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# The role of GLAST in multiwavelength observations of bright TeV blazars

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**Abstract:** The TeV blazars Mrk 421, Mrk 501, PSK 2155-304 and 1ES1959+650 are among the brightest known blazars, yet the existing experimental set of data does not allow one to make unambiguous statements about the physical mechanisms responsible for the electromagnetic emission. The lack of sensitive coverage in the energy range 1 MeV to 500 GeV (up to 2004), and the scarce truly simultaneous data result in a big inter-model and intra-model degeneracy. The LAT instrument on board of the GLAST satellite, which will start operation at the beginning of 2008, aims to perform gamma-ray astronomy in the energy range 20 MeV to 300 GeV. The sensitivity of LAT is about 25 times better than its predecessor, EGRET. Together with the enhanced sensitivity of the current generation of Imaging Air Cherenkov Telescopes (IACTs) in the energy range 100 GeV  500 GeV, LAT observations offer unprecedented capabilities to study the high energy emission of these objects in both quiescent and flaring state.

## Introduction

The large inferred luminosities of Active Galactic Nuclei (AGNs) led to a standard model of beamed AGN emission, with the ultimate energy source being the release of gravitational potential energy of matter from an accretion disk surrounding a supermassive black hole [1]. Although this general model has won broad support, discussion on the detailed emission processes underlying the broadband spectral energy distribution (SED) of AGNs is still ongoing.

Particularly interesting for the $\gamma$-ray community are the *blazars*, which are AGNs containing jets of plasma moving at relativistic speed towards the observer. A distinctive feature of blazars is their continuum emission, clearly non-thermal from radio to $VHE$ frequencies and characterized by two broad bumps in the $\nu F_\nu$ representation, peaking at, respectively, IR/X-ray and $\gamma$-ray frequencies [2, 3, 4]. Most (15 out of 16) of the well established extragalactic TeV sources belong to the subclass *High peaked BL Lac* (HBL), which are blazars with relatively low bolometric luminosity whose SED peaks are located at high energies ($X-rays$ and $VHE\ \gamma-rays$). Within current observational constraints, the Synchrotron Self-Compton models (thereafter SSC) are widely believed to provide an adequate description of the dominant emission process in blazar jets.

Another very exciting feature of blazars, is that they show states of high activity (*flaring state*), in which the emitted electromagnetic radiation can increase by more than one order of magnitude. The flaring states detected in the X-ray and TeV range are often characterized by spectral flux changes with respect to low state flux (see below), and the TeV fluxes are often correlated (up to some extent) with a flux increase in X-ray and sometimes also in the optical energy range.

Despite HBLs are being observed for tens of years, the existing experimental set of data does not allow one to make unambiguous statements about the physical mechanisms responsible for the electromagnetic emission. The lack of sensitive coverage in the energy range 1 $MeV$ to 500 $GeV$, and the scarce truly simultaneous data result in a big inter-model and intra-model degeneracy, which allows many theoretical models to accomodate the existing data. More and higher quality data at GeV-TeV energies are required for the understanding of these objects. This applies particularly at data corresponding to the *low state* of the blazars, where the previous instruments were not sensitive enough to obtain significant detections in reasonably short times. Some of the still open questions are very fundamental; the particle content of the jets (leptons/hadrons), intrinsic vs observed (EBL-affected) spectra, production of flares with timescales down to 1 min, acceleration/cooling in single or multi-zone, the role of external photon fields ...

The GLAST satellite, which is expected to be launched at the end of 2007, will shed some light into these puzzles. The main instrument onboard of the GLAST satellite is the Large Array Telescope (LAT). LAT will perform $\gamma$-ray astronomy in the energy range from $\sim$20 MeV to $\sim$300 GeV. Technical details of the detector, working principle and performance of LAT can be found elsewhere [5, 6]. For the purpose of this discussion, we only show in figure 1 the sensitivity of the instrument after 1 day, 1 month and 1 year of observation. Note that the sensitivity of LAT is best in the energy range 0.1-10 GeV, with the sweetest point moving slightly towards higher energies as the observing time increases. LAT will provide the scientific community with very valuable data in this poorly explored energy range. Together with the enhanced sensitivity and reduced energy thresholds ($\sim$ 0.1 TeV) of the current generation of IACTs, such as HESS, MAGIC and VERITAS, the proper characterization of the high energy emission of the most powerful TeV blazars will hopefully become a reality in the next 2 years.

