Gamma-ray Variability of Bright *Fermi* LAT Blazars

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on behalf of the Fermi LAT collaboration

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Abstract

Some highlights on gamma-ray light curves and gamma-ray variability properties above 300 MeV of blazars from the Fermi LAT Bright AGN Sample are introduced. Light curves are collected during the first 11 months of all sky survey.

Motivations for study LAT blazar variability

- Variability time scales: flares origin, jet matter content (e^+/e^- vs p^+/e^-), constraints on source size, geometry, emission regions (blazar zone), beaming tests, Doppler factors, bulk motion, black hole masses, luminosity power, classification based on flavor of variability (Fig. 1).
- Correlated variability, time lags: acceleration/deceleration processes, source geometry, external fields (disk, BLR, torus, ambient IR field).
- Hysteresis diagrams (flux vs index): acc./decel., SSC vs ERC models
- Orphan flares and anomalous components: test of SSC models, jet matter content (e^+/e^- vs p^+/e^-), UHECR acceleration.
- Radio knot ejection correlated with GeV flares: jet launching sites, jet acceleration/deceleration
- X-ray precursor: jet matter content (pairs vs Poynting flux, p+/e-), environment. Steady component: inner jet vs extended X-ray jets.
- Source detection problem: faint sources vs background/diffuse fluctuations.
- Multi-band correlated variability: counterpart association and identification
- Mono-band variability studies: local (wavelets, pulse analysis, intermittence vs oscillations) and global (power spectral density, slopes/breaks, 1/f, structure functions, auto-correlation function), linear vs non-linear physics, mathematics/statistics vs physics (Fig. 1, 2).

