HEASA 2024

Tuesday 1 October 2024 - Saturday 5 October 2024

Book of Abstracts

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Implications of Joint Spectral Analysis from Fermi(GBM, LAT, and LLE) on Phenomenological GRBs Correlations

Author: Tamador Aldowma[1]

Co-author: Soebur Razzaque

[1] *Johannesburg University, Omdurman Islamic University*

Corresponding Authors: srazzaque@uj.ac.za, tamtam2030@gmail.com

This study explores the implications of joint spectral analysis using data from Fermi's Gamma-ray Burst Monitor (GBM), Large Area Telescope (LAT), and LAT Low Energy (LLE) on phenomenological correlations in Gamma-Ray Bursts (GRBs). Combining spectral data from these three Fermi instruments, we aim to enhance our understanding of GRB characteristics and their potential as cosmological probes. We focus on refining key correlations, such as the Amati and Yonetoku relations, which relate intrinsic peak energy to energetics and luminosity. Our analysis covers GRB events from 2008 to 2022, emphasizing two critical time intervals—burst duration (T_{90}) and peak flux. Through this approach, we aim to improve fit quality and tighten constraints on critical spectral parameters, including E_{peak} and spectral indices. Building on previous studies, we compare the joint fit with the fit obtained from GBM data alone to assess any improvement. These spectral parameters will be used to evaluate the potential of GRBs as cosmological standard candles.

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Pulsar Wind Nebulae as Galactic PeVatron candidates

Author: Elena Amato[1]

[1] *INAF - Osservatorio Astrofisico di Arcetri*

Corresponding Authors: elena.amato@inaf.it

Pulsar Wind Nebulae are highly intriguing astrophysical objects in many respects. They are the brightest and closest class of relativistic sources, and hence the ultimate laboratory for the physics of relativistic plasmas, where we can study in unique detail processes such as acceleration and collimation of relativistic outflows, or the acceleration of particles at relativistic shocks. In recent times, these sources have also attracted the attention of the Cosmic Ray physics community, as potential sources of cosmic ray positrons and PeV gamma-rays.

I will review the current status of our understanding of Pulsar Wind Nebulae, as it emerges from modeling of their dynamics and high energy astrophysical observations. I will discuss in particular, the exciting developments coming from Ultra High Energy (>100 TeV) gamma ray observations.

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The reflecting panels for the Large Size Telescopes at the southern site of the Cherenkov Telescope Array Observatory (CTAO)

Author: Cornelia Hanna Esther Arcaro[None]

Corresponding Author: cornelia.arcaro@pd.infn.it

The Cherenkov Telescope Array gamma-ray Observatory (CTAO) is working on developing two large telescopes, each with a diameter of 23 meters, that will be installed in Paranal, Chile. They are referred to as Large Size Telescope South, LST-S. These telescopes will use a single mirror parabolic shape to capture images with moderate angular resolution. 198 hexagonal reflecting panels will be assembled into the telescope structure to achieve this shape. Each panel is roughly 150 cm in size and weighs less than 50 kg. It comprises two solid glass plates bonded to a lightweight honeycomb structure of an Aluminum alloy core. The panels are spherical and distributed in three coronas with different curvature radii to achieve the desired shape. They will be exposed to the atmosphere for several years and must withstand mechanical stresses, wind impact, and possible strong earthquake solicitations. The panels are the basic elements of the telescope's segmented primary mirror. The development activities for such large panels performed to optimize the mirror design and prototypes are presented in this contribution.

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Axions in the galactic centre

Author: Geoff Beck[None]

Corresponding Author: geoffrey.beck@wits.ac.za

As experiments continue to narrow the viable WIMP parameter
space, axions have become an increasingly popular candidate
for dark matter. The nature of the axion coupling to the Standard
Model makes them far more difficult to constrain, especially in
the mass ranges usually considered for cold dark matter. So far,
astrophysical experiments have struggled to place strong limits
on such axions. In this work we will consider if the stimulated
decay of axions, producing spectral lines, near Saggitarius A* provides more powerful constraints.
This is done by leveraging
models for the "spiked"dark matter density profile near black
holes as well as the reported radio flux around the galactic
centre. For density profiles compatible with recent studies of the
presence of a spike, we determine sensitivity projections for SKA,
MeerKAT, and SKA VLBI. These are up to two orders of magnitude
better than previous estimates for the SKA.

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The Cherenkov Telescope Array Observatory

Author: Markus Boettcher[None]

Corresponding Author: markus.bottcher@nwu.ac.za

The Cherenkov Telescope Array Observatory (CTAO) is the next generation ground-based gamma-ray telescope facility, currently under construction. It is envisioned to ultimately consist of about 100 Cherenkov telescopes on two sites: a northern site on the Canary Island of La Palma, Spain, and a southern site near Mt. Paranal, Chile. The initial array (called "Alpha configuration") with over 60 telescopes is currently expected to be completed by 2028. The CTA is expected to be about 10 times more sensitive than currently operating Cherenkov telescope facilities (H.E.S.S., MAGIC, VERITAS) and provide significantly improved spatial resolution and extended energy coverage, towards both lower and higher energies. A prototype of the large-sized telescopes (LSTs) is already fully operational on the northern site of La Palma (called LST-1). This review presents the current status of the CTAO construction and science prospects for the full CTAO, as well as first science results from LST-1.

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H.E.S.S. observations of composite Seyfert–starburst galaxies

Authors: Andrew Chen[None]; Dmitry Prokhorov[1]; Tim Lukas Holch[2]

[1] *University of Würzburg*

[2] *DESY*

Corresponding Authors: dmitry.prokhorov@uni-wuerzburg.de, andrew.chen@wits.ac.za, tim.lukas.holch@desy.de

Composite galaxies, containing both a starburst and Seyfert component, may produce very-high-energy (VHE; > 100 GeV) γ-ray emission at vastly different spatial scales ranging from several Schwarzschild radii of a supermassive black hole (SMBH) to a dozen kiloparsecs. In addition to core-collapse supernova remnants, various sources have been suggested to explain multiwavelength and/or multi-messenger neutrino and ultra-high-energy-cosmic-ray (UHECR) data collected on composite galaxies.

The closest composite Seyfert–starburst galaxies, NGC 1068, the Circinus galaxy, and NGC 4945, are observed with the High Energy Stereoscopic System (H.E.S.S.) to determine whether they are very high-energy γ-ray emitters and to provide stringent constraints on cosmic-ray populations in these systems.

Data obtained in dedicated H.E.S.S. observations have been analysed to search for VHE γ-ray counterparts to the detected Fermi-LAT GeV γ-ray signals and for potential spectral components substantially emitting in the VHE range.

No signals have been found in these H.E.S.S. data. Upper limits on the VHE γ-ray fluxes are derived and are compared to models, involving starburst activities in NGC 1068 and NGC 4945, kiloparsec-scale bubbles in NGC 1068 and the Circinus galaxy, possible multiple components in NGC 4945 previously suggested from Fermi-LAT data, propagation of VHE γ rays for a SMBH surrounded by gas or photons in NGC 1068, and lastly, hypothetical sources of UHECRs in NGC 4945.