## LAT capabilities on the bright TeV blazars: Mrk 421, Mrk 501, PKS 2155-304, 1ES1959+650

In the context of understanding the physical processes occuring in blazars, The GLAST/LAT group is organizing multiwavelength campaigns on the relatively nearby and bright TeV blazars **Mrk 421** ($z$ = 0.031), **Mrk 501** ($z$ = 0.034),

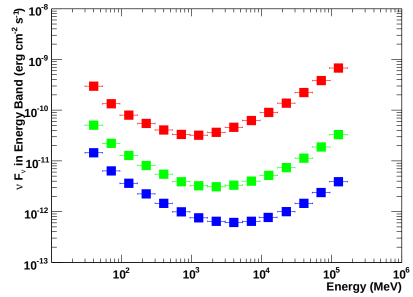


Figure 1: Sensitivity of the LAT instrument. The differential sensitivity points are defined as the flux level over an energy interval of 1/4 of a decade over which the statistical significance is 2 standard deviations in 1 day (red), 1 month (green) and 1 year (blue).

**1ES1959+650** ($z$ = 0.047), and **PKS2155-304** ($z$ = 0.117).

These objects have been intensively observed in the past; yet the physics governing them is far from being understood. Even though these four sources are very powerful TeV emitters, very little is known in the GeV range. Mrk421 and PKS2155-304 are in the 3rd EGRET catalogue [7], yet Mrk501 and 1es1959+650 are not. The EGRET source 3EG J1959+6342 is located $\sim$1.5 degrees away from 1ES1959+650, and can be considered as an upper limit for the average emission of this blazar. As far as Mrk 501, the only EGRET detection is reported in [8]; the source was detected at 5 sigmas during a flaring episode. It was however not detected during 1997, when the source underwent into a extremely high state at TeV energies.

Figures 2 and 3 show past measurments of these sources. Simple estimates for the expected flux in the energy range 0.1-10 GeV according to the the SSC model fits are also depicted. The required times to achieve a 5 sigma detection of those fluxes are reported in table 1. Note that the GLAST/LAT sensitivity permits the detection of these sources in observing times as low as several days, which is more than one order of magnitude better than EGRET.

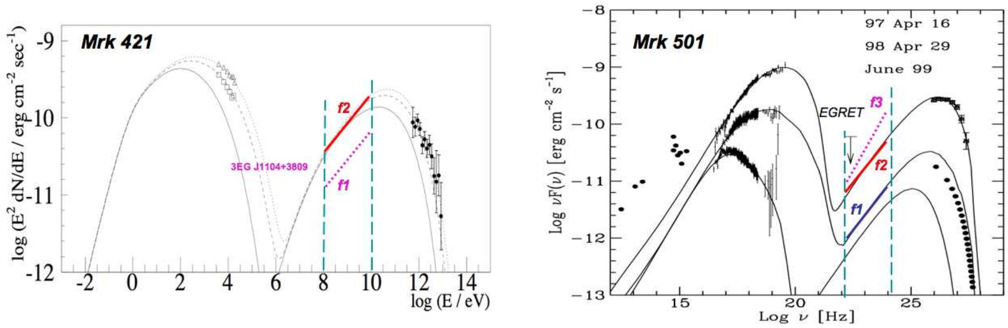


Figure 2: **Left)** Observed and modeled SEDs for Mrk 421. Squares and triangles show the RXTE spectra measured from MJD 51,581.1048-51,581.1148 and 51581.3557-51581.3652, respectively. Filled circles show the HEGRA data measured during MJD 51581.0702-51581.2119; which included the first RXTE pointing. Solid, dashed and dotted lines show the SSC model predictions for the low-flux spectrum before the flare, and during the first and the second RXTE pointing, respectively. Figure taken from [9]. The pink dotted line corresponds to the flux of the EGRET source 3EG J1104+3809, which is positionally coincident with Mrk 421 (obtained from [7]). **Right)** Observed and modeled SEDs for Mrk 501. The X-ray data are from observations with BeppoSAX performed on 1997 April, 1998 April, and 1999 June. The squares are data from CAT recorded in 1997 April [10], and the filled circles are data from HEGRA recorded in 1998-1999 [11]. The solid lines show several SSC model predictions for the different flaring states. Figure taken from [12]. The pink dotted line corresponds to the only detection (∼5 sigma) of Mrk501 with EGRET; which was obtained during a flare in 1996 [8].

