PAiP-2025 Conference

Constraining Jet Dynamics of PKS 2155-304 Through Time-Dependent SED Analysis

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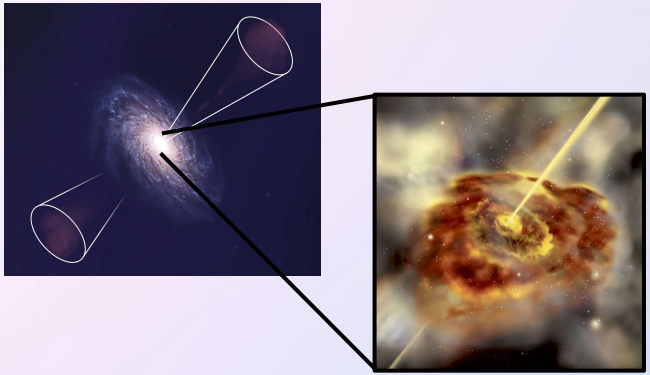
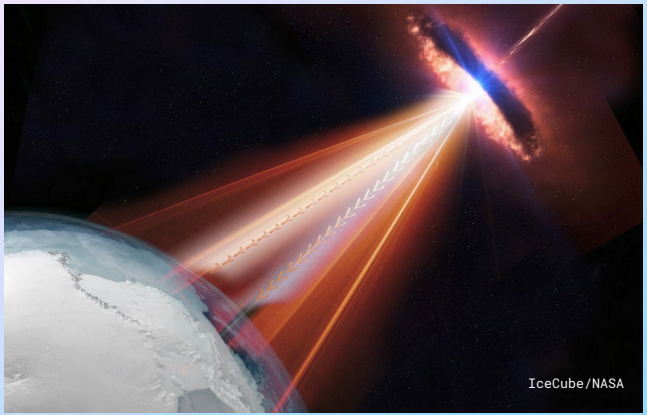
Blazars

Blazars are active galactic nuclei (AGN) with relativistic jets closely aligned to the observer's line of sight.



Active Galactic Nuclei (AGNs) are extremely bright central regions of galaxies, powered by SMBHs.

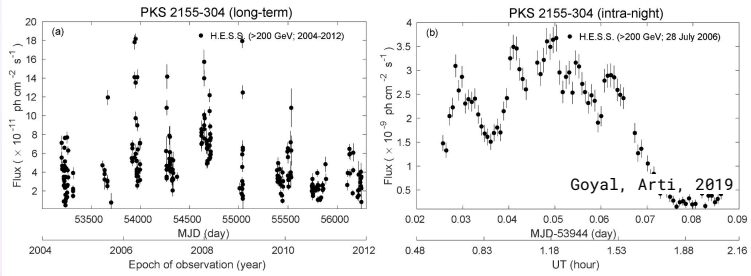
- The jet is oriented towards the observer and shows superluminal motion due to relativistic effects.
- Blazars are classified as radio-loud AGNs, exhibiting strong radio emissions.
- Blazars display high levels of optical polarization.
- Blazars can undergo intense flaring events that dramatically increase their luminosity over short time scales.
- Blazars are considered potential sources of high-energy cosmic rays and neutrinos.
- Blazars are classified into flat-spectrum radio quasars (FSRQs) and BL Lacertae objects (BLLs), based on their emission line properties.



Blazar: Variability

Blazars are known for their variability over diverse time scales, which is one of their defining properties.

In their multiwavelength observations, some blazars also show periodic and quasi-periodic flux variability.

