HEASA 2021

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Book of Abstracts

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

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Author: Anna Samara Larmuth[1]

[1] *University of Johannesburg*

Corresponding Author: aslarmuth@uj.ac.za

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Welcome by the Department of Science and Innovation

Author: Takalani Nemaungani[1]

[1] *Department of Science and Innovation*

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The transient high-energy sky seen with H.E.S.S.

Author: Fabian Schüssler[1]

[1] *CEA*

Corresponding Author: fabian.schussler@cea.fr

The last years have brought about unprecedented breakthroughs and discoveries in high-energy astro- physics. Most of them are related to transient phenomena and involve an increasing number of cosmic messengers ranging now from radiation across the full electromagnetic spectrum, to high-energy neutrino and gravitational waves. Due to their high sensitivity and increasingly optimized response to transient phenomena, high-energy gamma-ray observatories are playing a major role in this new field of time-domain and multi-messenger astrophysics at the highest energies.
In this talk I will review some of the recent highlights involving transient multi-messenger phenomena with a focus on studies using the H.E.S.S. Imaging Atmospheric Cherenkov Telescopes in Namibia. I will present recent target-of-opportunity observations searching for high-energy gamma-ray emission from a variety of sources including gamma-ray bursts, gravitational waves, high-energy neutrinos and Fast Radio Bursts.

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On the origin of very-high-energy gamma-rays from gamma-ray bursts

Author: Xiang-Yu Wang[1]

[1] *Nanjing University*

Corresponding Author: xywang@nju.edu.cn

Recently, very high-energy (VHE) photons above 100 GeV were detected from several GRBs (including GRB 190114C, GRB 180720B and GRB 190829A) by IACTs during the afterglow phase. We discuss the origin of VHE emission of GRBs and its implications. We propose that the available broadband data of these GRBs can be modelled with the synchrotron plus synchrotron self-Compton (SSC) emission of the afterglow shocks. The parameter values (such as the circumburst density and shock microphysical parameters) in the modeling are not unusual for both GRBs, implying that the detection of VHE photons from GRBs should be attributed to their large burst energies and low redshifts. I will also briefly mentoined the VHE observatoins of the prompt phases of GRBs with LHAASO.

Abstract field:

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Results from the SALT e-ROSITA transient followup programme

Author: David A.H. Buckley[1]

[1] *SAAO*

Corresponding Author: dibnob@saao.ac.za

From mid-2020, the SALT Large Science Program on transients has been following up on some X-ray transients discovered during the eROSITA all-sky survey. These include changing-look AGN, TDEs, Be X-ray and compact white dwarf binaries. I will review the results to date, including the discovery of two new examples of Quasi- Periodic Eruptions (QPEs) in non-active galaxies, the first time such events are not associated with AGN. These QPEs are thought to be due to flares associated with extreme mass-ratio inspiral (EMRI) events.

Abstract field:

AGN I / 84

First Event Horizon Telescope results and future prospects

Author: Sara Issaoun[1]

[1] *Radboud University*

Corresponding Author: s.issaoun@astro.ru.nl

The Event Horizon Telescope (EHT) is a millimeter VLBI array observing supermassive black holes. Its 2017 observing run led to the first images of a black hole shadow in M87, in total intensity and later in polarization as well. These data and images have allowed us to conduct a black hole mass measurement and a null hypothesis test of general relativity, and to put significant constraints on our general relativistic magnetohydrodynamics (GRMHD) model parameter space. In this talk, I will give an overview of the EHT observations and results, and provide an outlook into the future. Adding more stations to the array in strategic locations improves our image fidelity, dynamic range, and dynamical imaging capabilities. In particular, the Africa Millimetre Telescope (AMT), which is planned to be built on the Gamsberg in Namibia, could play a significant role as an extension of the EHT array in a unique geographical location. It will be especially valuable for observations of the Galactic Center black hole Sagittarius A*, which as a southern source is observable from southern Africa at a high elevation and for a large fraction of a VLBI observing run.

Abstract field:

AGN I / 85

A roadmap for a compensium of supermassive black hole images

Author: Venkatessh Ramakrishnan[None]

Co-author: Neil Nagar [1]

[1] *University of Concepcion*

Corresponding Author: vramakrishnan@udec.cl

The transformational science enabled by the Event Horizon Telescope (EHT) observations of M87* has opened a new paradigm wherein imaging the accretion and jet flows around supermassive black holes has become feasible. We embark on this potential of the EHT by constructing a sample of nearby AGNs whose immediate environment around the black hole will be explored at a high angular resolution. In support of these observations, we take a more prudent approach by addressing the accretion and jet properties of AGNs through a detailed General Relativistic SED modelling with high-resolution data spanning from radio through gamma rays. The structure of this project and the work in progress at various wavelengths will be discussed in the presentation.

Abstract field:

AGN I / 86

The M87 ring in polarised light and polarimetryc synthetic data modelling

Author: Iniyan Natarajan[None]

Corresponding Author: iniyannatarajan@gmail.com

The Event Horizon Telescope (EHT) is a global very long baseline interferometry (VLBI) network imaging supermassive black holes at horizon scales at millimetre wavelengths. In this talk, I will present an overview of the first polarised-light images of the black hole at the heart of the M87 galaxy, and the constraints they impose on the structure of the magnetic fields near the black hole. I will discuss the rigorous validation tests that were performed using synthetic data and how the polarimetric analysis was performed, with a focus on polarimetric leakage. I will further discuss the development of MeqSilhouette v2, a fully polarimetric synthetic data generation package in step with these analyses and its future directions and applications for mm-VLBI observations.

Abstract field:

AGN I / 87

Active galactic nuclei in the faint radio sky

Author: Jack Radcliffe[None]

Co-authors: Alasdair P. Thomson [1]; Michael A. Garrett [2]; Peter D. Barthel [3]; Robert J. Beswick [1]; Thomas W. B. Muxlow [1]

[1] *University of Manchester*

[2] *University of Manchester / University of Leiden*

[3] *University of Groningen*

Corresponding Authors: pdb@astro.rug.nl, jack.radcliffe@up.ac.za

It is now widely accepted that the evolution of galaxies and the growth of the central supermassive black hole (SMBH) are intimately connected. Those SMBH which are active (AGN) have been shown to influence the host galaxy and its evolution through various feedback mechanisms. This makes understanding the abundance of AGN within distant galaxies a cornerstone in current galaxy evolution research.
While other multi-wavelength studies are invariantly affected by dust; radio, fuelled by the burgeoning capabilities of modern arrays, can provide a dust-free window into star-formation and AGN activity. However, many radio surveys are often have resolutions more than an arcsecond which are insufficient to separate AGN and star-formation activity. To infer the existence of an AGN relies multi-wavelength diagnostics (e.g., X-rays, infra-red, radio-excess) which are often unreliable and incomplete.
There is one key weapon missing from the AGN identification arsenal namely high-resolution radio observa- tions. Here, we can isolate high brightness temperature objects (> 105 K) which can only be attributed to AGN in distant galaxies. In this talk, I will present the work from our recent publication which compares the various AGN classification techniques for our high-resolution radio-selected sample. We find that the radio excess and X-ray classification schemes are the most complete but find that no single classification technique can obtain a complete sample of AGN. Such results have profound implications for AGN studies with the next generation X-ray and radio surveys.
The talk will conclude with some recent results on X-ray selected AGN. This study shows that the faintest X-ray selected galaxies have radio emission that is consistent with star-formation rather than AGN activity. This proves that radio emission of AGN is just an optional feature that is not ubiquitous to all AGN.

Abstract field:

AGN I / 88

Comprehensive power spectral density analysis of the Fermi-LAT gamma-ray light curves of selected blazars

Author: Natalia Zywucka[1]

Co-authors: Mariusz Tarnopolski [2]; Volodymyr Marchenko [2]

[1] *North-West Uniwersity*

[2] *Astronomical Observatory, Jagiellonian University*

Corresponding Author: natttiz@gmail.com

We present results of Fermi-Large Area Telescope (LAT) light curve (LC) modelling of selected blazars. All objects have densely sampled and long-term LCs. For each blazar we generated three LCs with 7, 10, and 14 days binning, using the latest 4FGL catalogue and binned analysis provided within the fermipy package. The LCs were modelled with several tools: the Fourier transformation, the Lomb-Scargle periodogram (LSP), the autoregressive moving average (ARMA), the fractional autoregressive integrated moving average, the continuous-time autoregressive moving average (CARMA) processes, the Hurst exponents (H), the A–T plane, and the wavelet scalogram. The power law indices β calculated from the Fourier and LSP modelling are consistent with each other. Many objects yield β ⊠ 1, with PKS 2155-304 even flatter, but some are significantly steeper, e.g. Mrk 501 and B2 1520+31. The power law PSD is indicative of a self-affine stochastic process characterised by H, underlying the observed variability. Several algorithms for the H estimation are employed. For some objects we observe H > 0.5, indicating long-term memory. The ARMA results give in general higher orders for 7 days binned LCs and lower orders for 10 and 14 days binned LCs, implying temporal variations in the LCs are consistently captured by the fitted models. CARMA ts lead to featureless PSDs. The recently introduced A–T plane allows to successfully classify the PSDs based on the LCs alone.

