Modeling Blazar Jets: Bridging Theory and Observations

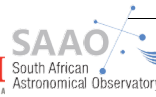*Invited Talk //*

Active Galactic Nuclei (AGNs)

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Blazars, a class of radio-loud Active Galactic Nuclei with jets closely aligned to the observer's line of sight, offer exceptional insights into the extreme physics of relativistic outflows. Despite extensive studies, fundamental questions persist regarding the origin of gamma-ray emission from these sources and the nature of blazar emission variability, from short rapid flares to long-term high states. To unravel the complex physical processes within blazar jets, detailed physical modeling of various observational data becomes essential. Importantly, spectral and timing properties of variable blazar emission across multiple wavebands carry invaluable information about the underlying acceleration, cooling, and emission mechanisms governing the blazar flaring behavior. In addition to the electromagnetic spectrum, the multi-band polarization data offers crucial insights into the intricate structure of blazar jets and their emitting regions, as well as the magnetic field geometry. Furthermore, observations of neutrinos from blazars hold the potential to unravel the particle acceleration and emission scenarios underlying various blazar phenomena. This talk presents a comprehensive overview of recent advancements in blazar modeling, emphasizing the latest developments in different emission and polarization models. Additionally, we delve into applications of these models to various multi-wavelength and multi-messenger datasets, exploring both previous efforts and future possibilities. We also highlight the significance of important predictions made by different models and their implications. Furthermore, we explore the exciting prospects offered by new and upcoming instruments, including the Imaging X-ray Polarimetry Explorer (IXPE) and the Cherenkov Telescope Array (CTA).

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