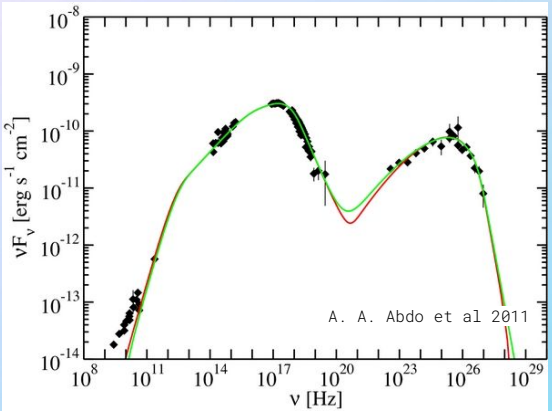


Blazar: Broadband SED

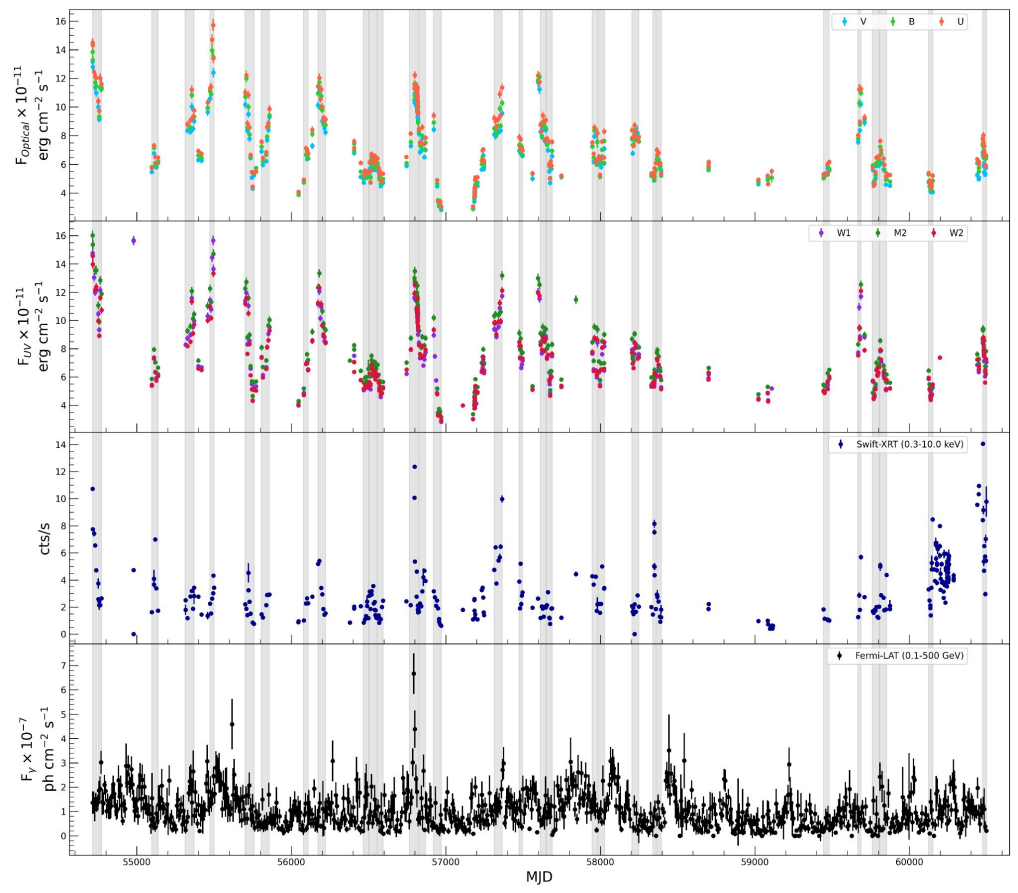
Low-Frequency Hump: Interpreted as synchrotron emission produced by relativistic electrons within the jet.

High-Frequency Hump: Two primary models proposed: leptonic and hadronic.

- Leptonic Model: The high-energy part of the blazar SED is produced by inverse Compton (IC) scattering. Which can occur through two processes: Synchrotron-Self Compton (SSC) and External Compton (EC).
- Hadronic Model: The high-energy radiation of a blazar is attributed to hadronic processes involving protons and other heavy particles in the jet.



PKS 2155-304



PKS 2155-304 is a well-studied blazar, specifically classified as a high-frequency peaked BL Lacertae object (HBL).

Discovered in the radio frequencies as part of the Parkes survey, located at z = 0.116.

Analyzed 16 years of data from 2008 to 2024, covering 30 epochs characterized by various activity states (quiescent, flaring, and intermediate).

