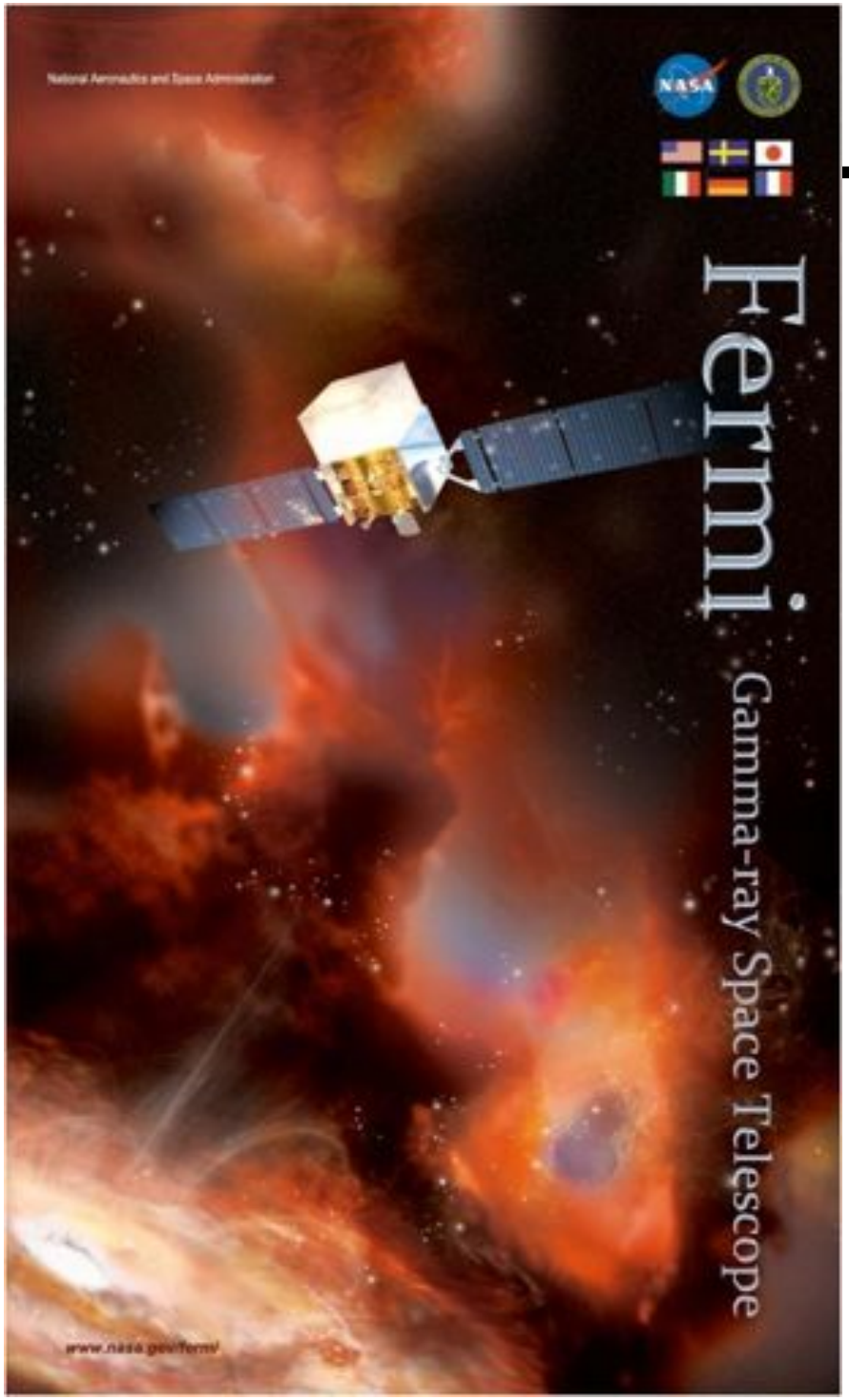


Revisiting Variability of Bright LAT Blazars

B. Lott & S. Larsson

on behalf of the Fermi-LAT collaboration

Fourth Fermi Symposium

Introduction

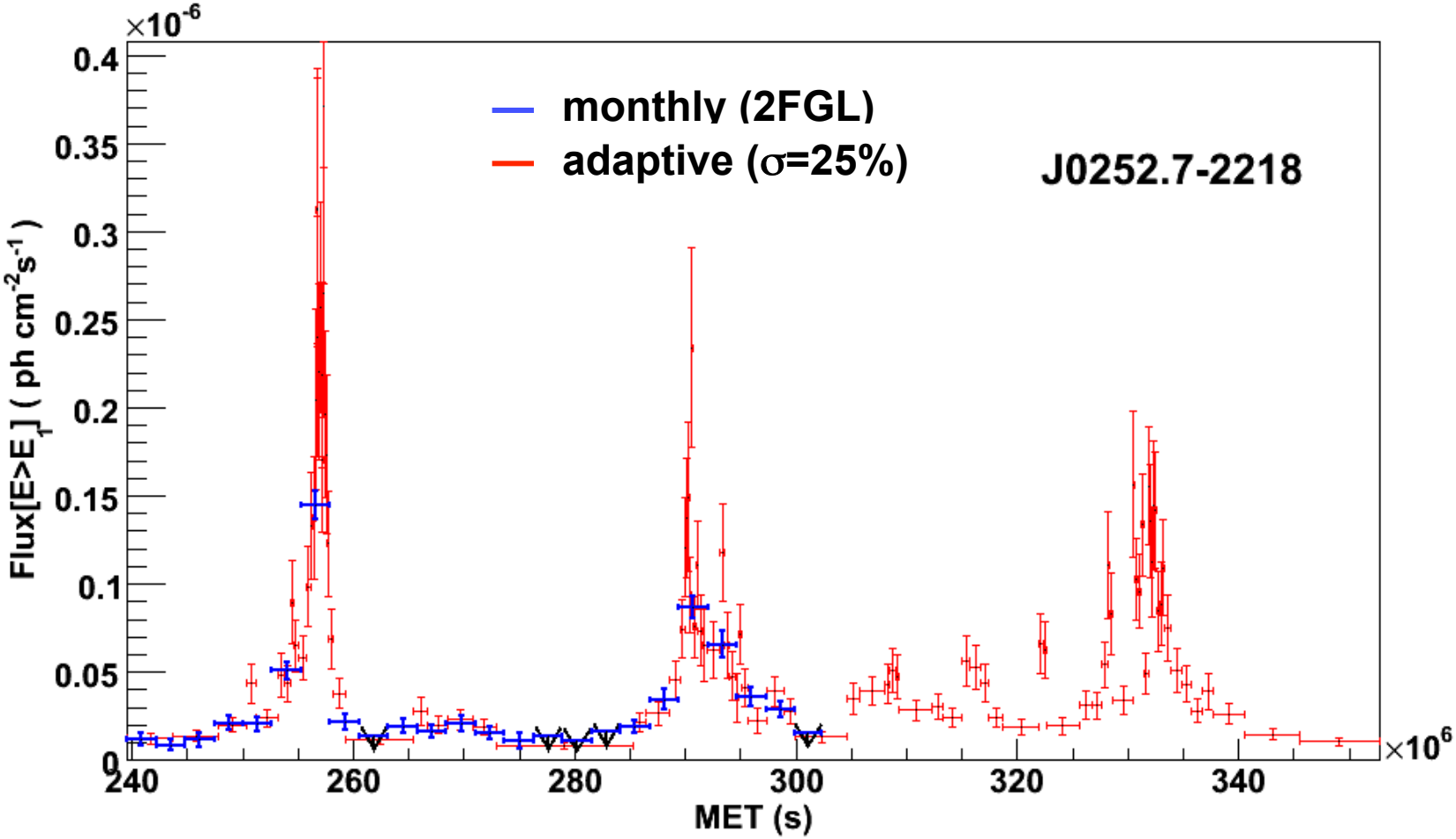
Variability at all time scales is a key feature of blazars.