Abstract field:

AGN I / 89

Disentangling the emission regions in blazars during flaring / transient states

Author: Joleen Barnard[1]

Co-authors: Antonio Martin-Carrillo ; Barghav Vaidya [2]; Brian van Soelen [1]; David A.H. Buckley [3]; Hester Schutte ; Izak van der Westhuizen ; JP Marais [1]; Justin Cooper [1]; Markus Boettcher [4]; Richard J. Britto ; Sriyasriti Achariya [2]

[1] *University of the Free State*

[2] *Indore Institute of Technology India*

[3] *SAAO*

[4] *North-West University*

Corresponding Authors: phd1801121008@iiti.ac.in, markus.bottcher@nwu.ac.za, justin.jb78@gmail.com, joleenels98@gmail.com, maraisjp73@gmail.com, vanderwesthuizenip@ufs.ac.za, schuttehester1@gmail.com, dibnob@saao.ac.za, vansoelenb@ufs.ac.za, bvaidya@iiti.ac.in, antonio.martin-carrillo@ucd.ie

Blazars are a radio-loud subclass of AGN with relativistic jets closely aligned with our line of sight. The jet-emission in blazars is highly Doppler-boosted and non-thermal emission can be seen across the entire electromagnetic spectrum. These sources are highly variable across all timescales and display rapid flares across multiple wavelength bands. Blazar spectral energy distributions (SEDs) are characterised by a double- humped structure, indicating that the emission is dominated by two broad, non-thermal components. The lower-energy component (radio to UV/X-ray) is powered by leptonic synchrotron emission, whereas two models are proposed for the higher-energy component (X-ray to gamma-ray). The leptonic model assumes inverse-Compton scattering of photons, and the hadronic model suggests that protons produce the high- energy component via proton-synchrotron and/or photomeson processes. At optical wavelengths, there is also an underlying thermal contribution originating in the accretion disc, BLR, dust torus and host galaxy. The aim of this project is to disentangle these emission components in blazar emission during flaring and non-flaring states. This will be done using optical spectropolarimetry to separate the thermal non-polarised and non-thermal polarised components. The observations form part of two SALT observing programmes that study the evolution of the linear polarisation in blazars. This will be coupled with photometric data from the LCO telescope network to improve flux calibration and study optical light curves. We present spectropolarimetry and photometry results on a selection of such blazars.

Abstract field:

AGN I / 90

Modeling the spectral energy distributions and multi-wavelength polarisation of blazars

Author: Hester Schutte[None]

Co-authors: Abe Falcone [1]; Amanpreet Kaur [1]; Andry Rajoelimanana [2]; Brian van Soelen [3]; David A.H. Buckley [4]; Haocheng Zhang [5]; JP Marais [3]; Justin Cooper [3]; Markus Boettcher [6]; Richard J. Britto

[1] *Penn State University*

[2] *University of the Free-State*

[3] *University of the Free State*

[4] *SAAO*

[5] *New Mexico Consortium*

[6] *North-West University*

Corresponding Authors: markus.bottcher@nwu.ac.za, justin.jb78@gmail.com, maraisjp73@gmail.com, phitlip2007@gmail.com, dibnob@saao.ac.za, vansoelenb@ufs.ac.za, auk971@psu.edu, schuttehester1@gmail.com, adf15@psu.edu

The radio through optical-UV/X-ray emission from blazars is dominated by highly polarised synchrotron emission from relativistic jet electrons. The total degree of polarisation is determined by the polarised non-thermal synchrotron emission and thermal unpolarised emission components from the dusty torus, host galaxy, emission lines from the broad line region (BLR) and accretion disk. The unpolarised accretion disk emission dilutes the synchrotron polarisation and reveals its presence through a decrease of the optical polarisation degree towards higher frequencies in spectropolarimetry observations. Considering a leptonic model, the high-energy X-ray and gamma-ray emission can be modelled as polarised synchrotron self-Compton radiation which is diluted by Compton up-scattering of unpolarised external radiation fields of the BLR and accretion disk. A target-of-opportunity, Large Science Program "Observing the Transient Universe"from the Southern African Large Telescope, provides spectropolarimetry data for flaring blazars. This program includes coordinated multi-wavelength observations from the Las Cumbres Observatory, the Swift-XRT and the Fermi-LAT. We present a spectral energy distribution and polarisation model fit applied to the optical-UV regime of the flat spectrum radio quasar 4C+01.02 (z = 2.1), constraining its black hole mass to 4 × 108 Msol, and further X-ray through gamma-ray studies from the fit results.

Abstract field:

Poster Session / 91

Development of tools for SALT/RSS spectropolarimetry reduction: application to the blazar 3C279

Author: Justin Cooper[1]

Co-author: Brian van Soelen [1]

[1] *University of the Free State*

Corresponding Authors: justin.jb78@gmail.com, vansoelenb@ufs.ac.za

Blazars represent a subset of AGN with relativistic jets where the direction of a jet lies very close to our line of sight. The highly Doppler boosted emission from the blazar's jet results in high apparent luminosities, and blazars display variability on periods from less than one day up to years. At optical wavelengths, the observed emission of the blazar is a superposition of the polarized non-thermal synchrotron emission, arising from the jet, and the unpolarized thermal emission, arising from the disc, broad line region, torus, and host galaxy. Polarimetry observations can, therefore, serve as an important tool for diagnosing the emission from blazars. The RSS spectrograph, on SALT, can operate in spectropolarimetry mode, and is currently being used to undertake spectropolarimetric observations of transient blazar sources. We present additional tools developed to work in conjunction with the current reduction pipeline (polsalt) that aims to streamline the reduction of the SALT polarization data, including the testing of the wavelength calibration of the individual O and E beams. This is applied to observations of 3C 279 during flaring/non-flaring states in 2017/2018.

Abstract field:

Poster Session / 92

Modelling cosmic-ray transport in jets as a correlated random walk

Author: Patrick Reichherzer[1]

[1] *Ruhr-University Bochum*

Corresponding Author: patrick.reichherzer@rub.de

This work provides the description of charged particle transport in magnetic fields via a correlated random walk of particles and derives a telegraph transport equation from first principles that describe the initial, ballistic, and later diffusive phases in a consistent manner. A novel high-performance numerical method based on the theoretical considerations is presented that propagates single particles while statistically satisfying the particle distribution described by the transport equation. This novel method is superior to diffusive propagation codes for compact objects, such as AGN blobs, pulsars, and supernovas, because of its ability to correctly describe the initial transport phase relevant for compact objects. The method is applied for blobs in AGN jets and compared to ballistic and diffusive propagation codes.

Poster Session / 93

Modellling the synchrotron emission of RMHD AGN jet simulations with the PLUTO par- ticle module

Author: Izak van der Westhuizen[None]

Co-authors: Barghav Vaidya [1]; Brian van Soelen [2]

[1] *Indore Institute of Technology India*

[2] *University of the Free State*

Corresponding Authors: vanderwesthuizenip@ufs.ac.za, vansoelenb@ufs.ac.za, bvaidya@iiti.ac.in

The spectral energy distribution of radio-loud AGN have a characteristic double bump structure, with emission at the lower wavelengths being dominated by synchrotron radiation from non-thermal electrons in relativistic jets. To investigate how the radio emission of these sources relate to the dynamical structure of the relativistic jets we model the synchrotron emission by using 3D hybrid particle relativistic magneto- hydrodynamic simulations. The simulations were run using the grid based hydrodynamic code PLUTO. The model set up for the simulation consisted of a stratified background medium with less dense jet material injected, at a constant rate, with a Lorentz factor of 10. To model the synchrotron emission a sample of Lagrangian particles are continuously injected with the jet fluid using the particle hybrid module of the PLUTO code. Each Lagrangian particle represent a distribution of non-thermal electrons, with a power-law energy distribution that is updated with time. Processes such as adiabatic expansion and radiative cooling are taken into account when updating the particle distribution. By using the spectral information of the particles their synchrotron

emissivity and absorption is calculated. These coefficients are integrated along a line of sight using ray tracing to reproduce intensity maps of the simulations at different radio frequencies.

Abstract field:

Poster Session / 94

Optical variability modeling of newly identified blazars and blazar candidates behind the Magellanic Clouds

Author: Natalia Zywucka[1]

[1] *North-West Uniwersity*

Corresponding Author: natttiz@gmail.com

We present results of an optical variability study of 44 newly identified blazar candidates behind the Magellanic Clouds. The sample contains candidates for 27 flat spectrum radio quasars (FSRQs) and 17 BL Lacertae objects (BL Lacs), with nine of them recognized as blazars, while the classification of the remaining objects is still uncertain. All objects possess high photometric accuracy and frequently sampled optical light curves (LCs) from the long-term (~2 decades) monitoring conducted by the Optical Gravitational Lensing Experiment in V and I filters. The LCs were modelled with the Continuous-time Auto-Regressive Moving Average (CARMA) process, using the publicly available Markov Chain Monte Carlo sampler described by Kelly et al. (2014) and with the Lomb-Scargle (LS) periodogram. The CARMA models allow us to investigate variability features of irregularly sampled LCs, especially their power spectral density (PSD), to determine variability-based classification of astrophysical objects and to detect quasi-periodic oscillations (QPOs). We found that some of the examined objects require high-order fits, implying a deviation from the simple single-Lorentzian PSD. The power law PSD is indicative of a self-affine stochastic process characterised by the Hurst exponent H, underlying the observed variability. An estimation of the H values was performed with a wavelet lifting transform. We find that most objects have $H \leq 0.5$, indicating short-term memory, but four BL Lacs and two FSRQs have $H > 0.5$, implying long-term memory. The higher-order CARMA fits suggest there are additional variations present in blazar jets and/or accretion discs that affect both the overall shape of the PSDand can give rise to QPOs. The non-power law features are also visible in some of the LS periodograms, and signs of flattening of the PSD at low frequencies observed in some of the CARMA fits hint at the blazar nature of the objects.

Poster Session / 95

Spectral analysis of S5 1803+784 in the recent flaring state

Corresponding Author: 1926749@students.wits.ac.za

S5 1803+784 is a BL Lac object. Unlike most low synchrotron peaked (LSP) blazars, the spectrum of S5 1803+784 is poorly fitted with a single zone synchrotron self-Compton (SSC) leptonic jet model. This could be why recent multiwavelength studies show no clear correlation between the synchrotron emission and the gamma-ray emission in this blazar. We utilize a simple single-zone leptonic jet emission model with external Compton (EC) originating from the dusty torus (DT) to explain the emission and to produce the best-fit parameters of the emission process. We present here the spectral analysis of the recent flaring state reported in Astronomy Telegram (ATel #13633) using data from Fermi-LAT and NED archival data. The spectral energy distribution (SED) model of the flare and the quiescent states best-fit parameters produced using Jetset code are used to constrain the upper limit of the γ-ray emission region length scale, the jet energetics, and the likely acceleration mechanism of the blazar during the flare.

