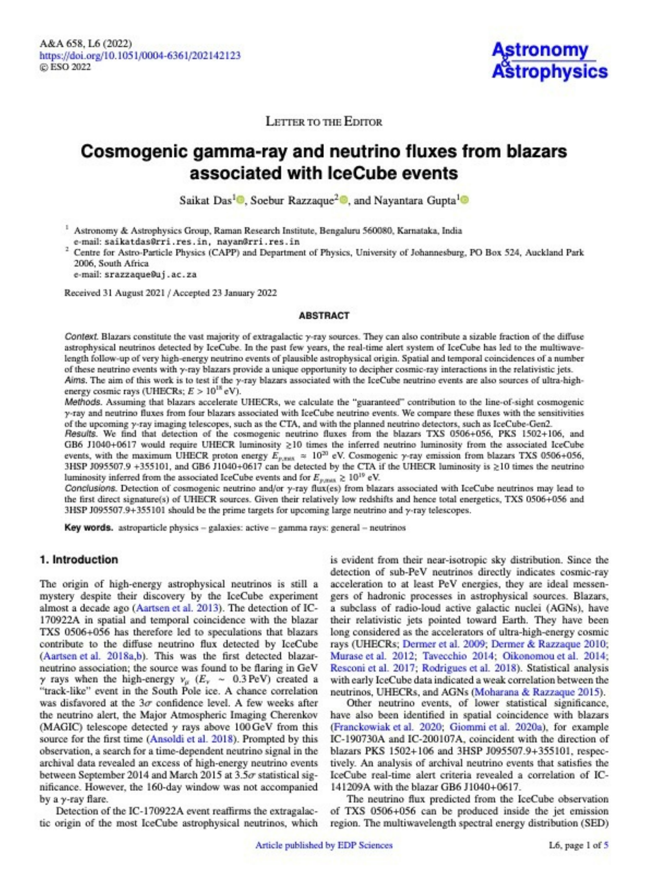
Postdoctoral Research Fellowship Position

The Centre for Astro-Particle Physics (CAPP) at the University of Johannesburg, South Africa invites applications for a postdoctoral research fellowship to work on astrophysical data analysis and machine learning, funded recently as a program of the National Institute of Theoretical and Computational Sciences (NITheCS). Candidates must have a track record of accomplishments in the relevant research area and must show promise to work independently. This is a one-year fellowship with possibility to renew for two more years, pending availability of fund and satisfactory performance by the incumbent. Candidates are required to obtain doctoral degree not more than 5 years prior to the starting date of the fellowship in order to be eligible for applying.

Interested candidates must send
Curriculum Vitae
List of publications
Proposed research plan
Names and email addresses of 2 referees

or any enquiry directly to **Ms. Anna Samara Larmuth** (capp@uj.ac.za). Applications received by **1 April 2022** will receive full consideration.

LATEST PUBLICATIONS BY CAPP MEMBERS



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Astronomy & Astrophysics

Letter to the Editor

Cosmogenic gamma-ray and neutrino fluxes from blazars associated with IceCube events

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ABSTRACT

Context. Blazars constitute the vast majority of extragalactic γ-ray sources. They can also contribute a sizable fraction of the diffuse astrophysical neutrinos detected by IceCube. In the past few years, the real-time alert system of IceCube has led to the multiwavelength follow-up of very high-energy neutrino events of plausible astrophysical origin. Spatial and temporal coincidences of a number of these neutrino events with γ-ray blazars provide a unique opportunity to decipher cosmic-ray interactions in the relativistic jets.
Aims. The aim of this work is to test if the γ-ray blazars associated with the IceCube neutrino events are also sources of ultra-high-energy cosmic rays (UHECRs; $E > 10^{18}$ eV).
Methods. Assuming that blazars accelerate UHECRs, we calculate the "guaranteed" contribution to the line-of-sight cosmogenic γ-ray and neutrino fluxes from four blazars associated with IceCube neutrino events. We compare these fluxes with the sensitivities of the upcoming γ-ray imaging telescopes, such as the CTA, and with the planned neutrino detectors, such as IceCube-Gen2.
Results. We find that detection of the cosmogenic neutrino fluxes from the blazars TXS 0506+056, PKS 1502+106, and GB6 J1040+0617 would require UHECR luminosity $\gtrsim 10$ times the inferred neutrino luminosity from the associated IceCube events, with the maximum UHECR proton energy $E_{p,\max} \approx 10^{20}$ eV. Cosmogenic γ-ray emission from blazars TXS 0506+056, 3HSP J095507.9 +355101, and GB6 J1040+0617 can be detected by the CTA if the UHECR luminosity is $\gtrsim 10$ times the neutrino luminosity inferred from the associated IceCube events and for $E_{p,\max} \gtrsim 10^{19}$ eV.
Conclusions. Detection of cosmogenic neutrino and/or γ-ray flux(es) from blazars associated with IceCube neutrinos may lead to the first direct signature(s) of UHECR sources. Given their relatively low redshifts and hence total energetics, TXS 0506+056 and 3HSP J095507.9+355101 should be the prime targets for upcoming large neutrino and γ-ray telescopes.

