The Fermi-LAT view of blazar variability and multiwavelength correlations

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on behalf of the Fermi LAT and F-GAMMA collaborations

THE GAMMA-RAY SKY IN THE ERA OF FERMI AND CHERENKOV TELESCOPES

EWASS

Åbo, 11-12 July 2013

Why and what?

Variability

- How do we characterize blazar variability?
  Duty cycle, time asymmetry, power spectrum etc

MW Correlations

- Do gamma-ray flares have radio (or optical/X-ray) counterparts?
- If so, how are they related?
- Where in the jet are the gamma-rays produced?

Multiwavelength data

Gamma-ray (Fermi LAT)

"Continuous" sampling,
Low to moderate S/N,
5 years

Likelihood Fluxes > 0 [Physically correct but statistically biased]

Radio, optical, X-ray

Uneven sampling
Often high S/N

Long time series (>>10yr)

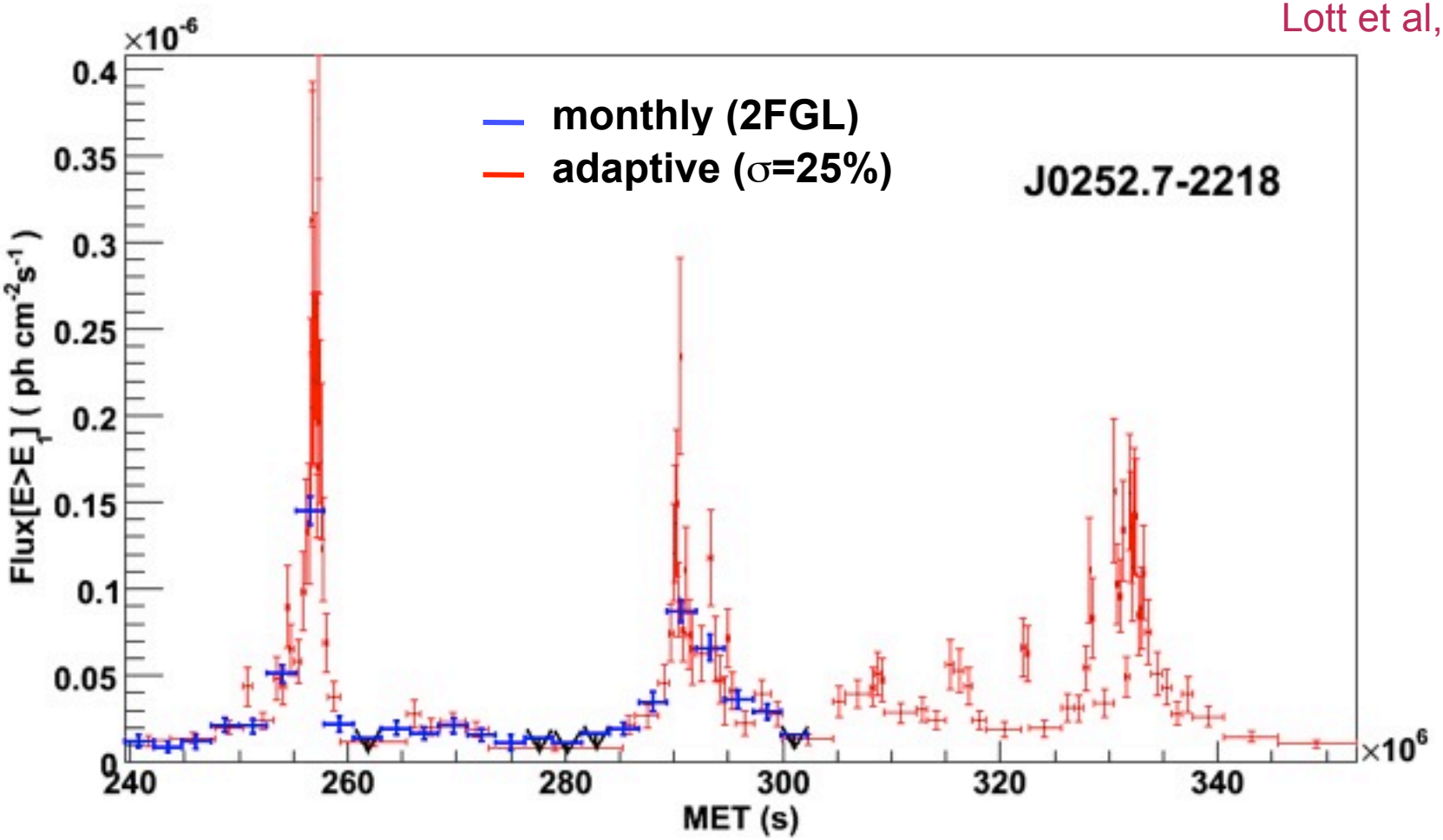
Main importance of long time series: Adding "independent" data

