Long Term Observations of 3C 66A

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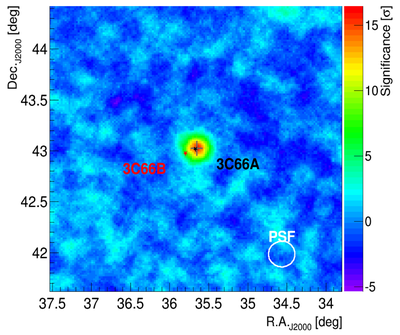
Introduction & Motivation: Why study 3C 66A?

Science Motivation for Studying Blazars:

- Possible progenitors of **ultra high energy cosmic rays (UHECRs)**
- Potential signatures of **secondary gamma rays** from UHECRs
- Constraints on **jet nature** and evolution of **blazar** classes

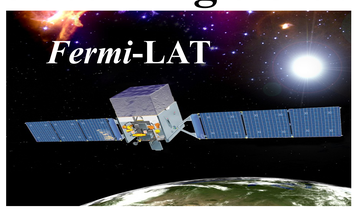
3C66A

- Intermediate synchrotron peaked BL Lac object (ISP)
- Spectroscopically constrained redshift:
  - $0.33 < z < 0.41$
- Relatively high redshift
- Multiwavelength data available
- Long term gamma-ray observations
- Exhibits flux variability
- Candidate for spectral variability



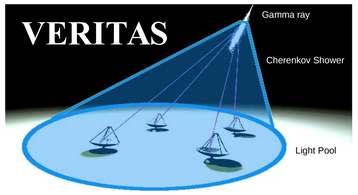
Right: Skymap >100 GeV from observations taken by VERITAS. The center of significance is associated with 3C 66A, excluding 3C 66B at 95% confidence level.

Observing 3C 66A: *Fermi*-LAT and VERITAS



Space based gamma-ray observatory

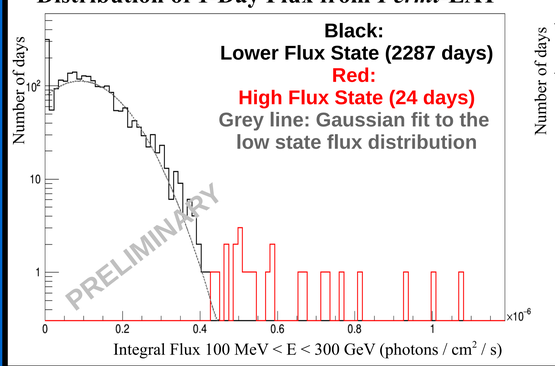
- Pair production telescope orbiting Earth
- Provides all sky monitoring by observing the entire sky every three hours
- Sensitive from 100 MeV to 300 GeV
- Observations on 3C 66A span 2008-2015



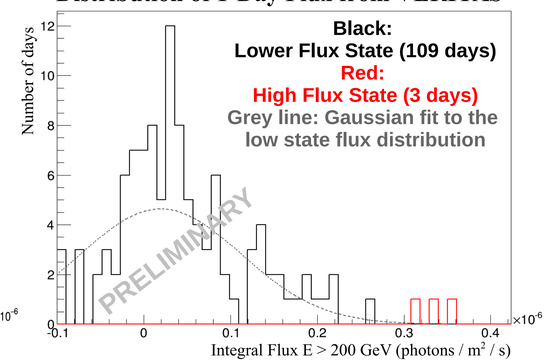
Ground based gamma-ray observatory (Arizona, USA)

- Very high energy (>100 GeV) gamma ray induces a particle shower in the atmosphere which produces Cherenkov light
- Shower is imaged by four 12m telescopes
- Sensitive from 100 GeV to above 10 TeV
- 65 hours of observations on 3C 66A spanning 2007-2015