Key words. astroparticle physics – galaxies: active – gamma rays: general – neutrinos

1. Introduction

The origin of high-energy astrophysical neutrinos is still a mystery despite their discovery by the IceCube experiment almost a decade ago (Aartsen et al. 2013). The detection of IC-170922A in spatial and temporal coincidence with the blazar TXS 0506+056 has therefore led to speculations that blazars contribute to the diffuse neutrino flux detected by IceCube (Aartsen et al. 2018a,b). This was the first detected blazar-neutrino association; the source was found to be flaring in GeV γ rays when the high-energy ν_μ ($E_\nu \sim 0.3$ PeV) created a "track-like" event in the South Pole ice. A chance correlation was disfavored at the 3σ confidence level. A few weeks after the neutrino alert, the Major Atmospheric Imaging Cherenkov (MAGIC) telescope detected γ rays above 100 GeV from this source for the first time (Ansoldi et al. 2018). Prompted by this observation, a search for a time-dependent neutrino signal in the archival data revealed an excess of high-energy neutrino events between September 2014 and March 2015 at 3.5σ statistical significance. However, the 160-day window was not accompanied by a γ-ray flare.

Detection of the IC-170922A event reaffirms the extragalactic origin of the most IceCube astrophysical neutrinos, which is evident from their near-isotropic sky distribution. Since the detection of sub-PeV neutrinos directly indicates cosmic-ray acceleration to at least PeV energies, they are ideal messengers of hadronic processes in astrophysical sources. Blazars, a subclass of radio-loud active galactic nuclei (AGNs), have their relativistic jets pointed toward Earth. They have been long considered as the accelerators of ultra-high-energy cosmic rays (UHECRs; Dermer et al. 2009; Dermer & Razzaque 2010; Murase et al. 2012; Tavecchio 2014; Oikonomou et al. 2014; Resconi et al. 2017; Rodrigues et al. 2018). Statistical analysis with early IceCube data indicated a weak correlation between the neutrinos, UHECRs, and AGNs (Moharana & Razzaque 2015).

Other neutrino events, of lower statistical significance, have also been identified in spatial coincidence with blazars (Franckowiak et al. 2020; Giommi et al. 2020a), for example IC-190730A and IC-200107A, coincident with the direction of blazars PKS 1502+106 and 3HSP J095507.9+355101, respectively. An analysis of archival neutrino events that satisfies the IceCube real-time alert criteria revealed a correlation of IC-141209A with the blazar GB6 J1040+0617.

The neutrino flux predicted from the IceCube observation of TXS 0506+056 can be produced inside the jet emission region. The multiwavelength spectral energy distribution (SED)

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Review

A Review of the Tension between the T2K and NOνA Appearance Data and Hints to New Physics

