



Synchrotron Self-Compton Modelling of Blazars in the SPOTS survey

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Abstract:

The Spectral Energy Distribution (SED) of emission produced by blazars, a sub-class of radio-loud Active Galactic Nuclei (AGN), typically exhibits a double-peaked spectrum. The lower-energy peak is attributed to synchrotron emission from relativistic electrons. The origin of the higher-energy peak remains debated and has been modelled by both leptonic and hadronic processes. In this study, we investigated the leptonic scenario for a selection of TeV detected blazars in the SPOTS (Spectro-Polarimetric Observations of TeV Sources) survey. The JetSet code was used to fit a purely-SSC model to multi-wavelength archival data of the selected blazars. The models can be used to constrain the physical parameters of the emitting region, such as the magnetic field strength and the size of the region. The best fit parameters and SEDs for each source are presented. These results provide the groundwork for our future research, which will focus on the lepto-hadronic scenario in order to put better constraints on the contribution of hadronic emission for these sources.

Introduction:

Blazars, a sub-class of radio-loud AGN, are characterised by a highly relativistic jet with its emission detected within 10° of the observers line-of-view. This emission spans the entire EM spectrum, and is Doppler-boosted. Blazars can be sub-classified into BL Lacertae type objects (BL Lacs) or Flat-Spectrum Radio Quasars (FSRQs). Observationally, this classification is based on whether or not the sources show strong emission lines with BL Lacs showing weak or absent emission lines. Additionally, the SED's of FSRQ's typically show thermal contributions in the optical regime with External Compton in the high energy regime, while BL lac objects are dominated by an SSC spectrum. BL Lacs are also differentiated based on the frequency at which the synchrotron emission peaks: $\nu_{\text{syn}} < 10^{14}$ (Low), $10^{14} < \nu_{\text{syn}} < 10^{15}$ (Intermediate), $\nu_{\text{syn}} > 10^{15}$ (High). The aim of this study is to model the broadband SED's of a selected group of TeV emitting blazars in order to constrain some of the properties of the emitting regions, as well as the contributions of high energy emission processes.

Source Selection and SED Modelling

SPOTS is a spectropolarimetry survey currently being undertaken using the Southern African Large Telescope (SALT) (Barnard, et al., 2026). This survey focuses on studying a sixth of all known very high-energy (VHE) gamma-ray sources. The survey contains fourteen blazars, both BL Lacertae objects and FSRQs.

In order to select good candidate sources to model, a list of properties was chosen based on previous literature outlining the technique.

The selected source should:

- Extend into the VHE gamma ray regime of its SED,.
- Have a high synchrotron peak – this indicates that particles are accelerated to high enough energies to produce the gamma rays.
- Have quasi-simultaneous wavelength data available.
- Exhibit a rapid flare(s); the rapid variability helps confine the size of the emission region.
- Have been previously hadronically modelled, so that a better model can be developed, or have been leptonicly modelled with evidence of a hadronic model possibly improving the fit.
- Classified as an HBL (High Synchrotron-peaked BL Lac object), in order to minimize thermal and External Compton contributions

The final source list chosen was:

- PKS 0447-439
- PKS 1440-389
- PKS 2005-489

These sources were first analysed using *Fermi*-LAT data. The Bayesian Block Analysis and HOP Analysis⁴ was used to determine periods of flaring. The data was obtained through SED-Builder and extracted from existing literature. The sources were then leptonicly modelled with a one-zone SSC model using the JetSet code. Each source was modelled with archival *Fermi*-LAT, H.E.S.S., *Swift*-XRT data. In some cases, and depending on the availability, *Swift*-UVOT and WISE data was added.