Poster Session / 96

A hadronic synchrotron mirror model for blazars - Application to 3C 279

Author: Laenita Oberholzer[1]

Co-author: Markus Boettcher [2]

[1] *North West University*

[2] *North-West University*

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

Blazars are a class of Active Galactic Nuclei (AGN) 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 termed orphan flares. The causes of this variabil- ity and conditions in and location of the high energy emission region are not completely understood. As a possible explanation for rapid gamma-ray variabil- ity, the hadronic synchrotron mirror model is suggested. A TeV orphan flare without Fermi-LAT counterpart 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 Fermi-LAT spectrum is used to constrain model parameters able to reproduce the proton-synchrotron SED through an analyt- ical fit to the data. The flaring very-high-energy emission is modeled by the hadronic synchrotron mirror model. First-principle analytical estimates predict a dense enough target photon field that is sufficiently efficient for photohadronic interactions to take place. Our numerical evaluation of this scenario reproduces a photo-pion induced very-high-energy gamma-ray flare without significant en- hancement of the Fermi-LAT flux. The photo-pion component of the spectrum is comparable in flux to that of the proton-synchrotron component.

Abstract field:

AGN II / 97

Probing magnetic fields in active galactic nuclei jets

Author: Evgeniya Kravchenko[1]

[1] *Moscow Institute of Physics and Technology*

Accreting systems in the centres of Active Galactic Nuclei (AGN) produce highly collimated relativistic jets.Magnetohydrodynamic simulations show that strong magnetic fields, twisted by the differential rotation of central black hole, play dynamically important role in these processes. Due to the dependence of the polarized radiation transfer coefficients on elementary composition and energy spectrum of magnetized plasma, polarimetric observations are an ideal tool for tracing the magnetic fields and probing properties of internal and external media of AGN jets. To date, polarimetric VLBI technique allows obtaining the highest angular resolution and thus spatially resolving polarization structure of relativistic jets. Moreover, Faraday rotation measures deliver the least model dependent information on jet physical properties. The feasibility of space polarimetric interferometric observations has been successfully demonstrated by VSOP (VLBI Space Observatory Programme) mission in early 2000s, that included a satellite antenna in near-Earth orbit. Recently, successful polarization observations of extragalactic objects by the RadioAstron project were carried out. The mission featured a 10-m space antenna orbiting the Earth in a high elliptical orbit, allowing detections of AGNs at projected baselines up to 28 Earth diameters. These space-VLBI polarization observations revealed the innermost compact jet regions, making possible to improve our understanding of magnetic fields and to address the physics of AGN jets. In this talk, I will discuss recent VLBI and space-VLBI polarimetric studies of Active Galactic Nuclei jets.

Abstract field:

AGN III / 98

Multi-wavelength study of HBL 1ES 1959+650 during various flares over 6 years of major activities

Author: Sunil Chandra[1]

Co-authors: Markus Boettcher [2]; Michael Zacharias [3]

[1] *SAAO*

[2] *North-West University*

[3] *Laboratoire Univers et Théories, Observatoire de Paris, Université PSL, CNRS, Université de Paris, 92190 Meudon, France*

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

1ES 1959+650 is a well known HBL with its synchrotron peak lying in soft X-ray band (0.3-10.0keV). It is also observed that the peak position of synchrotron component changes significantly with the brightness state of this blazar. This source underwent first major TeV activity in 2015 after a long silence in VHE bands. We have compiled all the multi-wavelength data between 2015 to 2021 accumulated over almost entire energy spectrum. A rigorous spectral and temporal investigation is performed to understand the detailed nature of the variability observed over the years. We plan to provide a detailed presentation of the findings during the conference.

Abstract field:

AGN III / 99

The many ages of AGN

Author: Kshitij Thorat[None]

Corresponding Author: kshitijthorat.astro@gmail.com

The nuclei of galaxies show episodes of activity and of quiescence. Through feedback mechanisms, such episodes have significant effects on their surroundings. Radio observations can be excellent probes of such episodes, measuring time-integrated influence of the AGN jet activity. Sensitive radio observations can record faint emission associated with the previous epochs of activity, and it is expected that new telescopes like MeerKAT, ASKAP and LOFAR will reveal whole populations of such sources. In this talk, I'll present an analysis of observations of a giant radio galaxy, carried out with MeerKAT, which shows three such epochs of activity. The observations are at the L-band and the new UHF-band, which allows for accurate estimates of spectral ages for each of the epochs as well as those of the ambient magnetic fields. Using these observations, I'll discuss what we should expect from new broad-band, deep surveys of the radio AGNs.

Abstract field:

AGN II / 100

RXS J08182+0122 - an AGN with an unusually broad Keplerian rotator line profile

Author: Hartmut Winkler[1]

Co-author: Amogelang Moeng [2]

[1] *University of Johannesburg*

[2] *Physics, University of Johannesburg*

Corresponding Authors: hwinkler@uj.ac.za, mogorwama@gmail.com

We have investigated the Balmer line profile of the AGN linked to the X-ray source RXS J08182+0122. We present a low-resolution spectrum of this target that we obtained at SAAO and subsequently analysed. This AGN displays broad emission lines with a double bump profile that is characteristic of fast moving gas in a Keplerian orbit around a supermassive black hole. This source is particularly interesting, as the rotational speeds inferred from the line widths are of the order of 13000 km⋅ s−1. This corresponds to some of the highest values measured in AGN with Keplerian rotator line profiles. We attempt to fit the profile with various models developed for this class of objects, and thereby estimate the dimensions, inclination and some additional properties of the broad emission line region of this AGN.

Abstract field:

AGN II / 101

Simulations of stochastic long-term variability in leptonic models for external-Compton and synchrotron self-Compton dominated blazars

Author: Hannes Thiersen[1]

Co-authors: Markus Boettcher [1]; Michael Zacharias [2]

[1] *North-West University*

[2] *Laboratoire Univers et Théories, Observatoire de Paris, Université PSL, CNRS, Université de Paris, 92190 Meudon, France*

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

In this work we investigate the nature of multi-wavelength variability of blazars from a purely numerical approach. We use a time-dependent one-zone leptonic blazar emission model to simulate multi-wavelength variability by introducing stochastic parameter variations in the emission region. These stochastic parameter variations are generated by Monte Carlo methods and have a characteristic power law index, $\alpha = -2$ in their power spectral densities (PSDs). We include representative blazar test cases for a flat spectrum radio quasar (FSRQ) and a high synchrotron peaked BL Lacertae object (HBL) for which the high energy component of the Spectral Energy Distribution (SED) is dominated by external Compton (EC) or synchrotron self-Compton (SSC) emission respectively. The simulated variability is analyzed in order to characterise the distinctions between the two blazar cases and the physical parameters driving the variability. We show that the variability's power spectrum is closely related to underlying progenitor variations for both cases. Distinct differences between the different progenitor variations are present in the multi-wavelength cross-correlation functions.

Abstract field:

AGN II / 102

Simulating AGN light curves of blob injection in RMHD jet simulations

Author: Daniel Kulik[1]

Co-authors: Brian van Soelen [2]; Izak van der Westhuizen

[1] *N/A*

[2] *University of the Free State*

Corresponding Authors: vanderwesthuizenip@ufs.ac.za, danielkuliksa@gmail.com, vansoelenb@ufs.ac.za

Active Galactic Nuclei (AGN) are compact regions in the centre of galaxies exhibiting higher than normal luminosity. Radio loud AGN produce relativistic jets which exhibit variability over various time-scales. This has been attributed to the formation of blob/shock structures propagating along the jet. Using relativistic magnetohydrodynamic (RMHD) simulations we investigate how blob injection can result in variable light curves. Three-dimensional RMHD jets were simulated using PLUTO, an astrophysical fluid simulation software, and allowed to develop in time forming multiple re-collimation shocks. A quasi-spherical blob was then injected and allowed to propagate along the jet, interacting with the shocks. A post-processing code was used to find the integrated specific intensity of the synchrotron emission in the radio regime, accounting for relativistic effects such as Doppler boosting and light-crossing time correction. Light curves for various viewing angles were calculated to investigate how the emission generated from a single blob differed from a radio galaxy to a blazar-like AGN.

Abstract field:

AGN II / 103

Jets and disc-winds from magnetically driven flows around black holes

Author: Indu Kalpa Dihingia[1]

Co-authors: Barghav Vaidya [2]; Christian Fendt [3]

[1] *Indian Institute of Technology Indore, India*

[2] *Indore Institute of Technology India*

[3] *Max Planck Institute for Astronomy*

Corresponding Authors: idihingia@iiti.ac.in, fendt@mpia.de, bvaidya@iiti.ac.in

Relativistic jets and disc-winds are typically observed in BH-XRBs and AGNs. However, many physical details of jet launching and the driving of disc winds from the underlying accretion disc (AD) are still not fully understood. This study will investigate the role of different flow parameters on the launching of jets, driving disc-winds, and the dynamical properties of the disc. We will also explore the connection between jet, wind, and the AD around the central black hole. We have performed axisymmetric ideal and resistive GRMHD simulations of the accretion-ejection system using AMR. Essentially, our simulations were initiated with a thin AD in equilibrium. Our study has found relativistic jets and disc-wind driven by the Blandford & Znajek and Blandford & Payne mechanism, respectively. We have also found that plasmoids are formed due to the reconnection events, and these plasmoids advect with disc-winds. Consequently, the enhanced magnetic tension force results in disc truncation and sporadic oscillation in the inner part of the AD. However, with truncated accretion disc, the sporadic oscillations become periodic. Further, we will also discuss possible applications of our models to understand the observed variabilities in AGNs and BH-XRBs.

Abstract field:

Poster Session / 104

Results from the O3 observing run of the LIGO-Virgo Collaboration

Author: ROSA POGGIANI[None]

Corresponding Author: rosa.poggiani@unipi.it

The third observation run (O3) of Advanced LIGO and Advanced Virgo started in April 2019 and ended in March 2020, with improved sensitivities compared to the previous observing run. The presentation will review the science results achieved during the O3 run, that include the GWTC-2, GWTC-2.1 catalogs of compact binary mergers and some exceptional events: GW190412, the merger of two black holes with asymmetric masses; GW190425, the second observed binary neutron star merger; GW190521, the first detection of an intermediate mass black hole; GW190814, a system with a secondary that could be either a black hole or a neutron star; GW200105 and GW200115, the first detected neutron star-black hole binary mergers.

