Project: Modelling polarization from RMHD simulations

Level of the project: Master

Primary supervisor:
Dr. Izak van der Westhuizen
vanderwesthuizenip@ufs.ac.za

Co-supervisor:
Prof Brian van Soelen
vansoelenb@ufs.ac.za

Department of Physics
University of the Free State

Project description

The extra-galactic gamma-ray sky is dominated by blazars, a subset of the jet-producing, radio-loud 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. The spectral energy distribution of blazars shows a double bump structure from the non-thermal emission, with a lower energy component extending from radio up to X-rays 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 (Böttcher et al. 2013). Blazars can also exhibit strong flares and rapid variability over multiple wavelength regimes. The exact physical changes that produce this variability are not yet fully understood.

In order to better constrain the properties of the emitting regions in blazars, a dedicated systematic spectropolarimetry survey using SALT is currently being undertaken (SPOTS: SpectroPolarimetry Of TeV Sources). By considering the polarization, it is possible to disentangle the contributions of unpolarized thermal and polarized non-thermal emission at optical wavelengths. This can also provide much better constraints on the electron population and the jet's magnetic field at the emission region (see, e.g. Schutte et al. 2022). At optical wavelengths, spectropolarimetry of blazars has shown that changes in the flux of these sources can be accompanied by changes in both the polarization fraction and angle (Barnard et al. 2024).

In this project, we aim to simulate the relativistic jets using the PLUTO hydrodynamic code (https://plutocode.ph.unito.it/) in order to reproduce some of the observed characteristics of blazars. We have developed post-processing methods to calculate the non-thermal emission from the PLUTO simulations (e.g. van der Westhuizen 2019) and are currently expanding using the PLUTO Lagrangian particle module (Vaidya et al., 2018). This allows us to incorporate a dynamic non-thermal electron distribution along with RHMD simulations to model the resulting synchrotron emission. We are currently updating the PLUTO module to also correctly calculate the level of the expected polarization. The project will consist of developing RHMD simulations of AGN jets and creating synthetic light curves of the flux and polarization produced by the non-thermal emission. The results will be compared to the observation from our dedicated systematic spectropolarimetry survey (SPOTS: SpectroPolarimetry Of TeV Sources) in order to obtain a better understanding of the physical properties of the emission region.

References

Barnard, van Soelen et al 2024 MNRAS 532 1991
Böttcher et al. 2013 ApJ, 768 54
Fichet de Clairfontaine et al. 2021 A&A 647 A77
Schutte et al. 2022 ApJ 925 139
Vaidya et al. 2018 ApJ 865 144
van der Westhuizen, van Soelen et al. 2019 MNRAS 485 4658