The Fermi-LAT offers an unprecedented all-sky coverage enabling us to produce a unique set of continuous light curves.

Better characterization of the variability properties of the bright LAT blazars
- over 4 years into the mission
- new adaptive-binning method available
  complementary to fixed binning method, Bayesian-Block method

Adaptive-binning method: Motivations

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



Technicalities

Input:
- Photon file (ROI centered at the source location, *time-ordered* photon list)
- Spacecraft file

« *Step 1* »: Computation of bin list with a simple python script (~10 min):
Iterative procedure over (tstop, flux, σ or TS)
Options:
- constant relative uncertainty on flux *or* constant significance (TS)
- normal *or* reverse time arrow

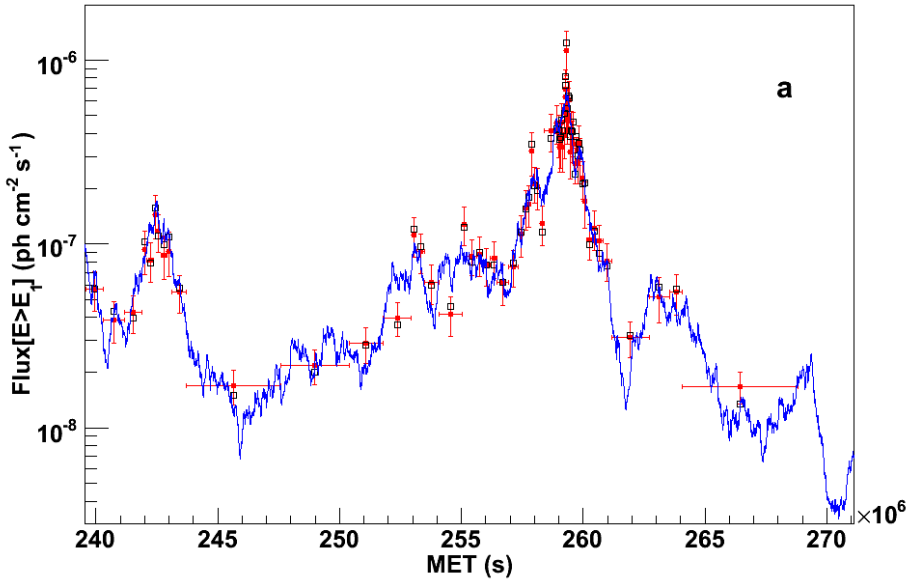
« *Step 2* »: Recomputation of flux, index, uncertainties, TS for the different bins with the standard pylikelihood analysis (batch jobs launched in parallel)

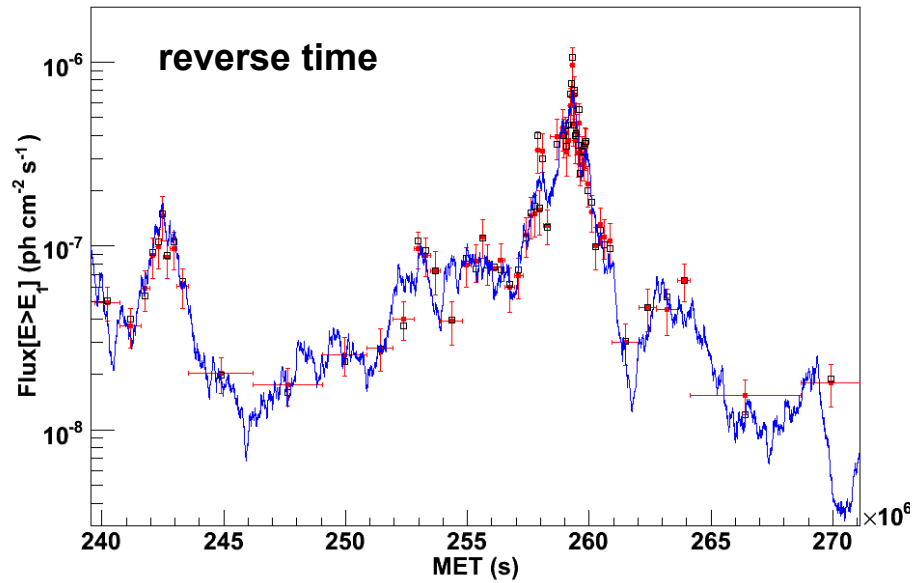
Checked for caveats/adverse effects using Monte Carlo simulations
The method has no significant impact on:
- average measured flux or photon index (no bias)
- measured flux/photon index dispersion
- correlation between measured flux and photon index
- correlation between fluxes in consecutive bins

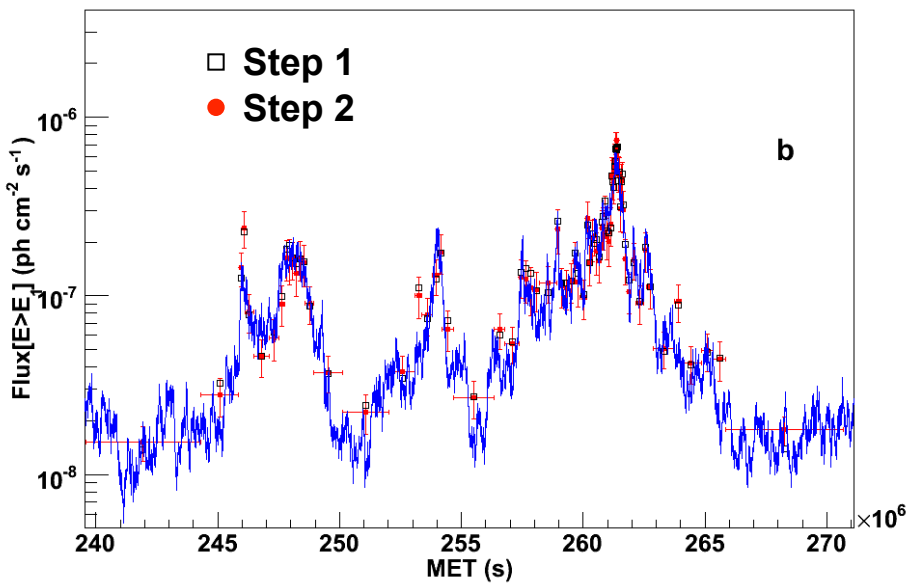
Slight skew (~ 1 sigma) in the measured flux distributions:
Positive fluctuations are more likely to be recorded than negative fluctuations.