Abstract field:

Multi-Messenger

XRB I / 105

A decade of black hole X-ray binary transients

Author: Phil Charles[1]

[1] *University of Southampton*

Corresponding Author: pac2soton@gmail.com

The last decade has seen a significant gain in both space and ground-based monitoring capabilities, producing vastly better coverage of BH X-ray binaries during their (rare) transient outbursts. This interval also included two of the 3 brightest X-ray outbursts ever observed, namely V404 Cyg in 2015, and MAXI J1820+070 in 2018, as well as Swift J1357.2-0933, the first such system to show a variable period optical dip. We have superb multi-wavelength archives of these outbursts, both photometric and spectroscopic, that show substantial outflows in the form of jets and disc winds, and X-ray spectroscopy/timing that reveals how the inner accretion disc evolves. There are now enough BHXTs to allow a study of their galactic distribution.

Abstract field:

XRB I / 106

Be X-ray binary 4U 1901+03: Cyclotron resonance scattering feature and its imprint on the pulse profile

Author: aru beri[1]

Co-authors: Chandreyee Maitra [2]; Nirmal Iyer [3]; Tinku Girdhar [4]

[1] *IISER Mohali, India*

[2] *CEA Saclay*

[3] *KTH Royal Institute of Technology, Department of Physics, Stockholm, Sweden*

[4] *IISER Mohali*

Corresponding Authors: mggirdhars@gmail.com, nirmal.iyer@gmail.com, chandreyee.maitra@cea.fr, aru.beri8@gmail.com

X-ray binaries are among the brightest objects of our Galaxy in the high-energy domain (0.1-100 keV). Despite a relatively good knowledge of their basic emission mechanisms, we still lack a complete understanding of their time, energy, and luminosity dependence. We will present results obtained from a detailed study of a transient Be X-ray pulsar 4U 1901+03. This source was followed by NuSTAR and Swift during its 2019 outburst. We found a strong dependence on the energy as well as luminosity for the source which can be used to map the accretion geometry. We further exploited a cross-correlation technique to compare the pulse profiles in different energy ranges and found that the pulse profiles display "phase-lags" at energies close to those of the cyclotron absorption feature at 30 keV. This feature at 30 keV is highly luminosity and pulse-phase dependent. We also discuss results from pulse phase-resolved spectroscopy to draw a coherent picture of the X-ray properties of the source using correlated timing and spectral studies.

Abstract field:

XRB I / 107

Determining the orbital parameters of the gamma-ray binary HESS J0632+057

Author: Natalie Matchett[1]

Co-authors: Brian van Soelen [1]; Richard Gray [2]

[1] *University of the Free State*

[2] *Appalachian State University*

Corresponding Authors: grayro@appstate.edu, vansoelenb@ufs.ac.za, natmatch98@gmail.com

Gamma-ray binaries are a rare subclass of high mass binary systems that display non-thermal emission peaking at energies greater than 1 MeV. All the identified systems contain an O/Oe or B/Be type star and a compact object in the mass range of a neutron star or black hole. Correctly interpreting how these sources can produce non-thermal emission, up to very high energy gamma-rays, depends on knowing the orbital parameters. Previous studies of the gamma-ray binary, HESS J0632+057, by Cesares et al. 2012 and Moritani et al. 2018 have obtained incompatible orbital solutions. Since the source has a ~320 day orbital period, long term observations are required to resolve this discrepancy. We are undertaking observations using the HRS on the SALT, to differentiate between the two proposed orbital solutions and we present the initial results from the first observing semester.

Abstract field:

XRB III / 108

Advances with NICER on neutron stars, accreting black holes, and optical transients in nearby galaxies

Author: Ronald Remillard[1]

[1] *Massachusetts Institute of Technology*

Corresponding Author: rrem@mit.edu

The Neutron Star Interior Composition Explorer (NICER) began science operations from the International Space Station in 2017 July, conducting observations in X-rays (0.4-12 keV) with sub-microsecond time resolution. Accomplishments to date are briefly reviewed for several types of sources. Pulse profiles for rotation-powered millisecond pulsars are modeled to constrain the equation of state of the neutron stars, achieving the primary objective of the Mission. Spectral-timing analyses of accreting black holes address technical questions regarding the disk:corona connection, and the measurements suggest a contraction of the corona as the source evolves from the intermediate to the hard X-ray state. Less anticipated is the wealth of information coming from observations of optical transients in nearby galaxies: tidal disruption events, change-look Active Galactic Nuclei, extreme supernovae, and quasi-periodic eruption sources. The characterizations of these transient subtypes is in the midst of a fundamental overhaul.

Abstract field:

XRB I / 109

Gamma-gamma absorption in gamma-ray binaries

Author: Brian van Soelen[1]

[1] *University of the Free State*

Corresponding Author: vansoelenb@ufs.ac.za

Gamma-ray binaries are a rare subclass of high mass binary systems, where the non-thermal emission peaks in the gamma-ray regime. Two scenarios have been proposed to explain the production of the emission; in the pulsar wind scenario the compact object is proposed to be a rapidly rotating pulsar, and the emission originates from particle acceleration that occurs at the shock that forms between the pulsar and stellar wind; in the microquasar scenario emission originates from the relativistic jet. In the pulsar wind scenario, acceleration would be most dominate at the apex of the shock, but hydrodynamic simulations have shown that a second shock could occur due to Coriolis forces. Since gamma-gamma absorption will strongly attenuate TeV emission originating from the apex of the shock, this my imply that it originates from this second shock region. We have undertaken a full calculation of the gamma-gamma optical depth around the known gamma-ray binary systems to investigate whether gamma-gamma absorption may introduce observable features that could be used to constrain the location of the gamma-ray production.

Abstract field:

XRB I / 110

On the long-term optical and X-ray behaviour of sibling SMC Be X-ray binaries SXP15.3 and SXP305

Author: Itumeleng Monageng[1]

[1] *University of Cape Town*

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, with luminosities less than 1037 erg./s) and type II (or giant, with luminosities greater than 1037 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.
In this talk I will present preliminary optical and X-ray results from long-term monitoring of two Be X-ray binaries in the Small Magellanic Cloud that are in close proximity, SXP15.3 and SXP305. The X-ray emission from the combined field of the two sources has recently displayed a series of outbursts, the origin of which is difficult to discern. I will discuss the long-term behaviour of the Be

discs of the two sources, where inferences about their structure and geometry are made from OGLE and SALT data.

Abstract field:

AGN II / 111

MeerKAT observations of radio galaxies

Author: Imogen Whittam[1]

[1] *Oxford University*

Corresponding Author: imogen.whittam@physics.ox.ac.uk

MIGHTEE is a galaxy evolution survey currently underway with the MeerKAT radio telescope. Once complete, the survey will cover 20 square degrees in four fields to a depth of 1 uJy rms/beam at 1.28 GHz, providing a unique combination of depthand breath. Crucially, the MIGHTEE fields have excellent multi-wavelength coverage, enabling a full census of galaxy properties. I will provide an overview of the first results from the MIGHTEE-continuum Early Science data, focussing on new insights into theproperties of radio galaxies.

Abstract field:

AGN III / 112

A study of the lobes of radio galaxy Hydra A using MeerKAT observations

Author: Mika Naidoo[1]

Co-authors: Andrew Chen [1]; Dmitry Prokhorov [2]; Paolo Marchegiani [3]; Paolo Serra [4]; Sphesihle Makhathini [1]

[1] *University of the Witwatersrand*

[2] *Linnaeus University*

[3] *Sapienza Universita' di Roma*

[4] *INAF*

Corresponding Authors: sphesihle.makhathini@wits.ac.za, dmitry.prokhorov@lnu.se, andrew.chen@wits.ac.za, 1678178@students.wits.ac.za

Hydra A is a type I Fanaroff-Riley radio galaxy that hosts a pair of 300-kiloparsec diameter radio lobes that are being powered by one of the most of the powerful AGN outbursts known to date. Radio observations provide us with an excellent probe for the study of high-energy particles residing in the lobes. The MeerKAT radio telescope carried out observations of Hydra A, from which we obtained radio maps at several frequencies. A spatial analysis of the radio maps reveals a pair of inner lobes and a pair of outer lobes. We computed the radiative flux densities using these observations and combined them with previous results from low- frequency VLA observations at 74 MHz and 327 MHz. We found that the spectrum in the MeerKAT frequency range is well described by a power law. We set constraints on the magnetic field strength and the age of the outer radio lobes through electron spectrum modelling which includes electron aging.

Abstract field:

AGN III / 113

Geodetic and astrometric VLBI observations to monitor radio source structure in the South

Author: Sayan Basu[1]

Co-authors: Alet de Witt [2]; Roger Deane [3]

[1] *University of the Witwatersrand*

[2] *South African Radio Astronomy Observatory*

[3] *University of Witwatersrand*

Corresponding Author: basusayan2020@gmail.com

Extragalactic radio sources selected for geodetic and astrometric VLBI observations are expected to have a core-dominated point-like structure. However, it is a well-known fact that extragalactic radio sources often exhibit time- and frequency-dependent intrinsic source structure at milliarcsecond (mas) scale, making them subjects of routine monitoring. In this talk, I will present mas resolution VLBI images of 164 radio sources at 2.3 and 8.4 GHz observed at multi-epoch in the Celestial Reference Deep South (CRDS) geodetic and astrometric VLBI sessions between 2018 and 2019. Along with the images, I will also present statistical results from the astrometric quality assessments of the sources indicating: 1. which sources are good candidates for geodetic and astrometric purposes and, 2. which sources should be avoided due to the source structure variability. However, the sources that show structure variability can also be interesting to monitor flux density variation at multi-epoch, for a range of research topics in high-energy astrophysics. The talk will conclude by showing that the CRDS geodetic and astrometric VLBI observations indeed can complement other ongoing radio surveys in the Southern Hemisphere.