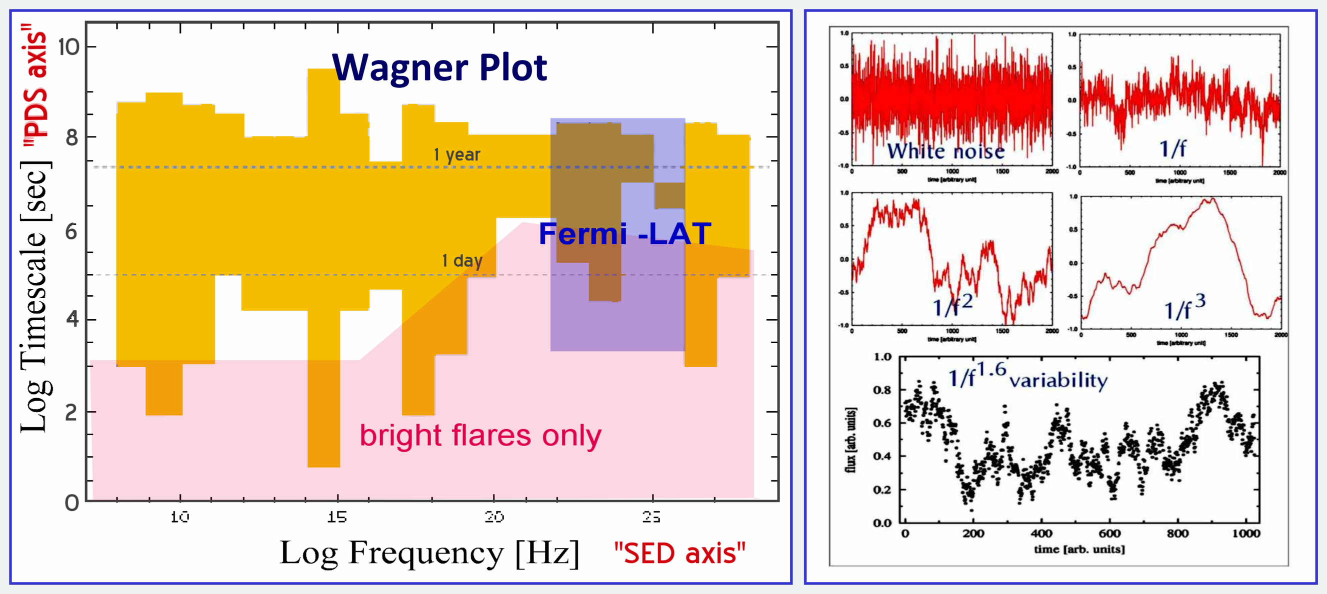

Figure 1: *Left panel*: Multi-waveband variability. the multifrequency SED-PSD plane (i.e. energy-time) explored in the past and accessible by current radio-to-gamma-ray observatories. *Right panel:* Mono-band variability. observed variability (at radio, optical, X-ray bands) of blazar-like sources show the typical $1/f^{\alpha}$ power spectrum decline in a wide range of frequencies *f*. Generally α lies between 1 and 3, i.e. between the pure flickering (pink-noise fluctuations), and a mode beyond Brownian motion (beyond shot-noise).

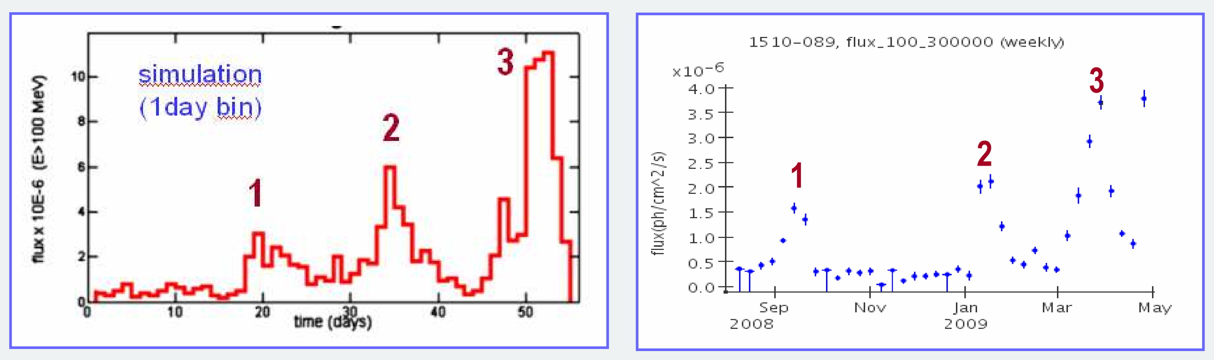

Figure 2: *Left panel*: pre-launch simulations. *Right panel:* one real blazar observed by Fermi LAT (ASP preliminary light curve with weekly-bin).

Bright LAT blazar sources

The first 3 months of sky-survey operation with Fermi LAT revealed 132 bright sources at |b|>10 deg with test statistic greater than 100 (corresponding to about 10σ, Fig. 3). High-confidence associations with known blazars (and 2 radiogalaxies) were found for 106 of these sources. These LAT blazars are used for our first variability analysis.