Results:

Bayesian Block Analysis

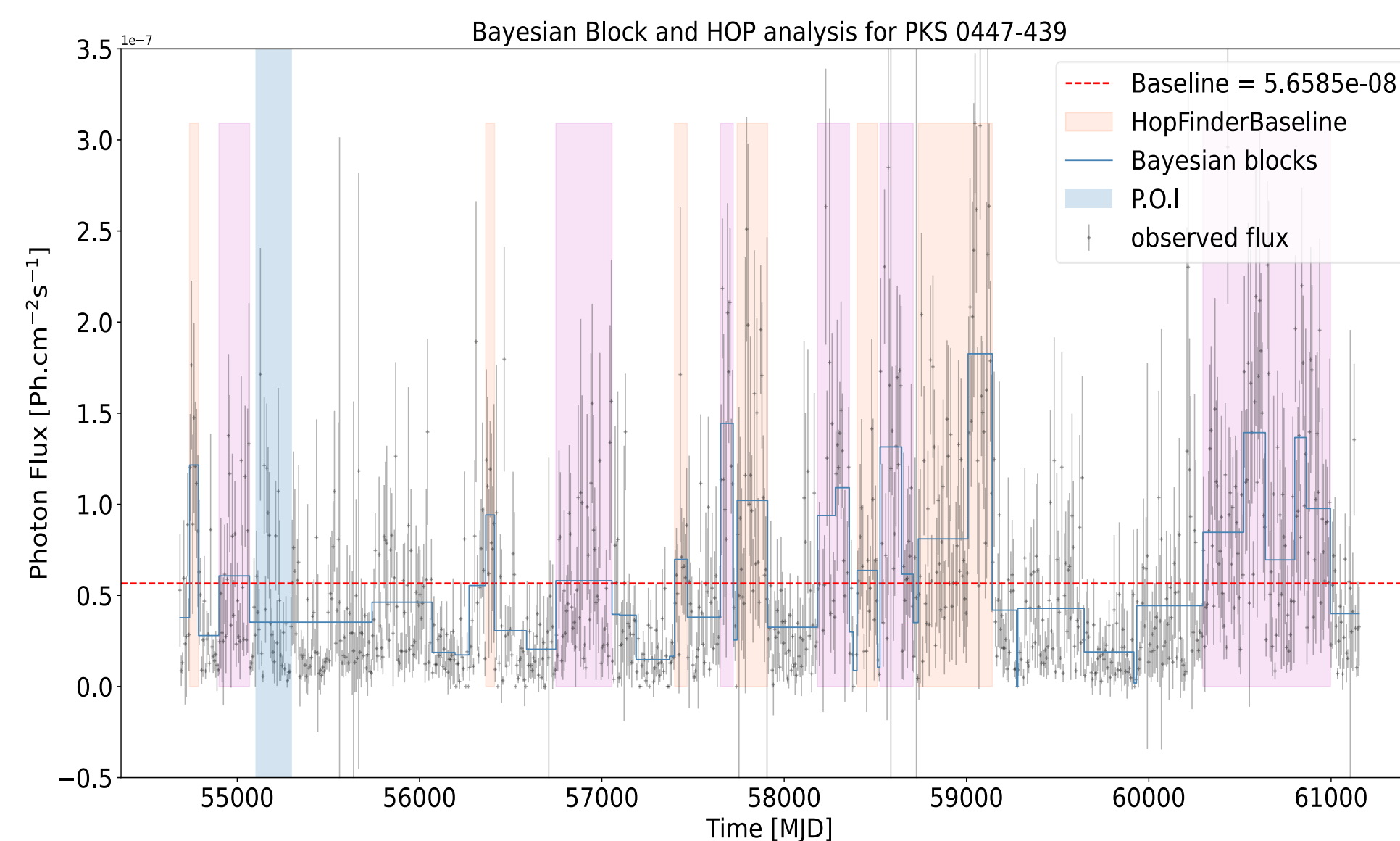


Figure 1: Bayesian Block and HOP Analysis of PKS 0447-439; Period of Interest 55100-55300 MJD.

