Studying Gamma-ray Blazars With The GLAST-LAT

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for the LAT Science Working Group on Blazars and Other AGNs

Abstract

Thanks to its sensitivity (4 10^{-9} ph (E> 100 MeV) cm^{-2} s^{-1} for one year of observation), the GLAST LAT should detect many more (up to over a thousand) gamma-ray blazars than currently known. This large blazar sample will enable detailed population studies to be carried out. Moreover, the LAT large field-of-view combined with the scanning mode will provide a very uniform exposure over the sky, allowing a constant monitoring of several tens of blazars and flare alerts to be issued. This poster presents the LAT performance relevant to blazar studies, more particularly related to timing and spectral properties. Major specific issues regarding the blazar phenomenon that the LAT data should shed light on thanks to these capabilities are discussed, as well as the different approaches foreseen to address them. The associated data required in other bands, to be collected in contemporaneous/simultaneous multiwavelength campaigns are mentioned as well.

The GLAST-LAT Project

The GLAST (Gamma-ray Large Area Space Telescope) is an international mission that will be launched in the last quarter of 2007. Its main instrument, the LAT (Large Area Telescope), will detect gamma rays with energies between 30 MeV and 300 GeV. Thanks to its large effective area (10000 cm^2 at 1 GeV) and large field of view, FOV, (2.4 sr), the 1-year LAT sensitivity will be 4 10^{-9} ph (E> 100 MeV) cm^{-2} s^{-1}, a factor 25 better than the Third EGRET Catalog sensitivity. The satellite will orbit the Earth at an altitude of 565 km with an inclination of 28.5 deg. In the first year, it will operate in survey mode, by rocking alternatively by ±35 deg with respect to the direction opposite to the Earth every second orbit. This will provide a very uniform coverage of the sky (Fig. 1). The mission expected livetime is 5 years. More details can be found in Atwood et al. 2006.

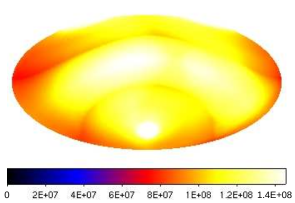

Fig. 1. Exposure map for the LAT or an integration time of one week. The good uniformity in the sky coverage will allow the Lat to continuously monitor the activity of several tens of blazars.

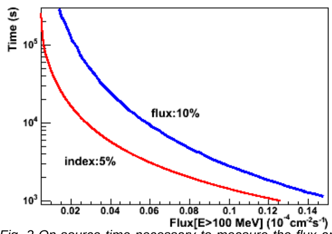

Fig. 2 On-source time necessary to measure the flux and the spectral index of a source at high-galactic latitude with an accuracy of 10% and 5% respectively, as a function of the source flux. The photon spectral index assumed in the calculation is equal to 2.

Blazar Populations

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 at X-ray frequencies, where most of the detected extragalactic sources are radio-quiet AGNs. To prepare for the identification of the blazars detected by the LAT, an all-sky optical/radio survey (Candidate Glast gamma-Ray Blazar Survey, CGRaBs) ultimately including about 1500 blazar candidates is currently underway (Healey 2006).

Extrapolation of the EGRET Log*N*-Log*S* curve (Mücke & Pohl 2000; Dermer 2006; see Fig. 3) indicates that the LAT will detect several hundreds 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 to a) extend the Log*N*-Log*S* to fluxes ~25 times fainter than EGRET, b) estimate the luminosity function and its cosmological evolution with very good accuracy, and c) 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, the evolutionary connection between different subclasses of blazars, in particular, BL Lacs and FSRQs, and test the unified model for radio galaxies and blazars (Urry and Padovani 1995).

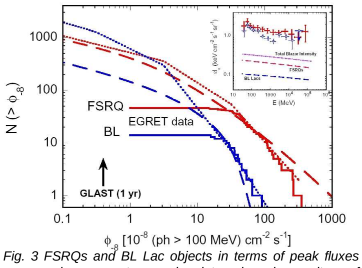

Fig. 3 FSRQs and BL Lac objects in terms of peak fluxes measured over two-week intervals, in units of ph(>100 MeV) $cm^{-2}s^{-1}$. Dotted curves show blazar model of Mücke and Pohl (2000), and dashed curve shows blazar model of Dermer (2006). Inset: The integrated intensity from EGRET measurements to the diffuse gamma-ray background, in comparison with model results (Dermer 2006).

The Physics of Gamma-ray Emitting AGNs

The LAT's wide FOV and good sensitivity will allow AGN variability to be monitored on a wide range of time scales (Figs. 1 and 2) and flare alerts to be issued. Flares as bright as those observed by EGRET from 3C 279, S (E>100MeV) =10^{-5} ph cm^{-2} s^{-1}, (Kniffen et al. 1993), and by Swift from 3C454.3 (Giommi et al. 2006), will be measurable with GLAST at gamma-ray energies on time scales less than an hour (Figs. 2 and 4). In addition, the duty cycle of a large number of blazars will be determined with good accuracy.

