Contribution ID: **1169** Type: **Poster**

# A lepto-hadronic multi-zone framework for studying neutrino emissions from AGN jets

Active Galactic Nuclei (AGN) and their relativistic jets that emit radiation covering almost the entire electromagnetic spectrum have been few of the most fascinating subjects in astronomy for decades, yet the composition of these relativistic jets is still not clearly known. The origin of the high energy peak in the Spectral Energy Distribution (SED) of blazars has been an open question in astronomy. Different models for the jet composition have been proposed in order to explain the high energy peak observed in the blazar SEDs, starting from the leptonic models, hadronic models to the lepto-hadronic model which combines both. The particles inside an AGN jet can be accelerated to high energies via different mechanisms, including shocks, stochastic turbulent acceleration and magnetic reconnection which can generate distinct multi-messenger observational signatures due to the rapid changes in magnetic field topology in the emission zone. These signatures can be used as pivotal diagnostic tools to study different jet composition models.

With the detection of high energy neutrinos with a significance of around 3.5 sigma coming from the direction of blazar TXS 0506+056 by IceCube Neutrino Observatory , it has reinvigorated the support and curiosity for the hadronic and lepto-hadronic models for AGN jets as unlike the leptonic scenarios, these models produce neutrino emission. While there exists numerical codes modelling single-zone lepto-hadronic scenarios in AGN jets, the availability of comprehensive multi-zone codes is limited. To tackle this notable gap in the field of lepto-hadronic modeling, particularly in the context of AGN jets and its observed multi-wavelength and neutrino emissions, we have developed a numerical multi-zone framework of the lepto-hadronic model for AGN jets by building upon the foundation of an existing single zone code called Katu. In this presentation, I shall describe our novel approach on integrating the multi-zone framework with the fluid dynamics code called PLUTO used for modeling the relativistic jet. This framework serves as a bridge between jet dynamics and the micro-physics within AGN jets, aiming to create synergy between relativistic magneto-hydrodynamic simulations and multi-messenger observations. We have applied this multi-zone framework to model the multi-wavelength and neutrino emissions arising from the jet which can provide valuable insights on how the complex interplay between the jet dynamics, particle acceleration mechanisms and jet composition effects the subsequent multi-messenger emissions from the jet.

## Collaboration(s)

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**Session Classification:** PO-Remote

**Track Classification:** Neutrino Astronomy & Physics