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Abstract: In this article, we review the status of the tension between the long-baseline accelerator neutrino experiments T2K and NOνA. The tension arises mostly due to the mismatch in the appearance data of the two experiments. We explain how this tension arises based on $\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillation probabilities. We define the reference point of vacuum oscillation, maximal θ_{23}, and $\delta_{CP} = 0$ and compute the $\nu_e/\bar{\nu}_e$ appearance events for each experiment. We then study the effects of deviating the unknown parameters from the reference point and the compatibility of any given set of values of unknown parameters with the data from T2K and NOνA. T2K observes a large excess in the ν_e appearance event sample compared to the expected ν_e events at the reference point, whereas NOνA observes a moderate excess. The large excess in T2K dictates that δ_{CP} be anchored at $-90°$ and that $\theta_{23} > \pi/4$ with a preference for normal hierarchy. The moderate excess at NOνA leads to two degenerate solutions: (a) NH, $0 < \delta_{CP} < 180°$, and $\theta_{23} > \pi/4$; (b) IH, $-180° < \delta_{CP} < 0$, and $\theta_{23} > \pi/4$. This is the main cause of tension between the two experiments. We review the status of three beyond standard model (BSM) physics scenarios, (a) non-unitary mixing, (b) Lorentz invariance violation, and (c) non-standard neutrino interactions, to resolve the tension.

Keywords: neutrino mass hierarchy; long-baseline experiments

check for updates

Citation: Rahaman, U.; Razzaque, S.; Sankar, S.U. A Review of the Tension between the T2K and NOνA Appearance Data and Hints to New Physics. *Universe* **2022**, *8*, 109. https://doi.org/10.3390/universe8020109

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1. Introduction

Neutrino oscillations have provided the first signal for physics beyond the standard model (SM). They were first proposed to explain the deficit in the solar neutrino flux observed by the pioneering Homestake experiment [1]. Oscillations between two neutrino flavours require them to mix and form two mass eigenstates. The survival probability of a neutrino with energy E and given flavour α, after propagation over a distance L in vacuum, is given by:

$$P(\nu_\alpha \to \nu_\alpha) = 1 - \sin^2 2\theta \sin^2\left(1.27\frac{\Delta m^2 L}{E}\right), \quad (1)$$

where Δm^2 is the difference between the squares of the neutrino masses and θ is the mixing angle. In Equation (1), the units are chosen such that Δm^2 should be specified in eV^2, L in meters, and E in MeV. The solar neutrino deficit was confirmed by the water Cerenkov detector Kamiokande [2], which detected the solar neutrinos in real time. Radio-chemical Gallium experiments, GALLEX [3], SAGE [4], and GNO [5], which were mostly sensitive to the low energy pp solar neutrinos, also observed a deficit. The high statistics water Cerenkov detector Super-Kamiokande [6] and the heavy water Cerenkov detector SNO [7] and Borexino [8] also have made detailed spectral measurements of the solar neutrino fluxes. Analysing the solar neutrino data in a two-flavour oscillation framework gives the oscillation parameters:

$$\Delta m^2_{sol} \sim 10^{-4}\ \text{eV}^2 \quad \text{and} \quad \sin^2\theta_{sol} \sim 0.33. \quad (2)$$

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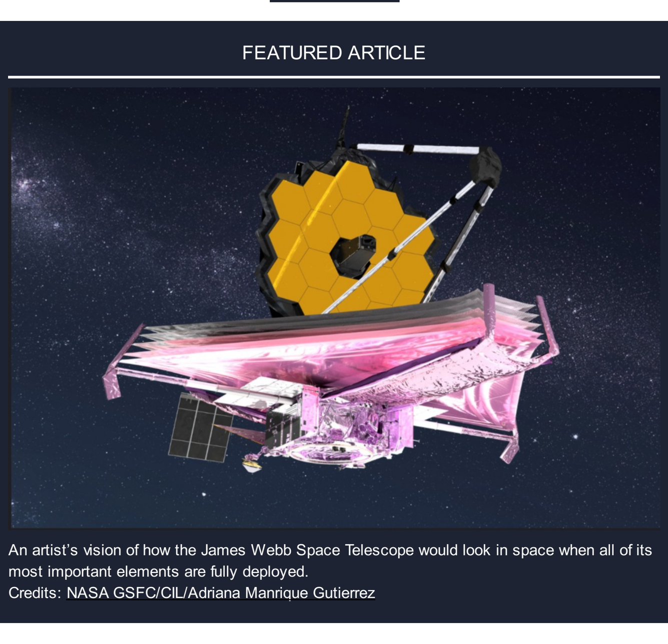
FEATURED ARTICLE



An artist's vision of how the James Webb Space Telescope would look in space when all of its most important elements are fully deployed.
Credits: NASA GSFC/CIL/Adriana Manrique Gutierrez

NASA's $10 Billion James Webb Space Telescope Home at Last

by Anna Samara Larmuth

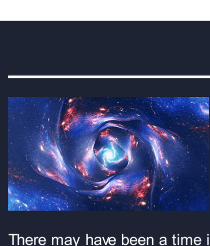
Interested in where the James Webb Space Telescope is right now? Check out live events and news here. You can also follow live updates on NASA's Webb Telescope Twitter page.