Since: Uncertainties dominated by the stochastic variability

Adaptive binned lightcurves

Principle: adapt the bin widths of a light curve according to a user-defined condition, constant relative uncertainty on flux or constant significance in each bin

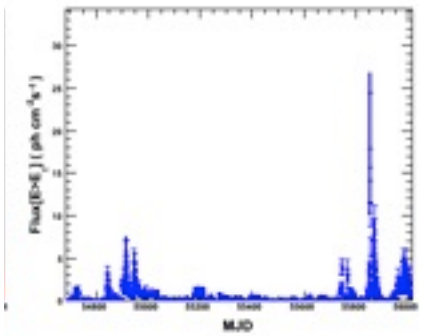
Lott et al, 2012

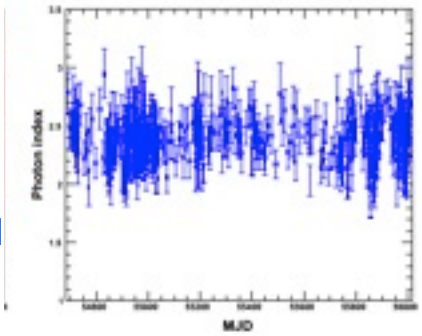


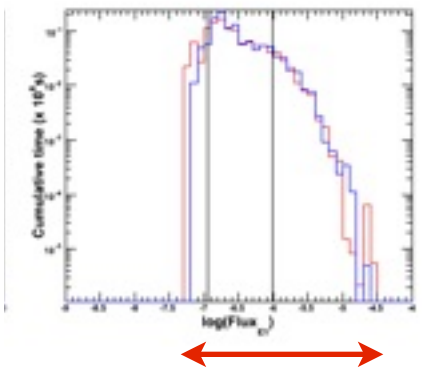
Flux and spectral variation

FSRQ

PKS 1510-089

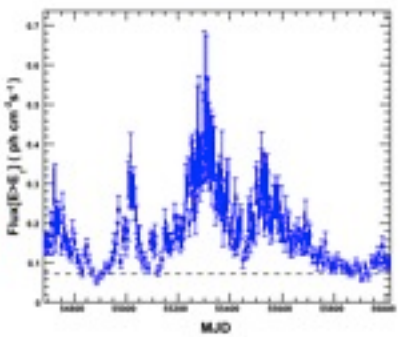


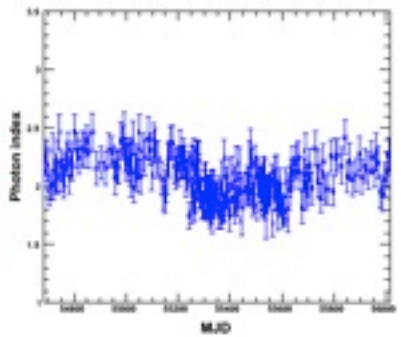


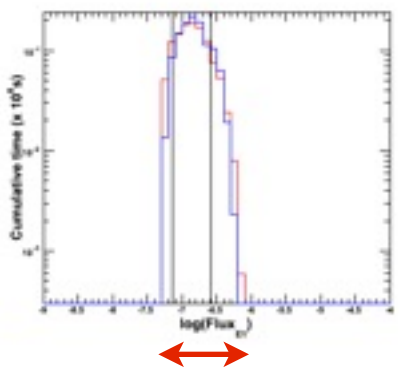