Data:

- **Fermi LAT (100 MeV - 300 GeV)**
- **Swift XRT (0.3 - 10 keV)**
- **Swift UVOT (v, b, u, w1, m2, w2)**

PKS 2155-304: SED Analysis

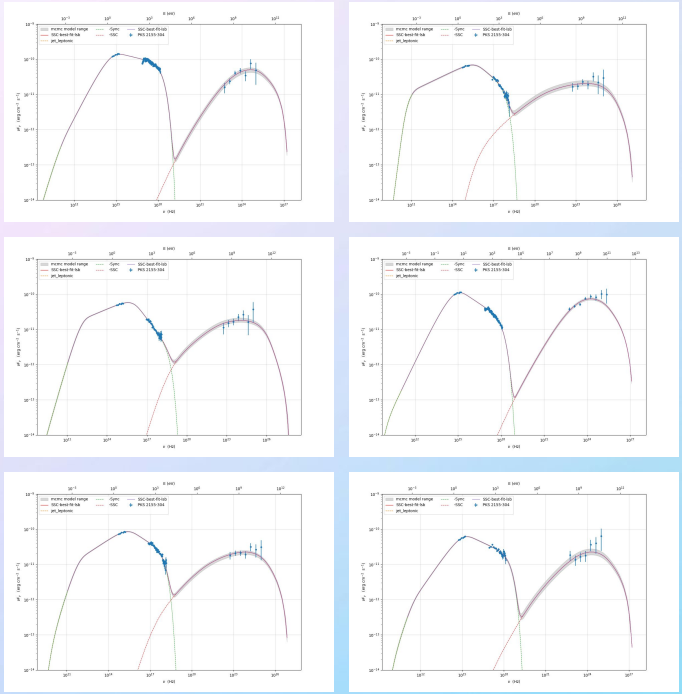
JetSeT
Jets SED modeler and fitting Tool

JetSeT is an open source C/Python framework to reproduce radiative and accelerative processes acting in relativistic jets, allowing to fit the numerical models to observed data.

One-Zone Leptonic Model:

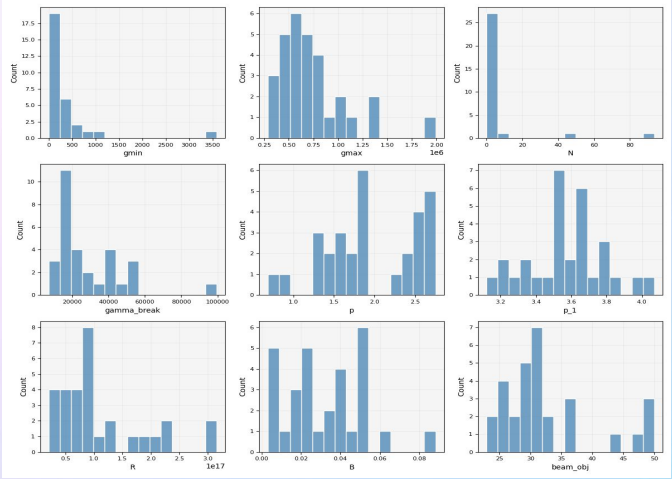
- Emission originates from a single, homogeneous region in the jet, where the region is taken to be a uniform sphere of radius R.
- Relativistic electrons are responsible for producing both synchrotron and inverse Compton components of the blazar's SED.
- Assumes a population of relativistic electrons with a broken power-law energy distribution.

$$N(\gamma) = N_0 \begin{cases} \gamma^{-p_1} & \gamma_{\min} \leqslant \gamma \leqslant \gamma_{\rm b}, \\ \gamma_{\rm b}^{p_2 - p_1} \gamma^{-p_2} & \gamma_{\rm b} < \gamma < \gamma_{\max}, \end{cases}$$



PKS 2155-304: Results

- The SED analysis across various flux states results in distributions of the modeling parameters.
- The *gamma_min* parameter shows a strong concentration at very low values indicating that the electron energy distribution consistently extends down to relatively low energies across different flux states.
- The spectral index parameters (*p* and *p_1*) show distinct preferred values, with p clustered around 1.5-2.0 and *p_1* showing peaks around 3.6-3.8, suggesting consistent underlying acceleration mechanisms despite flux variability.
- The Doppler beaming factor (*beam_obj*) shows a distribution primarily between 25-35, with a peak around 30, confirming the highly relativistic nature of the jet in this TeV blazar across its different activity states.
- The SED analysis shows the emission processes are complex, highlighting the need for further in-depth study to understand the mechanisms at play.



Thank You

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