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H.E.S.S. detection and multiwavelength study of the z ~ 1 blazar PKS 0346-27

Author: Ogochukwu Chibueze[1]

Co-author: Markus Bottcher [1]

[1] *NORTH WEST UNIVERSITY, POTCHEFSTROOM, SOUTH AFRICA*

Corresponding Authors: markus.bottcher@nwu.ac.za, ogochukwu.chibueze1@gmail.com

We report the detection of a TeV blazar PKS 0346-27 at redshift 0.99 by the High Energy Stereoscopic System (H.E.S.S.) on 3rd November, 2021 with a significance above 5 σ. The spectral energy distribution (SED) consists of the simultaneous observations by Fermi-LAT, Swift XRT and UVOT during the H.E.S.S detection period. We show that a hadronic one-zone model (modified by strong EBL absorption) can provide a satisfactory fit to the data. The lightcurve consists of the multiwavelength data for all the observation periods and we were able to test some time lag between the GeV and TeV bands.

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Astrophysical Insights into Pseudo-Dirac Neutrinos with IceCube Observations

Authors: Khushboo Dixit[1]; Luis Salvador Miranda[2]; Soebur Razzaque[1]

[1] *Centre for Astro-Particle Physics, University of Johannesburg*

[2] *{Instituto de Física de São Carlos, Universidade de São Paulo*

Corresponding Authors: smiranda@ifsc.usp.br, srazzaque@uj.ac.za, kdixit@uj.ac.za

Neutrinos, while often considered as Majorana fermions, can also behave as effectively Dirac fermions, making them candidates for pseudo-Dirac particles. This concept introduces the possibility of oscillations between active and sterile neutrinos, driven by a small mass-squared difference. This phenomenon differs from the standard oscillation scenario involving only the three active neutrino flavors observed across astrophysical distances. In this study, we focus on analyzing publicly available data from the IceCube neutrino observatory, searching for potential pseudo-Dirac signatures in high-energy neutrinos emitted from astrophysical sources such as NGC 1068, TXS 0506+056 and PKS 1424+240. In the pseudo-Dirac framework, the active neutrino flux from these sources diminishes due to their oscillation into sterile states. By employing astrophysical flux models, we fit the IceCube data for these sources under both the standard neutrino oscillation framework and the active-sterile oscillation scenario. This enables us to place constraints on the mass-squared difference driving the active-sterile oscillations, as well as on the intrinsic source flux. These constraints could be improved by future neutrino observatories such as KM3NeT and IceCube Gen-2.

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Searching for Signatures of Internal Gamma-ray Absorption in High-redshift Blazars

Author: Anton Dmytriiev[1]

Co-authors: Atreya Acharyya [2]; Markus Boettcher

[1] *North-West University*

[2] *University of Southern Denmark, SDU*

Corresponding Authors: amdmame@gmail.com, atreya@cp3.sdu.dk, markus.bottcher@nwu.ac.za

Blazars are a special type of AGN, with jets that happen to point very close to the direction towards Earth. The powerful gamma-ray beam from distant blazars represents a unique tool to explore the environment along its path, and allows us to probe opacity both inside the source and in the intergalactic medium. Internally, gamma-rays experience attenuation due to photon-photon absorption, a result of interactions with AGN-generated photon fields. This interaction introduces distinct features in gamma-ray spectra. Upon exiting the source, gamma-rays encounter attenuation due to the Extragalactic Background Light (EBL). Understanding and characterizing these absorption processes reveals the complex structure of blazars, including the spatial distribution of the photon fields, and the poorly known location of the gamma-ray emitting zone. In this work, we perform analysis and detailed physical modeling of Fermi-LAT data of nine high-redshift ($z > 3$) blazars, and search for characteristic features in the gamma-ray spectra induced by the internal absorption. Our results yield important constraints on the precise location of the gamma-ray production site along the blazar jet in these sources.

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Decoding Blazar Polarization

Author: Lenté Dreyer[1]

Co-author: Markus Boettcher [2]

[1] *North-West University*

[2] *North-West University, Potchefstroom, South Africa*

Corresponding Authors: lentedreyer@gmail.com, markus.boettchernwu@gmail.com

The intricate polarization patterns seen in blazar jets, particularly highlighted by findings from the Imaging X-ray Polarimetry Explorer (IXPE), require multizone model frameworks to describe polarization behavior in blazar jets accurately. Single-zone models, which assume a uniform magnetic field and particle distribution, cannot explain the significant polarization degree and angle variability across different energy bands, as observed in blazars like Mrk 421 and Mrk 501. These results emphasize the need for multizone models, which consider non-uniform magnetic fields and energy distribution to elucidate the observed polarization.

This presentation will delve into the multizone model's capacity to elucidate the intricate polarization characteristics of blazars, with a particular focus on the Double Depolarization effect. This phenomenon occurs when synchrotron seed photons, scattered across multiple jet regions with varying magnetic field orientations, undergo a two-step depolarization process, significantly lowering the observed polarization degrees.

Finally, we will demonstrate how the model predictions for high-energy polarimetry in blazars, incorporating multizone effects, as well as models for other spectral features like the Big Blue Bump in blazar spectral energy distributions (SEDs), can improve our understanding of blazar jets. These predictions provide deeper insights into jet composition, particle acceleration, and magnetic field structures, offering a complete framework for interpreting current and future polarimetric observations.

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Towards Modelling AR Sco: Convergence to Aristotelian Electrodynamics and First Results

Author: Louis du Plessis[None]

Co-authors: Alice Harding [1]; Christo Venter ; Constantinos Kalapotharakos ; Zorawar Wadiasingh [2]

[1] *Los Alamos National Laboratory*

[2] *NASA GSFC*

Corresponding Authors: zwadiasingh@gmail.com, ahardingx@yahoo.com, christo.venter7@gmail.com, louisdp95@gmail.com, c.kalapotharakos@gmail.com

The wealth of multi-wavelength observations for AR Sco at high cadence enables measurement of the system parameters versus orbital phase instead of averaging over large ranges of the orbital phase. Current emission and geometric models for AR Sco are unable to accurately and jointly model the light curves, spectra and polarisation signatures of the source AR Sco. Thus, it is crucial to develop an emission model that concurrently reproduces all of these signatures. One needs to solve the general dynamics for highly relativistic particles in large B-fields and induced $E_\perp$-fields to account for the mirroring and $\mathbf{E}\times\mathbf{B}$-effects experienced by these particles. To achieve this goal we have constructed a generalised emission model, solving the particle dynamics from first principles, including a generalised radiation-reaction force, and implementing similar radiation calculations to the pulsar emission model of Harding and collaborators.

We will present our particle dynamics' convergence to the radiation reaction regime of Aristotelian Electrodynamics. We will then present our calibration comparison results with the existing pulsar emission model for a pulsar 10% the field strength of Vela. Additionally, we will present two existing synchro-curvature radiation calculation methods identifying if they are appropriate for use in the high $E_\perp$-fields present in pulsar magnetospheres. Finally, we will present our first exploratory

results simulating the proposed magnetic mirror scenario for AR Sco and fitting the observational spectral energy distribution.