LSP BL Lac

PKS 0537-441

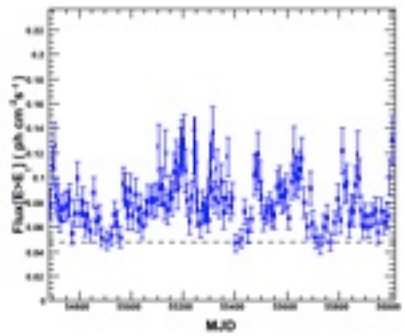


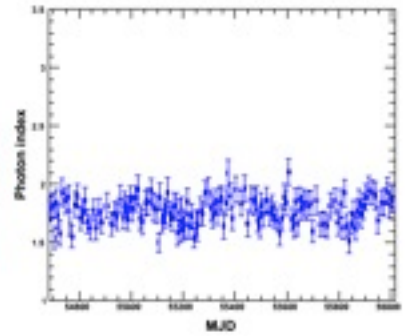


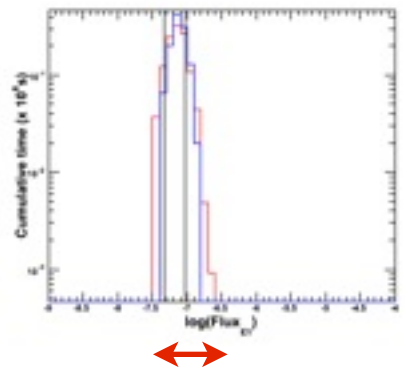


HSP BL Lac

Mrk 421







Soft

Hard

Flux

Photon index

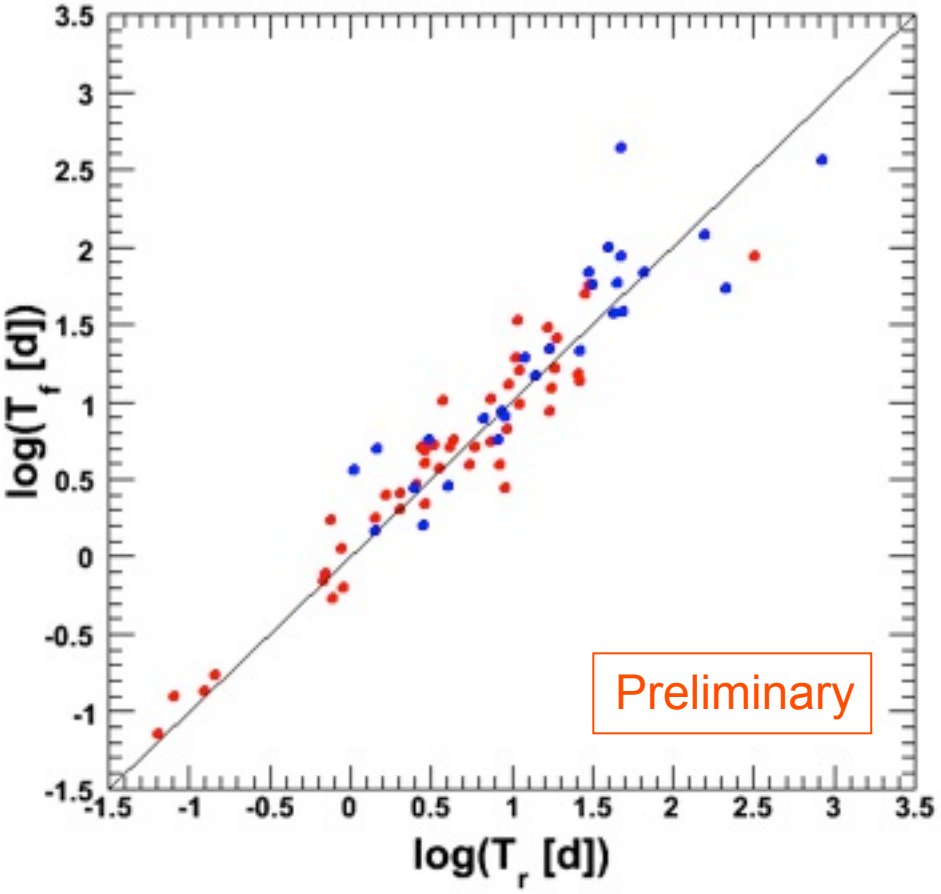
Flux distribution

Preliminary

Range in Log(Flux)

Rise/decay times

$R_S/c = 10^4$ s ~ 0.1 d for a 10^9 solar mass BH



$$R = c\, T_{var}\, \delta\, /(1+z)$$

Mean ratio T_r/T_f = 0.93±0.37 for FSRQs

0.91±0.34 for BL Lacs

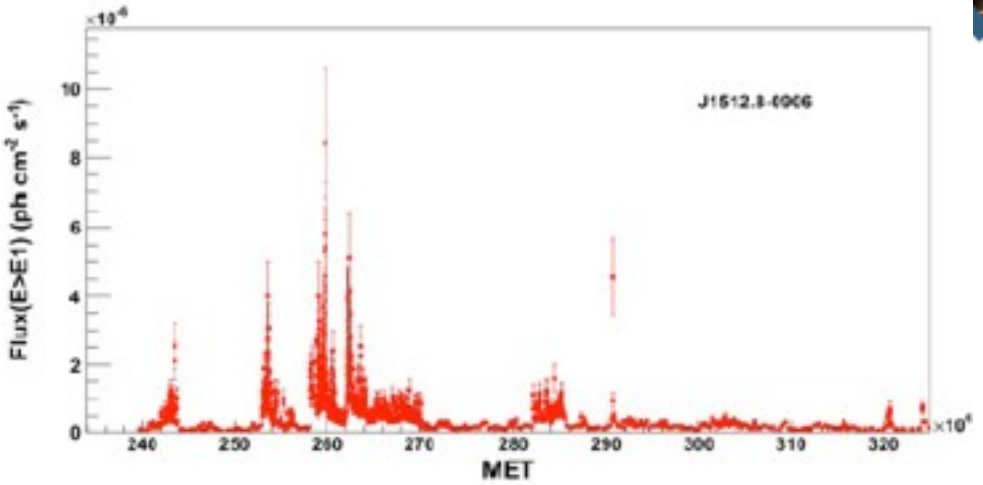
Governed by light crossing time?

