HONEST Workshops: Hot Topics in High Energy Astrophysics

Tuesday, 26 November 2024 - Thursday, 28 November 2024

Online

Book of Abstracts

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Pulsar striped wind emission: a multi-wavelength and population synthesis perspective

Since the launch of the Fermi/LAT telescope in June 2008, several hundred radio-loud gamma-ray pulsars have been detected. Observing simultaneously their radio and gamma-ray pulse profiles helps to constrain the geometry and radiation mechanisms within their magnetosphere and to localize the photon production sites. In this talk I show how time-aligned gamma-ray light curve fitting of young pulsars reveals their geometry, namely the magnetic axis and line-of-sight inclination angles. To this end, I assume a dipole force-free magnetosphere where radio photons emanate from high altitudes above the polar caps and gamma-rays originate from the pulsar striped wind, close to the light-cylinder. The striped wind emission model agrees well with the time-aligned single- or double-peaked gamma-ray pulses. Moreover the distinction between radio-loud, radio-quiet gamma-ray pulsars and radio-only pulsars is entirely related to the geometry of the associated emitting regions. The high-altitude polar cap model combined with the striped wind represents a minimalistic approach able to reproduce a wealth of gamma-ray pulse profiles for the whole young pulsar population.

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Modeling the observed spectra and light curves of synchro-curvature emission of pulsars

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Relativistic winds

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Pulsed TeV emission from pulsars in the sychrocurvature/inverse-Compton framework

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A number of pulsars have now been detected by ground-based Cherenkov telescopes, including PSR B1706-44, Geminga, Crab, and Vela. Vela exhibits a TeV component that is distinct from its GeV one, in contrast to the other detected pulsars. In the synchro-curvature radiation / inverse Compton (SCR-IC) framework, the same particles that are responsible for the GeV emission via SCR (with Lorentz factors of around 5e7) near the current sheet (CS) beyond the light cylinder radius, upscatter optical-near-infrared to X-ray photons to form a pulsed TeV component via inverse Compton (IC) scattering. The target photons may be synchrotron radiation (SR) from secondary pairs. I will review the assumptions of this model as well as its reasonably successful reproduction of available spectral and light curve data of some pulsars. I will also touch on recent work to develop and calibrate a visibility metric for TeV pulsars that may be used to focus future Cherenkov observations of plausible pulsar candidates.

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Numerical approaches for the study of the VHE emission of pulsar spectra

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Analytical approaches for the study of the VHE emission of pulsar spectra

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Electron-positron cascades in pulsars

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Welcome

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Introduction and motivation for the workshop

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The Crab Pulsar's Very High Energy emission: Insights from GeV to TeV Energies

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The Crab Pulsar is one of the few pulsars detected from GeV up to TeV energies. This talk will review recent gamma-ray observations of the pulsar performed with Imaging Atmospheric Cherenkov Telescopes (IACTs) and analyze their implications for current theoretical models that aim to explain the Very High Energy (VHE) emission from this source.

Experimental part: Review of the latest results / **13**

Geminga: the first discovered VHE middle-aged pulsar

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The detection of Very-High-Energy emission from pulsars is one of the milestone results in the field. Among the few sources know to date, Geminga is the only one with an age of a few hundred kilo-years. From its discovery to the recent observations with Cherenkov Telescopes, Geminga never ceases to surprise us.

Experimental part: Review of the latest results / **14**

Vela: the highest pulsed energies ever detected

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Other TeV pulsars detected by HESS

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Lessons learnt from Fermi-LAT pulsars

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The many facets of transitional millisecond pulsars: can accretion- and rotation-powered states coexist?

