Detection of Extended Gamma-ray Emission from Fornax A

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Summary: Prior to the launch of Fermi in 2008, the radio galaxy Fornax A was identified as one of the few extragalactic objects that might be detected as extended above 100 MeV. However, even though it was detected with high confidence in the first 2 years of the mission, it was not determined to be an extended source. Recently, the *Fermi*-LAT collaboration developed a new event-level analysis called Pass 8 which yields a larger acceptance, a better angular and energy resolution, as well as smaller systematic uncertainties. The improvements provided with Pass 8 combined with a larger exposure means that the extension of Fornax A is significantly detected. Details of this measurement will be presented along with modeling of the emission above 100 MeV.

The *Fermi* LAT

The *Fermi* observatory recently celebrated its sixth year in orbit and hosts two instruments: the **Gamma-ray Burst Monitor (GBM)** and the **LAT**[1, 2], a pair conversion telescope.

- The Pass 8 performace of the LAT:
  - Energy range: 20 MeV to $>$ 1 TeV
  - Acceptance:$\sim$2.5 m^2 sr ($>$1 GeV on axis)
- The LAT is **unique**:
  - Long time baselines (6+ years)
  - Large Field of View
  - Fast turnaround of data (public release)
  - Wide spectral range

Fermi has **opened a window** on the high-energy, extreme universe.

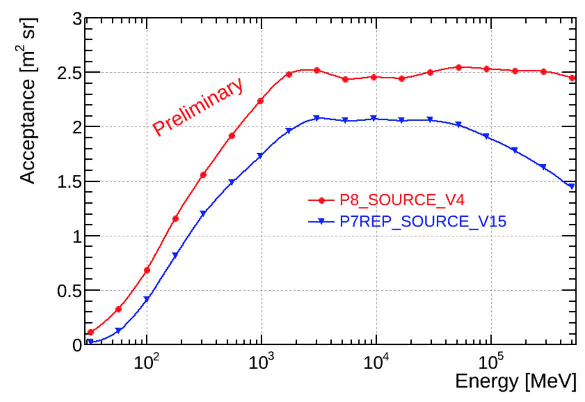
- γ rays are signatures of:
  - extreme events (GRB & AGN)
  - exotic particles (dark matter searches)
- γ rays are tracers of:
  - cosmic-rays and targets (diffuse & accel.)
- γ-ray sources are probes of:
  - extreme systems (accel. mech.)
  - the medium (extragalactic light and Lorentz Invariance)
  - the inter-Galactic magnetic field

Fornax A

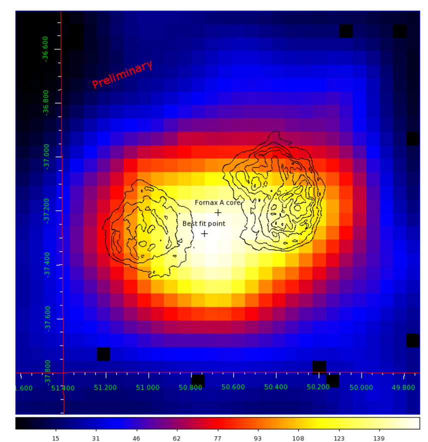
Fornax A (NGC 1316) is a radio galaxy at a red-shift of 0.006[]. The well resolved radio lobes span about 1 degree on the sky. After Centaurus A, this radio galaxy is the best case for measuring extended γ-ray emission from an extragalactic object.

Pass 8 provides greater acceptance over Pass 7 (Figure 1, top) which allows the determination of spatial extent from Fornax A for the first time. A test statistic (TS) map (Figure 1, middle) provides the first evidence that the data set is not compatable with a point source.

Assuming the X-ray emission from the lobes of Fornax A is inverse- Compton (IC) scattered emission of Cosmic Microwave Background photons on electons in the lobes, [4] predicted that extragalactic background light (EBL) photons would also scatter off of these same electrons into the γ-ray range and be detectable by *Fermi*-LAT. By measuring the SED of the lobes, the EBL can be indirectly determined (Figure 1, bottom).



Fermi-**LAT Acceptance** *[3] Pass 8 acceptance is larger than Pass 7 allowing for the measurment of extent from Fornax A.*



Fornax A TS Map *Residual TS Map (color levels) of Fornax A showing the radio lobes as contours [5]. The locations of the radio core and the center of the γ-ray emission are shown as crosses.*