Distribution of 1-Day Flux from *Fermi*-LAT



Distribution of 1-Day Flux from VERITAS

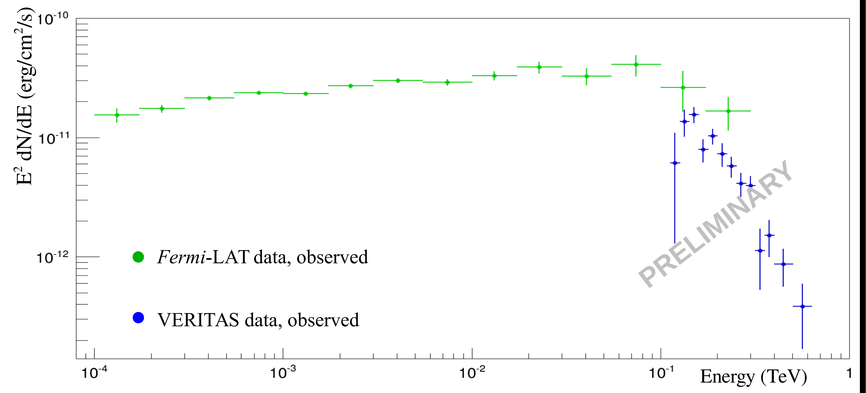


Results: Gamma-Ray Spectral Energy Distribution of 3C 66A

By selecting the low flux state days from each instrument, we can construct a spectral energy distribution (SED) which minimizes the effect of flux variability.

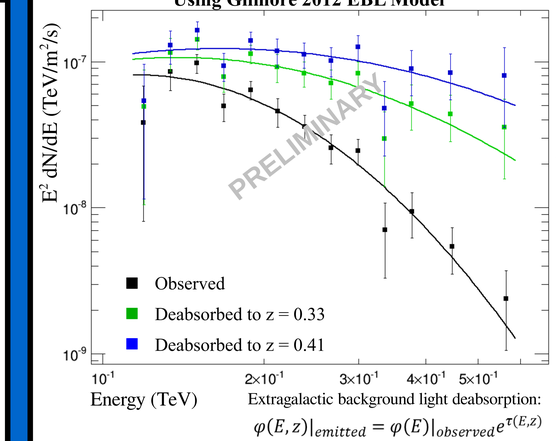
The combination of LAT and VERITAS data allows us to constrain the gamma-ray peak.

Further multiwavelength modeling is needed to understand the underlying physics.



Results: Investigating the Deabsorbed 3C 66A Spectra

Deabsorbed Low Flux State Spectra Using Gilmore 2012 EBL Model



Extragalactic background light deabsorption:

$$\varphi(E,z)|_{emitted} = \varphi(E)|_{observed} e^{\tau(E,z)}$$

The deabsorbed spectra show no statistically significant deviation from the fits. A deviation could be explained by contribution from ultra high energy cosmic rays.

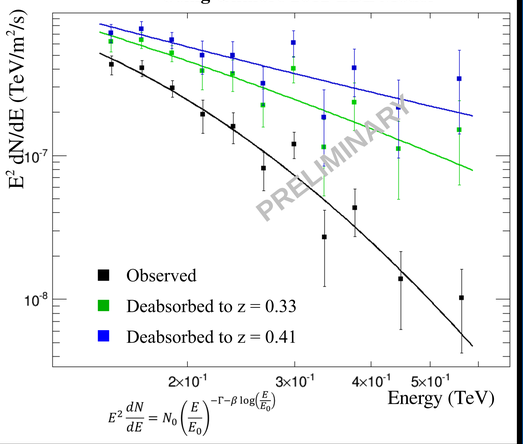
A log-parabolic fit to the spectra is best in all cases (although not always significantly) with the following preference:

	Low Flux State:	High Flux State:
Observed	4.1σ	1.5σ
z=0.33	1.3σ	0.1σ
z=0.41	0.8σ	0.3σ

No significant change in spectral parameters between high and low flux states:

$\Delta\Gamma = 0.5 +/- 0.4$
$\Delta\beta = 1.4 +/- 2.1$

Deabsorbed High Flux State Spectra Using Gilmore 2012 EBL Model



$$E^2 \frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{-\Gamma-\beta \log\left(\frac{E}{E_0}\right)}$$

Conclusions:

There is strong evidence for curvature in the observed low state VHE spectrum. The lack of curvature in the deabsorbed spectra indicates that it is largely an artifact of the EBL.

Combining VERITAS and *Fermi*-LAT data allow us to observe the gamma-ray peak of the SED.

The VHE spectra are consistent with a single log-parabolic component and does not require a hard component from UHECRs. There is no spectral evolution detected.

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