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Modelling Variability in the Emission and Polarization of Sub-Parsec Scale AGN Jets with 3D RMHD PLUTO Simulations

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Radio-loud active galactic nuclei (RLAGN) emit radiation across most of the electromagnetic spectrum. The lower-energy component (Radio - Soft X-rays) is typically dominated by synchrotron emission from non-thermal electrons in a relativistic jet. RLAGN are known to be highly variable on both short (intra-day) and long (months to years) timescales. Most of the variability observed in the optical and higher-energy regimes has been associated with sub-parsec to parsec scale emission regions located within the jet. In this study, we investigate the link between observations and the kinematics of the sub-parsec-scale relativistic jet using 3D relativistic magnetohydrodynamic (RMHD) simulations. The simulations employ a two-component jet model, consisting of a fast spine ($\Gamma = 10$) and a slower sheath ($\Gamma = 3$). The jet model features an initial helical magnetic field with a magnitude of 50 mG in the spine and 5 mG in the sheath. In order to simulate variability in the jet, a density perturbation is introduced at the jet inlet and allowed to evolve with time. The simulations are carried out using a modified version of the PLUTO code. To model the synchrotron emission, Lagrangian tracer particles, representing the non-thermal electron spectrum, are injected into the simulation. The spectral energy distribution of these particles are evolved over time to include effects from diffusive shock acceleration and radiative cooling. This is used to calculate the I, Q, and U Stokes parameters, for arbitrary lines of sight, accounting for relativistic transformations and light travel time. The Stokes parameters are used to reproduce simulated light curves of the flux, polarization degree and polarization angle.

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