Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 3 (OG part 2), pages 1077–1080

30TH INTERNATIONAL COSMIC RAY CONFERENCE

GLAST Large Area Telescope Observations of Blazars

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Abstract: The Large Area Telescope (LAT, 30 MeV $<$ E $<$ 300 GeV) aboard the Gamma-ray Large Area Space Telescope (GLAST), scheduled to launch in early 2008, promises a factor of 25 increase in sensitivity over its predecessor, EGRET. It is expected that the LAT will detect over a thousand blazars in its first year, enabling the first detailed population studies of these gamma-ray sources. The LAT's sensitivity is sufficient to measure the time-resolved spectra of dozens of blazars in flaring states over its lifetime and to study the time-averaged properties of hundreds more in quiescence. In addition, the LAT's large field of view (2.4 sr) and GLAST's all-sky scanning mode together provide a uniform sky exposure and even, well-sampled light curves of every source. In short, the LAT is a sensitive probe of the parsec-scale jets of AGN and the physics of the jets' gamma-ray emitting regions. We present an overview of the capabilities of the LAT for timing and spectral studies and a discussion of how these capabilities can constrain physical models of blazars. We also emphasize the important role of simultaneous observations at other wavelengths.

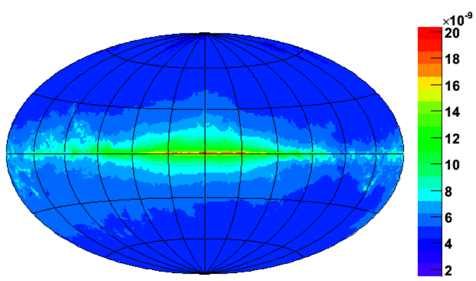

Figure 1: One calendar-year, 5σ sensitivity map.

The GLAST LAT Sensitivity

Due to its large effective area (10,000 cm^2 at 1 GeV) and large field of view (2.4 sr), the one-year LAT sensitivity will be $\sim 4 \times 10^{-9}$ ph (E $>$ 100 MeV) cm^{-2} s^{-1} at high galactic latitude, a factor 25 better than the sensitivity of the Third EGRET Catalog (see figure 1). The satellite will orbit the Earth at an altitude of 565 km with an inclination of 28.5 degrees. In the first year, it will operate in survey mode, by rocking alternately by ± 35 degrees with respect to the direction opposite of the Earth every second orbit. This will provide very uniform coverage of the sky.

Population Studies

With high confidence detections of more than 60 AGNs, almost all BL Lacs or FSRQs, EGRET has established blazars as a class of powerful gamma-ray emitters, in accord with the unified model of AGNs as supermassive black holes with accretion disks and jets. Although blazars comprise only several per cent of the overall AGN population, they largely dominate the high-energy extragalactic sky. This is because most of the non-thermal power that arises from blazar jets is emitted in the gamma-ray band whereas the emission from the accretion disk is most luminous at optical, UV, and X-ray energies. Most extragalactic sources detected by the LAT are therefore expected to be blazar AGNs, in stark contrast with the situation

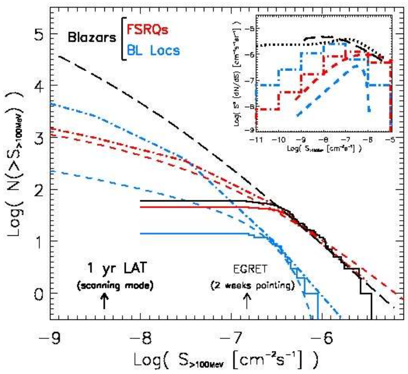

Figure 2: Cumulative number distribution of EGRET-detected blazars measured over two-week intervals (FSRQs: upper curves, BL Lac objects: lower curves) and various model predictions: Stecker & Salamon (1996)[1], long-dashed line; Mücke and Pohl (2000)[2], dashed-dotted lines; Dermer (2006)[4], dashed lines. The inset shows the predicted power distribution of radio-loud AGN for each model, with the dotted line representing the model of Narumoto & Totani (2006)[3]. The main contribution to the extragalactic diffuse gamma-ray background is predicted to come from sources at the peak of the respective model distributions.