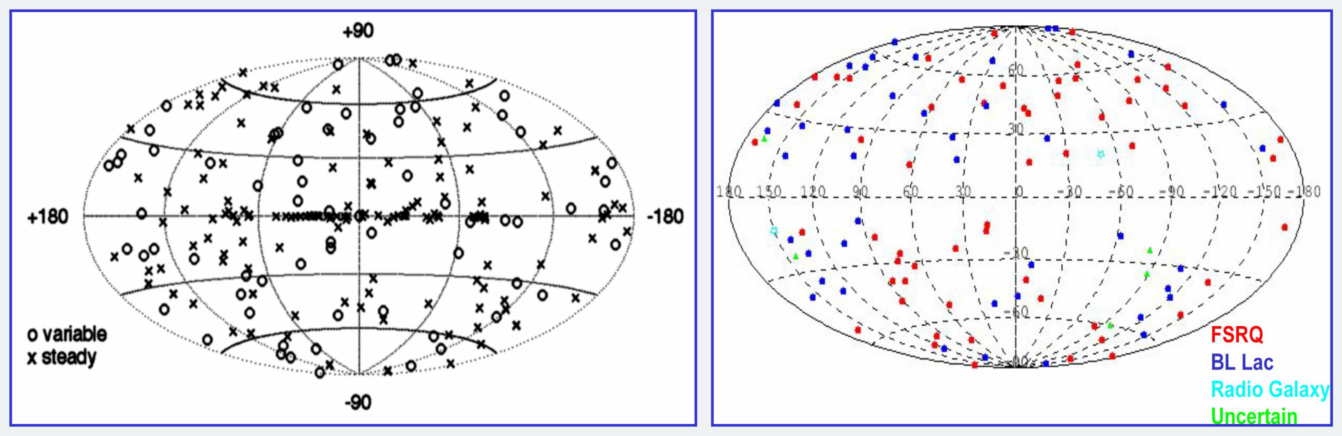

Figure 3: *Left panel* : variable and non-variable LAT bright sources (0FGL catalog, 205 sources with >10 sigma detection) observed during the first 3-months of Fermi all sky survey, based on 1 week time scale. 68/205 show variability with probability > 99%, and have isotropic distribution (i.e. are blazar candidates). *Right panel:* 132 sources with |b| > 10 deg (7 pulsars, 14 unid, the rest are identified blazars). This list of identified blazars is denoted as list of bright AGN sources (LBAS).

11-Month LAT Light Curves and Variability

Integrated flux light curves (E>300 MeV) of these 106 bright LAT blazar sources (LBAS) over the first 11 months of nominal Fermi LAT all sky survey (Aug. 04, 2008 - July 04, 2009), and extracted in weekly time bins are obtained with likelihood analysis using the standard gtlike tool (Fig.4, 5).

We investigated whether these gamma-ray light curves had significant variations using a chi-square test, taking into account statistical uncertainties and the estimate of the systematic error in each bin. Variability was found in 70 out of the 106 LBAS sources with a significance higher than 95%.

A first quantitative variability analysis is performed using local and global methods as the wavelet scalogram (Morlet mother function), first-order Structure Function (SF), and the Discrete Auto Correlation Function (DACF). The application to each light curve preliminary points out gamma-ray variability placed between pure flickering and Brownian noise (between long-term radio-band variability and fast X-ray variability observed often in blazars).

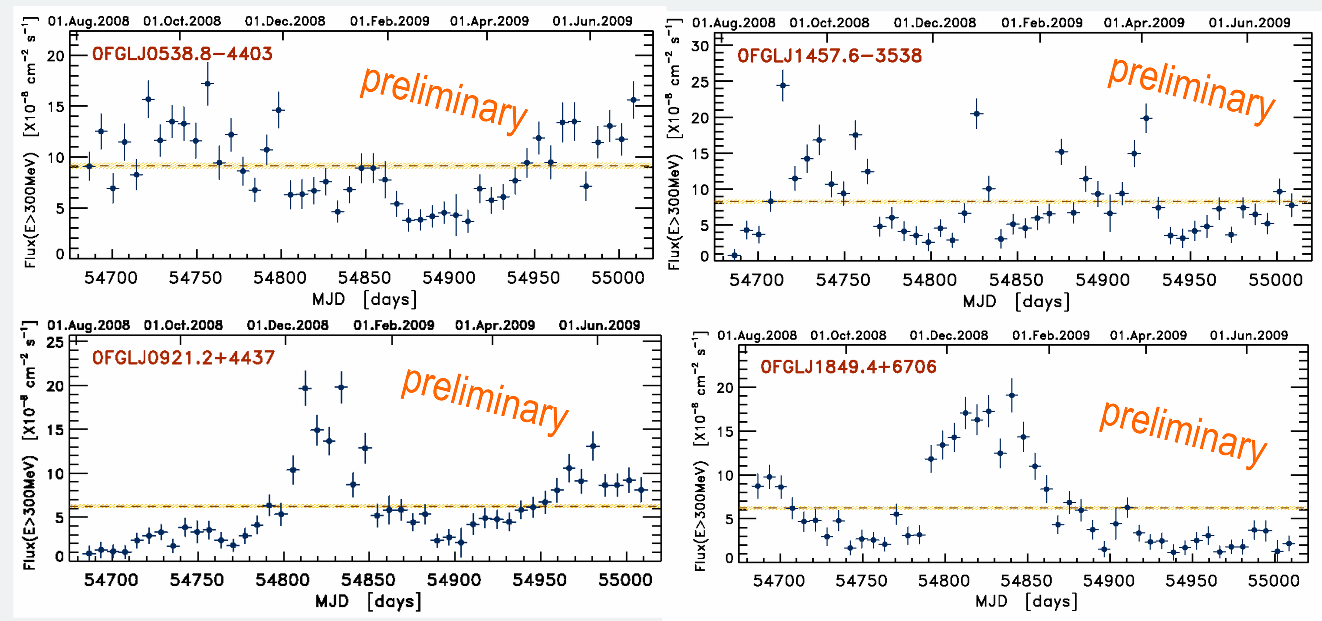

Figure 4: *Left* : Integrated flux light curves (E>300 MeV, 11-month duration , weekly time bins) of four blazars form the LBAS list.