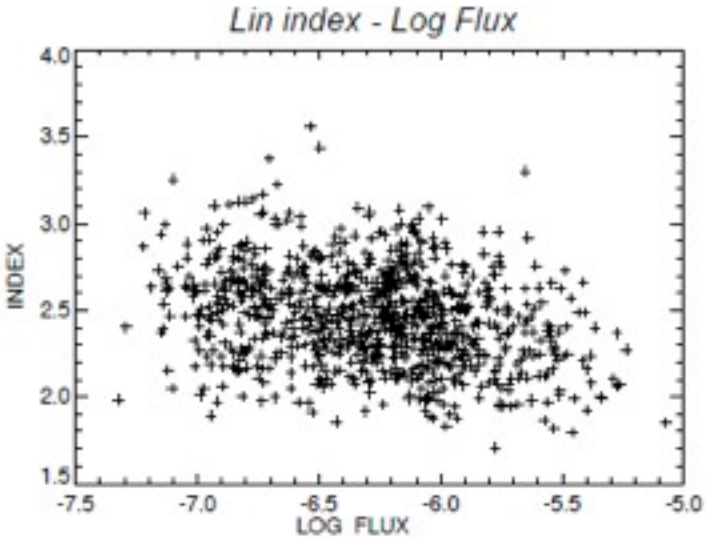
T_r = Rise time

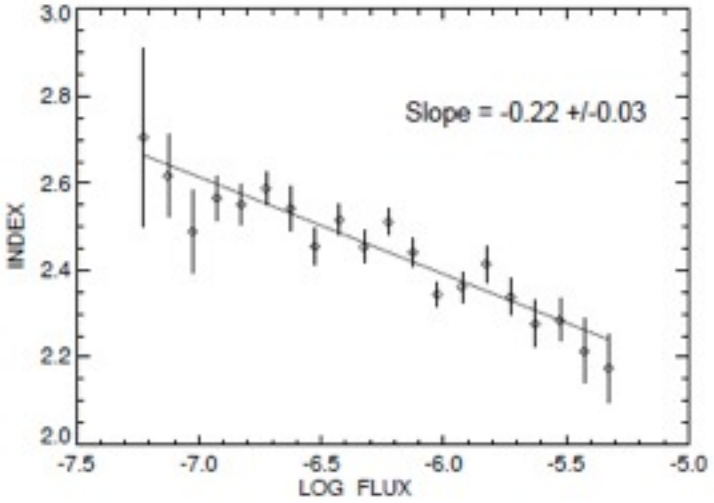
T_f = Fall time

Spectral index vs flux

«moderate » spectral variability reported for several individual sources



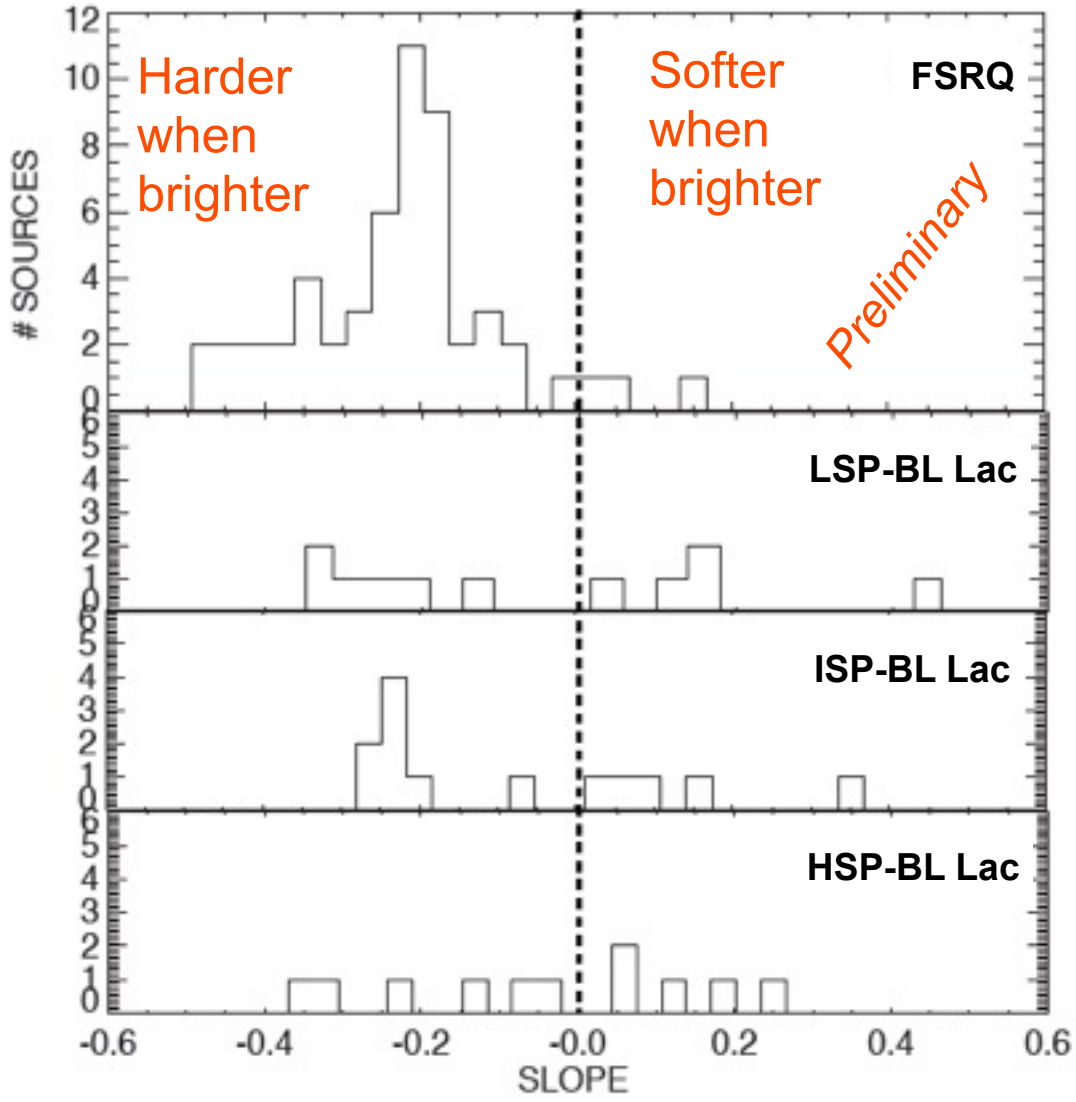




LOG FLUX(ph cm^{-2} s^{-1})

