Multi-messenger Lighthouses of the Universe: The Many Extremes of Active Galactic Nuclei

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Abstract:

Active galactic nuclei (AGN) make the most significant contribution to the overall energy balance in the Universe in all electromagnetic bands not dominated by the cosmic microwave background. A good understanding of physical processes and phenomena driving this contribution is paramount for addressing the key challenges in astrophysics and cosmology, including accretion onto black holes, electromagnetic fields, and shock waves in relativistic plasma. These factors can be best studied with comprehensive programs combining dedicated multi-band and multi-messenger measurements with ultra-high angular resolution imaging in the radio regime enabled by the technique of very long baseline interferometry (VLBI).

In this talk, I will present recent results from several studies that probe key aspects of AGN physics. Observations with space VLBI have revealed extraordinarily high brightness temperatures in blazars, pushing the known limits of energy dissipation in relativistic plasma. Growing observational evidence for neutrino production in blazar-type AGN is shedding new light on proton acceleration mechanisms, whether near supermassive black holes or within shocks embedded in relativistic jets. The recent detection of an extreme 220 PeV neutrino by the European KM3NeT telescope presents further challenges and opportunities for understanding these processes.

Looking ahead to the emerging era of multi-messenger astrophysics, I will conclude by introducing the MuSES ERC project, which aims to unravel the mechanisms of particle acceleration and neutrino production in AGN.