Fermi - Swift synergetic campaign on the new gamma-ray blazar PKS 1502+106

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(on behalf of the *Fermi* LAT Collaboration) §

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(the whole external collaboration to this *Fermi-Swift* campaign)

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Introduction

The Large Area Telescope (LAT, Atwood et al. 2009), one of two instruments on the *Fermi* Gamma-ray Space Telescope (Ritz 2007) is a pair conversion detector designed to study the gamma-ray sky in the energy range 20 MeV to >300 GeV. Because of its improved sensitivity with respect to previous missions, large effective area and the nominal all-sky survey observing mode *Fermi* LAT is improving our understanding of gamma-ray blazars as sources of high-energy radiation, as a cosmological population, and as enigmatic variable and flaring objects. As example of the optimal capabilities of *Fermi* in being an all-sky hunter for cosmic high-energy flares, an unprecedented all-sky monitor of GeV source variability, an essential companion of multi-frequency studies (especially when coupled to *Swift)*, we present some highlights about a radio, optical, UV, X-ray, and gamma-ray multi-wavelength campaign dedicated to the new and prominent high energy blazar PKS 1502+106 (also known as OR 103, S3 1502+10, z=1.839). This blazar was observed for the first time in gamma-rays by *Fermi*.

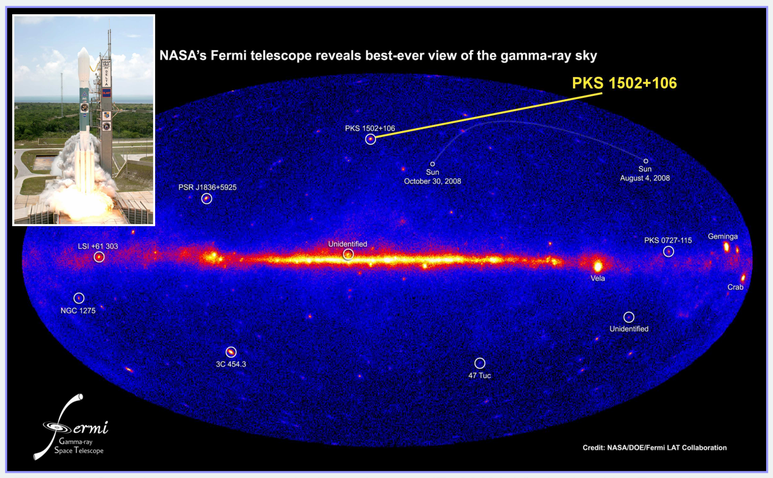

Figure 1. Cumulated gamma-ray sky intensity map (E>300MeV) obtained by Fermi LAT for the time range from 2008 Aug. 04 to 2008 Oct. 30 (3 months, Abdo et al. 2009c), with the highlighted position of the new bright and flaring gamma-ray blazar PKS 1502+106

The gamma-ray outburst of PKS 1502+106

PKS 1502+106 is a luminous and distant, quasar-like (optically broad-line and flat radio spectrum) AGN, previously unknown at gamma-ray energy (George et al. 1994). In the past a cumulated 2-sigma upper limit by EGRET of 7 X 10^{-8} ph cm^{-2} s^{-1} was reported (Phase I, Fichtel 1994) and the source was again not detected in the following EGRET cycles. At the beginning of August 2008, PKS 1502+106 was the second brightest extragalactic source in the gamma-ray sky (Abdo et al. 2009b,2009c), showing a rapid (factor >3 increase in less than 12h) and asymmetric high-energy outburst (Fig.2) announced in ATel #1650. A renewed major activity observed by *Fermi* LAT was reported again in January 2009 (ATel #1905). The LAT outburst triggered the first *Fermi* multi-frequency campaign not planned in advance.

PKS 1502+106 displayed a bright gamma-ray flux and enduring activity, to allow the LAT to detect easily it on a daily basis during the first months of mission (Fig.1, 2). During the 5 days of the asymmetric outbursts the detected averaged flux above 100MeV was (2.91 ± 1.4) X 10^{-6} ph cm^{-2} s^{-1}, and the averaged spectrum was consistent with a single power law model of index -2.06 ± 0.02. Beyond the excellent spatial association (Fig. 4) the most secure and distinctive signature for firm identification of this new gamma-ray source with PKS 1502+106 was the observed correlated multi-waveband variability.