Preliminary

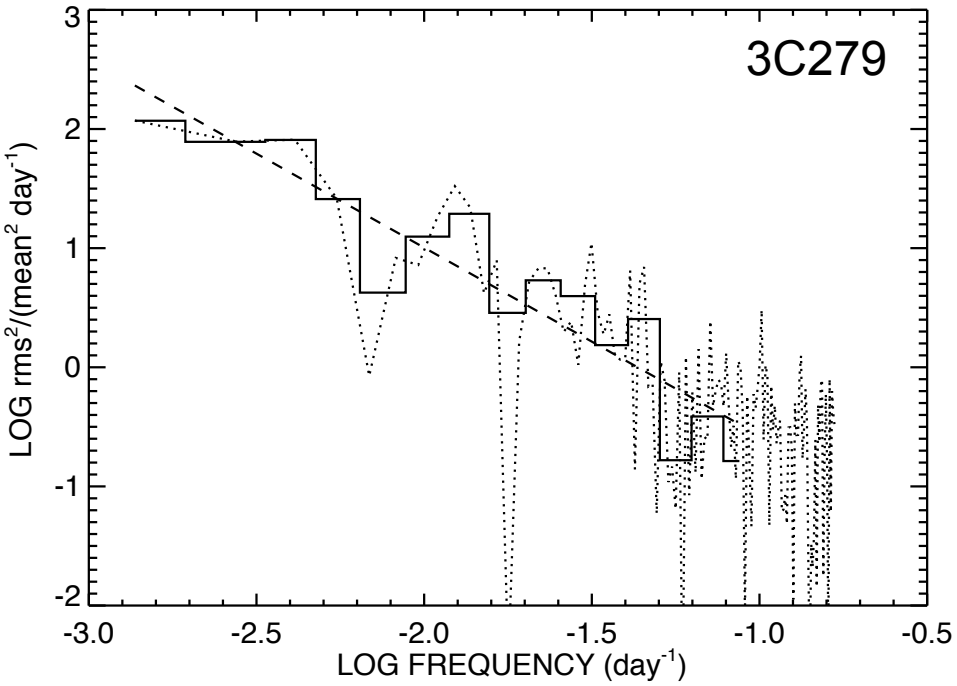
Index-flux slope vs source class

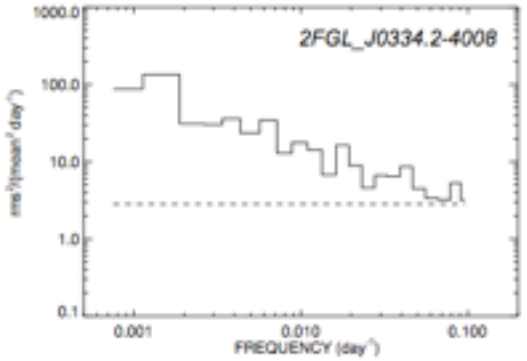


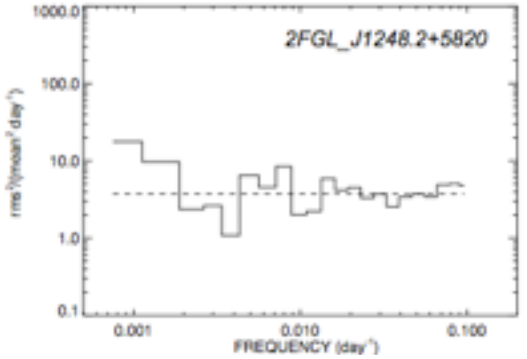
Slopes cluster at ~ - 0.2 for FSRQs. Why?

