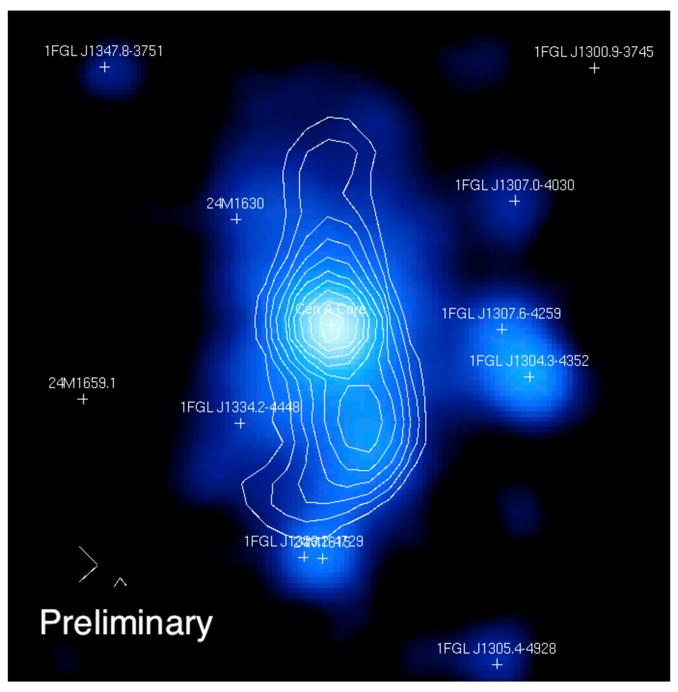
Two Years of Observations of the Radio Galaxy Centaurus A with the Fermi LAT

Jeremy S. Perkins (UMBC/CRESST/GSFC), C. C. Cheung (NRC/NRL),
L. Stawarz (ISAS/JAXA) and D. L. Wood (NRL)
on behalf of the Fermi Large Area Telescope Collaboration

Summary: 29 months of Fermi LAT observations of Cen A produce the most detailed γ-ray SED yet.

γ-ray emission from the giant radio lobes of Centaurus A was discovered by the Fermi LAT after 10 months of observation. The MeV/GeV emission was interpreted as inverse Compton-scattered radiation from the cosmic microwave background and the optical-to-infrared extragalactic background light. The large extent of the γ-ray emission implies that highly energetic electrons are either created within the lobes or are efficiently transported over the hundreds of kpc from the core to the emission region. In this contribution we expand the data set and report on the results of the first 29 months of γ-ray observations on Centaurus A using the Fermi LAT.

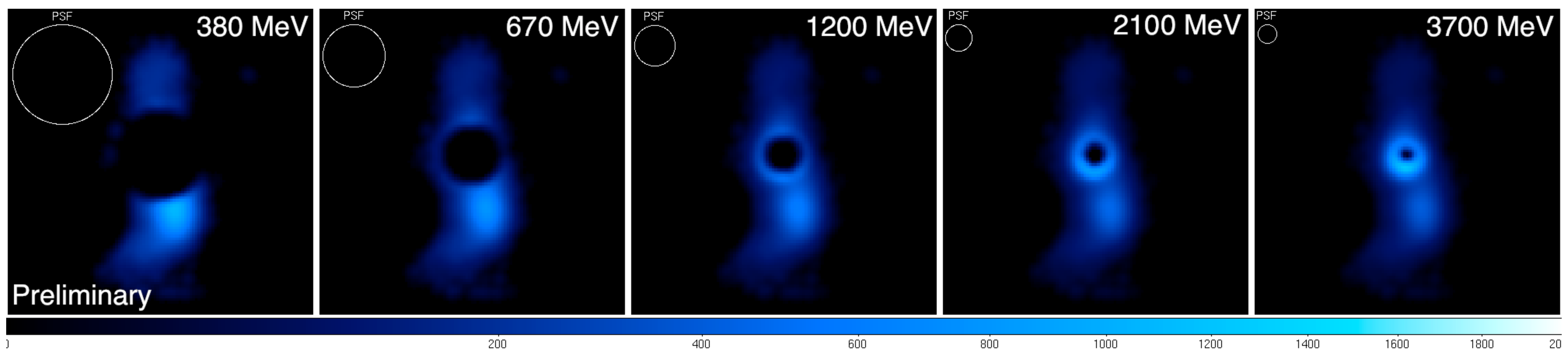
Centaurus A



Smoothed γ-ray counts map of the 10˚ x 10˚ region surrounding Centaurus A. The galactic and extragalactic diffuse emission has been subtracted from this image. The contours show the WMAP emission at 22 GHz and the crosses designate γ-ray Sources included in the likelihood model.