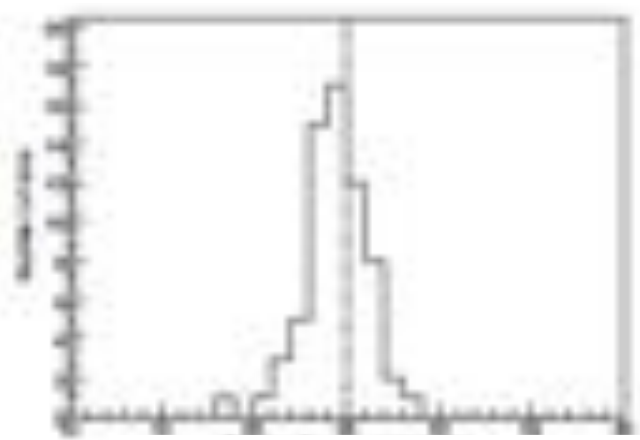
Results of simulated variable sources

gtobssim F_{100}= 2 x 10^{-7} ph $cm^{-2}s^{-1}$, Γ=2.4, RA=201°, DEC=34°, IRF=P6_V3_DIFFUSE









Relative flux uncertainty (%)

Selected 2LAC sources

82 brightest 2LAC blazars

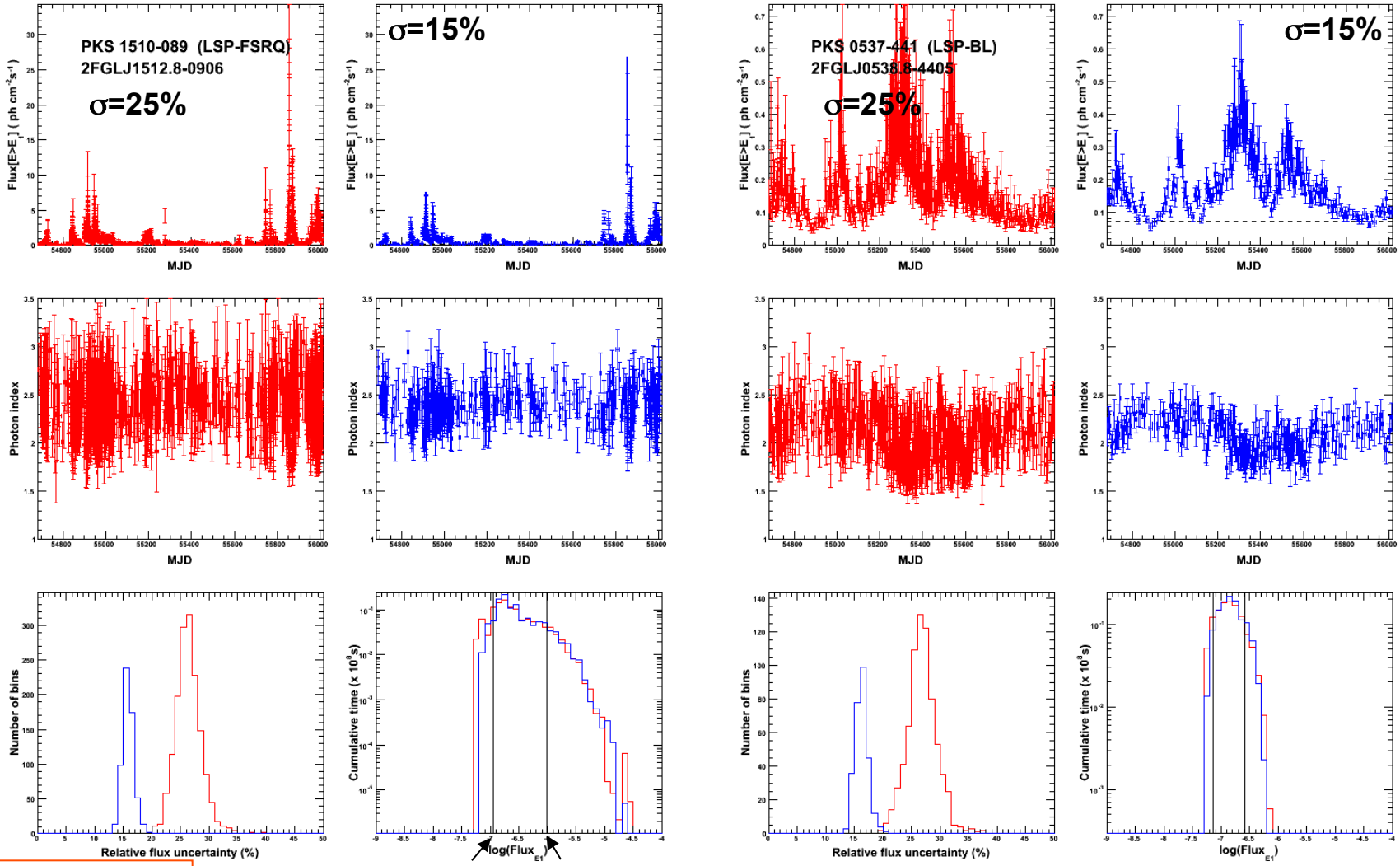
- **47 FSRQs**
- **32 BLLacs: 10 LSPs, 10 ISPs, 12 HSPs**
- **1 AGN (S4 1030+61),**
- **1 AGU, 1 Radio Galaxy (NGC 1275)**

σ=15%-25%, normal+reverse time
44 months of data

IRF=P7Clean_V6

Light curves for flux above optimum energy (E1)
(minimum correlation between flux and spectral index, thus smallest flux uncertainties)
Prescription in adaptive-binning method paper