NASA's James Webb Space Telescope mission did not begin the day it launched into space (25th December 2021 at 07:20 a.m. EST on an Ariane 5 rocket from Europe's Spaceport in French Guiana, South America), it began as far back as the year 1989. Howver, only in 1996 NASA decided to develop a telescope that uses infrared light, which can be described as the wavelength band that allows for astronomers to see through both dust and gas clouds, to see further into space and uncover the mysteries held in time. In order to do this, the telescope would have to have a mirror with a diameter of more than four metres, and most importantly be able to operate further than ever before, well beyond the orbit of the Moon. You can read the finer details of the telescope's timeline here.

Where is the telescope currently? Webb is currently at its observing spot, called Lagrange point 2 (L2). The spot is located approximately at 1.6 million km away, and is known as the telescope's "home". This is where the telescope can observe the cosmos like it is designed to do. However, it needs to stay ultra-cold in order to do so. This is done in order for the observations to not be affected by any additional warmth, as Webb observes infrared light (heat). Space.com is also sharing live updates about the whereabouts of the telescope. Check it out here.

Do you know how the James Webb Space Telescope beats the heat? Black paint. The telescope has a radiator that is painted black to retain heat in order for the rest of the telescope to stay cool.

LATEST STORIES



Ever Sat And Wondered How Many Black Holes There Are in the Universe? A Modest 40,000,000,000,000,000,000

by Anna Samara Larmuth

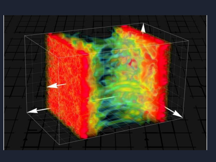
There may have been a time in your life when you have sat and wondered how many black holes are there in the universe. Well, this is also a pressing question for astrophysicists and cosmologists. With the help from SISSA researchers who have access to a new computational approach, they have come across some intriguing calculations.

We are not sure whether there is a normal way to calculate the number of black holes, but this approach is definitely not it. This new and revolutionary approach makes use of a new code called SEVN, which was developed by a SISSA (located in Italy) researcher. The code consists of the most crucial elements needed in order to not only identify how many stellar black holes there are in the universe, but also their mass.

Read More...

Introducing AI With a BIG BANG!

by Anna Samara Larmuth



The latest interest in Artificial Intelligence (AI) has not only captured the interest of the world, but also our very own, the University of Johannesburg (UJ).

If by chance you have missed out on the information that UJ is offering a short course on AI, do not worry, just check it out here.

Wondering how AI and the Big Bang have anything to do with one another? Well, if AI can be used to complete a vast amount of different tasks, then why can it not be used to study particle physics? It may seem simple, but the mathematical properties of particle physics makes it much more complicated for AI. Luckily, a neural network has been developed to save the day! A neural network is a system modelled on the human brain which consists of artificial "neurons" that are linked together to create a network. The neural network in this case is able to study the state of the universe after the Big Bang.

Read More...

FURTHER YOUR STUDIES

Cutting Edge Research by CAPP 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 a 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 offers a wide range of advanced courses, including Astrophysics courses, that can prepare students for future MSc and Ph.D. 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 Ph.D. studies. A limited number of top-up bursaries are available for MSc and Ph.D. students from CAPP.

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

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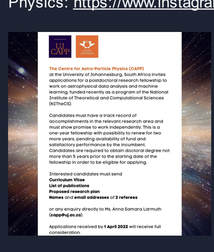

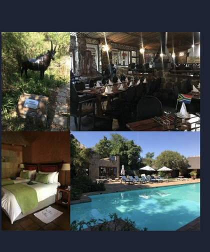
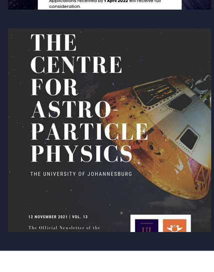

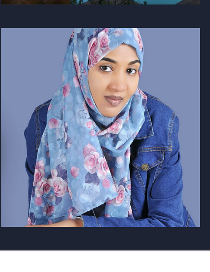

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