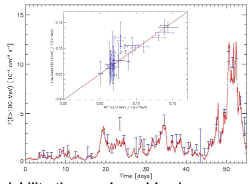

Fig. 4 Example of a daily light curve as will be measured by the LAT for 3C279 for a flare comparable to the brightest one detected by EGRET from this source. The red curve corresponds to the seed flux while the blue line segments are the results of the maximum-likelihood analysis. The inset displays the true F(E>1 GeV)/F(E<1 GeV) hardness ratio versus the measured one.

The short variability time scale and luminous gamma-ray emissions 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 with class membership in specific 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 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 (Fig. 5). The peak of the spectral energy distribution (SED) high-energy component is expected to lie within the LAT energy range for many AGNs. Simultaneous multi-wavelength 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. A crucial issue the LAT data are expected to give insight into concerns the composition of the jet, both in the innermost part and in the γ-emitting region.

A table summarizing the issues to be addressed with the LAT is given at the bottom of this poster. These "Science Goals" will drive the multi-wavelength observations performed in contemporaneous/ simultaneous campaigns, which are already being actively prepared (Thompson et al. 2006). A document on these "Science Goals" is in preparation and should soon be released (October 2006).

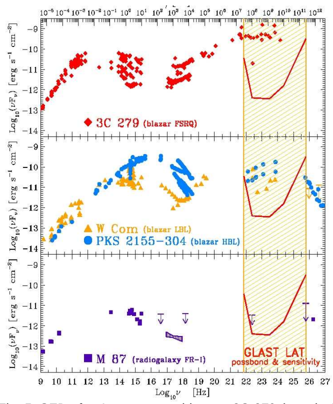

Fig. 5. SEDs for 4 gamma-ray blazars: 3C 279 (a typical FSRQ, top); W Com (a low energy peaked BL Lac object, LBL) and PKS 2155-304 (an high energy peaked BL Lac object, HBL) middle; M 87 (a FR-II radiogalaxy considered a misaligned blazar, bottom). Included in the SEDs are multiwavelentgh data points collected in different epochs (different brightness states) for each sources (errors bars not represented for clarity). A qualitative representation of the average expected LAT wide passband and improved sensitivity over 1 year of observation are shown.

The First GLAST Science Symposium on Feb. 5-8, 2007 will be the occasion for the community interested in joining this effort to gather.

Extragalactic Background Light

The Extragalactic Background Light (EBL) carries unique information regarding the galaxy formation and evolution history. The LAT should be able to measure the EBL redshift evolution in the optical/UV band via the attenuation in the high-energy flux from high-redshift blazars (Chen et al. 2004). Thanks to the large population of such blazars that should be detected by the LAT, one expects to be able to disentangle the attenuation due to the EBL from intrinsic effects. However, since the cutoff energy will lie in the 50 GeV range, a long integration time (~ 1 year) will be necessary. More details regarding the LAT capabilities with respect to this topic can be found in Reyes et al. 2006.

"Science Goals"

This table lists the specific issues regarding the physics of blazars that the LAT will enable us to address. 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. For each issue, the approach foreseen is given, as well as the most suitable targets. The last column provides the nature of the simultaneous/contemporaneous multi-wavelength data required to shed light on these issues.

Issue	Approach	Targets	Data (quality)
Jet structure/ composition: innermost part (ionic,e^+e^-,Poynting flux)	Search for "X-ray pre-cursors" to γ-flares, time delays (reveal e^+e^- content)	flaring bright blazars	soft X-ray, pre- to post-flare (~2 weeks, sample every 3 hrs)
Jet structure/ composition: γ-ray emitting part (pe^-,e^+e^-,B)	Identify operating radiation processes via broadband modeling with state-of-the-art emission models leptonic vs hadronic models?	bright variable FSRQs, LBLs	Simultaneous broadband SED + variable info (hysteresis, light curve, flare profiles)
	Estimate total jet luminosity: $U_{particle} + U_B + U_{kin,jet}$	blazars that are hard X-ray sources	hard X, soft γ-ray data
	Search for neutron-decay/cascade features	flaring bright QSOs, HBLs, radio galaxies	X and TeV; multi-λ at most highly variable synchrotron flares
Location of γ-ray production site	LE/HE cospatial/single zone? - measure lags of IR/opt/UV/X-ray/TeV to γ-rays	flaring HBLs	Simultaneous monitoring in IR/opt/UV/X-ray/TeV to temporally resolve flares
Location of energization site	$\tau_{\gamma\gamma}$ to set minimum distance of emitting region from black hole, and Γ_{bulk}	FSRQs	correlated X-ray
γ-ray flare production: importance of external photon fields	Measure of putative target photon fields (BLR, torus, accretion disk)	FSRQs, LBLs	BLR line strength during γ-activity
γ-ray flare production: relation to U_B dissipation	Modeling of correlated variability behavior between opt-GeV,X-TeV	flaring bright blazars	Simultaneous monitoring in IR/opt/UV/X to temporally resolve flare, long data trains
	Polarization behavior near LE-peak at time of γ-flare	bright QSOs with peak at IR/optical	Optical polarization at hour temporal resolution

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