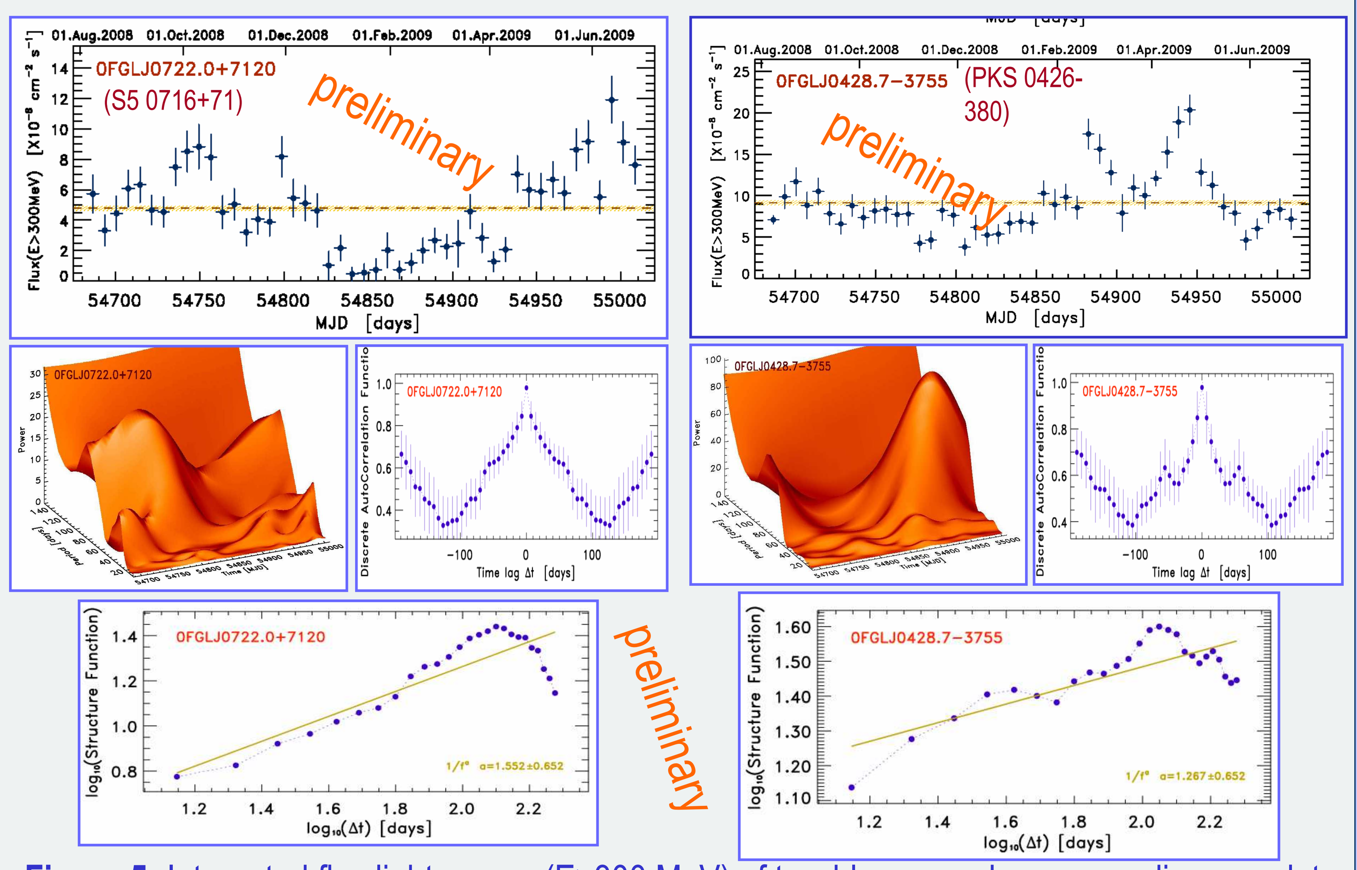

Figure 5: Integrated flux light curves (E>300 MeV) of two blazars and corresponding wavelet scalogram (Morlet mother waveform), discrete autocorrelation function and structure function

