A multi-wavelength study of AGN in the K-band celestial reference frame

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Background: Active Galactic Nuclei (AGN), stand out as the most prominent sources of electromagnetic radiation in the Universe. These sources not only command dominance over the extragalactic gamma-ray sky but also exhibit extraordinary behaviors characterized by rapid and often unpredictable high-amplitude flux variability across a broad spectrum of wavelengths, spanning from radio waves to gamma rays (refer to Figure 1). This captivating phenomenon is believed to originate from an exceptionally compact central region, typically hosting a supermassive black hole (SMBH). For a special group of AGN called blazars, this epicenter, propels substantial amounts of matter and energy through tightly collimated relativistic jets, closely aligned with our line of sight. This unique orientation results in relativistic boosting effects, increasing the source luminosity to levels that overshadow entire host galaxies, presenting them as brilliant, compact point sources.
Despite their spectacular prominence, the intricate physical processes governing their captivating behavior remain a profound mystery, rendering AGN as fascinating yet challenging subjects for astronomical research.

As of October 2023, the K-band Celestial Reference Frame (CRF) catalog has amassed a comprehensive dataset comprising high-precision positions of 1326 AGN. These positions are meticulously derived from ongoing Very Long Baseline Interferometry (VLBI) sessions employing the Very Long Baseline Array (VLBA) in the United States, the Korean VLBI Network (KVN) in Korea, the HartRAO antenna in South Africa, and the Mopra, Hobart, and Yebes antennas in Australia and Spain, respectively.
The K-band CRF project has published high-resolution very long baseline interferometry (VLBI) images of 731 AGN, and currently work is underway to image all VLBA sessions conducted between July 2015 and September 2023. This ambitious undertaking has resulted in a vast database comprising over 16000 images.

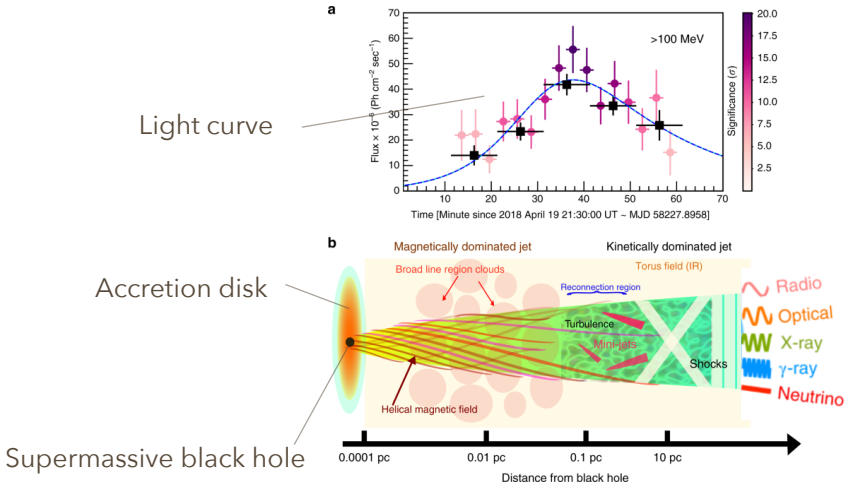

Figure 1

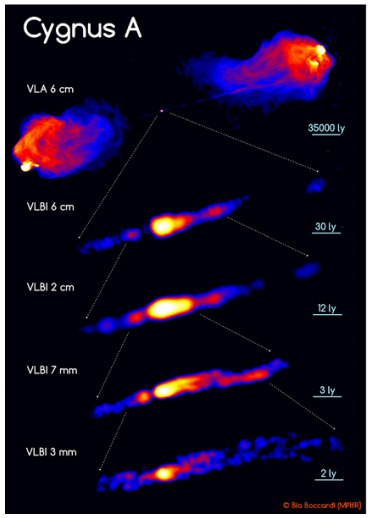

Figure 2

VLBI images offer essential spatial information (refer to Figure 2), complemented by single-dish observations that yield light curves. These curves unveil the temporal evolution of source activity, granting valuable insights into emission location and source structure at both mas and sub-mas scales.

The project: To unravel the mysteries of AGN behavior, we must focus our efforts on the multi-wavelength/multi-messenger space, where distinct emission regions offer unique perspectives into AGN activity, enabling us to construct a comprehensive view of these sources and their temporal evolution. In this project, we aim to leverage the rich dataset from the high energy Fermi-LAT Gamma-ray project, K-band CRF program together with single-dish HartRAO observations to study the temporal evolution of AGN sources over time at multiple spatial scales. We seek to highlight and uncover the possible correlated relationships that may exist in these sources by examining the time delays between different wavelengths. Combining data from gamma-ray to radio observations enables us to get a better understanding of these sources, allowing us to study both the large-scale features and the intricate details within the sources. This multi-scale approach is essential for advancing our understanding of the physical processes driving the observed variability and morphology in these objects. The student will learn how to gather data from different resources, reduce single-dish radio data, analyse multi-wavelength data, and produce correlation plots to detail this phenomenon.

Required skills / knowledge: Programming skills, preferably in Python, for data manipulation and analysis.