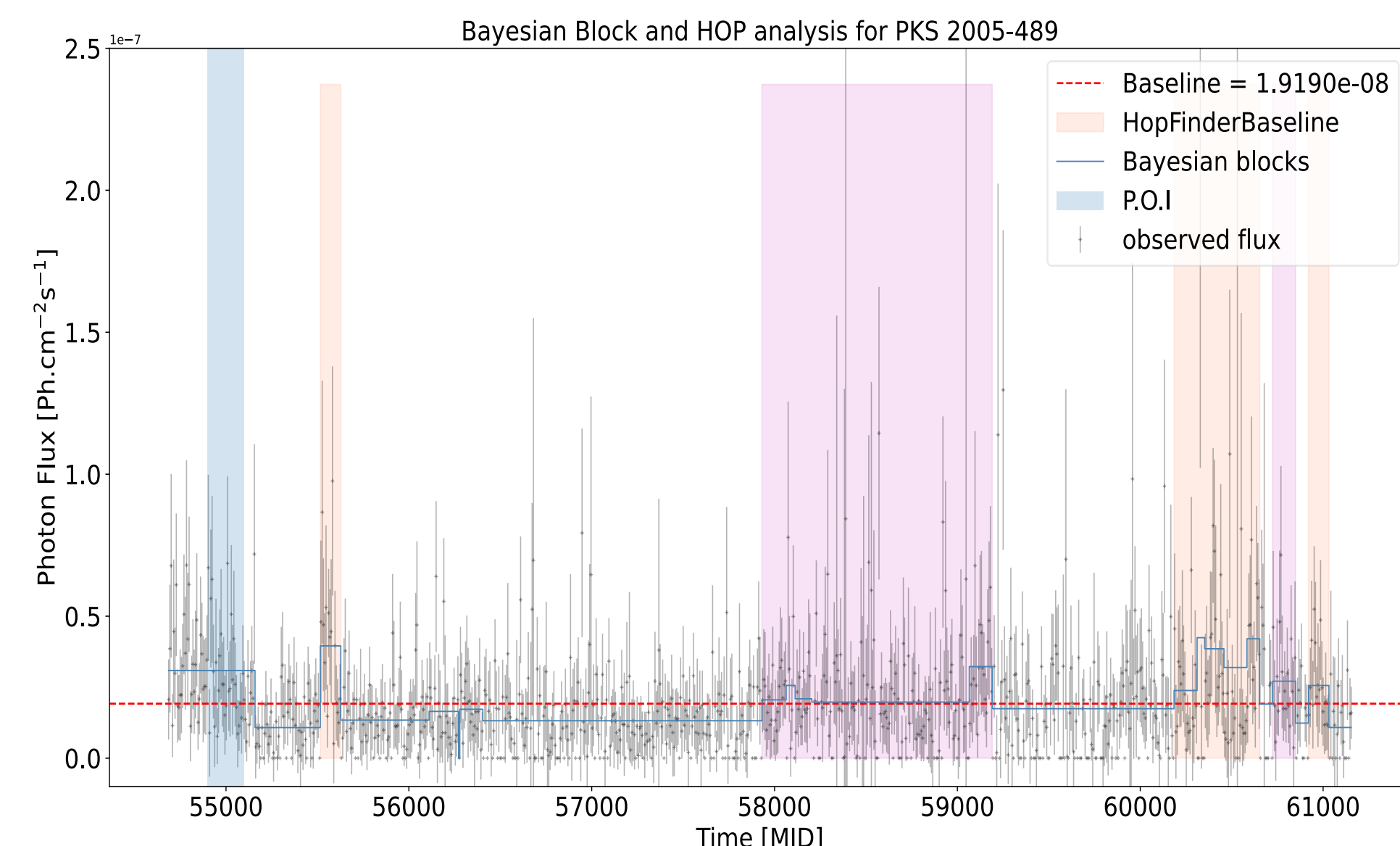


Figure 3: Bayesian Block and HOP Analysis of PKS 2005-489; Period of Interest 54900-55100 MJD.

