Comprehensive Study of Blazars: Insights from Multi-Wavelength Data

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Abstract

Blazars studies are pivotal in advancing our understanding of high-energy astrophysical phenomena. We extend the components used in NMF (Non-negative Matrix Factorization) reconstruction in the optical range to the infrared (IR) and ultraviolet (UV) domains. This approach provides valuable insights for studying the physical processes occurring in these extreme and dynamic environments. We will perform a multi-wavelength (MW) analysis, integrating data across the electromagnetic spectrum. By combining infrared, optical, ultraviolet, radio, and X-ray observations, we aim to uncover the physical mechanisms driving their emission, their role in galaxy evolution. We will model the emission of blazars through the use of applications designed for modeling the spectral distribution of energy (SED) in AGN.

Introduction

Blazars, a subclass of active galactic nuclei (AGN), represent some of the most energetic and luminous objects in the universe. They exhibit a broad range of emissions across the electromagnetic spectrum, primarily driven by relativistic jets powered by supermassive black holes. Recent advancements in observational capabilities across multiple wavelengths have enabled a more detailed exploration of these objects. Moreover, the diversity within the blazar population including flat-spectrum radio quasars and BL Lac objects highlights the importance of analyzing these objects in a multi-dimensional parameter space to uncover distinct physical characteristics and evolutionary trends.

Data Sources and Methodology

We use a sample of 26 balazar which has been used in (Otero-Santos et al. 2022) which contains 12 sources classified as FSRQs, 11 sources are BL Lac, and 3 objects whose optical spectra are dominated by the stellar emission from the host galaxy (galaxy-dominated blazars).

.Optical photometric data in the R and V bands were taken from the Steward Observatory program. We utilized the NASA/IPAC Infrared Science Archive (IRSA) to retrieve all photometric measurements for AllWISE and NEOWISE-R data in four MIR bands centered at 3.4 μm (W1), 4.6 μm(W2), 12 μm (W3), and 22 μm (W4). We obtained data from Swift satellite two instruments; The X-Ray Telescope (XRT), observing between 0.3 and 10 keV, and the Ultraviolet-Optical Telescope (UVOT), between 170 and 600 nm. The UVOT telescope can acquire data in optical (v, b, u) and UV (w1, m2, w2) bands.

Table 1. Spearman correlation for fraction variability for γ-Fermi vs. MIR-NEOWISE, and UV-UVOT for all data, BL LAC, and FSRQ.

Wavelength	All		BLLac		FSRQ	
	ρ	p-value	ρ	p-value	ρ	p-value
NEOWISE_W2	0.3446	0.0916	0.0839	0.7954	-0.3273	0.3259
UVOT_m2	0.1177	0.5753	0.2168	0.4986	-0.5455	0.0827

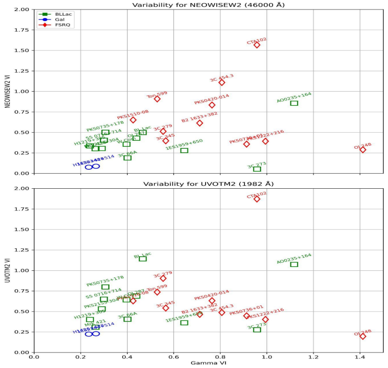

Figure 1: γ-Fermi fractional variability vs. MIR and UV fractional variability of the sample. Blue circles represent galaxy-dominated blazars red triangles represent the FSQR objects and green circle represent the BL Lac object.

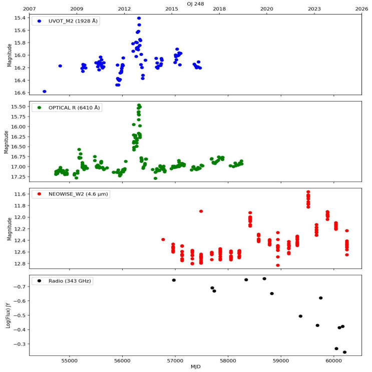

Figure 2: Light curves of OJ 248 at different wavelengths. From top to bottom: the Swift-UVOT M2 band (blue points); the R-band optical magnitudes (green points); the MIR-NEOWISE W1 (red points);the 343 GHz (black points) flux densities (Jy).

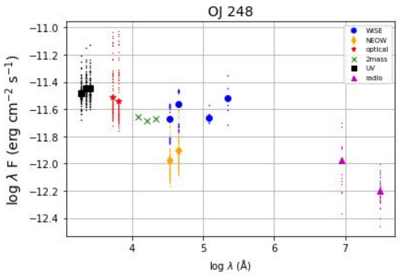

Figure 3: SED of OJ 248. Data from UVOT-SWIFT (black squares), Optical (red stars), 2mass (green x), MIR NEoWISE(orange diamonds), MIR_WISE(blue circles), and ALMA radio(purple triangles).

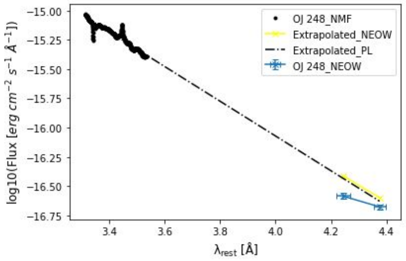

Figure 4: The reconstructed spectrum of OJ 248. The extrapolated PL for the of the reconstructed spectrum is represent in dash-dot black line. The MIR-NEOWISE data is represented in blue and the extrapolated Pl from the optical range to the MIR range is represented in yellow.

Analysis and Expected Outcomes

We report the preliminary results of the 26 blazars sample and OJ 248 (FSRQ).

GLobal Properties: We investigated the mid-infrared (MIR) and ultraviolet (UV) properties of the 26 blazars in our sample. For each source, we computed the fractional variability in all MIR and UV bands.

We performed comparison with Fractional Variability in the Gamma-Ray Band; in the MIR, the variability appears to correlate more strongly with the gamma-ray band compared to the UV, where this correlation is weaker. This trend is illustrated in figure 1.

Spearman Correlation Test further support our observation that MIR variability is more closely related to gamma-ray variability than UV variability, see Table 1 for more details. This highlights the connection between these energy regimes.

Individual source properties: We began a detailed investigation of a few sources, including OJ 248, due to its flare activity and a clear increase in magnitude after the flare event in the optical and UV bands (Figure 2). Although we lack sufficient data to identify the flare period in the MIR or radio bands, we hypothesize that sufficient observations near the flare event would reveal a corresponding brightness increase in these bands.

In Figure 3, we present the constructed broadband SED of OJ 248, which will be modeled using AGNfitter (Calistro-Rivera et al. 2016, Martínez-Ramírez et al. 2024). To achieve accurate modeling, we aim to construct broadband SEDs with data collected as close in time as possible.

Our primary objective is to determine whether the decomposition performed in the optical range can be extrapolated to the IR and UV domains. However, obtaining simultaneous data across these wavelength ranges remains a challenge. One of our trials is shown in Figure 4, where the optical emission of OJ 248, decomposed into two components (Otero-Santos et al. 2022), was fitted with power-law models and extrapolated to the MIR data for this object.

This study is still in progress, and further investigations are required. We will focus on Expanding the dataset to include simultaneous observations across all wavelengths. Perform SED modeling for additional sources in the sample.

Moreover, Investigating the connection between variability across the different wavelength bands.

References

Abdo A. A. et al., 2010a, ApJ, 716, 30
Otero-Santos, J., Acosta-Pulido, J. A., Becerra González, J., et al. 2022, MNRAS, 511, 5611
Martínez-Ramírez, L. N., Calistro Rivera, G., Lusso, E., et al. 2024, A&A, 688, A46

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