BLAZARS: THE GAMMA-RAY VIEW OF AGILE

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Since its launch in April 2007, the AGILE satellite detected with its Gamma-Ray Imaging Detector (GRID) several blazars at high significance: 3C 279, 3C 454.3, PKS 1510–089, S5 0716+714, 3C 273, W Comae, Mrk 421 and PKS 0537–441. Moreover, AGILE was able both to rapidly respond to sudden changes in blazar activity state at other wavelengths and to alert other telescopes quickly in response to changes in the gamma-ray fluxes. Thus, we were able to obtain multiband data from other observatories such as \textit{Spitzer}, \textit{Swift}, RXTE, \textit{Suzaku}, INTEGRAL, MAGIC, VERITAS, as well as radio-to-optical coverage by means of the GASP Project of the WEBT and REM. This large multifrequency coverage gave us the opportunity to study the Spectral Energy Distribution of these sources from radio to gamma-rays energy bands and to investigate the different mechanisms responsible for their emission. We present an overview of the AGILE results on these gamma-ray blazars and the relative multifrequency data.

1 Introduction

Blazars are a subclass of Active Galactic Nuclei (AGN) characterized by the emission of strong non-thermal radiation across the electromagnetic spectrum, from radio to TeV energy bands. The typical observational properties include irregular, rapid and often very large variability, apparent super-luminal motion, flat radio spectrum, high and variable polarization at radio and optical frequencies. These features are interpreted as the result of the emission of electromagnetic radiation from a relativistic jet that is viewed closely aligned to the line of sight (Blandford & Rees\textsuperscript{1}, Urry & Padovani\textsuperscript{2}). The EGRET instrument onboard Compton Gamma-Ray Observatory (CGRO) detected for the first time strong and variable high energy $\gamma$-ray emission from blazars in the MeV–GeV region and together with coordinated multiband observations provided evidence that the Spectral Energy Distributions (SEDs) of the blazars are typically double humped with the first peak occurring in the IR/optical band in the Flat Spectrum Radio Quasars (FSRQs) and in UV/X-rays in the BL Lacertae objects, depending by the total jet power of the source. This first peak is interpreted as synchrotron radiation from high-energy electrons in a relativistic jet. The SED second component, peaking at MeV-GeV energies in the FSRQs and at GeV-TeV energies in the BL Lacs, is commonly interpreted as inverse Compton scattering of seed photons, internal or external to the jet, by highly relativistic electrons (Ulrich et al.\textsuperscript{3}), although other models involving hadronic processes have been proposed (see e.g. Böttcher\textsuperscript{4} for a recent review).

With the advent of the AGILE and Fermi-GST $\gamma$-ray satellites, together with the ground based Imaging Atmospheric Cherenkov Telescopes H.E.S.S., MAGIC and VERITAS, a new exiting era for the gamma-ray extragalactic astronomy and in particular for the study of blazars is now open and in conjunction with a complete multiwavelength coverage will allow us to shed
light on the structure of the inner jet and the emission mechanisms of this class of objects.

2 Blazars and AGILE

AGILE (Astrorivelatore Gamma ad Immagini LEggero) is an Italian Space Agency (ASI) mission successfully launched on 23 April 2007 and capable of observing cosmic sources simultaneously in X-ray and γ-ray energy bands. The Gamma-Ray Imaging Detector (GRID) consists of a Silicon Tracker, a non-imaging CsI Mini-Calorimeter and a segmented anticoincidence system; the GRID is optimized for γ-ray imaging in the 30 MeV–30 GeV energy band. A co-aligned coded-mask hard X-ray imager (SuperAGILE) ensures coverage in the 18–60 keV energy band.

Gamma-ray observations of blazars are a key scientific project of the AGILE satellite (Tavani et al.5). In the last two years, the AGILE satellite detected several blazars during high γ-ray activity and extensive multiwavelength campaigns were organized for many of them. Table 1 shows the list of AGILE flaring blazars observed up now. The γ-ray activity timescales goes from a few days (e.g. S5 0716+714) to several weeks (e.g. 3C 454.3 and PKS 1510–089) and the flux variability observed has been negligible (e.g. 3C 279), very rapid (e.g. PKS 1510–089) or extremely high (e.g. 3C 454.3 and PKS 1510–089). Only few objects were detected more than once in flaring state by AGILE and only already known γ-ray emitting source showed flaring activity. This evidence together with the early results from the first three months of Fermi-LAT γ-ray all-sky survey (Abdo et al.) suggest possible constraint on the properties of the most intense γ-ray emitters. In the following section we will present the most interesting results on multiwavelength observations of the individual sources detected by AGILE.
3 Individual Sources

3.1 3C 454.3

3C 454.3 is the blazar which exhibited the most variable activity in the $\gamma$-ray sky in the last two years. In the period July 2007–January 2009 the AGILE satellite monitored intensively 3C 454.3 together with Spitzer, WEBT, REM, MITSuME, Swift, RXTE, Suzaku and INTEGRAL observatories, yielding the longest multiwavelength coverage of this $\gamma$-ray quasar so far. The source underwent an unprecedented long period of very high $\gamma$-ray activity, showing flux levels variable on short timescales of 24–48 hours and reaching on daily timescale a $\gamma$-ray flux higher than $400 \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$. Also the optical flux appears extremely variable with a brightening of several tenths of magnitude in a few hours. The comparison of the light curves shows that the emission in the optical and $\gamma$-ray bands appears to be well correlated, with a time lag less than one day, as confirmed also by the analysis of the early Fermi-LAT data in Bonning et al.\textsuperscript{7}. The dominant emission mechanism over 100 MeV seems to be the inverse Compton scattering of relativistic electrons in the jet on the external photons from the Broad Line Region (BLR), even if the $\gamma$-ray spectrum observed by AGILE in December 2007 seems to require also the contribution of external Compton of seed photons from a hot corona.