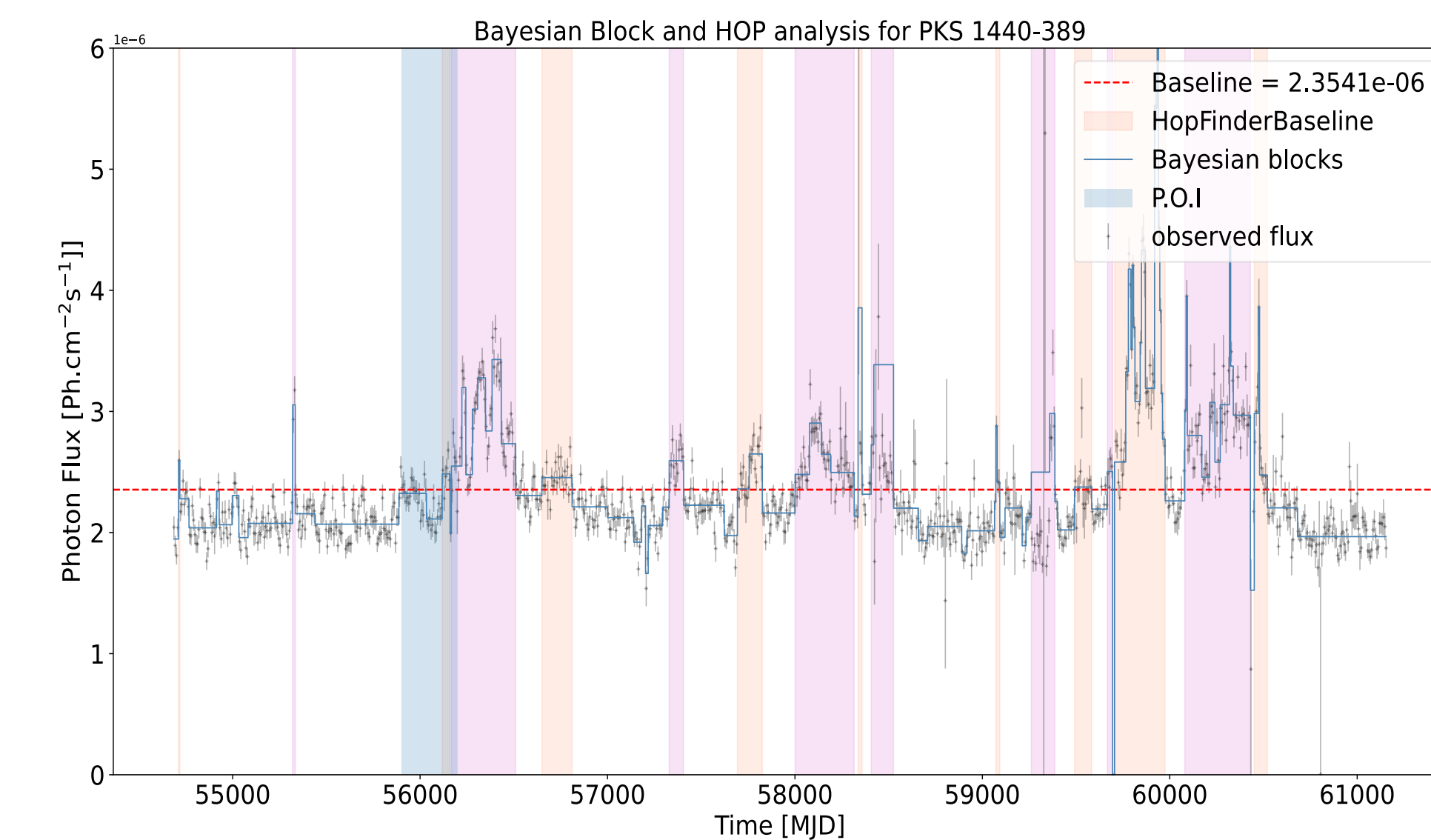


Figure 5: Bayesian Block and HOP Analysis of PKS 1440-389; Period of Interest 55900-56100 MJD.

Parameters:

Table 1: SED Parameters for all blazars

Parameters	PKS 0447-439	PKS 2005-489	PKS 1440-389
z	0.14	0.2	0.071
$\gamma_{\text{min}} [\text{Hz}]$	33	253	2.55×10^3
$\gamma_{\text{max}} [\text{Hz}]$	1.22×10^6	3.81×10^5	3.91×10^6
$\gamma_{\text{br}} [\text{Hz}]$	3.5×10^4	3.05×10^4	5.77×10^4
p_1	2	2	2
p_2	4.2	4.4	3.7
$B [\text{G}]$	0.045	0.12	0.002
$R [\text{cm}]$	2.28×10^{16}	4.32×10^{16}	4.81×10^{17}
$\delta [\text{cm}]$	42	29	60