Ex: FSRQ, LSP-BL Lac

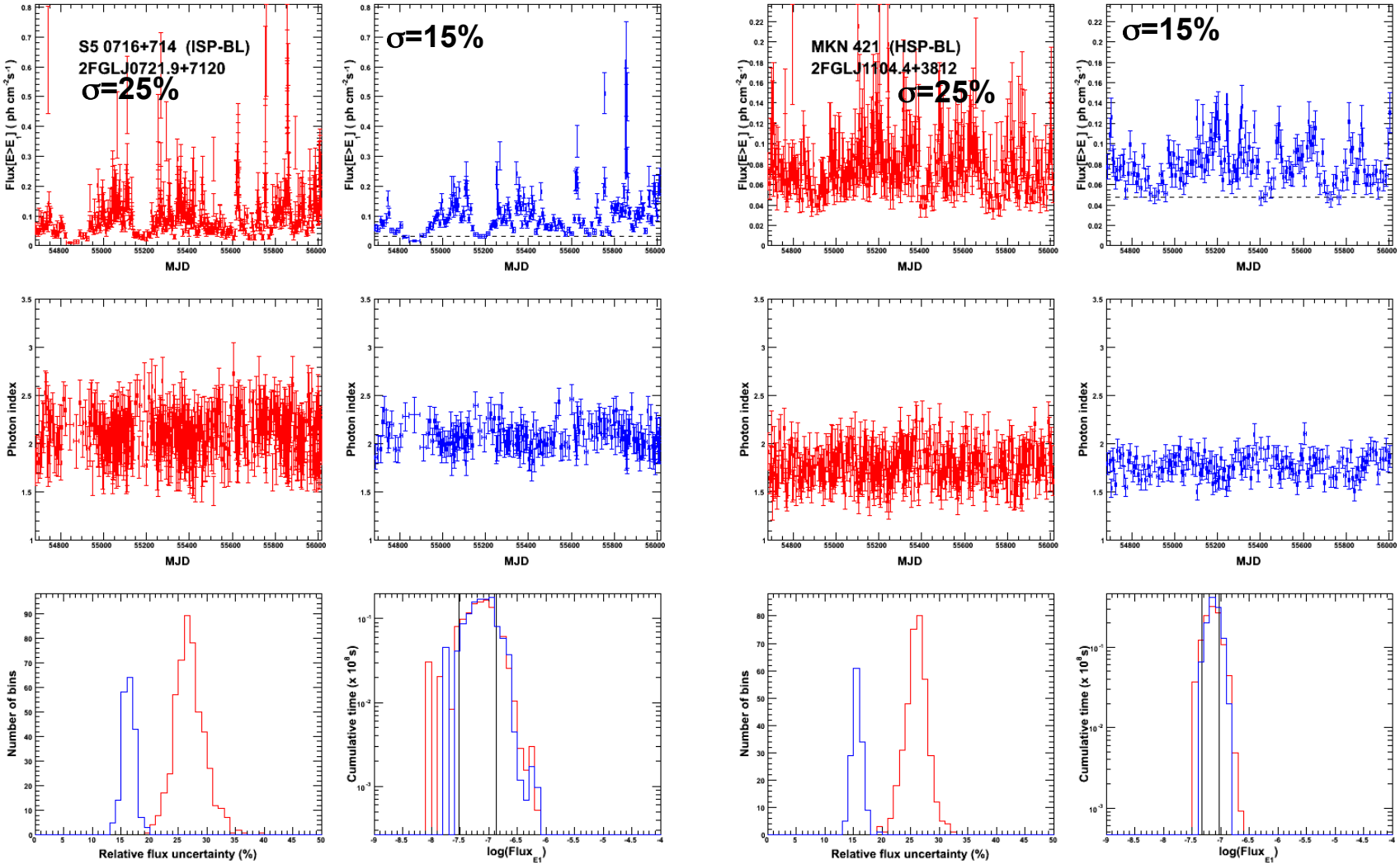


Preliminary

11/2/12

F_{10} F_{90} **Flux modulation**$\equiv \log(F_{90}/F_{10})$

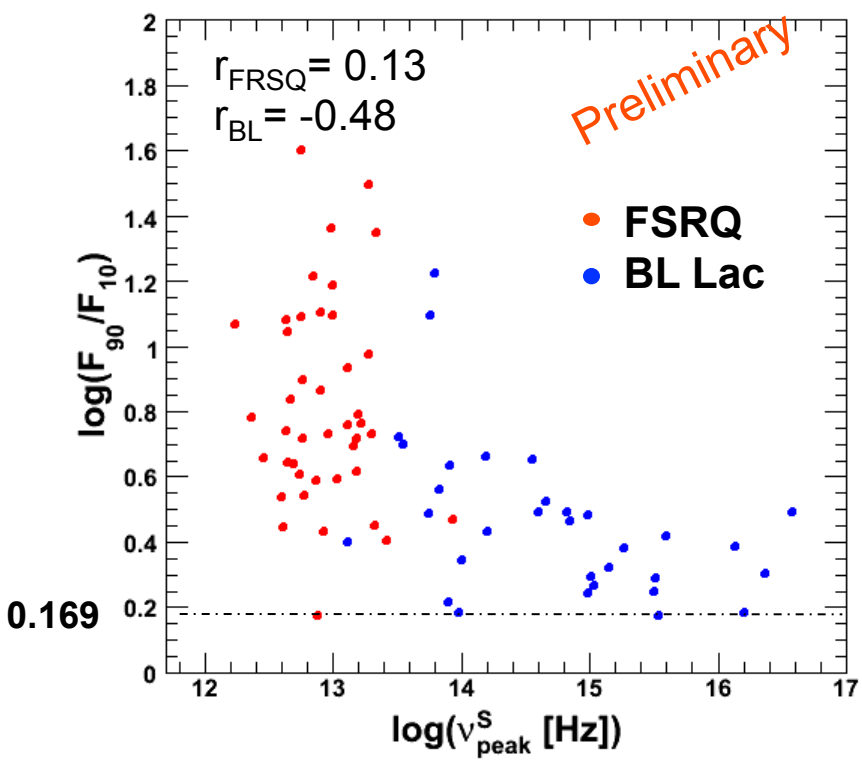
Ex: ISP-BL Lac, HSP-BL Lac

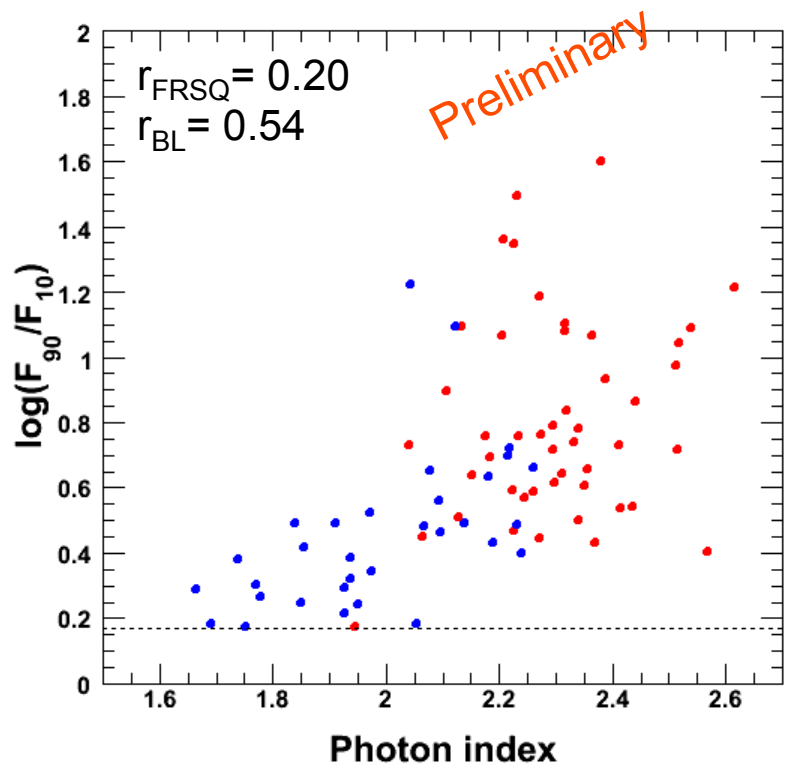


Preliminary

Flux modulation vs ν_{peak}, photon index

- Flux modulation≡log(F_{90} /F_{10})
- Both F_{10} and F_{90} well determined with the adaptive-binning method
- Another metric for variability