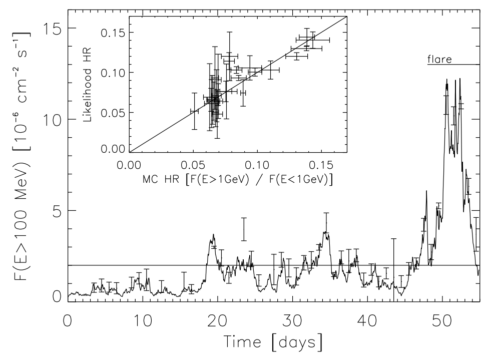

Figure 3: Example of a daily light curve as will be measured by the LAT for 3C279 for a flare comparable to the brightest one detected by EGRET for this source. The curve corresponds to the seed flux while the line segments are the results of a maximum-likelihood analysis. The inset displays the true F(E $>$ 1 GeV)/F(E $<$ 1 GeV) hardness ratios versus the measured ones.

at X-ray frequencies, where most of the detected extragalactic sources are radio-quiet AGNs.

Extrapolation of the EGRET LogN-LogS curve[1, 2, 3, 4] (see figure 2) indicates that the LAT will detect at least one thousand AGNs, many times the number of currently identified blazars. This very large and homogeneous sample will greatly improve our understanding of blazars and radio galaxies, and will be used to perform detailed population studies and to carry out spectral and temporal analyses on a large number of bright objects.

In particular, the very good statistics will allow us (a) to extend the LogN-LogS to fluxes $\sim$ 25 times fainter than EGRET, (b) to estimate the luminosity function and its cosmological evolution with very good accuracy, and (c) to calculate the contribution of blazars and radio galaxies to the extragalactic gamma-ray background. These observations will chart the evolution and growth of supermassive black holes from high redshifts to the present epoch, explore the evolutionary connection between different subclasses of blazars, especially BL Lacs and FSRQs, and test the unified model for radio galaxies and blazars[5].

The Physics of Gamma-ray-emitting AGNs

The LAT's wide field of view and good sensitivity will allow AGN variability to be monitored on a wide range of time scales (see figures 3 and 4) and flare alerts to be issued. Flares as bright as those observed by EGRET from 3C 279, F (E $>$ 100 MeV) $=10^{-5}$ ph cm^{-2} s^{-1}[6], and by Swift from 3C454.3[7], will be measurable with GLAST at gamma-ray energies on time scales less than an hour. In addition, the duty cycle of a large number of blazars will be determined with good accuracy.

The short variability time scale and bright gamma-ray emission will place lower limits on the Doppler factor of the jet plasma. The values of the Doppler factor can be correlated with gamma-ray intensity states for a specific blazar and correlated with membership in different subclasses for many blazars. The Doppler factors can also be compared with values obtained from superluminal motion observations in order to infer the location of the gamma-ray emission site. The correlation between gamma-ray flares and emission of new radio blobs will be studied in detail via intense monitoring of the bright blazars detected by GLAST.

The good sensitivity and the wide bandpass of the LAT will tightly constrain theoretical models and lead to the determination of spectral parameters with unprecedented accuracy. The peak of the high-energy component of the spectral energy distribution (SED) is expected to lie within the LAT energy range for many AGNs. Simultaneous multiwavelength observations will greatly strengthen our ability to test current models for the radiation mechanism of blazars, including synchrotron self-Compton and external Compton models, and to assess whether single or multiple zones are required to adequately fit the blazar SEDs. The LAT data are expected to provide insight into the crucual issue of the composition of the jet, both in the innermost part and in the gamma-emitting region. LAT data will also probe the correlation beteween the properties of the radio jet and the inner jet deduced from gamma-ray flares.