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The increasingly thrilling investigation of millisecond pulsars has recently overturned a long-standing paradigm. Traditionally, these pulsars were thought to shine as rotation-powered radio and/or gamma-ray sources only after a Gyr-long, X-ray bright phase fueled by the accretion of matter from a low-mass donor star. However, transitional millisecond pulsars challenge this classification by swinging between radio and X-ray states. All transitional pulsars have also been caught in an intermediate state, featuring an X-ray luminosity lower than that in the standard accreting phase and gamma-ray emissions up to ten times greater than those recorded during the rotation state. In this context, the recent detection of coherent optical and ultraviolet pulsations from the archetype of transitional millisecond pulsars in this intermediate state hints at the persistence of a rotation-powered magnetospheric process even in the presence of an accretion disk. I will review recent multi-wavelength campaigns on confirmed and candidate transitional millisecond pulsars to test the possible outcomes of the interaction between the pulsar wind of particles and radiation and matter in an accretion disk.

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Review and prospects of pulsar models

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Phenomenology and implications for current and next generation instruments

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Timing the future: pulsar ephemerides

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The field of high-energy pulsars is experiencing a fast development driven by the observations of Fermi-LAT, the current IACT experiments (MAGIC, VERITAS, H.E.S.S.), and CTAO. The detailed study of the emission properties and the proper accumulation of events require more and more advanced techniques to precisely determine the rotation parameters of pulsars and their evolution (rotational ephemerides). In this talk I will briefly discuss the methods currently in use to obtain a rotational solution, and review the prospects for the future.

Prospects / **21**

Prospects using the Cherenkov Telescope Array Observatory

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Prospects for the detection of very-high-energy pulsars with LHAASO and SWGO

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Pulsations from the Crab pulsar and the Vela pulsar have been detected at high energies by IACT. Potential candidates for detection with EAS experiments at very-high-energy (VHE) ranges have been identified. Our findings indicate that LHAASO and SWGO could detect these signal within a few years which will enhance understanding of VHE pulsar emissions.

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Summary/review of the workshop

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The Pulsar Tree: Visualizing the Pulsar Population using Graph Theory Techniques. Applications from Binary Pulsars to Fast Radio Bursts

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This talk will present an innovative application of graph theory using a type of graph known as the Minimum Spanning Tree (MST). This technique provides a novel tool to visualize and classify the population of pulsars by representing them together with their properties as nodes and edges through the MST, offering relationships and groupings that go beyond the traditional P-Pdot diagram. The application of this method to the entire population of pulsars cataloged in the ATNF reveals behaviors and connections that are not easy to discern with traditional methods.

The MST approach to the population of millisecond pulsars (MSPs) will be demonstrated, highlighting features and identifying possible key candidates for black widows, redbacks, and transitional millisecond pulsars (tMSPs). This could provide new insights into their behaviors and classifications.

In addition, it will be shown how the MST can act as an unsupervised method of classification for fast radio bursts (FRBs), distinguishing between repeaters and non-repeaters. The analysis reveals parts of the MST with a high density of repeaters, suggesting possible repeater candidates and offering a new perspective on the classification of FRBs.
This innovative visualization tool helps to identify targets for future observations and can contribute to the scientific understanding of FRBs by highlighting the importance of certain variables over others concerning what best describes the repetitive character of a source.

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Identification and characterisation of the gamma-ray counterpart of the transitional pulsar candidate CXOU J110926.4–650224

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Transitional millisecond pulsars (tMSPs) represent a crucial link between binary pulsars in their rotation-powered and accretion-powered states. During their active X-ray state, the tMSPs are the only low-mass X-ray binary systems that are detected up to GeV energies using the *Fermi Large Area Telescope* (LAT). CXOU J110926.4-650224 is a newly discovered tMSP candidate in an active X-ray state located close to a faint gamma-ray source, listed in the latest release of the *Fermi/LAT* point-source catalogue as 4FGL J1110.3-6501.
Confirming the association between CXOU J110926.4–650224 and the *Fermi* source is a key step towards validating its classification as a tMSP.