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Dissecting the Radiative Puzzle of VHE GRBs: Insights from Multi-Wavelength Modeling

Author: ankur ghosh[1]

Co-authors: Jagdish Joshi [2]; Monica Barnard [1]; Soebur Razzaque [1]

[1] *University of Johannesburg*

[2] *ARIES, India*

Corresponding Authors: ghosh.ankur1994@gmail.com, srazzaque@uj.ac.za, jagdishcjoshi86@gmail.com, monicabarnard77@gmail.com

The recent detection of very high-energy gamma-ray emission (VHE, > 100 GeV) from a subset of gamma-ray bursts (GRBs) has opened new opportunities for GRB research. The temporal and spectral evolution of VHE GRB afterglows requires comprehensive modeling and high-cadence, multi-wavelength observations across the electromagnetic spectrum (radio to VHE). Standard afterglow emission from VHE GRBs comprises a combination of synchrotron radiation from forward and reverse shocks, synchrotron self-Compton (SSC) emission, and external Compton (EC) radiation. To date, SSC models, assuming both stellar wind and constant density circumburst scenarios, have been the primary framework for interpreting VHE emission. In our study, we utilized the NAIMA code, which offers a suite of radiative models and Markov chain Monte Carlo (MCMC) tools, to fit multi-wavelength data for seven VHE-detected GRBs acquired from the literature. By fitting these data, we constrain key parameters associated with the burst and its surrounding environment. Our findings suggest that SSC is the dominant emission mechanism for VHE GRBs, with a negligible contribution from EC. Most VHE GRBs are well explained by a spherical jet with a forward shock model, except for GRB 221009A. Additionally, we find that VHE GRBs tend to occur in environments with lower magnetic fields and higher ambient medium densities. This population study improves our understanding of VHE GRBs and offers insight into the future detection and interpretation of VHE emission in GRBs.

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Optical spectroscopy and imaging of blazars for the Cherenkov Telescope Array Observatory

Author: Eli Kasai[1]

[1] *University of Namibia*

Corresponding Author: kunwijik@gmail.com

Blazars are the brightest persistent sources in the high-energy and very-high-energy (VHE) gamma-ray sky. Because their UV/optical radiation is often dominated by non-thermal, and, in the case of BL Lacs, featureless continuum radiation, the determination of their redshift is extremely difficult. Only about 50% of gamma-ray blazars have a firm measurement of their redshift. This strongly reduces the precision in the modelling of their VHE emission, involving the absorption due to the extragalactic background light, which is dependent on redshift. Furthermore, the effects on their radiation of proposed physics beyond the Standard Model such as Lorentz Invariance Violation and Axion-Like Particles cannot be reliably investigated. During the Cherenkov Telescope Array Observatory (CTAO) operations, several hundreds of new blazars will be detected, most of them without redshift. In order to mitigate this condition, we devised an optical observing campaign. Likely targets were selected through simulations of CTAO observations using the Fermi-LAT 3FHL catalog

as a starting point. Our campaign, started in 2019, has been recognized as necessary support for the AGN Key Science Project of the CTAO. It involves deep observations using, among others, 10-m class telescopes such as Keck, SALT, GTC and the VLT. In this talk, we will present the status of our campaign, its future developments and other activities we are pursuing.

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Multi-wavelength Study of Extreme High-energy Peaked BL Lac (EHBL) Source 1ES 0229+200 Using multi-waveband Observations

Author: Rukaiya Khatoon[1]

Co-author: Markus Boettcher[1], Jyotishree Hota[2], Ananta C. Pradhan[2], Ranjeev Misra[3]

[1] *Centre for Space Research, North-West University, South Africa*

[2] *National Institute of Technology, Rourkela, India*

[3] *Inter-University Center for Astronomy and Astrophysics, Ganeshkhind, Pune, India*

Corresponding Authors: rukaiyakhatoon12@gmail.com, markus.bottcher@nwu.ac.za

We present a comprehensive analysis of the broadband spectral energy distribution (SED) of the extreme high-energy peaked BL Lac (EHBL) source, 1ES 0229+200. Our study utilizes near-simultaneous data collected at various epochs between September 2017 and August 2021 (MJD: 58119−59365) from different instruments, including AstroSat-UVIT, SXT, LAXPC, Swift-UVOT, Fermi-LAT, and MAGIC. We investigate the one-zone synchrotron and synchrotron self-Compton (SSC) model, employing diverse particle distributions such as the log parabola, broken power law, power law with a maximum electron energy γ, energy-dependent diffusion (EDD), and energy-dependent acceleration (EDA) models to fit the broadband SED of the source. Our findings indicate that both peaks in the SED are well described by the one-zone SSC model across all particle distribution models. We estimate the jet power for different particle distributions. The estimated jet power for broken power law particle distributions is found to be on the order of $10^{47}(10^{44})$ erg s^{-1} for a minimum electron energy $\gamma_{\rm min} \sim 10(10^4)$. However, for intrinsically curved particle energy distributions (e.g., log parabola, EDD, and EDA models), the estimated jet power is $\sim 10^{44}$ erg s^{-1}. The SED fitting at five epochs enables us to explore the correlation between the derived spectral parameters of various particle distribution models. Notably, the observed correlations are inconsistent with the predictions in the power-law with a maximum γ model, although the EDD and EDA models yield the correlations as expected. Moreover, the estimated physical parameter values are consistent with the model assumptions.

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The Modelling of Accretion Driven Plasma Instabilities in the Accretion Columns of Polars Using PLUTO

Authors: Izak Van Der Westhuizen[1]; John-Paul Khumalo[1]; Petrus Meintjes[1]

[1] *University of the Free State*

Corresponding Authors: vanderwesthuizenip@ufs.ac.za, meintjpj@ufs.ac.za, jaahpie@gmail.com

This project explores the complex emission patterns and instabilities in the post-shock accretion columns (PSACs) of magnetic cataclysmic variables (mCVs). Utilizing the PLUTO code, the study integrates bremsstrahlung and cyclotron radiation mechanisms to simulate these phenomena under various initial conditions, such as white dwarf mass and magnetic field strengths. The findings reveal significant emission variability driven by shock dynamics, with bremsstrahlung dominating in high-density regions and cyclotron emission in temperature-sensitive areas. This research enhances the

theoretical understanding of radiative processes in mCVs and demonstrates the effectiveness of high-resolution magnetohydrodynamic simulations in interpreting complex observational data. Future work aims to extend these simulations to three dimensions and incorporate dynamic accretion rates for more accurate modeling of high-energy astrophysical sources.

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The Radiative Origins of Radio Emission in Galaxies

Author: Sthabile Kolwa[1]

[1] *University of Johannesburg*

Corresponding Author: sthabile.kolwa@gmail.com

The faint radio population contains a higher proportion of star-forming galaxies (SFGs) and radio-quiet or non-jetted active galactic nuclei (AGN) below radio flux densities of approximately 100 microJy. It is commonly understood that radio emission in SFGs is primarily thermal and for radio-loud AGN, it is mainly non-thermal. The radiative mechanisms producing radio emission in non-jetted AGN, however, are still up for debate. To investigate the production channels for radio emission at the faintest flux densities, we combine LOFAR 144 MHz, uGMRT early-science band-3 (390 MHz) and band-4 (650 MHz), and MIGHTEE DR1 flux detections to measure spectral indices and spectral curvature for radio-AGN and SFGs in XMM-LSS. We cross-identify our radio sources with multi-band data and find a distribution of galaxies peaking in number count at z=1 and detected up to z~6. We use results from CIGALE spectral energy distribution-fitting to obtain the stellar mass and star-formation rate of the radio-detected galaxies and classify them into AGN and SFGs. Our early results show evidence for peaked radio spectra indicative of both spectral of both synchrotron (self-)absorption and emission in the radio-loud AGN. For SFGs, the steep and downturned spectral curvatures indicative of thermal radiation and synchrotron emission from the sources in the star-forming galaxies (which may also contain a subset of non-jetted AGN). This work is an important step towards determining the mechanisms powering radio emission in jet-dominated and star-forming-dominant galaxies.