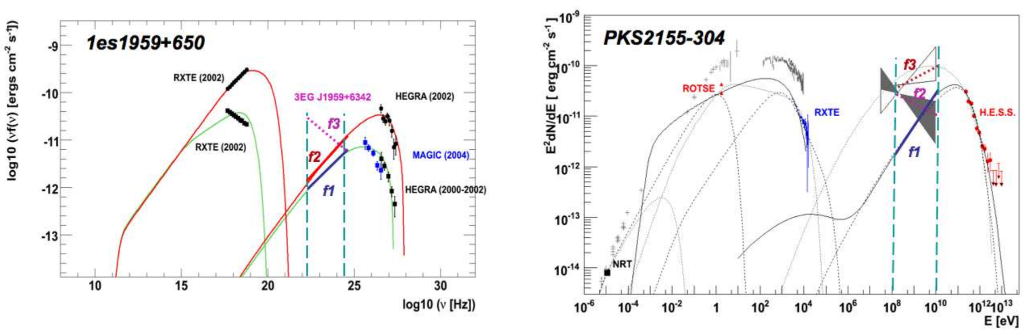


Figure 3: **Left)** Observed and modeled SED of 1ES1959+650 obtained during various epochs. The x-ray points are RXTE data taken during June 14th 2002 [13]. The black square points are data from HEGRA during the observing campaign 2000-2001 ($\sim\ 100\ hours$). Data extracted from [14]. The blue circles are data from MAGIC during the observing campaign of 2004 ($\sim\ 7\ hours$). Data extracted from [15]. In both occasions, the source was in quiescent state. The $VHE$ spectra are corrected for EBL extinction using the 'Low' EBL model described in [16]. The one zone SSC modeling of the spectra was performed with the code presented in [13]. The pink dotted line corresponds to the EGRET source 3EG J1959+6342, which is located ∼1.5 degrees away from 1ES1959+650, and can be considered as an upper limit for the average emission of this blazar. **Right)** Observed and modeled SED of PKS2155-304 in a low state, with 3 different emission models from [17]. The bowties and corresponding red and pink dotted lines are a high state seen by EGRET, and the average spectrum from the 3rd EGRET catalog [7].

| Spectral Flux | $Time_{TS=25}$ (day) | $\Delta F_{>0.1GeV}$ (%) | $\Delta\alpha$ (%) |
|---|---|---|---|
| Mrk421:*f1* | 0.6 | 60 | 14 |
| Mrk421:*f2* | 0.2 | 56 | 14 |
| Mrk501:*f1* | 7 | 62 | 13 |
| Mrk501:*f2* | 0.7 | 63 | 13 |
| Mrk501:*f3* | 0.2 | 68 | 13 |
| 1es1959:*f1* | 33 | 62 | 12 |
| 1es1959:*f2* | 17 | 66 | 13 |
| 1es1959:*f3* | 10 | 28 | 8 |
| PKS2155:*f1* | 4 | 58 | 12 |
| PKS2155:*f2* | 5 | 34 | 9 |
| PKS2155:*f3* | 0.5 | 52 | 13 |

Table 1: Observation times required for a 5 sigma detection ($Time_{TS=25}$) of the spectral fluxes depicted in figures 2 and 3. These estimates are valid for *survey mode operation*, in which GLAST scans the entire sky every 3 hours. The statistical uncertainties in the flux above 0.1 GeV ($\Delta F_{>0.1GeV}$) and the spectral index ($\Delta\alpha$) for those obs. times are also reported.

Therefore, GLAST will bring key data from these frequencies. Note however that, since these sources have a broad and time-evolving energy spectra, the data from one instrument alone is certainly not sufficient to study the physics governing those objects. The GLAST/LAT group is currently planning multiwavelength campaigns on these objects, covering frequencies from radio up to VHE $\gamma$-ray energies. The merit of those observations is the investigation of *a)* the (short and long term) flux variability, which is probably energy-dependent. This involves the study of the correlation and time lags between the different energies; *b)* the spectral changes in the spectrum, namely the hardening in the spectrum and the (possible) displacement of the position of the Synchrotron peak and the inverse Compton peak. Both aspects are deeply related to the physical mechanisms responsible for the acceleration of particles in the source, thus have the ability to break many model degeneracies. We also aim to perform a self-consisting time modeling of the overall spectra of these sources. Note that, because of the high $\gamma$-ray brightness, these are one of the very few sources where time modeling is feasible with current instruments. The results from these studies might be extended to other blazars which are weaker (in $\gamma$-rays), or located at further distances.

## Conclusions

The GLAST/LAT instrument will start to operate at the beginning of 2008, boosting our current capabilities to study blazars by providing data in the poorly sampled energy range 0.02-100 GeV. However, because of the broad and variable spectra of blazars, simultaneous multiwavelength observations are needed to understand the nature of these objects. Campaigns on the four brightest TeV blazars (namely Mrk421, Mrk501, 1es1959+650 and PKS2155-304) are being planned for 2008; agreements with instruments covering radio to TeV energies are currently being made. Observations at X-ray frequencies with RXTE have already been granted. More information on multiwavelength campaigns with GLAST/LAT on these and other objects can be obtained at http://glast.gsfc.nasa.gov/science/multi/, and general information on the blazar and AGN related topics we aim to address with LAT data can be found at http://www.slac.stanford.edu/ lott/agn.html.

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