3.2 PKS 1510–089

PKS 1510–089 showed in the last two years high variability over all the electromagnetic spectrum, in particular an high $\gamma$-ray activity was detected by AGILE with two intense flaring episodes in August 2007 and March 2008 and an extraordinary activity during the entire March 2009 with several flaring episode and a flux reaching $500 \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$. The multiwavelength data carried out by GASP-WEBT and Swift in 2008–2009 seems to indicate the presence in the spectrum of thermal features quasar-like such as the little blue bump and the big blue bump. Instead the X-ray spectrum exhibits a soft X-ray excess, of which the nature is unclear but that could be a feature of the bulk Comptonization mechanism. Moreover, the Swift/XRT observations seems to show a redder-when-brighter behaviour in X-rays (i.e. the spectrum is harder when the source is brighter) already observed by Kataoka et al.\textsuperscript{8} in this source.

3.3 3C 279

3C 279 is the first extragalactic source detected by AGILE in the $\gamma$-ray band. The average $\gamma$-ray flux over 4 days of observation is $F_{E>100\, \text{MeV}} = (210 \pm 38) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$, similar of the high state observed by EGRET. A strong minimum in the optical band was detected by REM two months before the GRID observations. The spectrum of this source during the flaring episode observed by AGILE is soft ($\Gamma = 2.22 \pm 0.23$) and this could be an indication of a low accretion state of the disk occurred some months before the $\gamma$-ray observations, suggesting a dominant contribution of the external Compton scattering of direct disk (ECD) radiation compared to the external compton scattering of the Broad Line Region clouds (ECC). In fact the reduction of the activity of the disk should cause the decrease of the photon seed population produced by the disk and then a deficit of the ECC component with respect to the ECD, an effect delayed of the light travel time required from the inner disk to the BLR.

3.4 3C 273

3C 273 was the first extragalactic source detected simultaneously by the GRID and SuperAGILE detectors during a multiwavelength campaign over three weeks between December 2007 and January 2008 involving also simultaneous REM, Swift, RXTE and INTEGRAL coverage. The average flux in the 20–60 energy band is $(23.9 \pm 1.2)$ mCrab, whereas the source was detected
by the GRID only in the second week, with an average flux of $F_{E>100\text{MeV}} = (33 \pm 11) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$. The comparison of the light curves seems to indicate a possible anti-correlation between the $\gamma$-ray emission and the soft and hard X-rays. The SED is consistent with a leptonic model where the soft X-ray emission is produced by the combination of SSC and EC models, while the hard X-ray and $\gamma$-ray emission is due to external Compton scattering by thermal photons of the disk. The spectral variability between the first and the second week is consistent with the acceleration episode of the electron population responsible for the synchrotron emission.

3.5 S5 0716+714

The intermediate BL Lac object S5 0716+714 was observed by AGILE during two different periods: 4–23 September and 23 October – 1 November 2007. In mid September the source showed an high $\gamma$-ray activity with an average flux of $F_{E>100\text{MeV}} = (97 \pm 15) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$ and a peak flux of $F_{E>100\text{MeV}} = (193 \pm 42) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$. This is one of the most high flux observed by a BL Lac object. An almost simultaneous GASP-WEBT optical campaign started after the AGILE detection and the resulting SED is consistent with a two-components SSC model. Recently Nilsson et al.\cite{nilsson} has estimated the redshift of the source ($z = 0.31 \pm 0.08$) and this allowed us to calculate the total power transported in the jet, which results extremely high and at limit of the maximum power generated by a spinning black hole of $10^9$ M$_\odot$.

During October 2007, AGILE detected the source at a flux about a factor 2 lower than September one with no significant variability. Instead, Swift observed strong variability in soft X-ray, moderate variability at optical/UV and approximately constant hard X-ray flux. Also this behaviour is compatible with the presence of two different SSC components in the SED.

3.6 Mrk 421

During a ToO towards W Comae on June 2008, AGILE surprisingly detected also this HBL object. SuperAGILE detected a fast increase of flux from Mrk 421 up to 40 mCrab in the 15–50 energy band, about a factor 10 higher than its typical flux in quiescence. The $\gamma$-ray flux detected by GRID, $F_{E>100\text{MeV}} = (42 \pm 13) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$, is about a factor 3 higher than the average EGRET value, even if consistent with its maximum. An extensive multiwavelength campaign from optical to TeV energy bands was organized with the participation of WEBT, Swift, RXTE, AGILE, MAGIC and VERITAS. The light curves show a possible correlated variability between optical, X-rays and the high part of the spectrum. The SED can be interpreted within the framework of the SSC model in terms of a rapid acceleration of leptons in the jet. A more complex scenario is that optical and X-ray emission come from different regions of the jet, with the inner jet region that produces X-rays and is partially transparent to the optical radiation.

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