Pulse Analysis and PSDs

A study on the single flares is performed using the extracted 3-days time bin light curves on the brightest sources of our 106 blazar list. The function used to reproduce the evolution of the flare is suited to study both the duration and symmetry of the individual events. This reduced sample of brightest source shows two different of temporal profiles: sources with a stable baseline with a sporadic flaring activity and sources with a strong activity with complex and structured features (Fig. 6). Furthermore we found only three flares markedly asymmetric. About 28 of the sources are almost continuously detected throughout the 11 month period and a 3-day or 4-day bin light curves were used to compute the power spectral density (PDS). All PSD were normalized to fractional variance per frequency unit and averaged in logarithmic frequency bins. Results are reported in Fig. 7.

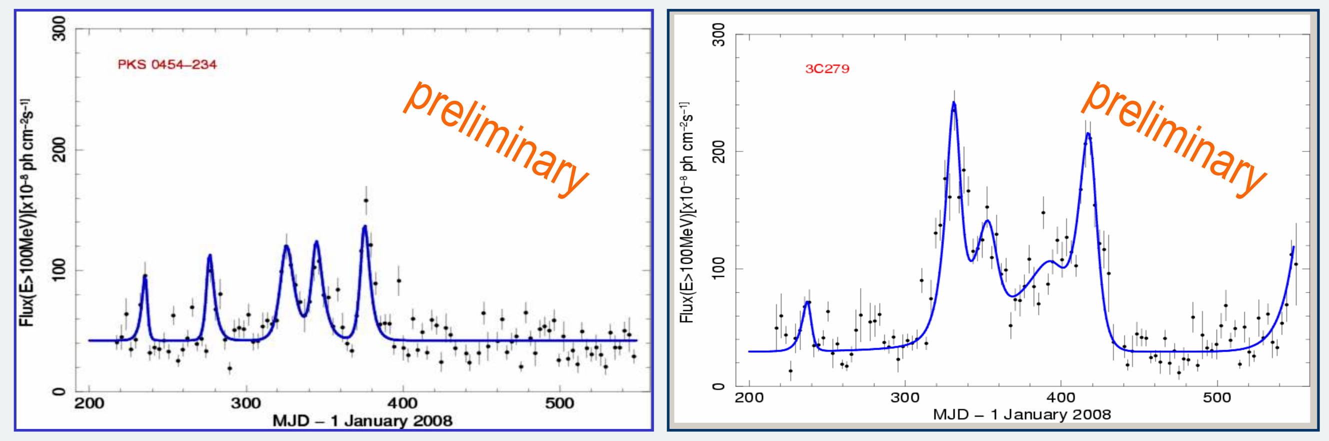

Figure 6: Two analysis examples of single flare pulse evolution (using 3-day bin light curves). In the left panel we can see an example of rather stable baseline with a sporadic flaring activity, while on the right a case of a source with a strong activity and with complex and structured features.