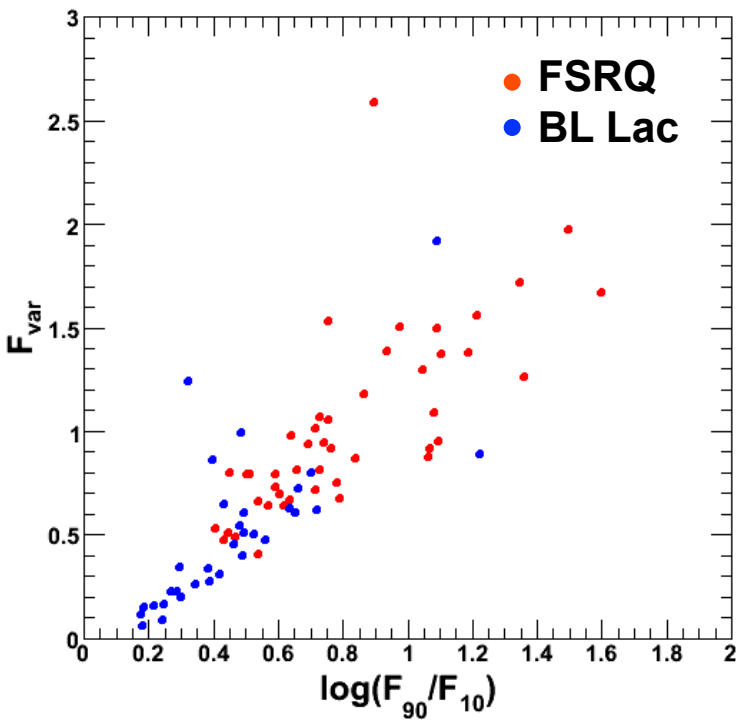


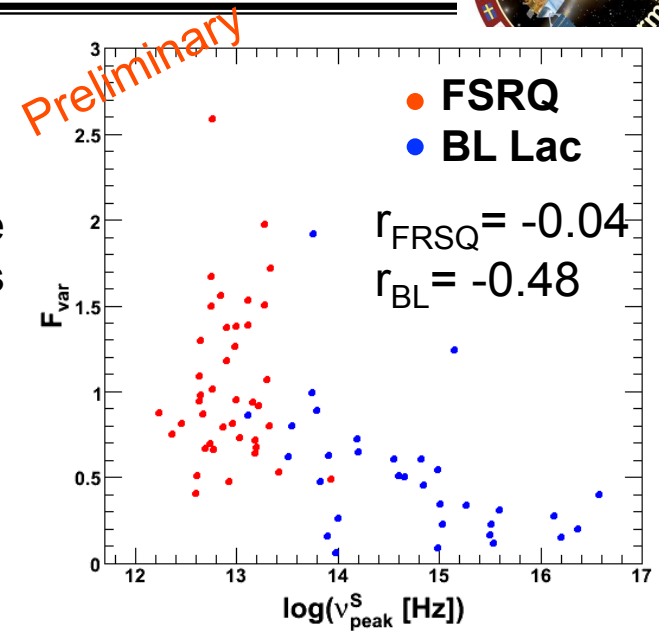
Normalized excess variance

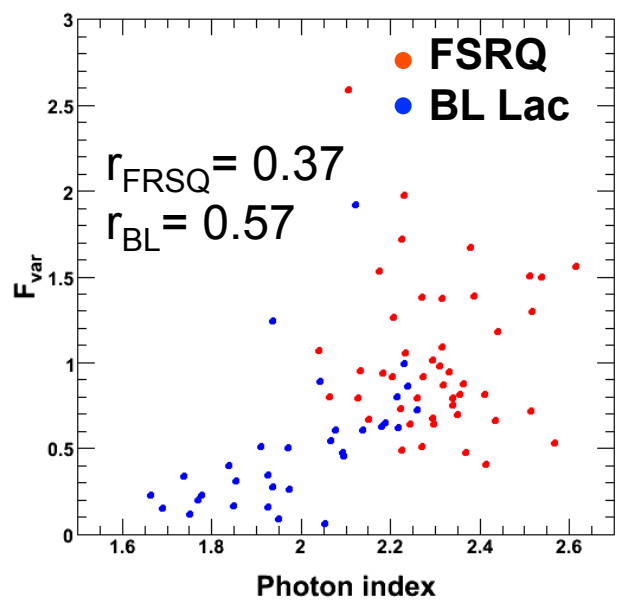
$$F_{\rm var} = \sqrt{\frac{S^2 - \overline{\sigma^2_{\rm err}}}{\bar{x}^2}}$$

(Vaughan et al. 2003)

- Different energies, different time binnings (bins are weighted according to widths), but normalized excess variance still meaningful.
- Significant correlation for BL Lacs, absent for FSRQs, consistent with 2LAC findings

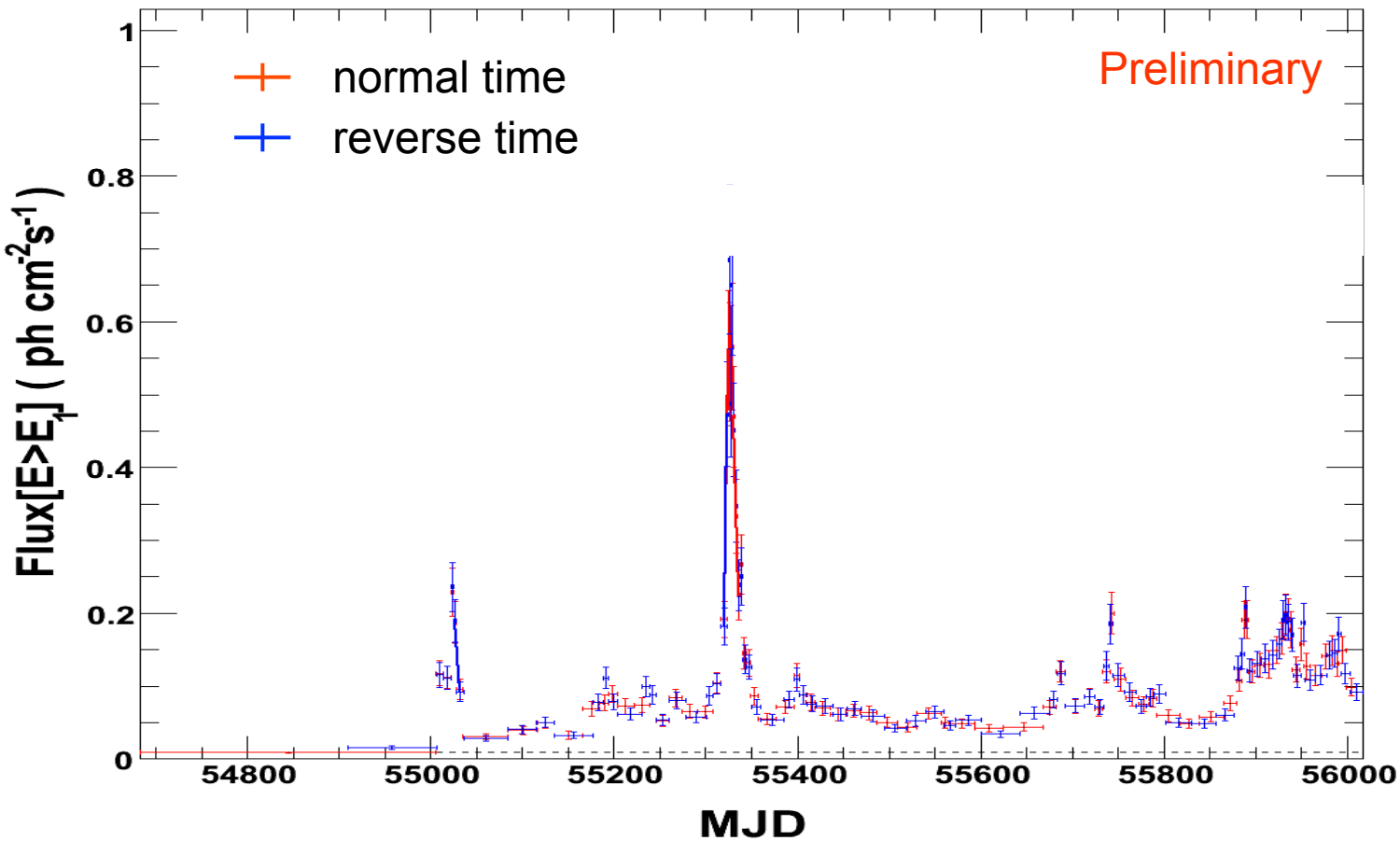






Rise/decay times

- Use σ=15% light curves
- Scan all bin-bin combinations, retain those with flux ratio>2, derive doubling/halving times via linear interpolation



