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The high-energy gamma-ray spectra of TeV blazars

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Blazars are a subclass of active galactic nuclei with relativistic jets pointed toward the observer, emitting high-energy gamma rays beyond 1 TeV. The underlying mechanism for the emission of these gamma rays may be inferred by the shape of the observed spectral energy distribution (SED), which can be modeled to include the underlying particle populations, and acceleration and cooling mechanisms in the jets.

High-frequency-peaked BL Lac objects (HBLs), are a subclass of blazars that have their synchrotron peak at frequencies $>10^{15}$ Hz, within the UV/X-Ray regime. This emission indicates synchrotron radiation from an accelerated population of charged particles.

In most cases, HBLs are observed after flares, leading to observation biases. On the other hand, the sources presented here have been monitored to spread out the observations and measure a wider range of states. The long-term variability is evident: from the multiple states observed (low, high, flaring, etc.) we can compile the distribution of flux to learn about the underlying acceleration and cooling mechanisms. A previous study quantified the distribution of these flux states for multiple sources, and for a single source, fit a spectral model to find the spectral curvature indicating the cooling of the electron population [1]. In this study, we systematically fit spectral models for multiple sources.

Selection of States During Time Variability

We use **Bayesian blocks** to define periods of steady flux, and reconstructed fluxes are deabsorbed from the EBL [2]. The blocks are calculated for each instrument with a 3 σ prior probability. Between VERITAS and *Fermi*-LAT, we form overlapping states and use data from each instrument to calculate SEDs for that block.

Blocks	1ES 1011+496	1ES 2344+514	MS 1221.8+2452
Fermi	11	3	3
VTS	5	3	1
Overlapping	12	5	2

