Motivations

- At Very-High-Energies (VHE; E=100 GeV), the dominant extragalactic sources are blazars, with very few radio galaxies (RG) e.g., NGC 1275, Cen A, M87 and 3C 264. As with blazars, the physical origin of TeV emission in these RG remains unclear.
- Large jet-viewing angles in RG -> low Doppler factor -> detection bias to nearby RG.
- Characterizing the low-state behavior of a source is crucial to gain further insights into its flaring states & variability.
- Compared to bright, flaring states, low-flux states of jetted active galactic nuclei require longer integration times for a detection.
- Objective: characterize both flaring and non-flaring states of NGC1275 to understand gamma-ray emission mechanisms.
- Current study: Low-state multi-wavelength SED over 2012-2017 fit to a single-zone Synchrotron self-Compton model.

NGC 1275 (3C 84)

- NGC 1275 (z=0.03176), central galaxy in the Perseus cluster, is host to an extremely bright compact radio source (3C 84). It has a complex morphology that has evolved with time.
- Previous low-state studies: Aleksić+2014 utilized MAGIC observations from 2009-2011 and attempted to explain the low-state emission with a single-zone SSC model.
- Significant NGC 1275 flare in January 2017: Multi-wavelength (MWL) SED fitting of the 2017 flare data indicates that a multi-zone model (with two SSC components) and a strong external inverse-Compton (EIC) component is required (Rutten+ in prep). The model points towards radio component C3 as the emission region of the flare.
- Another significant NGC 1275 flare in December 2022: Detected by MAGIC (Atel #15820; 150% Crab) and LAT1 (Atel #15819; ~140% Crab). Follow-up observations by VERITAS coordinated with Swift-XRT and NuSTAR on Dec 29th, 2022.

Multi-wavelength Low-State Data Selection

Two Stage Thresholding technique was applied. Threshold: $\alpha = 2.5\sigma$.
First iteration: most significant flares. Second iteration: any potential high states.

If a flare was identified on one band, simultaneous data were removed from the other bands as well.

All data were restricted to VERITAS observing windows of NGC 1275.

VERITAS Analysis

- VERITAS low state results are displayed in Table 1.
- The VERITAS low-state flux is comparable to MAGIC low-state flux reported in Aleksić+2014: 3% Crab (Camp I, Oct 2009-Feb 2010) and 2.4% Crab (Camp II, Oct 2010-Feb 2011).

<table>
<thead>
<tr>
<th>Exposure (h)</th>
<th>Significance</th>
<th>VTS Flux (2000 GeV)</th>
<th>$\gamma$</th>
<th>$N^s$ (TeV$^{-1}$cm$^{-2}$sr$^{-1}$)</th>
<th>E$_{p}$ (TeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>53</td>
<td>20$\sigma$</td>
<td>(4.8±1.2) -2.2 Crab</td>
<td>3.8±0.2</td>
<td>(4.8±0.5) -0.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 1: Summary of VERITAS low-state analysis

Fit of the Low-State Inverse-Compton SED Peak


Fitting of the Low-State Multi-wavelength SED

- Multi-wavelength data was fit to a single-zone SSC with the latest version of B+eMMC tool (Hervet+2023). The underlying leptonic particle distribution was assumed to be a broken power-law with the parameters shown in Table 2.
- The Doppler factor was constrained ($k_F > 3.2$) to keep it consistent with Rutten+ in prep which adopted a jet viewing angle of 18$^\circ$.
- Hyperparameters of the MCMC fit: nsteps=6500, nwalkers=200, and burnin=250.

Conclusions & Future Work

- This is the first comprehensive exploration of single-zone SSC parameter space in the low state SED of NGC1275 with data extending from radio to VHE $\gamma$-rays.
- The model shows a convincing SED fit when considering an angle with the line of sight of 18$^\circ$. A large emission zone is favored at least 0.3 pc (1\text{GHz})
- Such a large emission region may not be accommodated by emission from the core, suggestive of the radio-zone C3 as a potential TeV emitter in the low state, consistent with the 2017 flare state model in Rutten+ in prep.
- An ongoing investigation of the 2022 flare including the MWL SED is currently in progress.

References


Acknowledgements

This research was partially supported by the National Science Foundation under grants PHY-2304870 and PHY-2302356. This research is supported by grants from the Center for Astrophysics | Harvard & Smithsonian Foundation and the Smithsonian Institution, by NSERC in Canada, and by the Helmholtz Association in Germany. The research used resources provided by the Open Science Grid, which is supported by the National Science Foundation and the U.S. Department of Energy’s Office of Science, and resources of the National Energy Research Scientific Computing Center (NERSC), a U.S. Department of Energy Office of Science User Facility operated under Contract No. DE-AC02-05CH11231. We acknowledge the excellent work of the technical support staff at the Fermi-Lat Wisconsin Observatory and all the collaborating institutions in the construction and operation of the instrument.

Contact

Anjana Kaushik Talluri
University of Minnesota
Email: tel0010@umn.edu