Rise/decay times – Flux modulation

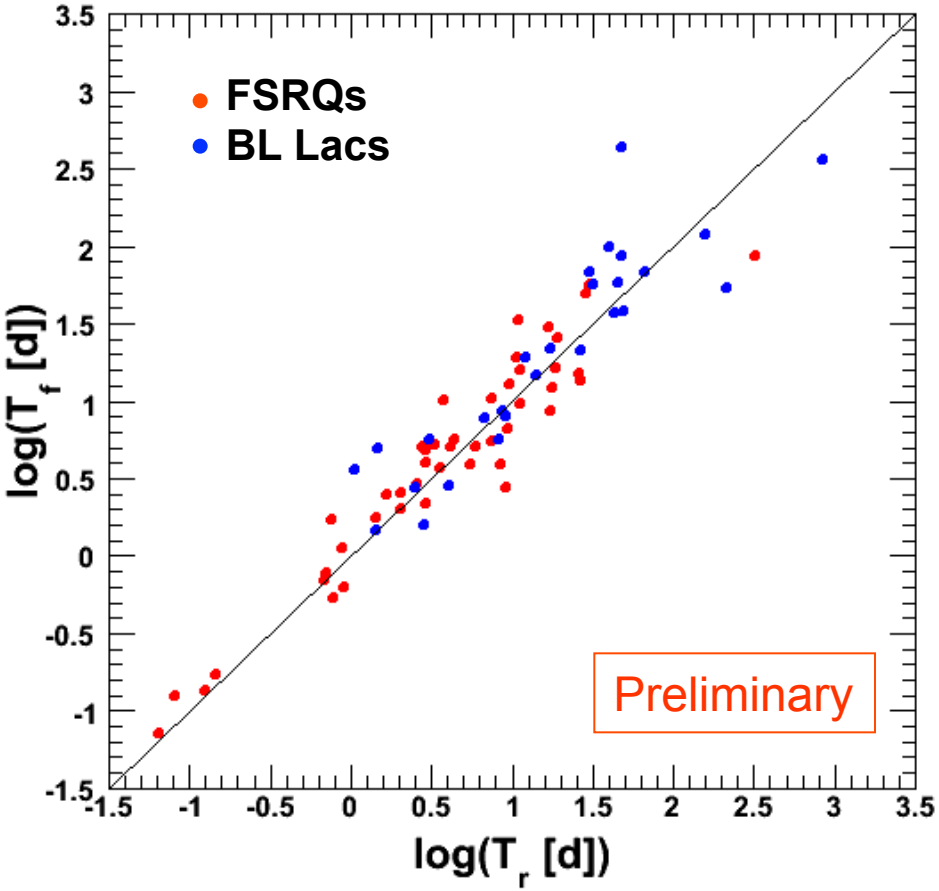
$R_S/c=10^4$ s ~ 0.1 d for a 10^9 solar mass BH

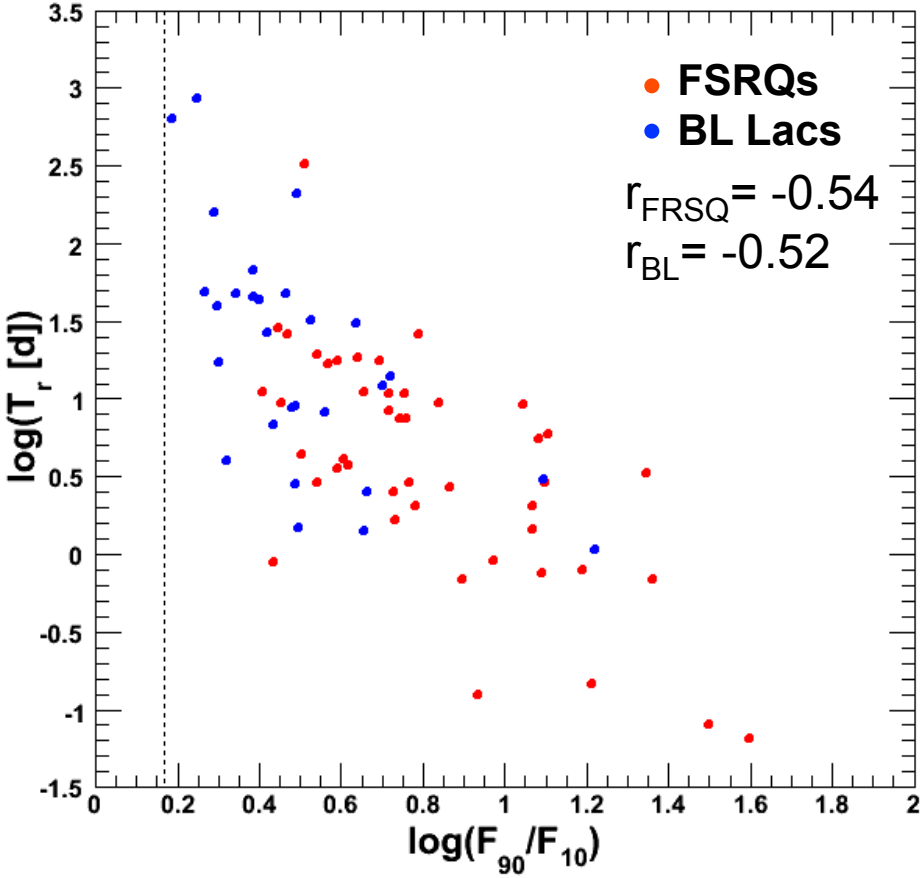
Mean ratio T_r/T_f = 0.93±0.37 for FSRQs

0.91±0.34 for BL Lacs

Governed by light crossing time?