One-zone Synchrotron Self-Compton Model

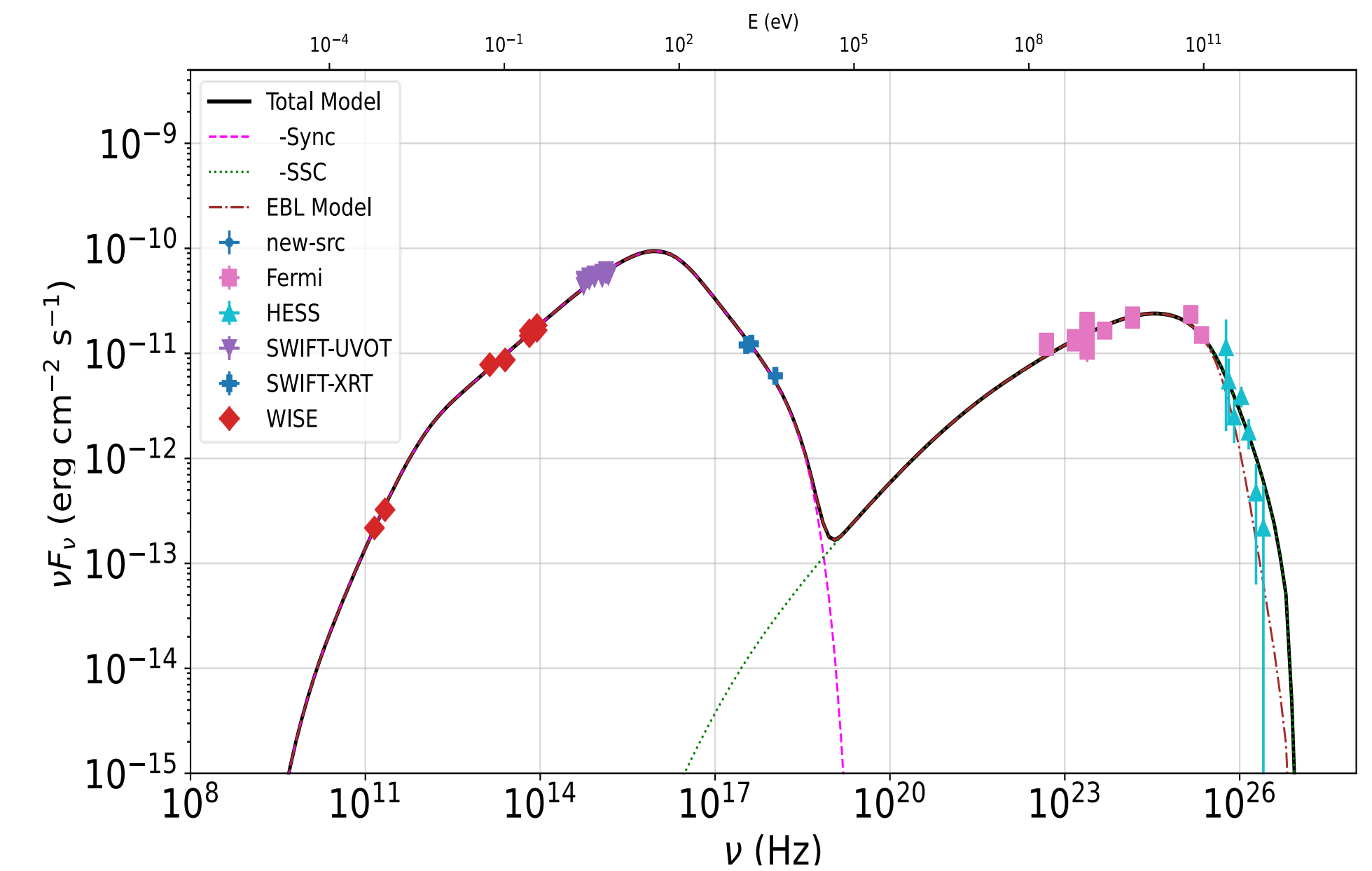


Figure 2: Spectral Energy Distribution of PKS 0447-439

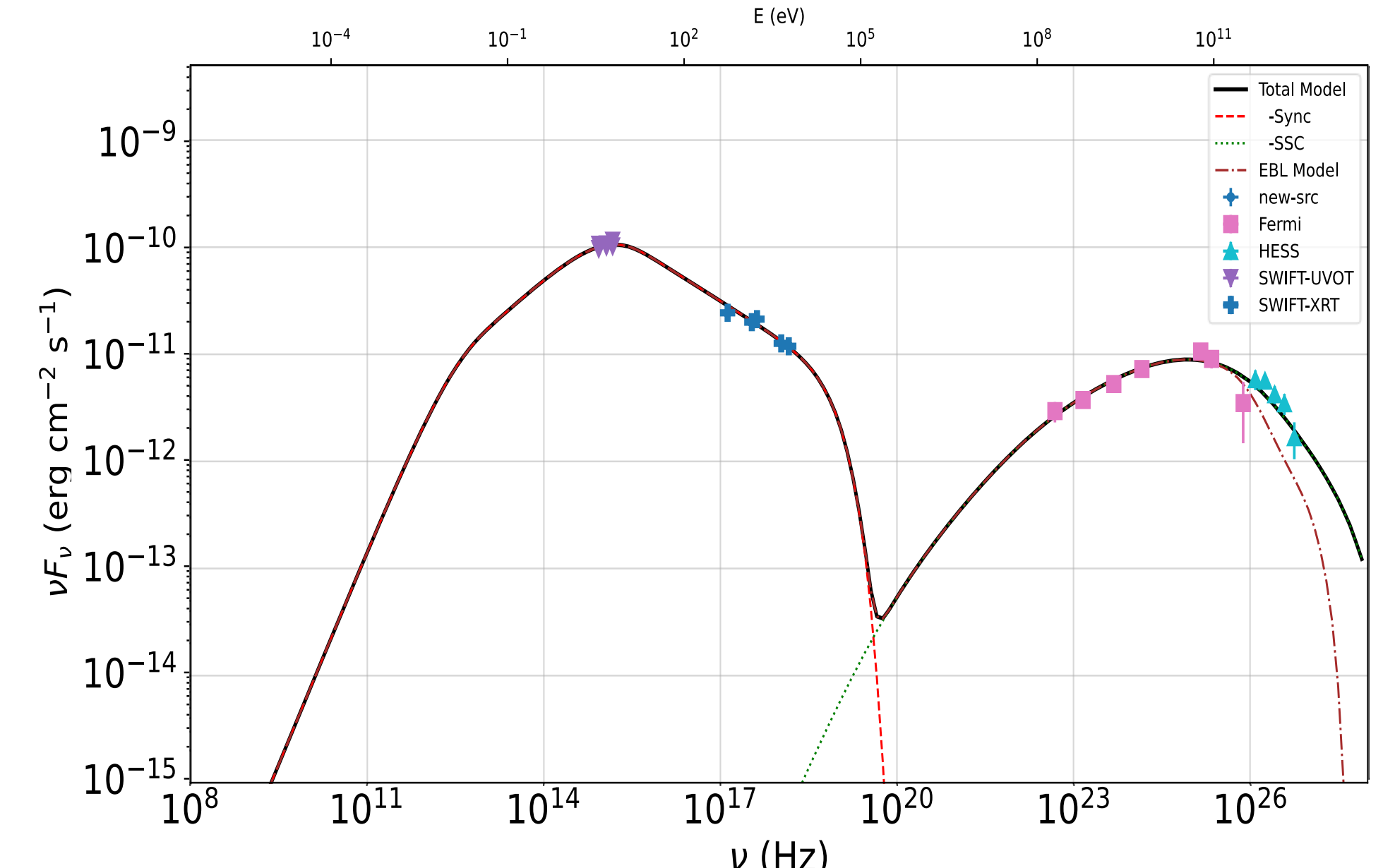


Figure 4: Spectral Energy Distribution of PKS 2005-489

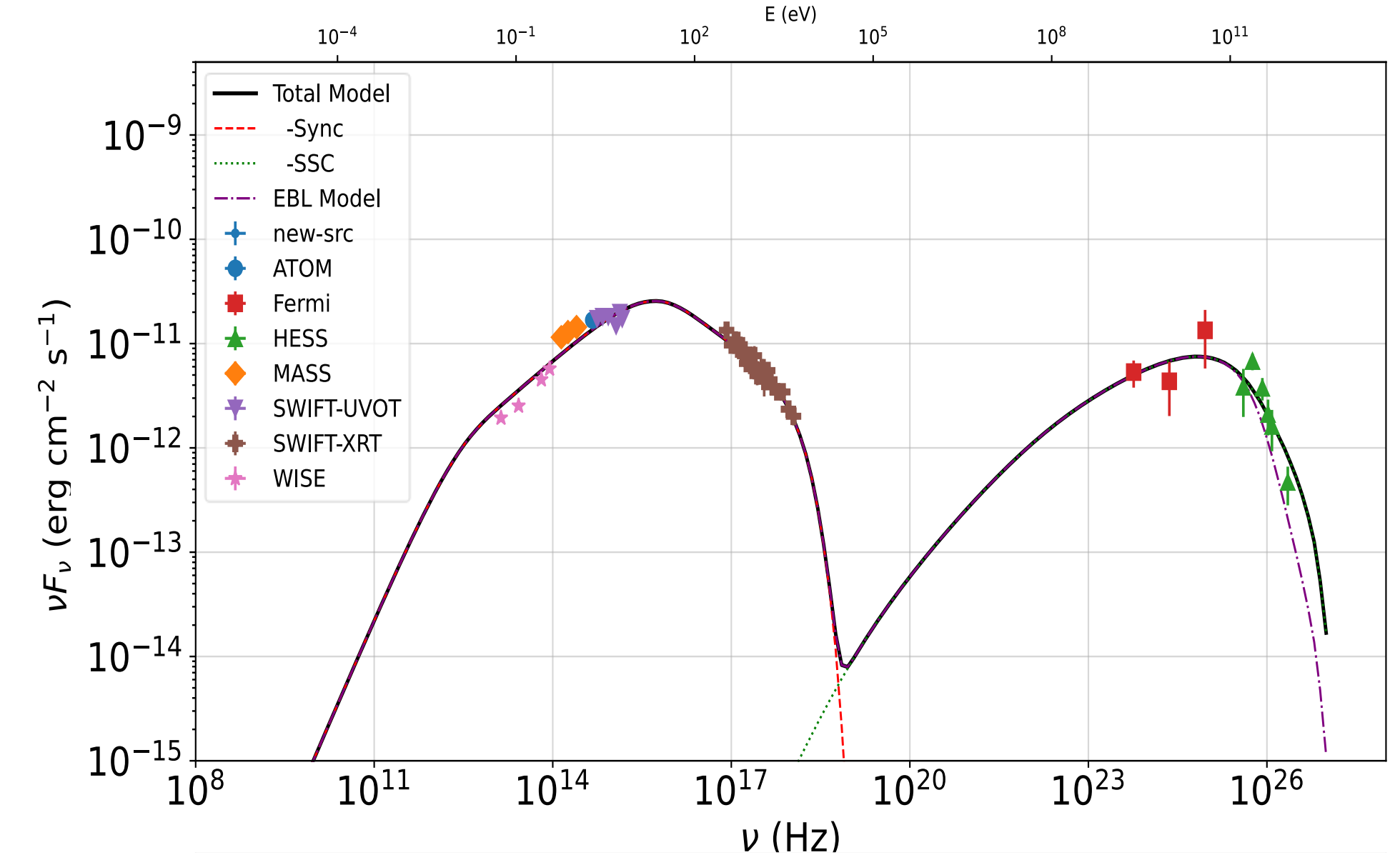


Figure 6: Spectral Energy Distribution of PKS 1440-389

Discussion and Conclusion:

JetSet was used to model the one-zone SSC scenario for three SPOTS Blazars: PKS 0447-439, PKS 2005-489, PKS 1440-389. For all three sources, our models fit the lower-energy peaks reasonably well but all three models do not account entirely for the flux observed at TeV energies. The parameters required to fit these high energies would require parameters, such as the Doppler factor or magnetic field, that fall outside the acceptable range. When compared to previous research, the parameters indicate that a leptonic scenario is not sufficient to fit the energies of these sources. The SED models exhibit the need for an investigation into underlying processes that can expand the models to fit these higher energies.

The next stage of this research will focus on modelling the hadronic scenario for each blazar, to determine whether this component can significantly improve the fit to the higher energy component.

References:

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