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Relativistic Dynamics and Structure Formation in a Friedmann Universe

Authors: Dismas Simiyu Wamalwa[1]; Kennedy Konga[2]

[1] *Meru University of Science and Technology*

[2] *Meru University of Science and Technology, Africa Pulsar timing*

Corresponding Authors: kennedykonga@gmail.com, dismasw@yahoo.com

The Friedmann-Lemaître-Robertson-Walker (FLRW) model, which forms the foundation of the Lambda Cold Dark Matter (LCDM) framework, is a key pillar in cosmology. It has effectively explained the formation and evolution of cosmic structures in line with most observational data. Central to the FLRW model is the cosmological principle, asserting that the universe is homogeneous and isotropic on large scales. However, recent three-dimensional catalogues present a contrasting view, showing the universe to be non-homogeneous and non-isotropic up to the furthest observational limits, raising questions about the FLRW model's precision and suggesting a need for its re-evaluation.
In this study, we derive new redshift-light intensity and redshift-number density relations using the Einstein Field Equations (EFE) based on the galaxy number count method, outlining the universe's dynamics and evolution within the FLRW framework. Our results demonstrate that these new relations can accurately describe galaxy formation and evolution, deepening our understanding of the cosmos. Notably, they reproduce the early burst of galaxy formation when z≥1, aligning with other

models. Additionally, our simulation results are consistent with observational data, further validating the FLRW model. These relations also present promising opportunities for future cosmological investigations.

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Recent results from KM3NeT and ANTARES and Introduction to the ACME project

Author: Antoine David Kouchner[1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: kouchner@apc.univ-paris7.fr

The pioneering underwater neutrino observatory, ANTARES, was in operation almost continuously in the Mediterranean Sea from its establishment in 2008 until its recent decommissioning in 2022. This presentation will shed light on its inception, principal findings in particle physics and astrophysics, including its extensive multi-messenger initiative. This encompassed sending alerts and following up on external astrophysical alerts.

Presently, attention has shifted towards KM3NeT, a scientific infrastructure accommodating the next generation detectors in the Mediterranean Sea. This infrastructure comprises two distinct detectors, ARCA and ORCA, each tailored to different scientific endeavors. ARCA is poised to explore remote astrophysical sources, while ORCA is optimised for the study of atmospheric neutrino oscillations with the main objective to infer the neutrino mass ordering. Upon completion, these detectors will encompass a volume exceeding one cubic kilometer. The most recent results in these domains, gleaned from the existing partial configurations of these detectors, will be showcased.

Finally, an introduction to the EU-funded ACME (Astrophysics Centre for Multimessenger Studies in Europe) project will be given. The project gathers 40 institutes in Europe with the main goal to help developing services related to the current research infrastructures in the domain, and to strengthen the links between the astroparticle and the astrophysics communities.

2

Studying the southerly eclipsing millisecond pulsar J1748–2446A using MeerKAT

Authors: Senate Lekomola[None]; Senate Lekomola[None]

Corresponding Author: lkmsen001@myuct.ac.za

In this discussion we will be focusing on the changes of the dispersion measure (DM), rotation measure (RM) and scattering characteristics of PSR J1748-2446A. PSR J1748-2446A is a "spider"binary in Terzan 5 where the pulsar blasts the surface of its orbiting companion star away. We used data from the MeerKAT telescope at L-band frequencies to look at the complex eclipse of this spider binary. Our observations of PSR J1748-2446A revealed that its radio emissions experienced an increase in DM as it moved into and out of eclipse phases. We also observed a change in the rotation measure up to tenfold compared to the initial RM value. We noted distinctive pulse widening, which can be attributed to multi-path propagation effects in the signal, and for the first time for this pulsar, we quantified the scattering time. Because measured the changes in DM and RM, we estimated the magnetic field strength of the companion's material to be an order of magnitude greater than that of the Crab Nebula. We have also estimated RM values deep into the eclipse to be about 20 times the initial value. Our findings inform us that the companion material is an ionised and turbulent magnetised plasma, with electron densities and density variations much higher than the typical interstellar medium.

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Characterisation of various §\gamma§-ray activity states of a sample of §\gamma§-NLS1 galaxies

Author: Anna Luashvili[1]

Co-authors: Catherine Boisson [2]; Andreas Zech [2]; Markus Boettcher [1]

[1] *North-West University, Potchefstroom, South Africa*

[2] *Observatoire de Paris*

Corresponding Authors: markus.boettchernwu@gmail.com, anna.luashvili@obspm.fr, andreas.zech@obspm.fr, catherine.boisson@obspm.fr

γ-ray emitting narrow-line Seyfert 1 galaxies (γ-NLS1) are jetted, γ- and radio-loud sources of a very puzzling sub-class of Active Galactic Nuclei (AGN), exhibiting properties similar to low power flat-spectrum radio quasars (FSRQs), but not quite identical. They are characterised by relatively low black hole masses and extremely high, near-Eddington accretion rates, with some members of this class showing very rapid and large amplitude flaring episodes, the main physical mechanism of which is still not fully understood. In order to better constrain it, we selected various γ-ray activity states for two genuine γ-NLS1 1H 0323+342 and PMN J0948+0022, one intermediate object between γ-NLS1 and FSRQ classes, B2 0954+25A, and a bright FSRQ 3C 279, for which we analysed an extensive set of multi-wavelength data and retrieved a maximum number of observational constraints, that were used in the multi-epoch and multi-component modelling of the sources. For each target and period of interest, we tested two different physical scenarii, where the high energy γ-ray radiation is produced by the inverse Compton scattering of the disc and broad-line region (BLR) or torus photons by relativistic electrons of the jet. Disc and BLR- dominated scenario was favored and the transition from low to high activity states is well explained by particle injection on a stationary emission zone in the jet. Total jet powers of the sources are quantified to investigate the nature of γ-NLS1 and FSRQs.