Abstract field:

AGN III / 114

A shock-in-jet synchrotron mirror model

Author: Markus Boettcher[1]

[1] *North-West University*

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

Previous work on time-dependent shock-acceleration and radiation transfer in relativistic jets has successfully reproduced many spectral variability features of blazars if flaring activity is mediated by increasingly efficient diffusive shock acceleration. However, flaring events exhibiting a significant increase of the Compton dominance, or even "orphan" gamma-ray flares, are very difficult to reproduce in this manner, suggesting that an enhancement of an external radiation field for Compton scattering may be responsible for the gamma-ray flaring. This work therefore investigates the signatures of a synchrotron mirror model in which the synchrotron emission of electrons accelerated by a mildly relativistic shock traveling along the jet, is reflected by a cloud, and the reflected synchrotron radiation acts as target photon field for enhanced Compton scattering further down the jet. The model is applied to recent flaring events exhibiting a significant enhancement of the Compton dominance, in 3C279 and PKS 1510-089.

Abstract field:

AGN III / 115

ExHaLe-Jet: An extended hadro-leptonic jet model for blazars

Author: Michael Zacharias[1]

Co-authors: Andreas Zech [2]; Anita Reimer [3]; Catherine Boisson [2]

[1] *Laboratoire Univers et Théories, Observatoire de Paris, Université PSL, CNRS, Université de Paris, 92190 Meudon, France*

[2] *Observatoire de Paris*

[3] *University of Innsbruck*

Corresponding Authors: catherine.boisson@obspm.fr, anita.reimer@uibk.ac.at, andreas.zech@obspm.fr

Blazars –active galaxies with the jet pointing at Earth –emit across all electromagnetic wavelengths. The so-called one-zone model has described well both quiescent and flaring states, however it cannot explain the radio emission. In order to self-consistently describe the entire electromagnetic spectrum, extended jet models are necessary. Notably, kinetic descriptions of extended jets can provide the temporal and spatial evolution of the particle species and the full electromagnetic output. Here, we present the initial results of a recently developed lepto-hadronic, extended-jet code. As protons take much longer than electrons to lose their energy, they can transport energy over much larger distances than electrons and are therefore essential for the energy transport in the jet. Furthermore, protons can inject additional leptons through pion production and decay, as well as Bethe-Heitler pair production, which can explain a dominant leptonic radiation signal while still producing neutrinos. We will present a detailed parameter study and provide insights into the different blazar sub-classes.

Abstract field:

AGN III / 116

Modeling emissions from secondary electron-positron pairs created by absorption of gamma-rays in the broad-line region of blazars and their contribution to the broadband SED

Author: Mfuphi Ntshatsha[None]

Co-author: Soebur Razzaque [1]

[1] *University of Johannesburg*

Corresponding Authors: srazzaque@uj.ac.za, mfuphin95@gmail.com

Blazars emit powerful electromagnetic (EM) radiation across all wavelengths. The broadband spectral energy distributions (SEDs) of EM emissions from these objects are characterised by two humps. The low frequency hump ranging from radio to infrared/X-ray emission is accepted as synchrotron radiation by primary leptons. The high frequency hump from X-rays to gamma-rays is attributed to inverse-Compton (IC) radiation. Their variable emission, on timescales as short as minutes, constrains the emitting region to a compact size relative to the scale of the host galaxy. The sub-class of blazars known as the flat-spectrum radio quasars (FSRQs) also show strong emission lines in the optical-ultraviolet (UV) spectrum in the broad-line region (BLR). The bright FSRQ 3C 279 has a distinct dip feature in the gamma-ray band of its SED. This feature is also present in other blazars. In a previous work we have shown that the BLR can interact with gamma-rays in the jet to produce secondary electron-positron (e+-) pairs. We also found that, given a sufficiently strong magnetic field in the jet, synchrotron self-Compton (SSC) emission from the e+- pairs can compensate for the gamma-ray dip in the SED of blazars. In this work we model the broadband SED of 3C 279 using JetSet. We add the SSC component from the e+- pairs produced in the BLR to the SED and constrain the magnetic field in the jet.

Abstract field:

AGN III / 117

Radiation from relativistic particles accelerated at shear layers in relativistic jets

Author: Tej Chand[1]

Co-author: Markus Boettcher [2]

[1] *North-West university, Centre for Space Research*

[2] *North-West University*

Corresponding Authors: markus.bottcher@nwu.ac.za, chandtej11@gmail.com

The supermassive black holes in the centers of some active galaxies (AGN) eject powerful relativistic jets which propagate over kpc scales, showing no significant momentum loss. Both observational evidence as well as theoretical considerations from MHD simulations of jets suggests that they are radially stratified, with a fast inner spine surrounded by a slower-moving outer sheath. The resulting relativistic shear layers are a prime candidate for the site of relativistic particle acceleration in the jets of AGN and gamma-ray bursts (GRBs). In this talk, we will present results of particle-in-cell simulations of magnetic-field generation and particle acceleration in the relativistic shear boundary layers of jets in AGN and GRBs including the self-consistent calculation of radiation spectrum produced by inverse Compton scattering of relativistic electrons in the isotropic soft photon field. We outline future plans to include self-consistent calculation of angle-dependent radiation produced by the particles accelerated at these shear boundary layers.

Abstract field:

XRB II & HE Polarimetry / 118

Jets in accreting X-ray binaries

Author: Andrzej Zdziarski[None]

Corresponding Author: andrzej.zdziarski@gmail.com

I will review our current knowledge about three well-studied jets in X-ray binaries, MAXI J1820+070, Cyg X-1, and Cyg X-3. The first two accrete from their donors onto black holes, while this is likely but not certain in Cyg X-3. Thanks to an extensive multi-wavelength campaign during the recent outburst of MAXI J1820+070, the structure of its compact jet emitting in radio to optical frequencies is now very well understood. The relatively long time lags measured between various radio and sub-mm frequencies prove that emission is formed at distances several orders of magnitude higher than the gravitational radius. We determine the jet opening angle, the location of the onset of the emission, the magnetic field strength and the electron distribution, and put constraints on the bulk Lorentz factor, the content of electron-positron pairs and the jet power. Then, I will compare those jet parameters with those in Cyg X-1 and Cyg X-3, both of which emit also high-energy gamma rays.

Abstract field:

XRB II & HE Polarimetry / 119

Hercules X-1 (Her X-1): New results from the past decade of observations

Author: Denis Leahy[1]

[1] *University Of Calgary*

Corresponding Author: leahy@ucalgary.ca

Her X-1 is an accreting X-ray binary with well-determined properties based on measurements of light- curves and spectra since its discovery in 1972. Since discovery, it has been observed with most major X-ray astronomy instruments. Observations of Her X-1 over the past decade include those from AstroSat, Swift, and MAXI. These have added to the range of phenomena detected from this system. The new aspects of the binary will be reviewed, including new orbital and 35-day measurements of pre-eclipse dips. These will be used to test models for the system, including accretion disk and stream from the L1 point on HZ Her to its impact point on the disk.

Abstract field:

XRB II & HE Polarimetry / 120

The 2019 outburst of the accreting millisecond pulsar SAX J1808.4-3658

Author: Kelebogile Bonokwane[1]

Co-authors: Itumeleng Monageng [1]; Rob Fender [2]

[1] *University of Cape Town*

[2] *University of Oxford*

Corresponding Authors: rob.fender@physics.ox.ac.uk, itu@saao.ac.za, kelebogile@saao.ac.za

X-ray binaries (XRBs) comprise of compact objects, black hole or a neutron star, and a companion (donor) star. Depending on the mass of the companion, the XRB is classified as low-mass (Mdonor < 1 M⊙) or high-mass (Mdonor > ~ 8 M⊙). SAX J1808.4–3658 is a low-mass neutron star XRB, the first accreting millisecond pulsar (AMXP) known. The pulsar was confirmed with the detection of 401 Hz pulsations in 1998 from the Rossi X-ray Timing Explorer (RXTE) after the discovery of the x-ray source with the BeppoSAX satellite in 1996. In 2019 the source underwent an outburst which was monitored with Swift and observed with MeerKAT at 1.28 GHz as part of the ThunderKAT Large Survey Programme. We monitored SAX J1808.8-3658 weekly during its 2019 outburst with MeerKAT and Swift. In this talk I will report on the results of the campaign, where I will show the flux variability during the outburst and discuss the location of SAX J1808.4-3658 in the radio/X-ray plane.

Abstract field:

XRB II & HE Polarimetry / 121

X-ray spectropolarimetric observations of black holes and magnetars with IXPE and XL- Calibur

Author: Henric Krawczynski[1]

[1] *Washington University*

Corresponding Author: krawcz@wustl.edu

The Imaging X-ray Polarimetry Explorer (IXPE), scheduled for launch in Fall 2021, will open up the window of X-ray polarimetry. IXPE will be joined by XL-Calibur in 2022, adding 15-75 keV polarimetric capabilities to IXPE's 2-8 keV coverage.The exciting science topics that can be addressed with

IXPE include observations of stellar mass black holes and observations of magnetars. I will report here on the IXPE and XL-Calibur observation programs of these two source classes, the models that havebeen developed to analyze the data. and results from fitting archival spectroscopic observations with these models. Last but not least,. I will discuss simulated IXPE and XL-Calibur observations, and discuss the scientific questions that we expect to be ableto answer with these observations.

Abstract field:

XRB II & HE Polarimetry / 122

Monte-Carlo Applications for Partially Polarized Inverse External-Compton Scattering

Author: Lente Dreyer[1]

Co-author: Markus Boettcher [1]

[1] *North-West University*

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

The spectral energy distributions (SEDs) of some blazars exhibit an ultraviolet (UV) and/or soft Xray excess, which can be modelled with different radiation mechanisms. Polarization measurements of the UV/X-ray emission from blazars may provide new and unique information about the astrophysical environment of blazar jets and could thus help to distinguish between different emission scenarios. I will present a new Monte-Carlo code –MAPPIES (Monte-Carlo Applications for Partially Polarized Inverse External-Compton Scattering) –for polarization-dependent Compton scattering. I will present the code by showing results of the polarization signatures in a model where the UV/soft X-ray excess arises from the bulk Compton process. Predictions of the expected polarization signatures of Compton emission from the soft X-ray excess in the SED of AO 0235+164, and the UV excess in the SED of 3C 279 are made for upcoming and proposed polarimetry missions.