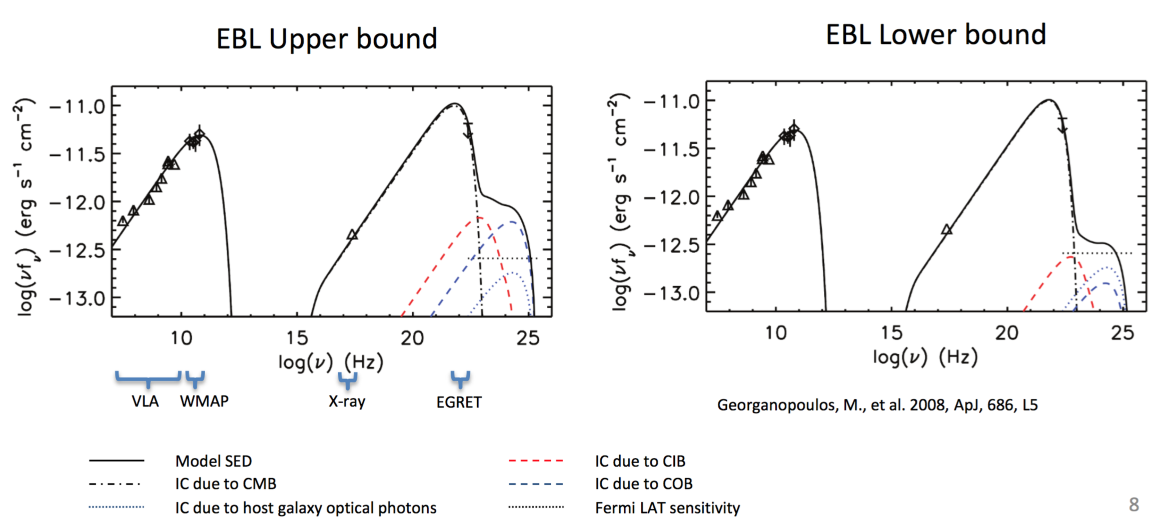


Figure 1: *Prediction from [4] for γ-ray emission from the lobes of Fornax A. Based upon the radio and X-ray emission, [4] predicted that γ-rays shold be produced via IC scattering of EBL photons off of electrons in the radio lobes. The left and right plots show upper and lower bounds on the level of EBL. Both cases predict a detectable level of emission in the LAT band (horizontal dotted line).*

Analysis Details

73 months of Pass 8 source class events are used from 100 MeV to 300 GeV with an ROI of 10 degrees around Fornax A. The background is modeled via point sources from the 3FGL [6] and the galactic and isotropic diffuse templates. A zenith angle cut of 100 degrees is used to remove contamination from the Earth's limb. Standard quality cuts are used.

Using the radio template [5] as a spatial map is preferred over a simple point source model at the level of 6.3 σ. A scenario containing both a point source and the radio lobes is not prefered. A profile likelihood method is used to determine that the level of containimation from the core is minimal.

Studies are underway to further quantify the spatial extent of the lobes and to estimate the systematic uncertainties.

Preliminary Modelling

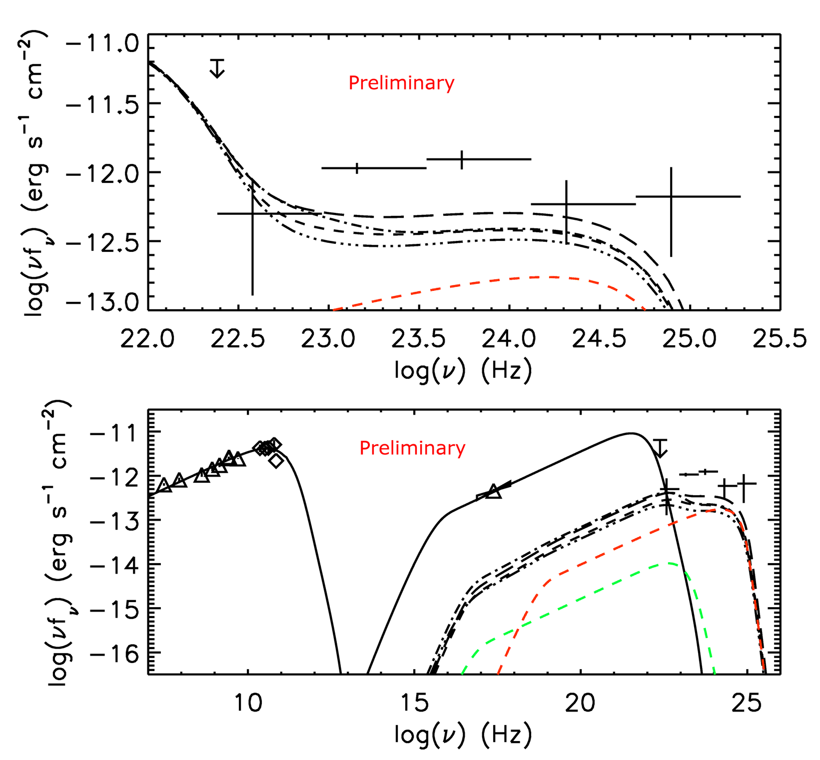


Figure 2: *The SED of the lobes plotted along with updated modelling using the EBL models of []. The EBL emission is fully constrained by the radio and X-ray emission. The SED from the lobes is higher than expected indicating the presence of additional processes, a higher than expected level of EBL, or misidentification of thermal emission in the X-ray data.*

References

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[5] Fomalont, E. et al., ApJ, 346, 17 (1989).
[6] http://arxiv.org/abs/1501.02003

Acknowlegements

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