In this study, we present an analysis of *Fermi/LAT* data collected from August 2008 to June 2023, for a total of about 15 years, aiming to achieve a more accurate localisation of the gamma-ray source and characterise its spectral properties. By thoroughly reconstructing the gamma-ray background around the source, we obtain a new localisation that matches the position of the X-ray source at the 95% confidence level, with a Test Statistic value ~ 40. This establishes a possible spatial association between the gamma-ray source and CXOU J110926.4–650224.

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A quantitative analysis of the similarity of gamma-ray pulsar light curves

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In this talk, I will present a method to measure the morphological similarity of pulsar light curves and apply it to those recorded in the Third Fermi Pulsar Catalog. The method produces a quantitative determination for the similiarity of time series, something that is usually only qualitatively discussed via light curve features (such as the number of peaks, their relative height and separation, the peak widths, etc.). Using such quantitative determination, it is possible to cluster the population into groups of pulsars with similar light curves and to explore the connection of these groups with respect to other pulsar features. The methodology is of general nature, and can be applied to light curves at different frequencies beyond gamma-rays, e.g., in radio or X-rays, to bursts, and also used with different aims, e.g., to analyze the similarity of mode changing between confirmed transitional pulsars and candidates.

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Pulsar wind nebulae meeting the circumstellar medium of their progenitors

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A significative fraction of high-mass stars sail away through the interstellar medium of the galaxies. Once they evolved and died via a core-collapse supernova, a magnetized, rotating neutron star (a pulsar) is usually their leftover. The immediate surroundings of the pulsar is the pulsar wind, which forms a nebula whose morphology is shaped by the supernova ejecta, channeled into the circumstellar medium of the progenitor star in the pre-supernova time. Consequently, irregular pulsar wind nebulae display a large variety of radio appearances, screened by their interacting supernova blast wave and/or harboring asymmetric up–down emission. Here, we present a series of 2.5-dimensional (2 dimensions for the scalar quantities plus a toroidal component for the vectors) non-relativistic magneto-hydrodynamical simulations exploring the evolution of the pulsar wind nebulae (PWNe) generated by a red supergiant and a Wolf-Rayet massive supernova progenitors, moving with Mach

number M = 1 and M = 2 into the warm phase of the galactic plane. In such a simplified approach, the progenitor's direction of motion, the local ambient medium magnetic field, the progenitor and pulsar axis of rotation, are all aligned, which restrict our study to peculiar pulsar wind nebula of high equatorial energy flux. We found that the reverberation of the termination shock of the pulsar wind nebulae, when sufficiently embedded into its dead stellar surroundings and interacting with the supernova ejecta, is asymmetric and differs greatly as a function of the past circumstellar evolution of its progenitor, which reflects into their projected radio synchrotron emission. This mechanism is particularly at work in the context of remnants involving slowly-moving and/or very massive stars. We find that the mixing of material in plerionic core-collapse supernova remnants is strongly affected by the asymmetric reverberation in their pulsar wind nebulae.

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Overview of the VERITAS VHE and optical pulsar programs

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With very few pulsars detected in both optical and VHE - the edges of the high-energy pulsar spectrum - it remains difficult to infer pulsar emission mechanisms from observational data. VERITAS observation programs aim to populate these discovery spaces by searching for multi-TeV components from Northern Hemisphere pulsars and optical pulsations from energetic X-ray and Fermi-LAT pulsars with a recently implemented rapid optical backend. In this talk, I will summarize the VERITAS optical and VHE programs, including source selection, analysis, and future prospects for pulsar discovery with continued VERITAS upgrades.

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The Pulsar Tree: Visualizing the Pulsar Population using Graph Theory Techniques. Applications from Binary Pulsars to Fast Radio Bursts

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Identification and characterisation of the gamma-ray counterpart of the transitional pulsar candidate CXOU J110926.4–650224

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A quantitative analysis of the similarity of gamma-ray pulsar light curves

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Overview of the VERITAS VHE and optical pulsar programs

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