Abstract field:

Multi-Messenger & Astro-Particle / 123

Probing AGN jets with high-energy neutrinos

Author: Maria Petropoulou[1]

[1] *National & Kapodistrian University of Athens*

Corresponding Author: mpetropo@phys.uoa.gr

Active galactic nuclei (AGN) with relativistic jets, powered by mass accretion onto the central supermassive black hole of their host galaxies, are the most powerful persistent sources of broadband electromagnetic radiation in the Universe. Despite decades of multi-wavelength observations, there are still several key questions about AGN jet physics that remain open, such as "What is the plasma composition of AGN jets? Are they composed of electrons and positrons or do they contain baryons too?" and "Where and how are gamma-rays produced in jets?" Unlike photons, neutrinos can only be produced in inelastic collisions of relativistic protons or heavier nuclei with radiation or matter. In contrast to gamma-rays and cosmic rays, neutrinos can freely escape their astrophysical sources and travel over cosmological distances without being affected by ambient photon fields and intergalactic magnetic fields due to their extremely rare interactions with matter and radiation. Carrying important information about the physical conditions in their production sites, neutrinos are thereby a unique messenger for understanding how the most powerful and persistent particle accelerators of the Universe work. The detection of a high-energy neutrino (IC-170922A) coincident with an electromagnetic flare from TXS 0506+056 in 2017 and the subsequent discovery of a neutrino excess from the same direction have strengthened the hypothesis that jetted AGN are cosmic neutrino sources. The lack, however, of gamma-ray flaring activity during the latter period challenges the idea of co-spatial production of gamma-rays and neutrinos in jets, suggesting multiple production sites. In this talk, I will present results of widely adopted physical models trying to explain the aforementioned associations, while highlighting the lessons learned and the newly created puzzles. I will conclude with a new proposal linking the neutrino production in AGN jets to periods of enhanced X-ray activity and discuss its testability with IceCube observations.

Abstract field:

Multi-Messenger & Astro-Particle / **124**

Line of sight neutrinos and gamma-rays from blazars associated with IceCube neutri- nos

Author: Soebur Razzaque[1]

Co-authors: Nayantara Gupta [2]; Saikat Das

[1] *University of Johannesburg*

[2] *Raman Research Institute*

Corresponding Authors: srazzaque@uj.ac.za, saikatdas@rri.res.in, nayan@rri.res.in

Blazars are potential candidates of cosmic-ray (CR) acceleration up to ultrahigh energies (UHE, E > 1017 eV). Association of a number of blazars with IceCube neutrino events supports this hypothesis. If the intergalactic magnetic field strength is reasonably low, the UHECRs escaping from the blazar jet will produce neutrinos and gamma rays along the line-of-sight (LoS) by interacting with the extragalactic background light (EBL) and cosmic microwave background (CMB) while propagating. This talk will focus on LoS neutrino and gamma-ray fluxes from four blazars associated with IceCube neutrinos, namely TXS 0506+056, PKS 1502+106, 3HSP J095507.9+355101 and GB6 J1040+0617, and their possible detection.

Abstract field:

Multi-Messenger & Astro-Particle / **125**

High energy emissions heralding binary black hole inspiral

Author: Justine Tarrant[1]

Co-author: Geoff Beck [2]

[1] *WITS*

[2] *University of the Witwatersrand*

Corresponding Authors: justine.tarrant@wits.ac.za, geoffrey.beck@wits.ac.za

Useful to LIGO detections would be an electromagnetic signal which heralds the start of a binary black hole inspiral. Primarily, this would also aid in multi-messenger follow-up studies. We look to the potential presence of an accretion disk as a source of emissions. We consider this problem by computing geodesics numerically from an approximate, analytic metric to determine the amount of energy released by each particle due to inverse Compton scattering and the eventual accretion

onto the binary. Once we find the total emission flux from the accretion process and inverse Compton scattering, we can determine how bright the emitted electromagnetic signal will be. Then we can characterize the signal and determine its temporal relation to LIGO binary black hole inspirals.

Abstract field:

Multi-Messenger & Astro-Particle / 126

Shaken, not stirred: Test particles in binary black hole mergers

Author: Pieter Van der Merwe[1]

Co-author: Markus Boettcher [1]

[1] *North-West University*

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

In 2015 the advanced Laser Interferometer Gravitational-Wave Observatory (aLIGO) detected the first ever gravitational event, gravitational wave event GW150914, with multiple new gravitational wave events, originating from both binary neutron stars and binary black hole (BBH) mergers, detected in subsequent years. In light of these detections, we simulate the dynamics of ambient test particles in the gravitational potential well of a BBH system close to its inspiral phase with the goal of simulating the associated electromagnetic radiation and resulting spectral energy density distribution of such a BBH system. This could shed light on possible detection ranges of electromagnetic counterparts to BBH mergers. The potentials are numerically calculated using finite difference methods, under the assumption of non-rotating black holes with the post-Newtonian Paczynski-Wiita potential approximation in tandem with retarded time concepts analogous to electrodynamics. We find that the frequencies of potential electromagnetic radiation produced by these systems (possibly reaching earth), range between a few kHz to a few 100kHz. The bulk of radiation is distributed at frequencies below 100kHz.

Abstract field:

Multi-Messenger & Astro-Particle / 127

Simulation of the binary black hole merger rate with ultraluminous X-ray source pro- genitors

Author: Lutendo Nyadzani[1]

Co-author: Soebur Razzaque [1]

[1] *University of Johannesburg*

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

Ultraluminous X-ray sources (ULXs) were first discovered in the 1980s by the Einstein Observatory. The most interesting property of ULXs is that they exceed the Eddington luminosity of a neutron star. Data from the 2XMM-Newton and Chandra contain 470 ULX candidates in 238 galaxies (Walton et al. 2011) and 629 ULX candidates in 309 galaxies (Kovlakas et al. 2020), respectively. In this study, we use the properties of ULXs in these catalogues to simulate a population of ULXs with realistic astrophysical distributions. Assuming that all intermediate-mass BH-BH mergers evolved through a ULX phase as in Finke & Razzaque (2017), we compute the merger rate of intermediate-mass black hole binaries in the local universe using the simulated ULXs population.

Abstract field:

Multi-Messenger & Astro-Particle / 128

Linking the LHC and astrophysics with anomalies

Author: Geoff Beck[1]

Co-authors: Bruce Mellado Garcia [1]; Elias Malwa [2]; Mukesh Kumar [2]; Ralekete Khilly Temo [2]

[1] *University of the Witwatersrand*

[2] *University of the Witwatersrand (ZA)*

Corresponding Authors: ralekete.khilly.temo@cern.ch, mukesh.kumar@cern.ch, geoffrey.beck@wits.ac.za, elias.malwa@cern.ch, bruce.mellado.garcia@cern.ch

Emerging anomalies in both di and multi-lepton data from the LHC have been used to motivate for an extension to the Standard Model in the form of a second Higgs doublet and a singlet scalar (2HDM+S). Here we explore a dark matter candidate drawn from this model: a scalar particle that couples to the Standard Model through the 2HDM+S degrees of freedom. Using the best-fit 2HDM+S model from LHC data, and consequent dark matter annihilation/decay yields, we explore whether this model can account for the galactic-centre Fermi-LAT and anti-particle excesses. Additionally, we will study the general constraining power of gamma-ray data on this model. This study is part of a project exploring potential connections between collider and astrophysical excesses, thus seeking to illustrate new synergies between large and small-scale probes beyond the Standard Model.

Abstract field:

Multi-Messenger & Astro-Particle / 129

A new approach to search for binary black holes with Fermi-LAT

Author: Michael Kreter[None]

Co-authors: Markus Boettcher [1]; Philipp Arras [2]; Philipp Frank [3]; Torsten Ensslin [3]; Vincent Eberle [3]

[1] *North-West University*

[2] *Max-Planck Institutes (in MetaDir of GWDG)*

[3] *MPI f. Astrophysics*

Corresponding Authors: ensslin@mpa-garching.mpg.de, parras@mpa-garching.mpg.de, michael@kreter.org, markus.bottcher@nw

Blazars are powered by super-massive black holes in their centers and are known for extreme variability on time scales from minutes to years. In case of a binary black hole system, this duality is traceable as periodic modulation of their gamma-ray emission. So far, high-significance periodicity has been reported for a very few blazars with standard approaches. We developed a method to search for periodic patterns in Fermi/LAT light curves, using information field theory (IFT). IFT is a formulation of Bayesian statistics in terms of fields. Bayesian statistics is ideal for the problem at hand since the data is incomplete, irregularly sampled and obeys non-Gaussian statistics such that common least-squares methods do not apply. Simulated Fermi/LAT light-curves are used for significance testing and to provide a proof of the used method. We present first results, analyzing a sample of promising binary black hole candidates like PG 1553+113 and Mrk 501.

Abstract field:

Pulsars I / 130

Modeling globular clusters as multi-wavelength emitters

Author: Hambeleleni Davids[1]

Co-authors: Christo Venter ; Christo Venter [2]; Michael Backes [3]

[1] *University of Namibia, North-West University*

[2] *North-West University Potchefstroom Campus*

[3] *University of Namibia*

Corresponding Authors: mbackes@unam.na, hambeleleni.ndiyavala@gmail.com, christo.venter@nwu.ac.za, christo.venter7@gmail.com

At present, only a single Globular Cluster (GC) has plausibly been detected at very high energies (VHEs) by H.E.S.S. The future CTA is expected to detect more GCs in this band. We present results from an emission code that assumes millisecond pulsars (MSPs) to be sources of relativistic particles diffusing through GCs that will give broad-band radiation due to their interaction with the cluster magnetic and soft-photon fields. We perform a parameter study to investigate the GC model's behaviour and study the detectability of Galactic GCs for H.E.S.S. and CTA. We also present new Fermi-LAT data on Terzan 5 and model its broadband spectrum, constraining our model with available multi-wavelength data. We furthermore derive constraints on the embedded population of MSPs'luminosity function. Finally, we note that stacking upper limits by H.E.S.S. on the γ-ray flux of a population of 15 Galactic GCs are very constraining for leptonic emission models. We therefore show that uncertainty in model parameters leads to a large spread in the predicted flux, and there are indeed regions in parameter space for which the stacking upper limits are satisfied.

