

Project: Disentangling the emission mechanisms of blazars

Level of the project:

Master

Supervisors :

Dr Encarni Romero Colmenero (erc@salt.ac.za) & Prof. Brian van Soelen (vansoelenb@ufs.ac.za)

Host institution:

University of the Free State

Introduction

The extra-galactic gamma-ray sky is dominated by blazars, a subset of jet-producing, radio-loud Active Galactic Nuclei (AGN). This is because, for blazars, our line of sight lies very close to the direction of propagation of the relativistic jet, and the non-thermal emission produced in the jet is highly Doppler-boosted, greatly increasing the apparent luminosity of the observed emission. Blazars can exhibit strong flares and rapid variability over multiple wavelength regimes, the exact mechanisms of which are not yet fully understood. The spectral energy distributions of blazars show a double bump structure from the non-thermal emission, with the lower energy component extending from radio up to X-ray energies, and a higher energy component from X-ray up to gamma-ray energies. The lower energy component is produced via leptonic synchrotron radiation, while both leptonic and hadronic processes have been proposed for the higher energy component. However, it is difficult to differentiate between the two processes since it is possible to fit the observed SED using either model with different parameters (Böttcher et al. 2013).

One of the difficulties in modelling these sources is placing a constraint on the non-thermal electron population. This is because at optical wavelengths, the observed emission is a superposition of the non-thermal emission originating from the jet and the thermal emission arising from the accretion disc, broad and narrow line regions, the dust torus, etc., which forms around the supermassive black hole. Measuring the brightness alone makes it very difficult to disentangle the different components. However, measuring the polarization can be used as a powerful diagnostic tool in blazar studies, as it provides a way to disentangle the unpolarized thermal and polarized non-thermal emission at optical wavelengths. This provides much better constraints on the jet's magnetic field at the emission region. To this end, over the last few years, we have been undertaking spectropolarimetry of known gamma-ray bright blazars, using SALT. Results from SALT have been used to simultaneously model the emission and polarization of two blazars, 4C +01.02 (Schutte et al. 2022) and PKS 1510-089 (H.E.S.S. Collaboration 2023). Additionally, the long-term polarimetric behaviour of some sources, as well as the behaviour between active (flaring) and quiescent states of other blazars have been investigated (Barnard et al. 2024). Beyond this, a dedicated systematic spectropolarimetry survey using SALT, of $\sim 1/6$ of all known TeV blazars (SPOTS: Spectro-Polarimetry Of TeV Sources) is currently being undertaken (Barnard et al. 2026).

Project aim:

The current SPOTS monitoring programme has built up approximately two and a half years of monitoring data of known TeV blazars, including both optical photometry and spectropolarimetry. During this period, the majority of these sources have been in a lower/quiescent state, with no major gamma-ray outbursts. This provides a large sample for comparing the polarization state during periods of low gamma-ray activity to that during high-activity states, as well as investigating the long-term behaviour of these sources by statistically comparing the SPOTS sample to samples from the Steward Observatory's *Ground-based Observational Support of the Fermi Gamma-ray Space Telescope* (<https://james.as.arizona.edu/~psmith/Fermi/>) and the RoboPol programme (Pavlidou et al. 2014; <https://robo.pol.physics.uoc.gr/>). The aim is to determine the degree to which the measured level of

polarization and ordering of the jet's magnetic field can be used as an indicator of jet activity and the likelihood of a source being in a gamma-ray-loud state.

As part of the project, the candidate will also need to undertake analysis of the SALT data, including the ongoing development of the data reduction pipeline to improve data extraction and analysis for lower signal-to-noise observations.

Requirements:

The candidate should be familiar with optical spectroscopy, the analysis of optical data and FITS files, and Python programming, and should have familiarity with the field of active galactic nuclei, particularly blazars.

References

Barnard, **van Soelen**, et al 2024 MNRAS 532 1991
Barnard, **van Soelen** et al 2026 MNRAS, 549, stag859
Böttcher et al. 2013 ApJ, 768 54
H.E.S.S. Collaboration 2023 ApJ Letter 952 L38
Pavlidou et al. 2014 MNRAS 442, 1693
Schutte et al. 2022 ApJ 925 139