Centaurus A is a radio galaxy located at a distance of 3.7 Mpc [1], making it the closest radio galaxy to Earth. Aside from its bright central radio source, it has two luminous large radio lobes extending over 10 degrees to the north and south of the core. This is a well studied source at many different wavelengths. The physical extent of the lobes (~600 kpc) means that the previously detected γ-ray emission is produced by energetic particles within the lobes themselves or efficiently transported out from the core [2]. The initial 10-month detection was not sensitive enough to differentiate different EBL models and expanding the data set to the full 29-month observing period improves the statistics and increases the energy range.

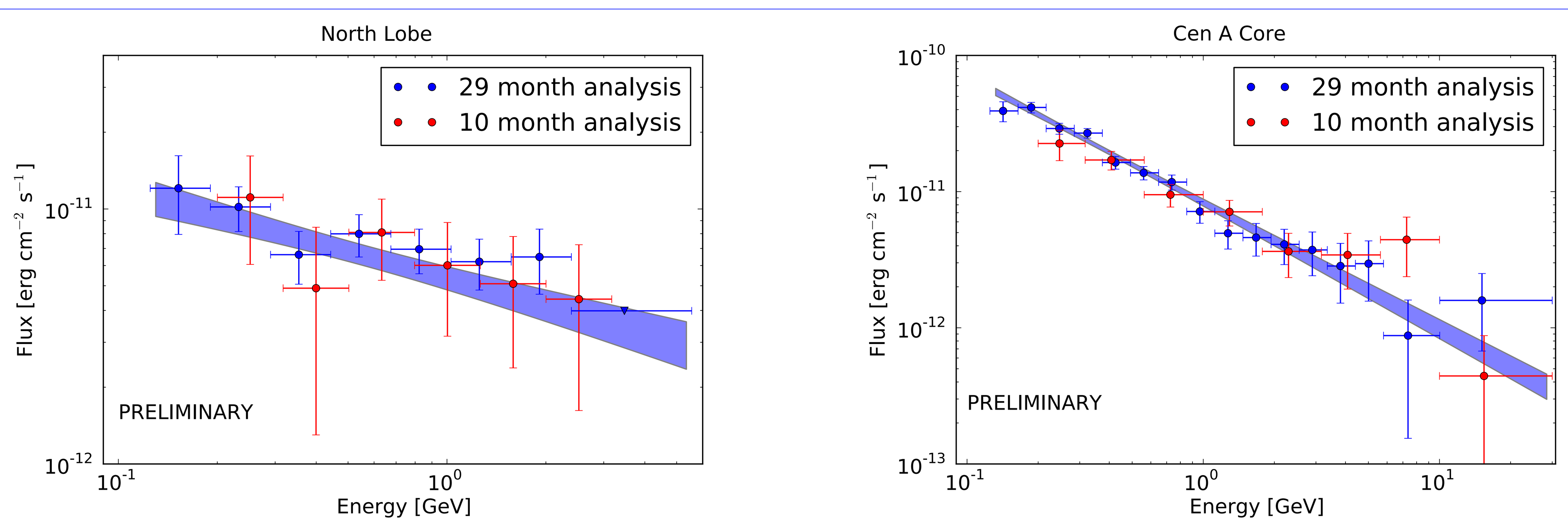
Fermi Analysis

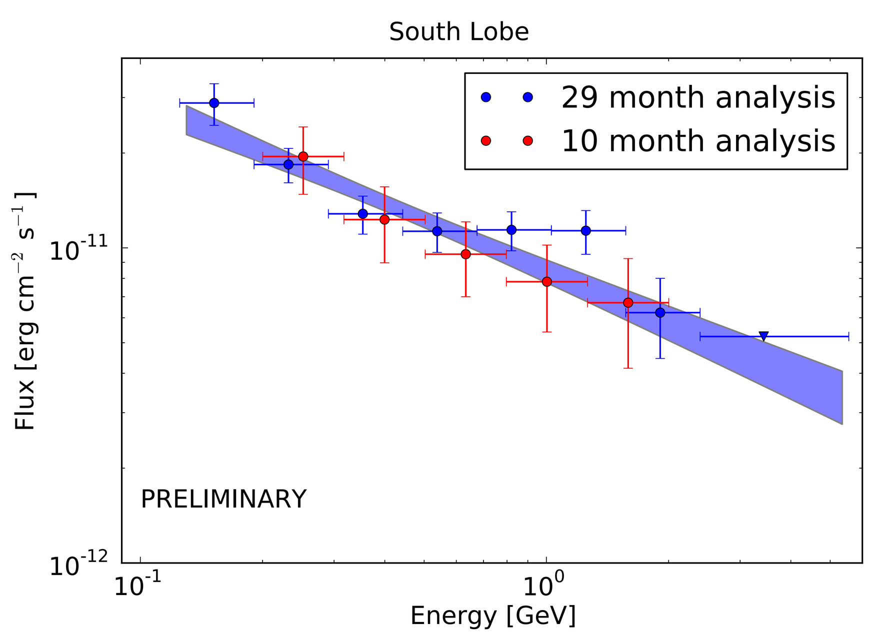


Smoothed energy dependent model of the γ-ray emission from the radio lobes of Centaurus A. This model is based on the 22-GHz WMAP emission with the core removed. The radius of the region subtracted at the core is determined from the LAT PSF at that specific energy. Shown here are five specific energy bins (the full model map includes thirty logarithmically spaced bins). The LAT PSF at each energy is shown in the top left of each image.

The Fermi LAT is a pair-conversion telescope [3]. The data used in this analysis spans 29 months (August 4, 2008 to January 4, 2011). Only events arriving at zenith angles < 105˚ and passing the standard 'P6V11 DIFFUSE' class cuts were used. An additional cut on the rocking angle was used as is recommended [4]. The analysis was performed from 125 MeV to 30 GeV. The 10 month model for the lobe emission was based on the WMAP k-band image of the region with the core emission subtracted. For this work, the WMAP image was further modified to allow for an energy dependent core size due to the energy dependence of the LAT PSF [5]. This more accurately describes the emission from the core and the lobes. It was found that three additional point sources were needed to adequately model the region compared to the 10 month analysis (see the plot at the top left). The galactic and isotropic diffuse were modeled using the P6V11 versions of the standard models and the normalizations of these diffuse models were left free in the fit.