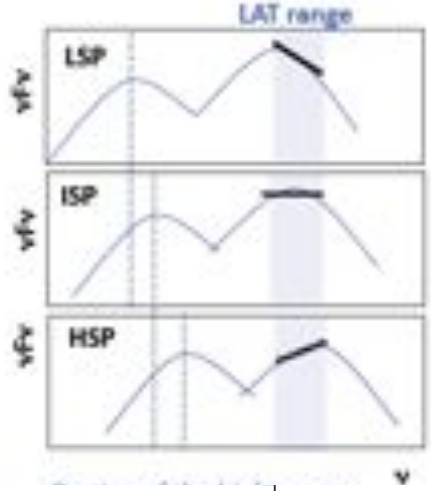
$$R = c\, T_{var}\, \delta /(1+z)$$

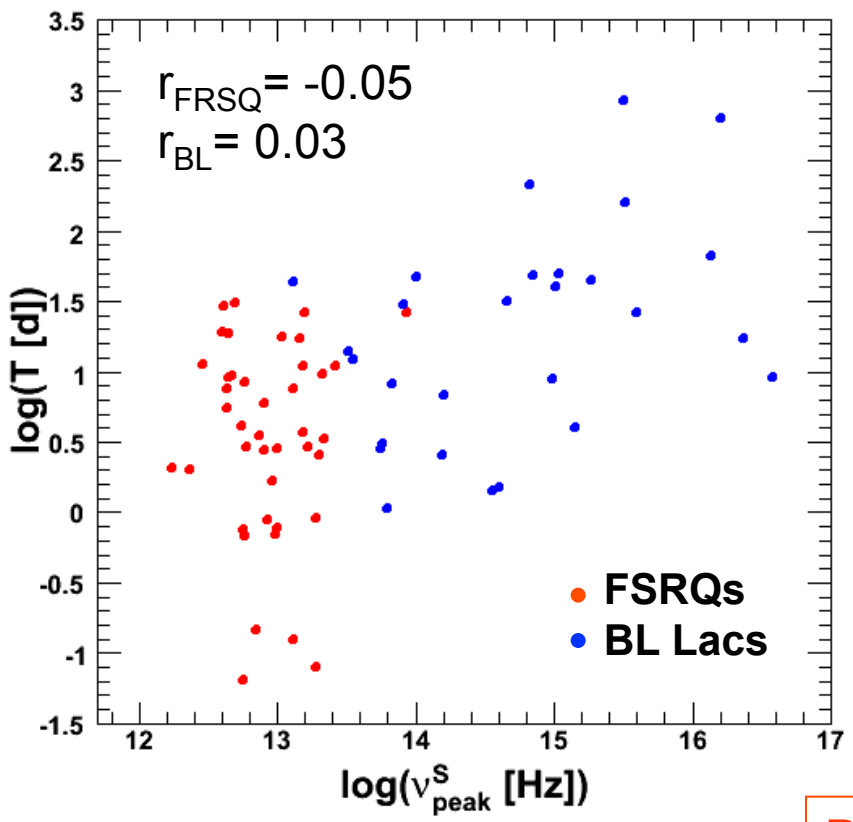


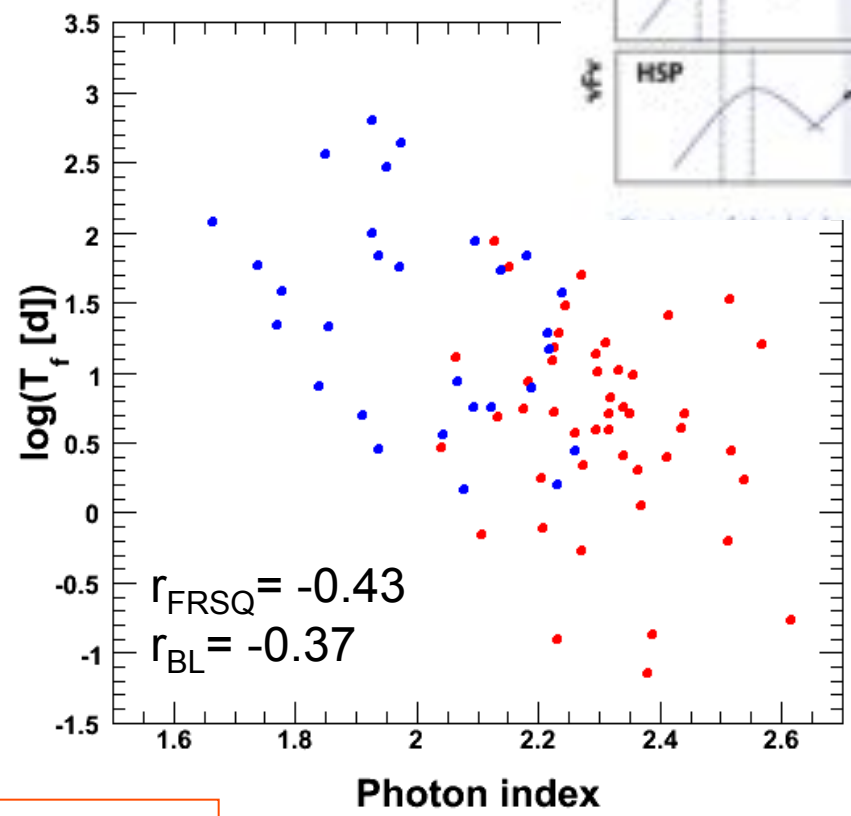


Rise times vs ν_{peak}, photon index

- no correlation of doubling time with ν_{peak}
- moderate correlation with photon index both for FSRQs and BL Lacs