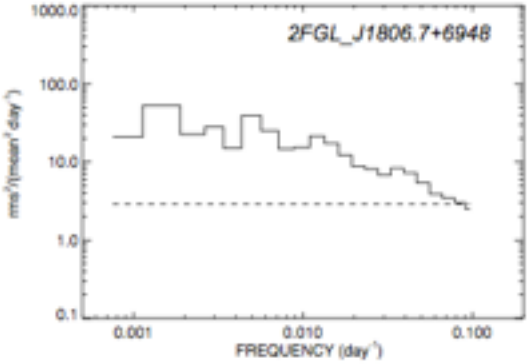
Power Density Spectra

Hayashida et al, 2012







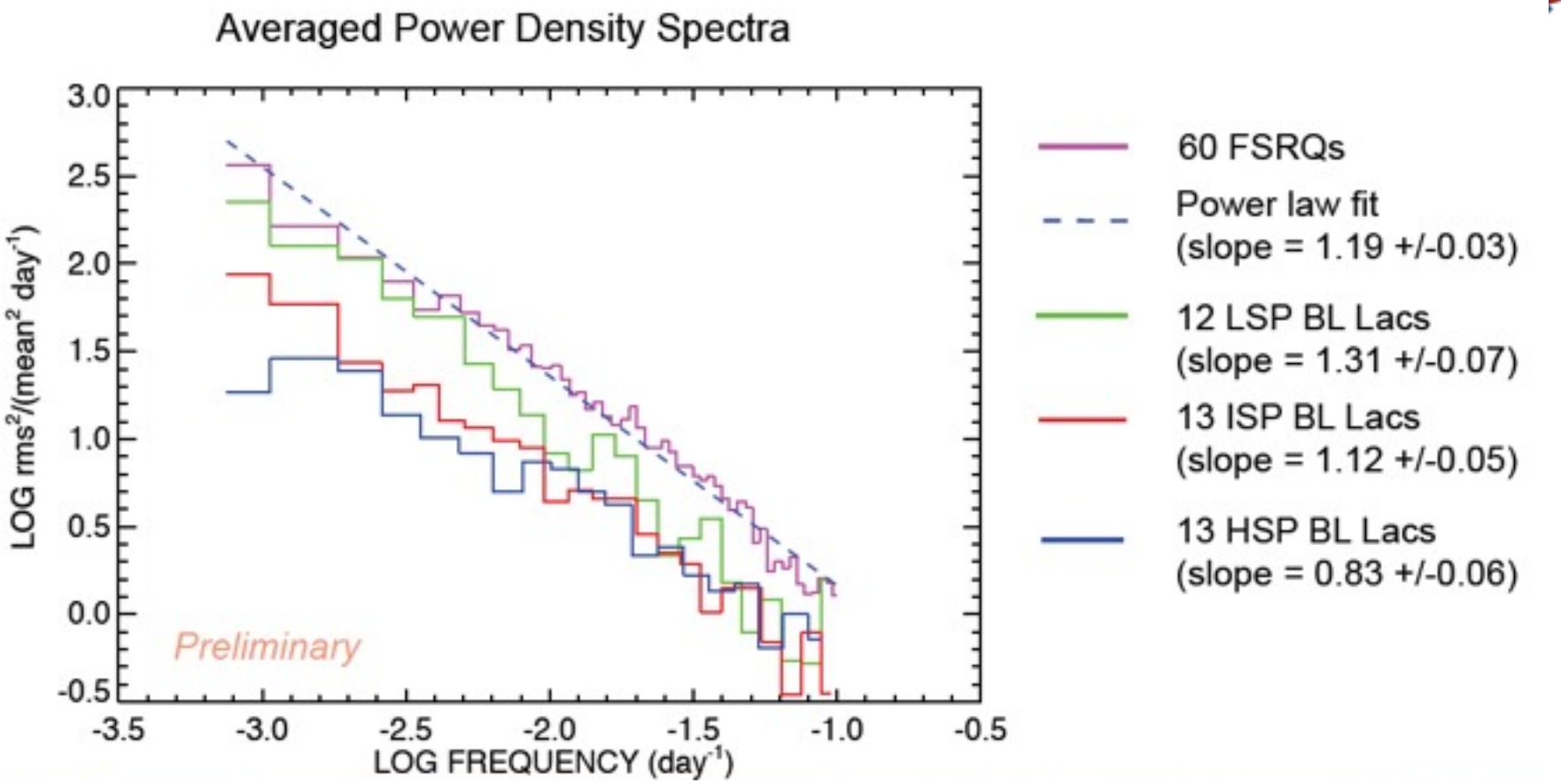


ISP
BL Lacs

Examples

PDS breaks: Some
Persistent: ??