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Pulsed Gamma-Ray Emission from AR Scorpii, AE Aquarii, and LAMOST J024048.51+195226.9 using Fermi LAT Data

Author: Spencer Tendai Madzime[1]

Co-author: Peter J Meintjes [1]

[1] *University of the Free State*

Corresponding Authors: supets94@gmail.com, meintjpj@ufs.ac.za

We report the detection of steady and pulsed gamma-ray emission from AR Scorpii and AE Aquarii using data from the Fermi Large Area Telescope (LAT). Both sources exhibit a detection significance above Fermi LAT threshold (5 σ), despite not being listed in the Fermi LAT catalog due to the standard analysis approach rendering them insignificant. Previous studies have indicated a detection for AR Scorpii at a marginal significance level ($\leq 4.3\ \sigma$), but no firm detection above Fermi LAT threshold had been reported. By employing time gating techniques for event selection alongside standard analysis, we enhanced the detection significance to exceed Fermi LAT threshold for both sources. Additionally, we searched for pulsed emission within a 0.6-degree region of interest and observed AR Scorpii with a significance just above Fermi LAT threshold at the fundamental ($P_{spin} = 117s$) but no indication of double pulse was observed using all events in the region of interest. To further refine event selection for timing analysis, we utilized the HDBSCAN clustering method, which allowed us to associate events with AR Scorpii and AE Aquarii. Accordingly, both systems showed significant pulsed emission above Fermi LAT threshold at the fundamental and second harmonic frequencies, with double-peaked light curves providing further evidence of the periodic nature of the emissions.

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Probing Pulsed Gamma-ray Emissions from 4FGL J0647.7-4418 by Searching for Orbital and Spin Modulation in Fermi LAT Data.

Author: Spencer Tendai Madzime[1]

Co-author: Peter J Meintjes [1]

[1] *University of the Free State*

Corresponding Authors: supets94@gmail.com, meintjpj@ufs.ac.za

The gamma-ray source 4FGL J0647.7−4418 has undergone multiple associations across recent Fermi catalogues, from its initial identification with the radio source SUMSS J064744−441946 in the 3FGL, to its connection with the subdwarf O-type binary HD 49798 in the 4FGL catalogue. However, a more recent multiwavelength investigation by Martí et al. (2020) challenges these associations, suggesting instead a connection to the blazar candidate BCU SUMSS J064744−441946. Despite this, the possible association with the high-mass X-ray binary RX J0648.0−4418 raises the prospect of 4FGL J0647.7−4418 being a rare white dwarf gamma-ray binary. In this project, we aim to further investigate this system by searching for pulsed gamma-ray emissions modulated to either the spin period of the white dwarf or the orbital period of the binary system. Detection of such modulated gamma-ray emissions would support the white dwarf binary hypothesis and enhance our comprehension of the intricate processes governing these systems.

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System Agnostic Data Reductions for Astronomy

Author: Sphesihle Makhathini [1]

[1] *University of the Witwatersrand*

Corresponding Author: sphesihle.makhathini@wits.ac.za

Presenting the Containerized Automated Radio Astronomy Calibration (CARACal) pipeline, a system and telescope agnostic reduction pipeline for radio interferometer data. CARACal leverages the portability and flexibility enabled by the Stimela framework (Makhathini, 2016) to provide a simple yet powerful pipeline for both experienced and novice users. Unlike other pipelines, which are instrument-specific (e.g. CASA, SPAM, CAPTURE, LOFAR) and tend to be opaque and hard to configure, CARACal can be used on data from any radio interferometer as long the data are stored in the standard Measurement Set format (Kembal and Wieringa 2000). CARACal can be configured via a simple YAML file and only requires a Python3 interpreter and containerization software like Apptainer and Docker. This means astronomers, non-expert users in particular, can focus on configuring and optimizing their pipelines instead of installation and system configuration issues. I will also present some inter

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Multi-wavelength Monitoring of Two Gamma-ray Binaries: 1FGLJ1018.6-5856 and LMC P3

Author: Masekaisha Andries Mathiba[1]

Co-author: Itumeleng Monageng [2]

[1] *University of Cape Town*

[2] *UCT/SAAO*

Corresponding Authors: itu@saao.ac.za, mthmas034@myuct.ac.za

Gamma-ray binaries are a subclass of high-mass binary stellar binary systems consisting of a compact object (neutron star/ black hole) and an O- or B-type stellar companion. They emit across the entire electromagnetic spectrum, with a characteristic energy spectrum that peaks in the gamma-ray energy range. Currently, only ten such systems have been discovered.

1GLJ1018.6-5856 and LMC P3 are two gamma-ray binary systems discovered in 2011 and 2016, respectively. In this study, we utilize observational radio data from the MeerKAT telescope, along with archival X-ray and gamma-ray data from the Swift and Fermi-LAT space telescopes, to investigate these two systems. The primary objectives are to:

- Perform a radio analysis for these sources.
- Conduct a multi-wavelength variability cross-correlation analysis.

The findings from this study aim to shed light on the dominant emission mechanism in both these sources, offering insights into the nature of the compact object in each binary (i.e., whether we have a neutron star or black hole).

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Locating the gamma-ray emission regions in the relativistic jet of 3C 279.

Author: Tekano Mbonani[1]

Co-author: Brian van Soelen [1]

[1] *University of the Free State*

Corresponding Authors: mbonanits@ufs.ac.za, vansoelenb@ufs.ac.za

We present an analysis of the optical and GeV gamma-ray behaviour of the flat-spectrum radio quasar 3C 279 during four phases of significant gamma-ray flux variability between 2014 –2019. Multiple flares were observed during this period, with the most rapid flare exhibiting a flux doubling time of 2.66 hr. A ZDCF analysis of the optical and gamma-rays light curves show a near-zero time-lag during flares, while a consideration of the photon-photon opacity places a constraint on the minimum Doppler factors (δ >10.0). Spectral analysis shows the gamma-ray SEDs are well described by a broken-power law during the flare phases, with a spectral break energy between 0.7 - 2.0 GeV. From the spectral behaviour and temporal variability, we infer that the optical and gamma-ray emission during all the flares is produced at a similar location in the jet, which is situated on the outer boundary of the BLR.

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The possible detection of γ-ray pulsations from J1912-4410 and EUVE J0317-855 using Fermi-LAT observations.

Author: Lurgasho Minnie[1]

Co-authors: Petrus J. Meintjes [1]; Jacques Maritz [1]

[1] *University of the Free State*

Corresponding Authors: minnielh@ufs.ac.za, maritzjm@ufs.ac.za, meintjpj@ufs.ac.za

We report the possible detection of γ-ray pulsations from both the recently discovered ~4.03 hour binary system J1912-4410 which consists of a white dwarf rotating at Pspin=319.34903(8)s (~5.32 minutes, Pelisoli et al. 2023) with an M-dwarf companion and the 725.5(8)s (~12 minutes, Ferarrio et al. 1997) rotating, isolated white dwarf EUVE J0317-855 using ~15 years of observations from the Fermi -LAT telescope. Pulsed emission in the energy range 0.5-10 GeV was found at a period Pspin=319.3491(3)s which corresponds to the spin period of the white dwarf in J1912-4410. No significant pulsations in the γ-rays were found at the beat frequency or other orbital sideband frequencies. The γ-ray light curve of J1912-4410 folded on the detected period is aligned with recent MeerKAT radio light curves using the same spin ephemeris which might suggest that the radio and γ-ray photons are produced at the same regions on the white dwarf. The folded γ-ray light curve of J1912-4410 at energy 0.1-500 GeV are also aligned with the radio light curves but also show a faint peak at phase ~0.5 which we interpret as pulsed γ-ray emission from the second magnetic pole of the white dwarf in J1912-4410. Pulsed γ-ray emission from EUVE J0317-855 were also detected at a spin period Pspin=725.500(4)s and its first harmonic P=362.750(1)s. The first harmonic was found to be more prominent in the 0.5-10 GeV energy band whereas the spin period is more prominent in the 0.1-500 GeV band. These results suggest that fast spinning, highly magnetized white dwarfs that are isolated or in binary systems might mimic the behaviour that is seen from pulsars.