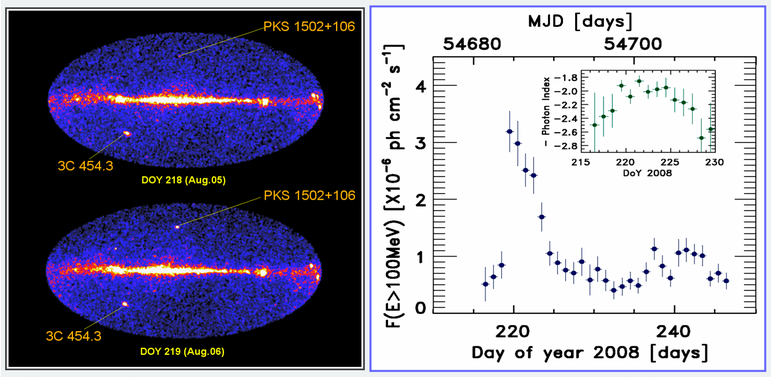

Figure 2: *Left panel*: all-sky daily count maps showing the fast outburst of PKS 1502+106. *Right panel*: likelihood flux (at E>100MeV) light curve of PKS 1502+106 obtained by *Fermi* LAT and reported in daily time bins during August 2008. The outburst state and the subsequent post-flare activity is visible. In the inset panel the photon index daily bin light curve around the outburst period is reported.

The *Fermi-Swift* multi-frequency campaign

The *Fermi* multi-frequency campaign on PKS 1502+106, started soon after the first day of discovered outburst. In this campaign there was the participation of *Swift* (through a triggered ToO, and with a 16-day follow up of this blazar) and, from the ground, of VLBA (through the MOJAVE program), Owens Valley Radio Observatory 40m, Effelsberg-100m, Metsähovi-14m, RATAN-600 and Kanata Higashi-Hiroshima observatories (Fig. 3). The analysis of archival un published observations by INTEGRAL, XMM-Newton and Spitzer space telescopes are also performed for a more complete picture on this source. PKS 1502+106 is a sub-GeV peaked, powerful flat spectrum radio quasar (luminosity about 10^{49} erg s^{-1}), exhibiting marked gamma-ray bolometric dominance, in particular during the outburst (L_γ/L_{opt} about 100, Fig. 5).

The outburst was simultaneously observed from optical to X-ray bands and was likely controlled by in-jet synchrotron self-Compton (SSC) process during from radio-to-X-ray and by Comptonization of external-jet photons (ERC) produced in the broad line region (BLR, Abdo et al. 2009d). The maximum photon energy detected in the first 4-months was 15.8 GeV. Despite the well matched correlation among gamma-ray, X-ray, and UV-optical emission a possible radio counterpart of the LAT outburst can be assumed only if a delay of about 250 days is considered (Fig. 6). The rotation of the electric vector position angle observed by VLBA from 2007 to 2008 (Kovalev et al. 2009, Abdo et al. 2009d) could represent a jet field ordering and alignment, likely a precursor feature of the ejection of a superluminal radio knot and the high-energy outburst (Fig. 6).

Figure 3. A pictorial view of the facilities participating in the multi-frequency and simultaneous *Fermi-Swift* campaign on PKS 1502+106 (with also several radio-optical telescopes from the ground). Data from past archival and unpublished observations of PKS 1502+106 by Spitzer, XMM-Newton and Integral (bottom of the figure) were also analyzed and reported.

These findings are introduced in Ciprini et al. (2009), while the whole comprehensive data and analysis are reported in the first *Fermi* LAT (multi-frequency) paper dedicated to PKS 1502+106 (Abdo et al. 2009d). Figures 4, 5, 6 below, highlight some of such results. The powerful synergy between *Swift*, i.e. X-ray astronomy, and *Fermi*, i.e. gamma-ray astronomy is evident from the level of results obtained.