Abstract field:

Pulsars I / 131

Constraining the magnetic field geometry of the millisecond pulsar PSR J0030+0451 using NICER and Fermi data

Author: Anu Kundu[1]

Co-authors: Alice Harding [2]; Christo Venter [3]; Constantinos Kalapotharakos [4]; Demosthenes Kazanas [5]

[1] *NWU*

[2] *Los Alamos National Laboratory*

[3] *North-West University Potchefstroom Campus*

[4] *UMCP CRESST / NASA GSFC*

[5] *Astrophysics Science Division, NASA/Goddard Space Flight Center*

Corresponding Authors: demos.kazanas@nasa.gov, ckalapotharakos@gmail.com, christo.venter7@gmail.com, anukundu02@yahoo.com, ahardingx@yahoo.com

The Neutron star Interior Composition Explorer (NICER) was installed aboard the International Space Station (ISS) in 2017 with the major aim of gaining a better understanding of the extreme nature and composition of neutron stars (NSs). With its exceptional sensitivity, it hopes to constrain the equation of state for these compact objects to high precision. Modelling thermal X-ray light curves (LCs) of pulsars can also provide us insights into the magnetic field structure of NSs which further helps in understanding the morphology of the surface hot spots. Recently, works by Miller et al. (2019) and Riley et al. (2019) suggested strong evidence for a multipolar magnetic field of the millisecond pulsar PSR J0030+0451, constraining its mass and radius with unprecedented accuracy. Kalapotharakos et al. (2021) constrained the parameter space for an offset-dipole plus quadrupole field configuration, by calculating polar caps which accurately produce the NICER X-ray LC (and inferred surface hotspots) of J0030 making use of Markov chain Monte Carlo (MCMC) methods. This approach indicates field degeneracies for offset static vacuum and force-free field configurations, meaning different configurations adequately describe the same observed LCs. Exploring the same configuration to fit the gamma-ray LCs measured by Fermi data breaks the field degeneracies –giving a more constrained model solution. We are extending the above study (Kalapotharakos et al. (2021)) by changing the static vacuum field configuration to a more realistic retarded field in terms of a multipole expansion, where we include higher multipoles, i.e. beyond quadrupole, and then including general relativistic effects and an offset configuration. Exploring the field parameter space by using an MCMC technique for this configuration to fit the X-ray LCs and corresponding Fermi gamma-ray LCs will help us constrain the field structure, and eventually the stellar mass and radius, more robustly. In the talk, the impact of this work and future applications will be discussed.

Abstract field:

Pulsars I / **132**

Constraining the non-thermal emission site and geometry of AR Sco via optical po- larimetry

Author: Louis Du Plessis[1]

Co-authors: Alice Harding [2]; Christo Venter [3]; Zorawar Wadiasingh [4]

[1] *Centre for Space Physics, North-West University*

[2] *Los Alamos National Laboratory*

[3] *North-West University Potchefstroom Campus*

[4] *NASA GSFC*

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

Marsh et al. detected radio and optical pulsations from the binary system AR Scorpii (AR Sco). This system, with an orbital period of 3.55 h, is composed of a cool, low-mass star and a white dwarf (WD) with a spin period of 1.95 min. Takata et al. also detected X-ray pulsations from this source. These observations indicate no presence of an accretion disk or column. Buckley et al. found that optical pulsations from the white dwarf are strongly linearly polarised (up to 40%). The multitude of observations on the source has led to a plethora of models to explain these observations especially the pulsed non-thermal emission. These models fall into two groups proposing two different emission locales. The first suggests that the particles are accelerated and radiate at the interacting magnetic fields of the binary members, where shock could form. The majority of these models invoke magnetic reconnection, using precession of the WD to explain the optical and X-ray variations. The second group proposes that the particles radiate and cool inside the WD magnetosphere close to its magnetic poles. One prevalent idea is that particles are injected from the companion and encounter a magnetic mirror close to the WD. We previously fitted a standard pulsar rotating vector model to the polarisation emission angle data allowing us to constrain the magnetic field geometry in the emission region to a dipole-like field structure. Additionally, we determined that synchrotron radiation dominates as long as the pitch angles of the particles can be maintained. We then applied our model to orbitally phase-resolved polarisation position angle data and obtained a variation in magnetic inclination and observer angles over the orbital period. In this talk, we scrutinise the various models in light of our own findings as well as current observations. Finally, we make some speculations to explain the time evolution of the geometric parameters that we obtain.

Abstract field:

Pulsars I / **133**

Low power pulsed emission at the spin period of the WD in AR Scorpii?

Author: Quinton Kaplan[1]

Co-authors: H.J. van Heerden [1]; P.J. Meintjes [1]

[1] *University of the Free State*

Corresponding Authors: kaplanq.physics@gmail.com, meintjpj@ufs.ac.za, vanheerdenhj@ufs.ac.za

Previous studies indicate that AR Sco's surrounding region complicates the search for Gamma-ray emission from this source. The fact that AR Sco lies close to the Galactic plane and strong nearby VHE *Fermi* sources, make it difficult to constrain and quantify an upper-limit of the emission from AR Sco's location in the sky. In this study, a search for high energy gamma-ray emission was conducted to identify possible pulsed emission signatures within or above the noise level. A period analysis revealed low level but consistent emission at the spin period of the white dwarf (117 sec) over a period of 10 years. A control analysis also shows a decrease in signal strength at the spin period in regions further away from the coordinates centred on AR Sco, which may indicate the presence of low level pulsed Gamma-ray emission from AR Sco.

Abstract field:

Pulsars I / 134

The detection of pulsed emission at the spin period of the white dwarf in AE Aquarii in MeerKAT and Fermi-LAT data

Author: Spencer Tendai Madzime[1]

Co-authors: David A.H. Buckley [2]; H.J. van Heerden [1]; K.K. Singh [1]; P.J. Meintjes [1]; Rob Fender [3]

[1] *University of the Free State*

[2] *SAAO*

[3] *University of Oxford*

Corresponding Authors: tsmadzime@gmail.com, rob.fender@physics.ox.ac.uk, meintjpj@ufs.ac.za, kksastro@barc.gov.in, vanheerdenhj@ufs.ac.za, dibnob@saao.ac.za

Here we present the first report of pulsed emission at the spin period of the white dwarf in MeerKAT data, which is also the first report of pulsed emission at the spin period of the white dwarf in radio frequencies (L-band). Further support for the pulsar-like behaviour of AE Aqr is the detection of pulsed emission at the spin period of the white dwarf in AE Aqr in Fermi-LAT data. By isolating data sections that show emission above the 2 sigma level our periodic analysis reveal clear indications of pulsed emission at the spin period of the white dwarf and its associated first harmonic, which implies particle acceleration from both poles of the white dwarf. The emission detection in Fermi-LAT data mimic to a large extend the emission profiles detected in VHE gamma-ray observations made by two independent groups at Pothefstroom and Durham. Furthermore, Fermi-LAT data sections that were made simultaneous with optical flares show clear pulsed emission patterns at the spin period of the white dwarf similar to those reported in the late 1980's. The results presented here confirm AE Aqr as a transient gamma-ray source with clear indications of spectral hardening during sections enhanced gamma-ray activity. It is also shown that AE Aqr may be detectable with CTA and a strategy is presented how detectable pulsed emission may be extracted from the data.

Abstract field:

Pulsars I / 135

Pulsar high-energy emission models

Author: Alice Harding[1]

[1] *Los Alamos National Laboratory*

Corresponding Author: ahardingx@yahoo.com

Ground-based Air-Cherenkov telescopes have detected pulsations at energies above 50 GeV from a growing number of Fermi pulsars. These include the Crab, Vela, PSR B1706-44 and Geminga, with the first two having pulsed detections above 1 TeV. There appears to be VHE emission that is an extension of the Fermi spectra to high energies as well as additional higher-energy components that require a separate emission mechanism. A variety of models for emission from rotation-powered pulsars at gamma-ray energies invoke different combinations of mechanisms. They also assume different emission locations in the magnetosphere including outer gaps, extended slot gaps and the current sheet outside the light cylinder. I will review the most recent models for VHE emission in light of the present data and their predictions for observations by existing and future telescopes.

Abstract field:

Pulsars II & Other HE Sources & Outreach / 136

Astronomy for development: The namibian example

Author: Hannah Dalgleish[1]

Co-authors: Eli Kasai [2]; Garret Cotter [3]; Michael Backes [2]

[1] *University of Oxford*

[2] *University of Namibia*

[3] *University of Oxford, Department of Physics*

Corresponding Authors: mbackes@unam.na, hannah.dalgleish@physics.ox.ac.uk, garret.cotter@physics.ox.ac.uk, kunwijik@gmail.com

Astronomy for development is making great strides in Namibia. Forged by a collaboration between the Universities of Oxford and Namibia, together we are using astronomy as a means for capacity-building and to benefit Namibia socio-economically. Namibia is already recognised as a world leader in sustainable tourism; astronomy offers great potential to expand and diversify the market with minimal environmental impact. With access to some of the darkest and driest skies on the planet –a completely free resource –astrotourism is a relatively easy way for tour guides to complement their earnings. It also presents an opportunity to preserve the indigenous stories about the stars, which are already being lost. With H.E.S.S. already in place and the Africa Millimetre Telescope on the horizon, astronomy education provides further opportunities for sustainable socio-economic growth. Co-led by Radboud University and UNAM, we are developing a Social Impact Plan in the hope to inspire future generations of Namibian scientists and engineers.