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Long-term Be disc/neutron interaction of the peculiar Galactic Be X-ray binary, MAXI J0903-531

Author: Itumeleng Monageng[1]

Co-authors: David Buckley ; Lee Townsend ; Malcolm Coe

[1] *University of Cape Town/South African Astronomical Observatory*

Corresponding Author: itu@saao.ac.za

Be X-ray binaries, which make up the largest subclass of the high mass X-ray binary systems, comprise a neutron star in an eccentric orbit around Be star companion with a geometrically thin Keplerian disc. The interaction of the neutron star with the Be disc results in the accretion of matter leading to X-ray outbursts. The X-ray outbursts occur in two flavours: Type I (or normal outbursts, with luminosities less than 10^{37} erg./s) and Type II (or giant outbursts, with luminosities greater than 10^{37} erg./s). The disc variability is traced through the variability of the Balmer emission lines in the optical spectra, the strongest and best-studied of which is the H-alpha emission line.

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MIGHTEE: The radio luminosity and star-formation rate relation for galaxies in the COSMOS field

Author: Thando Mothogoane[None]

Co-authors: Kshitij Thorat [1]; Soebur Razzaque [2]; Sthabile Kolwa [3]

[1] *University of Pretoria*

[2] *University of Johannesburg*

[3] *university of johannesburg*

Corresponding Authors: skolwa@uj.ac.za, ramodubjane@gmail.com, srazzaque@uj.ac.za, kshitijthorat.astro@gmail.com

Utilising the MeerKAT International GHz Tiered Extragalactic Exploration (MIGHTEE) Early Science data from the COSMOS field, we select radio-detected galaxies down to a radio flux density limit of 2 μJy. Source detection was performed using the PYTHON Blob Detector and Source Finder (pybdsf) catalogue. Cross-matching these detections with multiwavelength photometric data in the X-rays, optical, and infrared allows us to select the radio active galactic nuclei (AGN) host galaxies and star-forming galaxies (SFGs) across the redshift range $0 \lesssim z \lesssim 6$. Using MAGPHYS, we fit the spectral energy distribution for the selected radio galaxies to obtain their stellar masses (M_*) and star formation rates (SFR). Our key objective is to calibrate the SFR-1.4 GHz radio luminosity ($L_{1.4\ \mathrm{GHz}}$) relation for non-jetted AGN (i.e., radio-quiet AGN), radio-loud AGN (RL AGN), and SFGs. We obtain a positive correlation for non-jetted AGN, with an average slope of 0.81, while RL AGN deviates significantly from the linear trend observed for non-jetted and SFGs, particularly at $L_{1.4\ \mathrm{GHz}} > 10^{23}$ W/Hz. Our findings indicate that at $z < 0.5$, the radio emission observed in non-jetted AGN is driven by star formation processes within the host galaxies, following a relation like SFGs. However, at higher redshift ($z > 0.5$), the radio-FIR correlation becomes shallower, suggesting that while FIR luminosity (tracing star formation) increases significantly, the corresponding increase in radio luminosity is slower. This suggests that in the early universe, non-jetted AGN experience increased star formation, but the radio emission is suppressed. This is likely due to young stellar populations that have not yet evolved to produce supernova remnants.

3

The study of extended radio galaxies in MERGHERS fields

Author: Banele Mthembu[1]

[1] *University of KwaZulu-Natal (National Astrophysics & Space Science Programme)*

Corresponding Author: mphomthembu53@gmail.com

Radio galaxies play an important role in the formation of structure in the Universe. Studying the physical properties of both classical radio galaxies (FRI and FRII), as well as their more morphologically complex counterparts (NATs, WATs, BTs, X-shaped, etc), can help in understanding their specific role and how their local environment affects their properties, and vice versa. The MERGHERS survey is carrying out targeted observations of galaxy clusters using MeerKAT's L- and/or UHF bands. The wide-field images contain many instances of extended radio galaxies, across all morphologies. This project aims to catalogue and study the extended radio galaxies in the 21 cluster fields from the first tier of MERGHERS data, investigating their environmental link and studying their spectral properties.

AIMS & OBJECTIVES:
This project aims to use the first tier MERGHERS data, in conjunction with available multiwavelength data, to catalogue and study the extended radio galaxies in the cluster fields. The project will:

investigate the statistics of the radio galaxies and their relationship to their environment (field versus cluster),
study the spectral properties of the sources by producing in-band spectral index maps, or other frequency data where available, and
investigate the environmental impact on sources with non-classical morphologies.

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Refinement of the Proposed Gamma-Ray Burst Time Delay Model

Author: Godson ABBEY[1]

Co-authors: Alok Srivastava [1]; Golden Nyambuya [2]; Joseph Simfukwe [1]; Prospery Simpemba [1]; Saul Phiri [1]

[1] *Copperbelt University Zambia*

[2] *National University of Science & Technology, Bulawayo, Zimbabwe*

Corresponding Authors: godson.abbey@cbu.ac.zm, saulphiri@gmail.com, pcs200800@gmail.com, josephsimfukwe2013@gmail.com, physicist.ggn@gmail.com, alok0314@gmail.com

This paper is the second instalment in our study of the observed time delay in the arrival times of radio photons emanating from Gamma-ray Bursts (GRBs). The mundane assumption in contemporary physics as to the cause of these pondersome time delays is that they are a result of the photon being endowed with a non-zero mass. While we do not rule out the possibility of a non-zero mass for the photon, our working assumption is that the major cause of these time delays may very well be that these photons are travelling in a rarefied cosmic plasma in which the medium's electrons interact with the electric component of the Photon, thus generating tiny currents that lead to dispersion, hence, a frequency-dependent Speed of Light (FDSL). In the present instalment, we "improve"on the model presented in the first instalment by dropping the assumption that the resultant pairs of these radio photons leave the shock front simultaneously. The new assumption of a non-simultaneous —albeit systematic—emission of these photon pairs allows us to obtain a much more convincing and stronger correlation in the time delay. This new correlation allows us to build a unified model for the four GRBs in our sample using a relative distance correction mechanism. The new unified model allows us to obtain as our most significant result a value for the frequency equivalence of the interstellar medium (ISM)'s conductance $\nu^* \sim 1.500 \pm 0.009$ Hz and also an independent distance measure to the GRBs where we obtain for our four GRB samples an average distance of: ~69.40 ± 0.10, 40.00 ± 0.00, 58.40 ± 0.40, and 86.00 ± 1.00 Mpc, for GRB 030329, 980425, 000418 and 021004 respectively

Keywords
Gamma-ray bursts (GRB), Photon Mass, Plasma, Time Delay, Fireball Model

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Study of the hadronic synchrotron mirror model for orphan flares in blazars - Application to 3C279

Author: Laenita Lorraine Oberholzer[None]

Co-author: Markus Boettcher [1]

[1] *North West University*

Corresponding Authors: markus.bottcher@nwu.ac.za, laenitaoberholzer@gmail.com

Blazars are a class of Active Galactic Nuclei (AGN), found in the centres of elliptical galaxies, that are radio loud and have a small angle between the jet and the observer's line of sight. In some cases, flaring events in one frequency band are not accompanied by flaring in other bands. Such events are called orphan flares. The causes of this variability and conditions in and location of the high energy emission region are not completely understood. As a possible explanation for rapid orphan gamma-ray variability, the hadronic synchrotron mirror model has been suggested in previous work. A TeV orphan flare was observed on the 28th of January 2018 by the H.E.S.S. observatory from 3C 279. A primary flare was observed 11 days earlier by Fermi-LAT. The hadronic synchrotron mirror model, is applied to this flare. A study is done using the SED and multi-wavelength light curve results to see which parameters provide the best fit and to draw conclusions about the radiation mechanism that caused this orphan flare. A search for neutrino emission is also conducted to establish if orphan flares are a possible source.