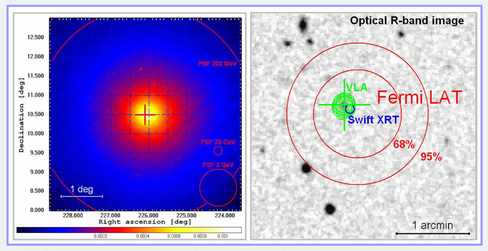

Figure 4: *Left panel*: LAT count map cumulated on a 9-month baseline, weighted and smoothed by the point spread function (PSF). *Right panel*: LAT source localization with 95% and 68% uncertainty radii (red circles, pointlike tool) superimposed on an arcmin-scale (R-band) optical image showing also the X-ray counterpart error box by the Swift-XRT observations and the radio position and intensity contours by VLA of PKS 1502+106.

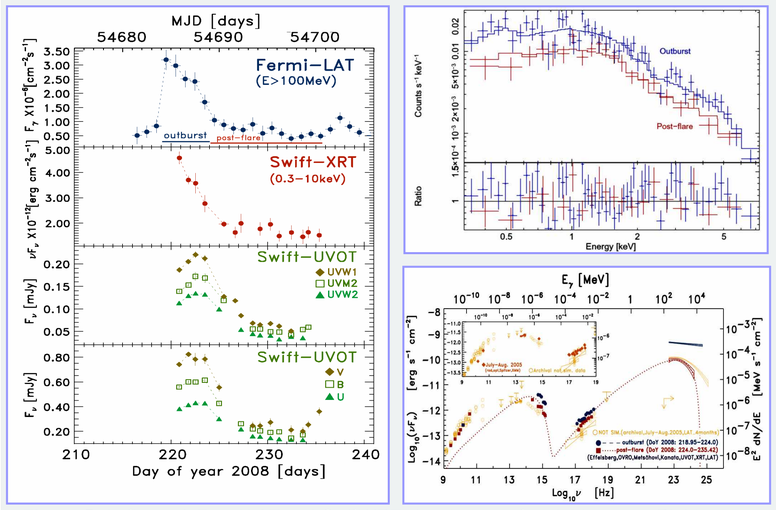

Figure 5: *Left panel: Fermi* LAT and *Swift* XRT simultaneous flux light curves. *Right upper panel:* 0.3-10 KeV spectra of PKS 1502+106 extracted for the high state (MJD: 54685-54689) and the subsequent relaxation phase (MJD 54690-54701), mapping the X-ray behavior during the LAT flare and the days of the post-flare state. *Right lower panel:* the radio-to-gamma-ray averaged SEDs collected during the campaign for the two states.

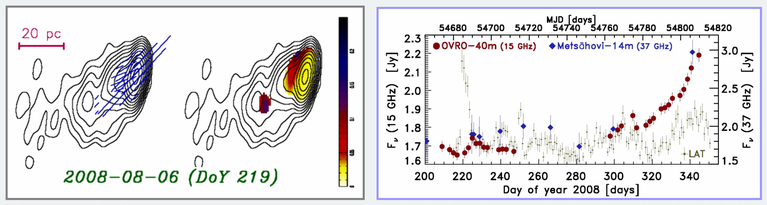

Figure 6: *Left panel:* total intensity and linear polarization image obtained on Aug.06, 2008 (simultaneously to the peak of the LAT outburst) by VLBA at 15 GHz as part of the *Fermi* supporting MOJAVE program. *Right panel:* Long term 15GHz and 37GHz flux light curves obtained by the Owens Valley Radio Observatory (OVRO 40m) and the Metsähovi 14m radio observatory.

§ *NOTE: P. Bruel, T. Burnett, E. Cavazzuti, T. Cheung, J. Chiang, L. Costamante, L. Foschini, L. Fuhrmann, N. Gehrels, S.Germani, M. Giroletti, S. Healey, M. Kadler, B. Lott, G. Madejski, E. Massaro, W. Max-Moerbeck, N. Mazziotta, T. Mizuno, V. Pavlidou, T. Pearson, A. Readhead, J. Richards,, M. Stevenson, H. Takahashi, A. Tramacere, G. Tosti, P. Ubertini, H. Yasuda, and J.A. Zenzus, also participating.*

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