29 Month MeV/GeV SED





γ-ray SED for the North and South Lobes and Core of Centaurus A. The red points show the results from the 10 month data set. The blue points are for the analysis presented in this work (29 months using an energy dependent model map, see the analysis section). The blue butterfly is the likelihood fit to the full data set (see the box to the right). The errors shown here are only statistical. Each of the SED points in the 29 month lobe SEDs are above a TS value of 9 and the upper limit at ~4 GeV is at 90% confidence. Modeling of the 29 month SED is ongoing.

Overall Likelihood Results

Source	Significance [sigma]	Flux (> 100 MeV) [10^{-7} ph s^{-1} cm^{-2}]	Index
Cen A Core	37	2.27 ± 0.12	2.92 ± 0.05
North Lobe	11	0.56 ± 0.08	2.35 ± 0.09
South Lobe	19	1.19 ± 0.11	2.54 ± 0.08

Each source in the model was fit using a binned likelihood method [6]. The final model results for the core of Cen A and the lobes is shown in the above table and plotted as the blue butterfly in the box to the left. Note that the fits are done from 125 MeV to 30 GeV while the 10 month data were fit from 200 MeV and up. The overall model results for the lobes are statistically similar to the 10 month data set. The main differences stem from the energy dependent model. If the 10 month mono-energetic template is used, the resulting fits are statistically identical to the 10 month analysis. In both cases, the statistical errors are smaller in the 29 month dataset (this work).

Conclusions

29 months of Fermi-LAT γ-ray observations of Centaurus A were analyzed. This analysis improves upon the original spatial template of the lobes by using an energy dependent core subtraction region that more accurately describes the PSF of the Fermi LAT. The power-law fits to the γ-ray SED are similar to those seen in the 10 month data. However, the 29 month γ-ray SED of the lobes is more constraining and spans a slightly broader energy range. Ongoing modeling of these will provide a detailed understanding of the physics at work within the lobes. The lobe emission templates are being further refined using higher resolution radio images.

Acknowledgments

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References

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