

Simultaneous Radio to (Sub-) mm-Monitoring of Variability and Spectral Shape Evolution of potential GLAST Blazars

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Abstract. The Large Area Telescope (LAT) instrument onboard GLAST offers a tremendous opportunity for future blazar studies. In order to fully benefit from its capabilities and to maximize the scientific return from the LAT, it is of great importance to conduct dedicated multi-frequency monitoring campaigns that will result comprehensive observations. Consequently, we initiated an effort to conduct a GLAST-dedicated, quasi-simultaneous, broad-band flux-density (and polarization) monitoring of potential GLAST blazars with the Effelsberg and OVRO radio telescopes (11 cm to 7 mm wavelength). Here, we present a short overview of these activities which will complement the multi-wavelengths activities of the GLAST/LAT collaboration towards the 'low-energy' radio bands. Further we will give a brief outlook including the extension of this coordinated campaign towards higher frequencies and future scientific aims.

Keywords: blazars, variability, radio bands, broad-band emission, radiation mechanisms: non-thermal

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INTRODUCTION

The well known and unusual properties of blazar-type AGNs (e.g. extreme variability, high degree of polarisation, highly superluminal motions and brightness temperatures exceeding the inverse Compton limit; e.g. [11]) are collectively interpreted within the context of emission originating in relativistic jets oriented very close ($\leq 20 - 30^\circ$) to the line of sight (e.g. [10]).

The overall emission scenario explaining the double-humped spectral energy distribution (SED) of blazars (e.g. synchrotron emission plus synchrotron self-Compton (SSC) and/or external Compton (EC), hadronic processes) is still poorly understood. So is the case for the origin of the observed flux density and polarisation variability on time scales of weeks to months. The study of this rapid blazar variability in the radio bands provides insight into the AGN structure on linear scales or flux density levels not accessible even to interferometric imaging. Here, different models are discussed such as shock-in-jets (e.g. [6]) or colliding relativistic plasma shells (e.g. [4]). Further, in the case of precessing binary black-hole systems, rotating helical jets or helical trajectories of plasma elements, they suggest changes in the direction of forward beaming, thus introducing flares due to the lighthouse effect (e.g. [3], [2], [12]). Hence, variability studies furnish important clues about size, structure, physics and dynamics of the emitting region. Here, AGN/blazar monitoring programs are of great importance as they provide the necessary observational constraints for the different theoretical models towards understanding the physical origin of energy production in AGN.

A powerful tool in the study of relativistic jets is the analysis and modeling of the simultaneous spectral and temporal behavior of blazars, over frequency bands as broad as possible (ideally covering the whole SED from radio to TeV energies). In particular, it allows the detailed study of different emission mechanisms and variability scenarios. So far, this was usually limited to particular well suited cases, e.g. BL Lacertae and 3C 279 (e.g. [7], [13]) often combining not truly simultaneous broad-band data. The demand for quasi-simultaneity is important in view of the high activity and rapid variability of these sources. Here, the lack of continuous, (quasi-) simultaneous observations at all wavebands and the historical lack of sufficient γ -ray data hampered past efforts to understand and study in detail the broad-band jet emission. This situation will dramatically change thanks to the launch of the GLAST satellite. The LAT detector onboard GLAST with a sensitivity of a factor of ~ 30 increased over EGRET is expected to detect more than a thousand blazars and to observe γ -ray spectra resolved at a variety of time scales. Furthermore, dense sampled flux monitoring data is expected due to LAT's large field-of-view (2.4 sr) and the GLAST's survey observing mode. Consequently, GLAST will provide a tremendous opportunity for future, systematic blazar studies addressing important, still open questions about the physical processes involved.

GLAST DEDICATED MULTI-WAVELENGTHS OBSERVATIONS

In order to fully benefit from these offered GLAST capabilities and to interpret the high energy data in comparison with theoretical models, the GeV γ -ray observations have to be combined with an extensive suite of multi-wavelength (MW) observations of satisfactory spectral and temporal coverage. Consequently, dedicated MW monitoring campaigns are required which will produce comprehensive and complementary observations for a large number of potential GLAST blazars (see also Tosti et al., current proceedings).

In this framework, the GLAST/LAT AGN science group is planning extensive broad-band campaigns including ToO observations of flaring sources, MW Planned Intensive Campaigns (PICs) and MW long-term monitoring (Tosti et al., current proceedings). These activities also include proposals to facilities such as Chandra, RXTE, Spitzer, Suzaku, *INTEGRAL*. In addition, IR/optical monitoring observations are performed with several telescopes.

THE 'LOW-ENERGY' BANDS: COORDINATED CM- TO MM-MONITORING OF POTENTIAL GLAST BLAZARS

In order to complement these MW activities towards the 'low-energy' synchrotron part of blazar SEDs, we initiated a GLAST dedicated monitoring campaign in a mutual effort between the MPIfR and the Caltech group. Both groups jointly are now starting a broad-band flux density and polarization monitoring of potential GLAST blazars. It is planned that at 15 GHz the Owens Valley Radio Observatory (OVRO) 40m telescope will soon start to monitor a large number of radio sources per day (about 1000 GLAST candidates), thus providing e.g. a quasi-continuous record of activity (flaring states, 'variability index', duty cycles etc.) that can later be combined with (quasi-) simultaneous MW - in particular GLAST γ -ray - observations.