8

The evolution of the 98 GHz ACT source population since z = 4.5

Author: Obakeng Phiri[1]

[1] *Student*

Corresponding Author: 2327123@students.wits.ac.za

This research focuses on more than 15,000-millimetre wavelength sources, Observed using the Atacama Cosmology Telescope. These sources cover an area of approximately 18,000 square degrees. The ACT data observed at 98 GHz allows us to have a large population of AGNs at different redshift bands, making it possible to study the light these AGNs released at a redshift of up to 4.5, corresponding to the lookback time of about 11.9 Gyr. We also cross-matched the ACT data with radio data from RACS, MALS, VLASS, and FIRST surveys, enabling us to look at sources other surveys could not detect (as the sources are faint). Also, we use redshift data from Gaia-unWISE Quasar catalogue, consisting of spectrophotometric redshifts. We will look at luminosity functions for the number density of these sources at different redshift bands. We will fetch images from different wavelengths (radio, infrared, optical, and X-ray) to look at the environments and morphologies of these sources and see if they have common structures at different redshift bands.

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Deciphering Blazar Emission Zones through Polarisation and Spectral Energy Distribution Studies

Author: Hester Schutte[None]

Co-authors: Brian van Soelen ; Justin Cooper ; Markus Boettcher

Corresponding Authors: schuttehester1@gmail.com, markus.bottcher@nwu.ac.za

Blazars produce highly polarised nonthermal synchrotron emission, detectable from radio to optical-UV/X-ray wavelengths. In contrast, the dusty torus, broad line region, accretion disk, and host galaxy emit unpolarised thermal radiation, which reduces the observed synchrotron polarisation. This effect is often visible as a decline towards shorter wavelengths in the total optical-UV polarisation degree. However, some observations show a decline in the polarisation degree at longer wavelengths, which can be attributed to partially ordered magnetic fields downstream of a shock in the jet. We present co-ordinated observations for 4C +01.02, PKS 0637 - 75, PKS 1510 - 089 and 3C 279 from the SALT, H.E.S.S., *Fermi*-LAT, *Swift*, ATOM/ASAS-SN and LCO observatories. From this, we discuss distinct emission zones - single, dual, or multiple regions - to model both the polarisation degree and the multi-wavelength spectral energy distributions simultaneously.

5

A spectral and timing study of MAXI J1820+070 during it's outburst

Author: Kyle Solomons[1]

Co-authors: Itumeleng Monageng [2]; Sunil Chandra [3]

[1] *University of Cape Town, South African Astronomical Observatory*

[2] *University of Cape Town*

[3] *Physical Research Laboratory*

Corresponding Authors: itu@saao.ac.za, sunil.chandra355@gmail.com, slmkyl003@myuct.ac.za

Black Hole X-ray binaries (BHXRBs) represent a unique class of astrophysical systems where a stellar-mass black hole accretes matter from a companion star via accretion disks. The accretion disk emits X-ray and UV because of the radiative losses. The transfer of matter can occur through continuous donor supply or episodic capturing of material from stellar winds, leading to sudden enhancements in X-ray flux known as outbursts. The instabilities in the disk, the geometry of the inner disk, the coupling between the disk and corona, etc, also contribute to the observed variability. The exploration of BHXBs contributes significantly to our understanding of the broader astrophysical landscape. These offer a unique testing ground for theories related to accretion physics, extreme gravity, jet formation, and the evolution of binary systems. Moreover, the BHXBs play a pivotal role in shaping galactic dynamics and evolution in their neighbourhood. Among the myriad BHXBs, MAXI J1820+070 stands out as a particularly intriguing target. This low-mass X-ray binary, located in the constellation Ophiuchus, garnered attention due to its exceptional outburst in March of 2018. The intense luminosity of MAXI J1820+070, which reached a peak X-ray flux of $\sim$ 4 Crab, allowed for detailed multi-wavelength campaigns, facilitating comprehensive investigations into its properties and behaviour. MAXI J1820+070 provides a unique opportunity to deepen our understanding of accretion processes near black holes, enabling the refinement of theoretical models and enhancing our ability to interpret observations across the electromagnetic spectrum. This study presents a comprehensive analysis of the archival X-ray data of \source\ from \nustar, \nicer, and \swiftxrt. The investigation focusses primarily on the system's spectral properties and timing characteristics. Spectral evolution and transitions between the hard and soft states are examined, with key parameters defining these states extracted. The inner disk radius was constrained to $lesssim$ 2.6 ISCO, extending down to 1.5 ISCO before the state transition. The disk temperature steadily increases from 0.71 keV, peaking at 0.8 keV. Our simplistic spectral model prefers different inclinations at various stages of the outburst, varying from $\sim$ 45 to 73 degrees, probably due to the model's limitations. Furthermore, the power-law index was restricted to $\sim$ 1.6 and the coronal electron temperature to $\sim$24-38 keV. We identify the presence and evolution of quasi-periodic oscillations and quantify them through Lorentzian curve fitting. Additionally, we identified hard and soft time lags, varying in amplitude and frequency during the outburst. Together, the spectral and timing results suggest a QPO originating from the corona, with the corona contracting during the hard state and expanding during the state transition. Possible signatures of outflows are detected through absorption features between 6.9-7.3 keV.

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A record-breaking energetic dwarf nova outburst hosting a massive white dwarf

Author: Yusuke Tampo[1]

[1] *South African Astronomical Observatory*

Corresponding Author: yusuke@saao.ac.za

Some accreting white dwarf (WD) systems show dwarf nova (DN) outbursts. These are characterized by an outburst amplitude of a few magnitudes and a duration of days to weeks in optical bands, as explained in the thermal instability model. We report the detailed optical and X-ray observations of the 2021 outburst in MASTER OT J030227.28+191754.5 (hereafter J0302). The X-ray spectrum at outburst maximum showed a ~30 eV blackbody component which we interpret as emission from the boundary layer. Its luminosity suggests the WD mass as 1.15 - 1.34 solar mass, much more massive than the typical WD mass found in DNe. Moreover, the overall optical light curve exhibited an outburst amplitude of 10.2 mag and duration of ~60 d, both are the record-breaking largest and longest among DNe with a highly-evolved donor star. Our analyses suggest that the outburst energetics of J0302 are not explained solely by the effect of its massive WD but that a lower disk viscosity in quiescence provides a natural explanation for both its outburst amplitude and duration. We also discuss the possibility of J0302 leading to an accretion-induced collapse.