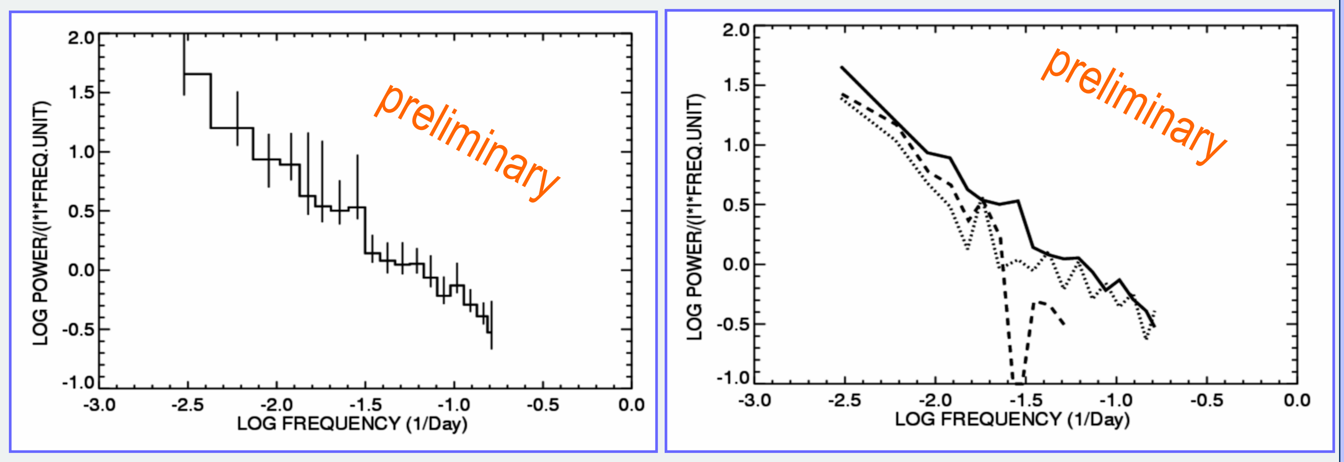

Figure 7: *Left panel*: average Power Spectral Density PSD, for the 9 brightest FSRQs. White noise level based on light curve error estimates has been subtracted. The error bars are asymmetric 1 sigma errors of the mean. Our best fit estimate is an intrinsic PSD slope of -1.5 +/-0.2. *Right panel:* a comparison of the averaged PDS for three sets of sources,
the 9 brightest FSRQs from left panel figure (solid line), the 6 brightest BL Lacs (dotted line) and 13 additional FSRQs with TS > 1000 (dashed line). Best fit slope for the BL Lac and fainter FSRQs is -1.9 +/-0.4 and -1.6 +/-0.3 respectively.

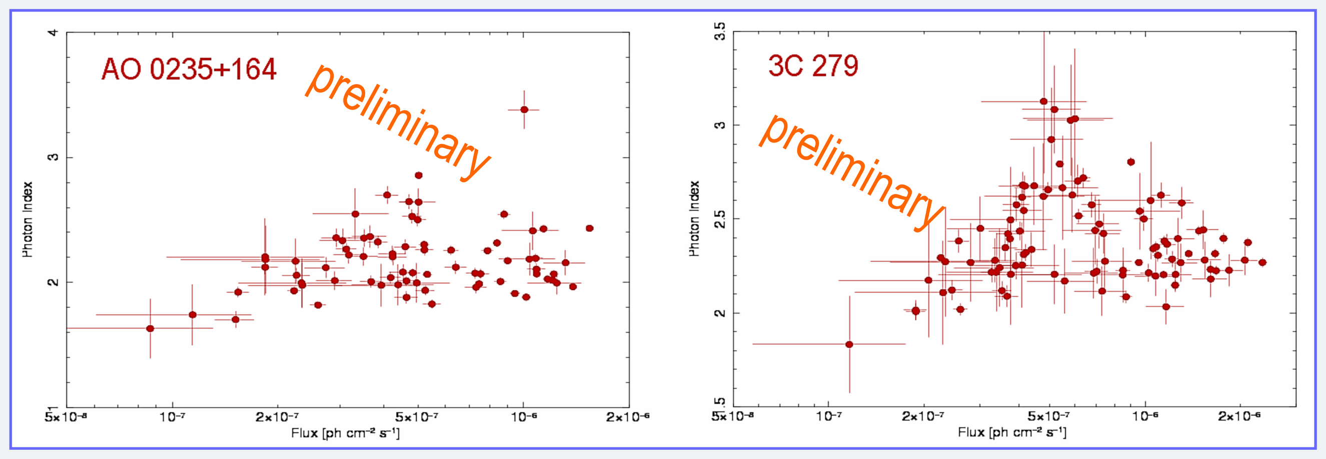

Figure 8: Spectral photon index variability of bright blazars, extracted from light curves with 3-days time bins and TS > 25 in each bin.

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