Complementary, a sub-sample of initially ~ 50 sources (later more) are being monitored with the 100m Effelsberg radio telescope (EB). The Effelsberg telescope provides high sensitivity, fast frequency-switching and polarisation capabilities, as well as a broad frequency coverage. Consequently, EB is the ideal instrument to obtain high-precision, densely time-sampled and (quasi-) simultaneous broad-band (11 cm to 7 mm) data for a larger sub-sample of sources in a reasonable amount of observing time. The EB monitoring program started recently (January 2007) with observations at 110, 60, 36, 28, 20, 13, 9 and 7 mm wavelengths which are planned to be continued over the next years with a sampling of one epoch every 3–4 weeks. The present source list comprises a list of ~ 50 'famous', bright and flat-spectrum blazars selected from the 'high priority blazar list' of the LAT AGN science group, i.e. those sources which will be of highest interest for later MW studies with the LAT instrument. The sources were selected such that (i) the list includes all sources which will be target of future, coordinated and intensive MW campaigns by the LAT AGN group, and (ii) a maximum overlap with current VLBI projects is achieved, i.e. 35 of the selected objects are also part of the MOJAVE monitoring program (see also Lister et al., Kadler et al. current proceedings) and thus are regularly observed with VLBI.

TOWARDS HIGHER FREQUENCIES (MM-, SUB-MM BANDS, IR/OPTICAL)

An important next step is to complement this monitoring efforts with observations at shorter wavelengths (mm/sub-mm). In the standard synchrotron scenario of evolving outbursts, the flux density variability appears first at higher frequencies (e.g. optical/X-ray) and then propagates through the spectrum towards longer wavelengths. Here, the variability at short mm/sub-mm bands is usually much more pronounced and faster than in the longer cm-radio regime. Hence, complementary observations at short mm to sub-mm bands are crucial as they provide the important link between the long wavelengths radio bands (OVRO/EB) and the more energetic IR/optical/X-ray regime, where blazars usually show their maximum synchrotron output.

The IRAM 30 m telescope on Pico Veleta (PV) is the ideal instrument to effectively fill this gap (3, 2, 1.3 mm) due to its high sensitivity, frequency coverage/agility and now also polarisation capabilities. Hence, a coordinated effort between EB/OVRO and PV is planned and was proposed to combine and intensify the ongoing monitoring at PV ([9]). If successful, this coordinated campaign will provide densely time-sampled, precise and (quasi-) simultaneous broad-band (11cm to 1 mm) spectra and variability data for a large number of potential GLAST blazars. Additionally, efforts are currently being put in employing sub-mm facilities as well in order to further extend the wavelength coverage towards the sub-mm bands.

In addition, we further aim at extending these broad-band monitoring efforts with quasi-simultaneous observations in the IR/optical regime. Here, observing time was already approved and observations (V/R/I/H bands) will be performed with the 1.2m Kryoneri telescope (Greece), the Rapid Eye Mount (REM) in Chile and the Perugia automatic telescope in Italy (see also Tosti et al., current proceedings).

OUTLOOK

Finally, we will give a short summary of the possibilities which this monitoring campaign will provide for future blazar studies in the upcoming GLAST era. The broad-band monitoring presented here will in detail allow to perform:

(i) Variability and spectral evolution studies across the cm- to (sub-) mm-bands: This includes e.g. the study of the frequency dependent variability of a large blazar sample, e.g. to search for correlations, time lags etc. in comparison with variability models; the determination of variability Doppler factors and a first-time systematic study of polarisation variability at mm-wavelengths in comparison with the cm-regime; the study of simultaneous radio spectra (which are not affected by the overall variability) and their evolution (spectral indices, turnover) in comparison with synchrotron/variability models (e.g. [8], [5]). The polarisation information will further allow to e.g. determine magnetic fields and systematically study rotation measures.

(ii) VLBI related studies: Here, a strong overlap with VLBI and AGN jet physics exists. Since many sources of our sub-sample are included in current VLBI projects (MOJAVE as well as 3 mm GMVA monitoring), a combination with quasi-simultaneous VLBI data becomes possible. This will allow to directly relate the observed VLBI structure and jet kinematics to the overall single-dish flux density, spectral variability and Doppler factors, e.g. to study possible flare-ejection relations and to identify the jet-regions responsible for the cm/mm-variability (e.g. [1]).

(iii) Broad-band studies in the GLAST era: The monitoring efforts presented here will complement and support the future MW activities (IR/optical/X-ray/ γ -ray/TeV) of the GLAST/LAT collaboration towards the 'low-energy' radio bands. In this framework, future MW studies will include e.g. (quasi-) simultaneous, time-resolved broad-band (radio to γ -ray-) spectra in comparison with jet emission models (leptonic vs. hadronic models, SSC/EC etc.); the interplay between the variability across all bands (correlations, time lags etc.) - in particular in view of the GLAST γ -ray data - and the study of geometrical and radiation induced variability. In combination with VLBI, these efforts will furthermore allow to investigate the jet regions responsible for the γ -ray emission and to study in more detail e.g. the relation between γ -ray flares and newly ejected jet components on VLBI scales.

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