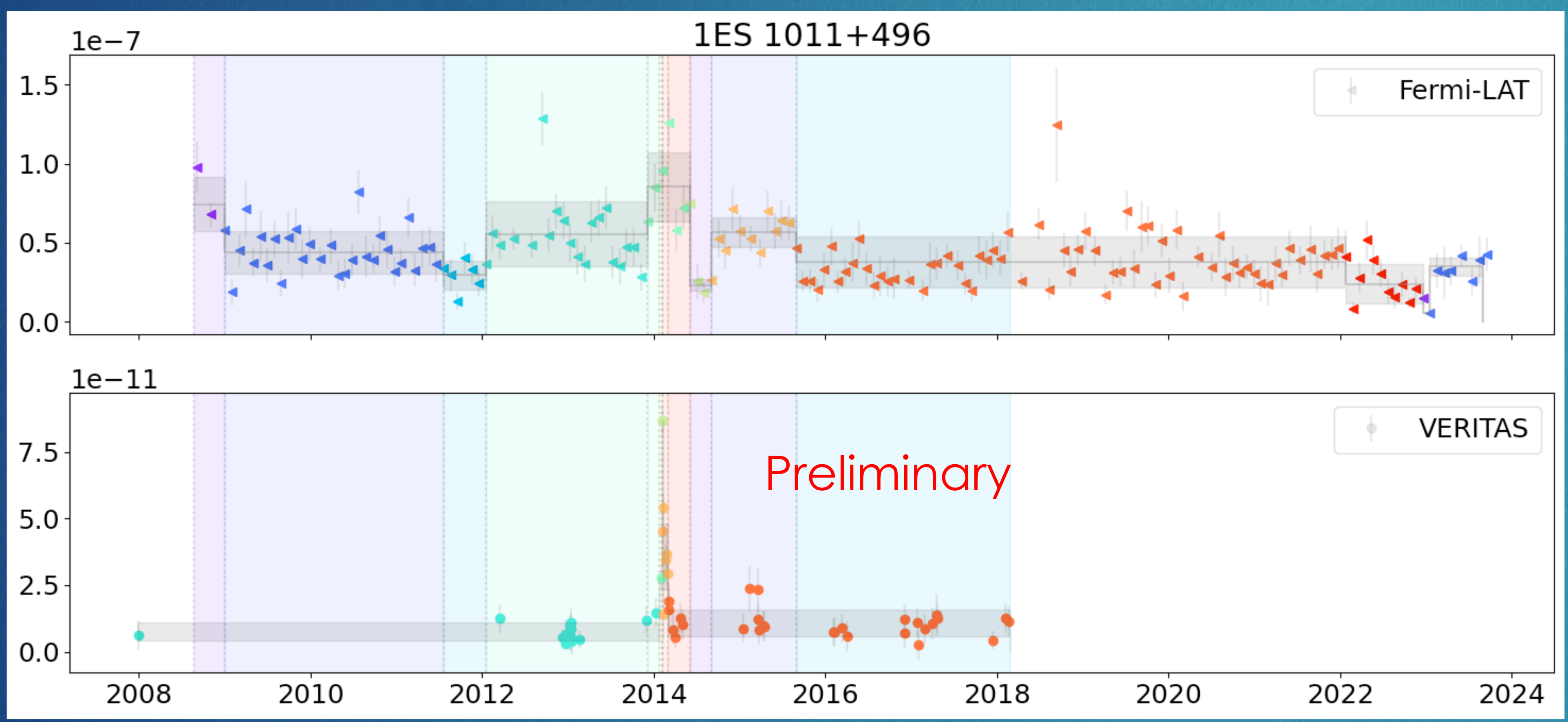

Figure 1. *Above)* Light curve of 1ES1011+496. Grey shaded regions indicate block per instrument, while colored shading indicating overlapping blocks.

Instruments

The **Fermi-LAT** is a space-based telescope sensitive to gamma rays with energies from 50 MeV to 1 TeV. Given its ability to survey the full sky every 3 hours, it is possible to compile long-term monitoring observations to find time variability over many years. This ability is enabled by ~1 m^2 effective area, which lowers the spectral sensitivity.

VERITAS is a ground-based observatory that detects VHE gamma rays from 85 GeV to 30 TeV. Although it has ~10^5 m^2 effective area significantly improving the sensitivity, it is a pointing telescope where observations must compete for time. Therefore, only small observation windows are available of the many years.