The LAT will enable us to address many other issues regarding the physics of blazars. These issues, closely interrelated, concern the jet structure composition, the location of the gamma-ray production/energetization sites and the determination of the local environment. These issues are explored in a document[8] produced by the LAT Science Working Group on AGN. The document describes the approaches identified to address each issue, the most suitable targets, and the nature of the simultaneous/contemporaneous multi-wavelength data required. These Science Goals will drive the multiwavelength observations performed in contemporaneous/simultaneous campaigns, which are already being actively prepared. Dedicated campaigns on 3C279, PKS 0528+134, BLLac, Mrk 421, Mrk 501, 1ES 1959+650, PKS 2155-304 are currently planned.

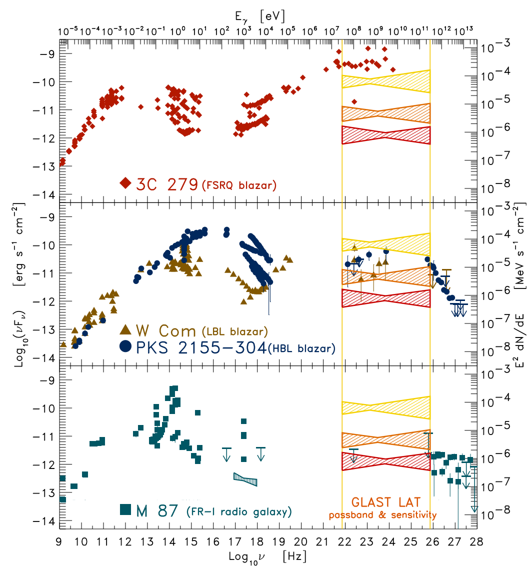

Figure 4: SEDs for 4 gamma-ray blazars: 3C 279 (a typical FSRQ), top; W Comae (a low-energy-peaked BL Lac object, LBL) and PKS 2155-304 (a high-energy-peaked BL Lac object, HBL), middle; M 87 (a FR-II radio galaxy considered a misaligned blazar), bottom. Included in the SEDs are multiwavelength data points collected at different epochs and brightness states for each source (errors bars not represented for clarity). A qualitative representation of the average expected LAT passband and sensitivity for one day, one month and one year (from top down) of observations are shown.

Extragalactic Background Light

The Extragalactic Background Light (EBL) is the accumulated electromagnetic radiation at IR-optical-UV wavelengths resulting from the formation and evolution of structure in the universe. The main contributors to the EBL are: (i) starlight at the optical-UV and (ii) re-processing of starlight by dust at the IR. Measurement of the EBL density provides therefore a fundamental insight into the history of the universe. In particular, the UV-optical EBL flux to which GLAST is sensitive contains information about the star formation rate and dust-extinction process. Unfortunately, direct measurements of the EBL intensity are extremely difficult due to the bright foreground from nearby sources (interplanetary dust, stars and gas in the Milky Way, etc.).

The EBL is strongly connected to gamma-ray astrophysics because gamma rays emitted by blazars (or any other extragalactic source) are subject to absorption due to pair-production with EBL photons. One exciting consequence of this effect is that the magnitude of this absorption can then be used to measure – or at least constrain – the column density of background photons between the source and the observer[9]. Gamma-rays detected by ground-based telescopes (E $>\sim 200$ GeV) are subject to strong attenuation by the near-and mid-infrared part of the EBL, limiting (sub-)TeV probes of the EBL to low redshifts. GLAST, on the other hand, is sensitive to the less drastic attenuation of multi-GeV photons by the UV-optical part of the EBL, with no attenuation expected (at any redshift) for photons with energy below 10 GeV. Thus, EBL attenuation will not limit GLAST's ability to detect blazars. Depending on the blazar luminosity function – something that GLAST itself will measure, GLAST is expected to detect a large number of blazars with redshifts up to z ≈ 5. How many of these sources have an intrinsic spectrum that is suitable for EBL studies is not something that can be definitely answered before GLAST observations. Nevertheless, the energy range of GLAST is ideal for probing the EBL to cosmological distances.

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