Power Density Spectra



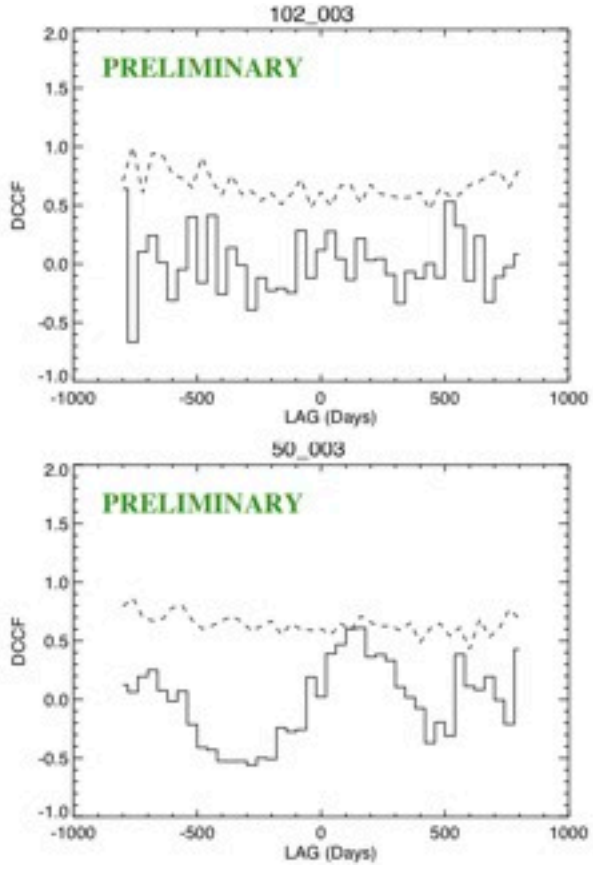
No persistent breaks found in PDS of individual sources

Power Density Spectra in radio, optical, X-ray typically power-laws with index 1 to 2