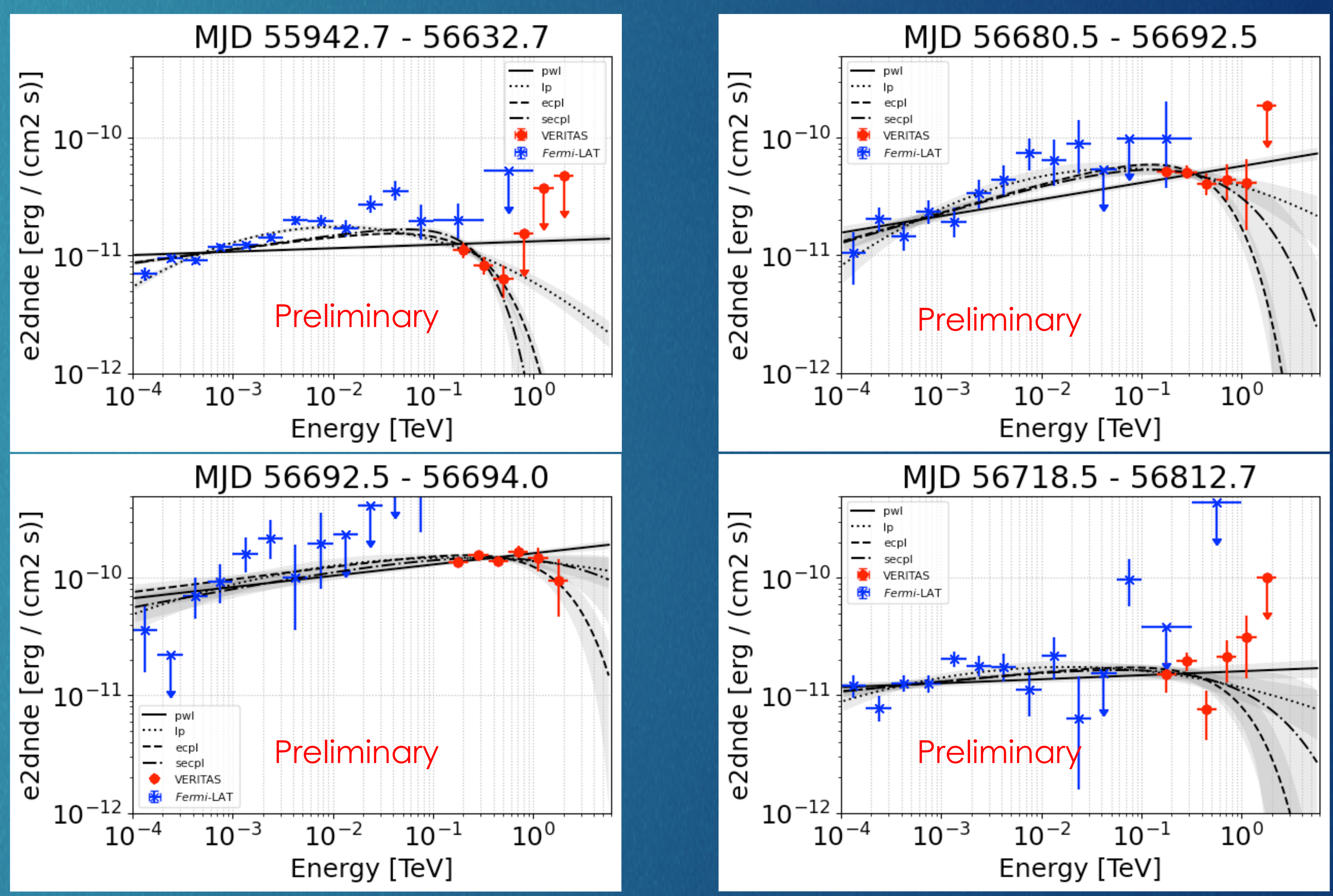

Figure 2. *Right)* SEDs for 4 overlapping blocks from 1ES1011+496, where data sourced from strictly each block. Red marker are VERITAS fluxes, and blue are Fermi-LAT fluxes.

SEDs

- The SEDs are fit with power law (PWL), log parabola (LP), exponential cutoff power law (ECPL), and Super ECPL (SECPL).
- Since these sources have known redshifts, the data is deabsorbed for EBL [3] to the find the intrinsic spectrum.
- The curved models (LP, ECPL, SEPL) are compared to PWL using the Akaike Information Criterion (AIC), where the smallest $\Delta AIC = AIC_{curved} - AIC_{PWL}$ indicates a better fit.
- In some cases, curvature is **preferred** (ΔAIC > 10), which may indicate that models with suppressed TeV emission is preferred.

Table 1. $\Delta\mathrm{AIC}$ for each curved model for 1ES 1011+496. Highlighted in red are the preferred models, where a curved model is most common against power law models.

	$\Delta\mathrm{AIC}_{\mathrm{LP}}$	$\Delta\mathrm{AIC}_{\mathrm{ECPL}}$	$\Delta\mathrm{AIC}_{\mathrm{SECPL}}$
4	-89.9	-67.2	-74.5
5	0.4	1.5	-0.6
6	-6.2	-3.1	-7.1
7	-1.9	3.3	-3.0
8	-1.2	4.2	-1.5
9	-2.2	0.3	-2.2
11	-36.3	-16.6	-20.1
12	-33.3	-14.3	-18.1

Electron Cutoff

In the cases where curvature is sub-exponential ($\alpha < 1$) in each SED

$$\beta_E = {}^{4\alpha}/_{(1-\alpha)}$$

The photon cutoff energy α can indicate the electron energy cutoff β_E, of the Synchrotron self-Compton (SSC) model [4,5]. In Table 1, in the blocks where the SECPL model is a good fit, $\alpha \approx 0.4 \pm 0.2$, or a sharp electron cutoff $\beta_E \approx 3 \pm 2$.

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