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An angle- and polarization-dependent synchrotron and synchrotron self-Compton blazar model

Author: Motseothata Tisang[None]

Corresponding Author: tisangtms@gmail.com

Blazars, radio-loud active galactic nuclei with relativistic jets pointing toward us, exhibit features such as polarized emission and non-thermal, double-peak spectral energy distributions (SEDs). Various parameters, including the magnetic field orientation relative to the jet direction, influence these features.

We developed a polarization-dependent synchrotron and synchrotron self-Compton (SSC) blazar model accounting for the observer's line of sight and different magnetic field orientations relative to the jet axis. Using this model, we simulate perpendicular and oblique (and toroidal) magnetic-field orientations relative to the jet axis and analyze their effects on the SED and linear polarization degree (PD) of a typical blazar.

Our results show that an oblique magnetic field strongly impacts the synchrotron SED component, while the SSC component remains largely unaffected. Interestingly, the PD of the SSC process shows a more pronounced dependence on the field polar angle compared to that of the synchrotron process.

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Compton polarization signatures in gamma-ray burst models

Author: Pieter Vd Merwe[None]

Co-author: Markus Boettcher

Corresponding Authors: markus.bottcher@nwu.ac.za, pietervdmerwejnr@gmail.com

Since the first detection of Gamma-ray Bursts (GRBs) in 1967, GRBs have been an active subject of study with many questions still left unanswered. In particular, the dominant radiation mechanism responsible for the prompt emission of GRBs remains an open question. As the host of possible GRB prompt emission models grows it has become clear that relying on spectral information alone to discern between these models may be insufficient. With IXPE successfully operating and several other high-energy polarimetry missions in the planning, high-energy polarimetry offers a new avenue to disentangle different models. To this extent we employ the use of Monte Carlo inverse Compton scattering simulations of various GRB prompt emission models in order to calculate the associated polarization signatures of these models. A particular focus is placed on calculating not only time-integrated polarization predictions, but also time-resolved polarization predictions in addition to energy-resolved polarization predictions.

6

Comparing the optical variability characteristics of different subclasses of AGN

Author: Hartmut Winkler[None]

Corresponding Author: hwinkler@uj.ac.za

A sample of 143 AGN, mainly Seyfert 1s, has been monitored photometrically (BVugr) using the Las Cumbres Observatory robotic telescope network with a ~1-month cadence for up to three years. While almost all targets show some variation if tracked long enough, the amplitude of the variations appears correlated with some of the AGN spectral characteristics. For example, significantly smaller nuclear optical luminosity fluctuations were recorded for Narrow-line Seyfert 1's with strong iron

emission spectra. Other spectral characteristics tested for association with specific variability traits include enhanced helium emission, Keplerian rotator line profiles and past changing-look events. The implications of the findings on AGN nuclear structure and mechanics will be discussed.

6

Emission models for extreme blazars

Author: Andreas Zech[1]

[1] *LUTH, Observatoire de Paris*

Corresponding Author: andreas.zech@obspm.fr

Extreme-TeV blazars represent a distinct sub-class of BL Lac type Active Galactic Nuclei with very hard spectra and a high-energy bump peaking above ~ 1 TeV. The multi-wavelength emission from such objects is difficult to interpret with standard emission models. The very narrow electron distribution and unusually low value of the jet magnetization that are required for a good fit are difficult to justify.

A solution to this problem might be a scenario where protons and electrons are co-accelerated on internal or recollimation shocks inside the relativistic jet. In this situation, energy transfer from the protons to the electrons naturally leads to a high minimum electron energy, while low magnetization is a necessary condition for efficient particle acceleration. Values of the magnetic field strength of a few mG and minimum electron Lorentz factors of 10^3 to 10^4 result here from first principles.

After a short introduction to blazar models, I will review a few leptonic and lepto-hadronic scenarios proposed for extreme-TeV blazars, before concentrating on the promising co-acceleration scenario.

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Dark matter or ”dark matter”?

Author: Konstantin Zloshchastiev[1]

[1] *Durban University of Technology*

Corresponding Author: kostiantynz@dut.ac.za

In the theory of relativity, the notion of a particle is based on the irreducible representation of the Poincaré group. However, there are post-relativistic theories which generalize the relativistic notions, including that of a particle. One such theory is the theory of superfluid vacuum, which describes the physical vacuum as a Euclidean 3D superfluid; whereas Lorentzian 4D spacetime and symmetry are phenomena induced by superflow. This theory views relativistic particles as small fluctuations of the background superfluid, but the superfluid itself is a kind of quantum nonlocal matter, which cannot be regarded as consisting of particles defined in the relativistic sense. Therefore, it cannot be observed by conventional particle detectors, or Michelson-Morley-type tests; instead it manifests itself as 4D curved spacetime and other long-range fields of integer spin. To test the theory's predictions on a galactic scale, we derive the gravitational potential within the weak-gravity limit and apply best-fitting procedures to the rotation curve data obtained from fifteen galaxies by the HI Nearby Galaxy Survey; assuming their stellar disk's parameters to be fixed to the mean values measured using photometric methods. The fitting results correspond closely with observational data, even for those galaxies whose rotation velocity profiles do not have flat regions.

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UHF OBSERVATIONS OF THE TAIL-LIKE REGION OF HYDRA A

Authors: Andrew Chen[1]; Mika Naidoo[1]; Sibongakonke Zondo[1]; Sphesihle Makhathini[1]

[1] *University of the Witwatersrand*

Corresponding Authors: 2303837@students.wits.ac.za, 1678178@students.wits.ac.za, sphesihle.makhathini@wits.ac.za, andrew.chen@wits.ac.za

Hydra A is a FR-I type radio galaxy located at the centre of the Abell 780 cluster with a redshift of $z = 0.054$. Previous observations of the radio galaxy have been conducted at low frequencies by the Very Large Array (VLA) telescope and using the L-band frequencies of the MeerKAT array telescope. The Chandra X-ray observatory also carried out a detailed survey of the X-ray emission from the radio galaxy. These observations gave us invaluable information regarding the morphology of the galaxy. They revealed that Hydra A is composed of: a bright central core, pair of relativistic jets, pair of inner radio lobes, pair of diffuse outer radio lobes with the south-facing lobe having a tail-like extension and three pairs of X-ray cavities surrounding the lobes.

A spectral break in the radio spectrum is exhibited by the low frequency observations of Hydra A and this has been ascribed to the process of spectral ageing. The spectral age is the time it takes an electron in the lobe region of a radio galaxy to radiate all of its energy through synchrotron and inverse-Compton emission. Minimal research has been done on the tail-like region of Hydra A. One of the few studies done used MeerKAT's L-band frequencies and reported the tail-like region as having a spectral index that is dissimilar to the lobe regions. This raised questions about the spectral age, electron injection history and possible emission mechanisms in the tail-like region.

Our research aims to directly measure the spectral break frequency in the radio spectrum of the tail-like region of Hydra A using MeerKAT's UHF band observations. By directly determining the spectral age of the tail-like region and we hope to investigate the possible emission mechanisms and history of electron injection in the region. In this talk, I will present preliminary UHF MeerKAT images of Hydra A.