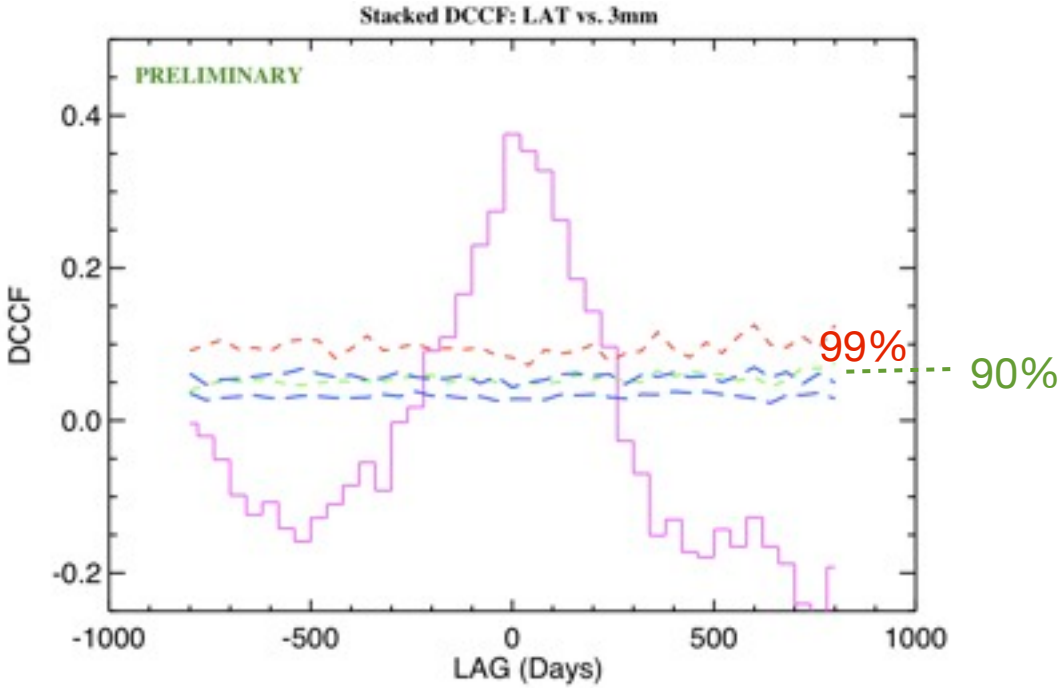
Gamma-ray vs radio correlation

LAT / 3mm Discrete Cross Correlation Function (DCCF)

Single sources
Low significance

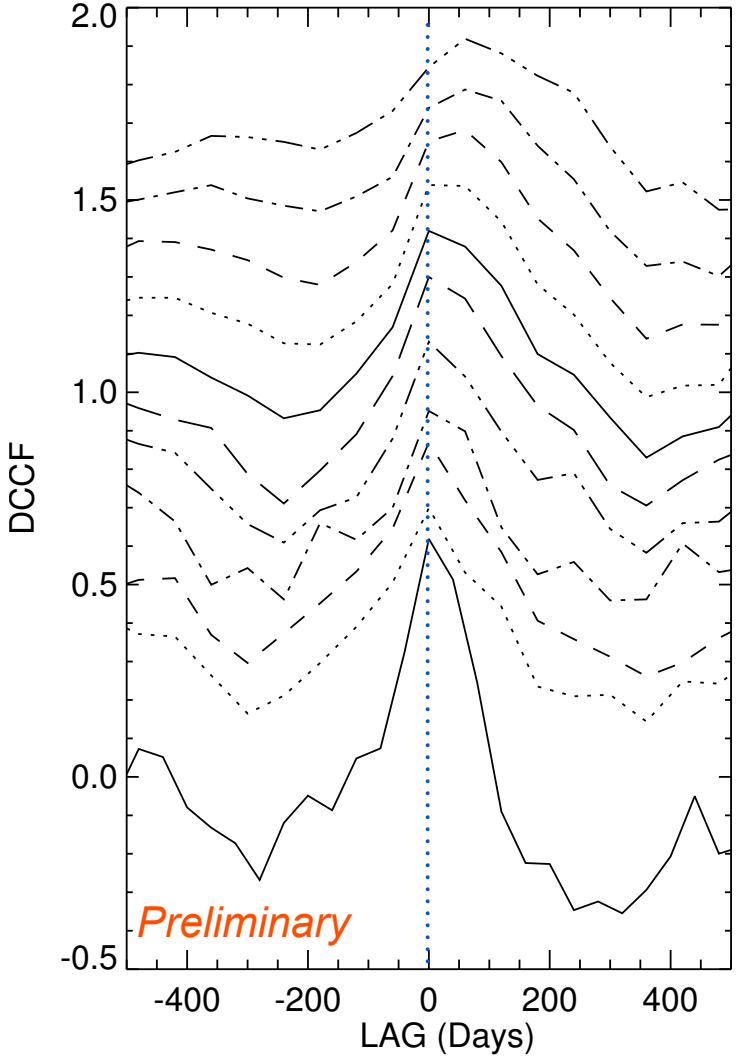


Stacking of 54 sources
Highly significant correlation!



DCCF significances: Mixed source correlation
Lag uncertainties: Monte Carlo
(Method: Larsson, 2012 Results: Fuhrmann et al in prep)

Stacked DCCFs [rest frame]



11 cm

0.8 mm

Radio lagging: Lags close to 0 at mm/sub-mm bands & increasing towards lower frequencies

Positive delay: gamma-rays from inside / upstream of "mm-core"

Delay origin: opacity/synchrotron self- absorption

Fuhrmann et al in prep

Summary

On variability:

1. Spectral: Harder-when-brighter (FSRQs) mixed (BL Lacs)
2. Time asymmetry: No
3. PDS: Power law index ~ 0.8 - 1.3 (Flatter than radio)
   No persistent break (= characteristic time scale)

Main points on MW correlations of this talk:

1. Individual: Uncertain (radio) or variable (optical)
2. Sample: Highly significant!
3. General: No simple MW Correlation.
4. Strength: Increases towards lower radio wavelengths (to sub-mm)
5. Time lag: Increases with radio wavelength