Abstract field:

Pulsars II & Other HE Sources & Outreach / 137

Leptonic non-thermal emission from supernova remnants evolving in the circumstellar magnetic field

Author: Iurii Sushch[1]

Co-authors: Pavlo Plotko [2]; Robert Brose [3]; Samata Das [4]; martin pohl

[1] *North-West University*

[2] *DESY*

[3] *Dublin Institute for Advanced Studies*

[4] *DESY, 15738 Zeuthen, Germany*

Corresponding Authors: pohlmadq@gmail.com, robert.brose@desy.de, pavlo.plotko@desy.de, iurii.sushch@nwu.ac.za

The very-high-energy (VHE; E>100 GeV) gamma-ray emission observed from a number of Supernova rem- nants (SNRs) suggests that particles are accelerated to high energies at the shock of the remnants. However, it is extremely difficult to determine which particles are responsible for this emission as both protons (through hadronic interactions and subsequent pion decay) and electrons (through inverse Compton scatter- ing on ambient photon fields) can potentially generate gamma-ray photons. Recent detection of the abrupt cut-off at lower energies in the gamma-ray spectra of several SNRs with the Fermi-LAT has been interpreted as a characteristic pion-decay feature, indicating emission from cosmic-ray protons. However, a similar spectral feature may possibly arise also in the leptonic scenario as a result of spatial or temporal variability of the ambient medium. SNRs created in core-collapse explosions expand inside the stellar wind bubble blown up by a progenitor star. In the free wind, the circumstellar magnetic field decreases as $B \propto 1/r$ with the distance from the star with high values at the stellar surface, e.g. 1-10 G for red supergiants, which is followed by the transition to the shocked wind medium accompanied by abrupt changes in the magnetic field strength. An interaction with such a magnetic-field distribution might result in strong modifications of the electron and subsequently radiation spectrum. In certain phases of the SNR evolution the gamma-ray spectrum resulting from the inverse Compton scattering of accelerated electrons might strongly reassemble the one expected from hadronic interactions. Moreover, the evolution of the SNR inside the stellar wind bubble might leave substantial imprints on the temporal evolution of the non-thermal radiation as well as its observable morphology impacting the whole range of the electromagnetic spectrum from radio to VHE gamma-rays. In this work, we conduct a detailed study of the impact of the circumstellar magnetic field on the resulting non-thermal emission from SNRs through numerical simulations with the RATPaC code, designed for the time- and spatially dependent treatment of the particle acceleration at the shocks of SNRs.

Abstract field:

Pulsars II & Other HE Sources & Outreach / 138

Probing the nature of the young and energetic nebula Kes 75 via spatio-spectral modelling

Author: Christo Venter[1]

Co-authors: Anu Kundu [2]; Carlo van Rensburg [3]

[1] *North-West University Potchefstroom Campus*

[2] *NWU*

[3] *University of Namibia, Department of Physics and the Centre for Space Research, North-West University*

Corresponding Authors: christo.venter7@gmail.com, carlo.rensburg@gmail.com, anukundu02@yahoo.com

Being less than a thousand years old, Kes 75 (G29.7-0.3) represents one of the youngest composite supernova remnants in the Milky Way. It contains the nebula of PSR J1846-0258, a glitching young pulsar with a particularly high spin-down luminosity of 8e36 erg/s. This pulsar has furthermore manifested magnetar-like bursts in 2006. The H.E.S.S. Collaboration detected gamma-ray emission from HESS J1846-029, which is spatially coincident with Kes75. However, they were not able to distinguish between shell and nebular emission, nor could any pulsations be found in the very-high-energy domain. It has been speculated that the gamma-ray emission may be a mixture of leptonic and hadronic components. At X-ray energies, recent Chandra observations revealed a jet and torus nebular structure, as well as a relatively rapid expansion of this nebula over the past two decades along with a flux decrease of 10% in 7 years. We apply a multi-zone spatio-temporal leptonic model to the morphological and spectral data of Kes 75 over several epochs. We investigate different scenarios to explain the spatial and spectral data, including different forms of the nebular magnetic spatial profile and an increase in bulk plasma flow speed due to acceleration of particles following the magnetar-like outbursts. By simultaneously fitting the spectral and morphological data, we can hope to constrain model parameters more robustly, and this may aid in clarifying the nature of this enigmatic source.

Abstract field:

Pulsars II & Other HE Sources & Outreach / 139

Spectral and temporal analysis of GRB 210410A detected by Fermi-LAT

Author: Dimakatso Maheso[1]

[1] *University of Johannesburg*

Corresponding Author: d.j.maheso@gmail.com

Gamma-ray bursts (GRB's) are highly energetic impulses of γ−rays that are categorised into two major categories, namely long and short GRBs. Their distinction lies in their duration, the former lasts for more than 2 s whilst the latter lasts for less than 2 s. Their prompt emission has an energy range of keV to GeV energy band. On the 10th of April 2021, the \emph{Fermi} Large Area Telescope (LAT) was triggered at trigger time T0 = 639708801 MET by a GRB located at RA, DEC = 268.9, 42.5 with a redshift z < 3.6, this event was subsequently dubbed GRB 210410A. Its extended LAT data was analysed for 1000 s using fermitools from the \emph{Fermi} Science Support Center. The LAT and the Gamma Bursts Monitor (GBM) data were fitted using the RMFIT software. Various spectral fitting models were utilised and the best spectral was the combination of power law (PL) and GRB band function which are the most common models that best describes GRB data amongst others. The analysis was done over a time window of 48s. GRB 210410A is a long GRB lasting for T90 = 48.1280 s. Its GeV emission is barely observed and this suggests that the GRB is not energetic. This is also confirmed by observations of its rather low rest frame Band function peak energy of 419.886 keV. The fit parameters that give the best-fit spectral model suggest that GRB 210410A is a long soft GRB with peak photon energy Epeak = 220.644 keV and a PL photon index of 1.224. Moreover, GRB 210410A is associated with an isotropic energy of Eiso ≈ 9.249 ± 1.131 × 1051 keV and intrinsic peak energy of Eip = 419.886 ± 84.579 keV.The Eiso and Eip obtained satisfies the Amati relation. From attributes, it is reasonable to conclude that GRB 210410A originated from the collapse of a massive star to form a black hole or a magnetar.

Abstract field:

Pulsars II & Other HE Sources & Outreach / 140

Fast radio bursts - Current state of the field

Author: Zorawar Wadiasingh[1]

[1] *NASA GSFC*

Corresponding Author: zwadiasingh@gmail.com

I will briefly introduce fast radio bursts and highlight recent developments of the field from a theorist' s perspective, as well as exciting observational developments presented at FRB 2021. I will also discuss the low-twist magnetar model for FRBs.

Abstract field:

Pulsars II & Other HE Sources & Outreach / 141

Phase-resolved spectroscopy of millisecond pulsars in the Third Fermi-LAT pulsar catalogue

Author: Hend Yassin[1]

[1] *North-West University*

Corresponding Author: hendyassin.m@gmail.com

The number of detected gamma-ray millisecond pulsars (MSPs) has been increasing rapidly since the launch of the Fermi Large Area Telescope (LAT) in 2008. The Third Fermi LAT Pulsar Catalogue (3PC) will present high-quality data for about 250 gamma-ray pulsars based on 11 years of observation. Out of that number, more than 100 are MSPs. The stability of MSPs light curves makes them interesting targets to study. Phase- resolved spectroscopy was performed for only 25 MSPs by Renault-Tinacci et al. (2015). This talk will be an overview of PhD work that will extend the research done by Renault-Tinacci et al. We will perform phase-resolved spectroscopy of about 50 bright MSPs using the lates Fermi LAT data (3PC). Working on a larger sample will increase the chance of finding new trends across the pulsar population. Our work will enable us to study the characteristics of the gamma-ray spectra and model the MSPs emission mechanisms and sites in much more detail than was possible before.

Abstract field:

Pulsars II & Other HE Sources & Outreach / 142

Models for Sgr A* flares: from a general analytical to magnetic reconnection model

Author: Anton dmytriiev[1]

Co-authors: Andreas Zech [1]; Frederic Vincent [1]; Nicolas Aimar [1]

[1] *Observatoire de Paris*

Corresponding Authors: nicolas.aimar@obspm.fr, frederic.vincent@obspm.fr, anton.dmytriiev@obspm.fr, andreas.zech@obspm.fr

Despite the growing amount of observational data, the physical conditions in the vicinity of supermassive black holes (SMBH) are still poorly understood. Thanks to its proximity, Sgr A*, being the SMBH located in the center of our Galaxy, represents an ideal target to probe physical processes in the surroundings of massive compact objects, including details of accretion/advection flows, particle acceleration, general relativity (GR) effects, etc. In our work, we aim at investigating the physical origin of infrared (IR) flares of Sgr A*, observed by the GRAVITY instrument, and typically occurring on time-scales of around 30 minutes. We develop here a new model for Sgr A*varying emission, improving previous theoretical developments from the literature. In our model, we consider that the flaring emission arises from a plasmoid that gradually grows with time. High-energy particles are injected into the plasmoid via magnetic reconnection process producing a kappa particle distribution. Relativistic particles emit synchrotron radiation and cool. We numerically calculate the time evolution of the electron spectrum in the plasmoid and the associated broadband synchrotron emission spectrum, as well as the IR light curve at 2.2 micrometers, with a dedicated time-dependent radiative code. The effects of GR are taken into account using a separate numerical code performing backward ray-tracing* *following null geodesic and integrating the radiative transfer equation. We find that the simulated time-dependent IR flux behavior appears to be qualitatively similar to recent Sgr A* flare data obtained by GRAVITY.

Abstract field:

XRB III / 143

Farewell

Authors: Soebur Razzaque[1]; Markus Boettcher[2]

[1] *University of Johannesburg*

[2] *North-West University*

Corresponding Authors: srazzaque@uj.ac.za, markus.bottcher@nwu.ac.za