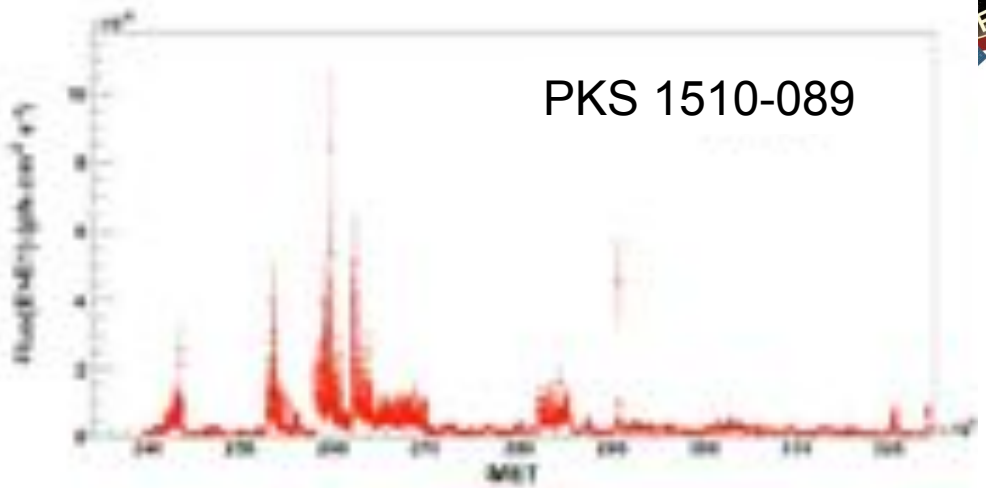


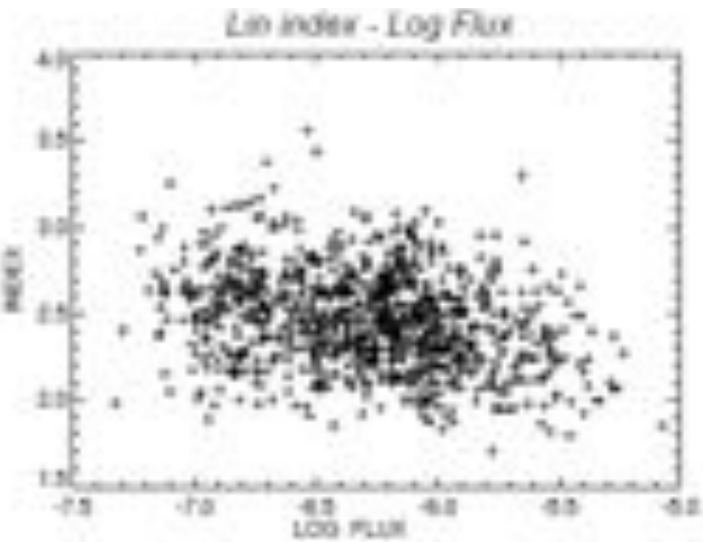


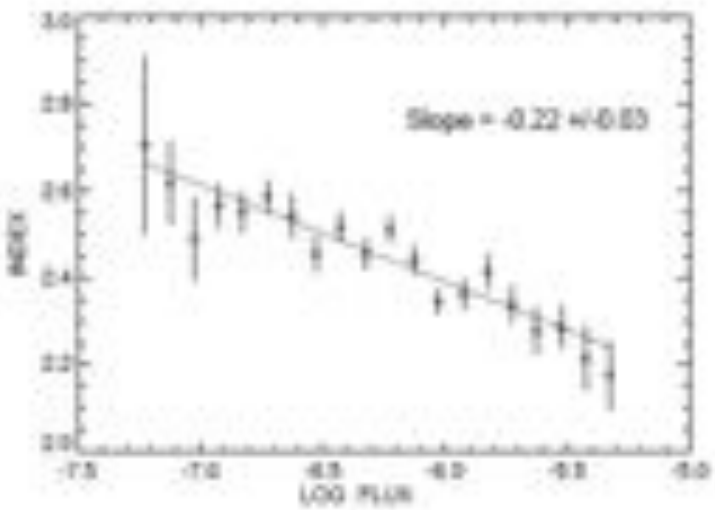
Preliminary

Spectral variability with flux

«moderate » spectral variability reported for several individual sources

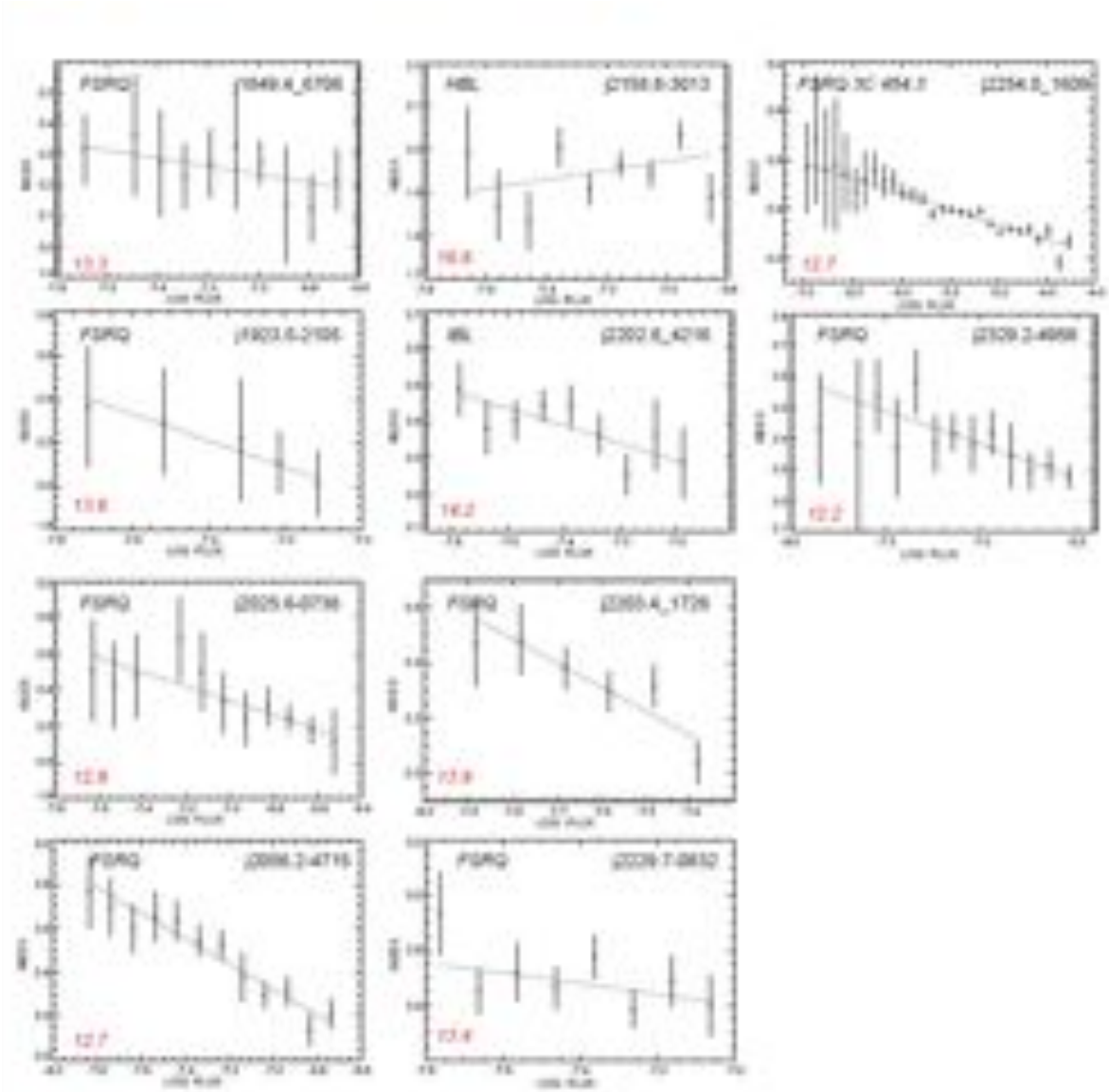






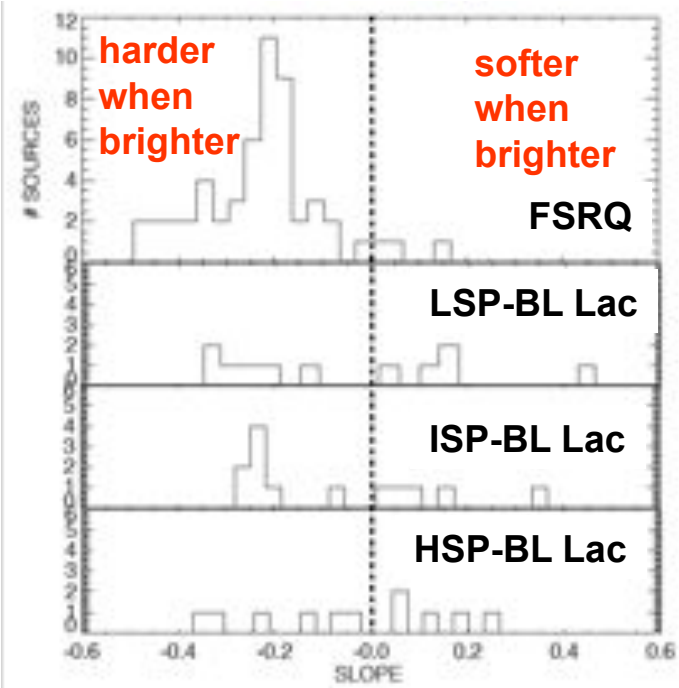
Preliminary

Spectral variability with flux (2)

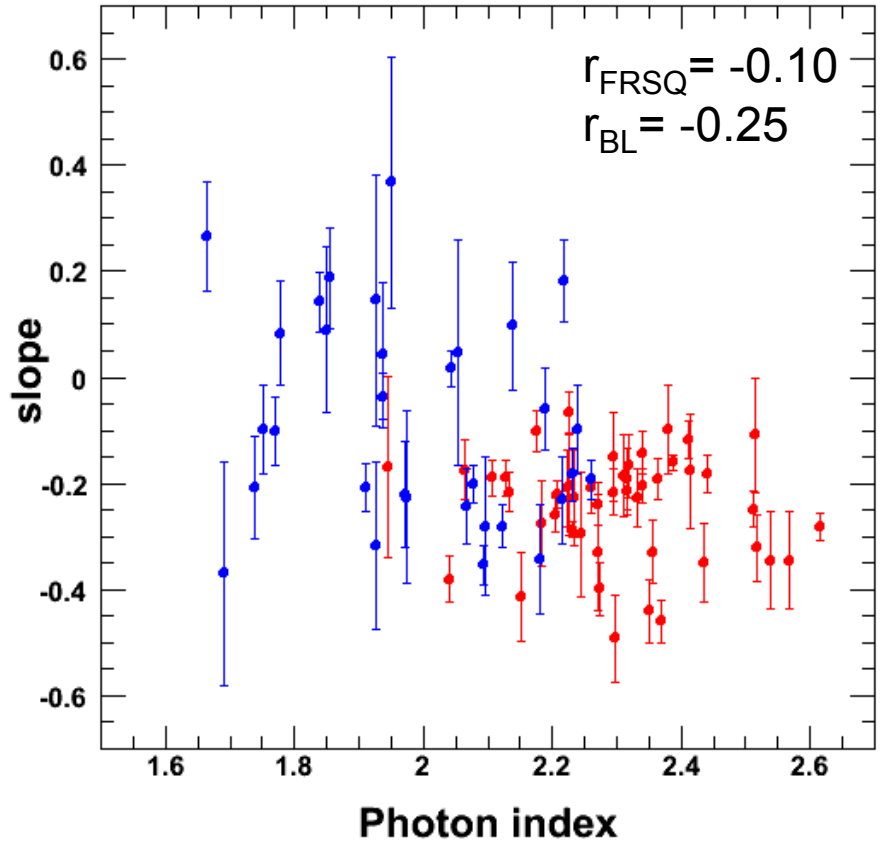


Preliminary

Index- flux slope vs source class, photon index

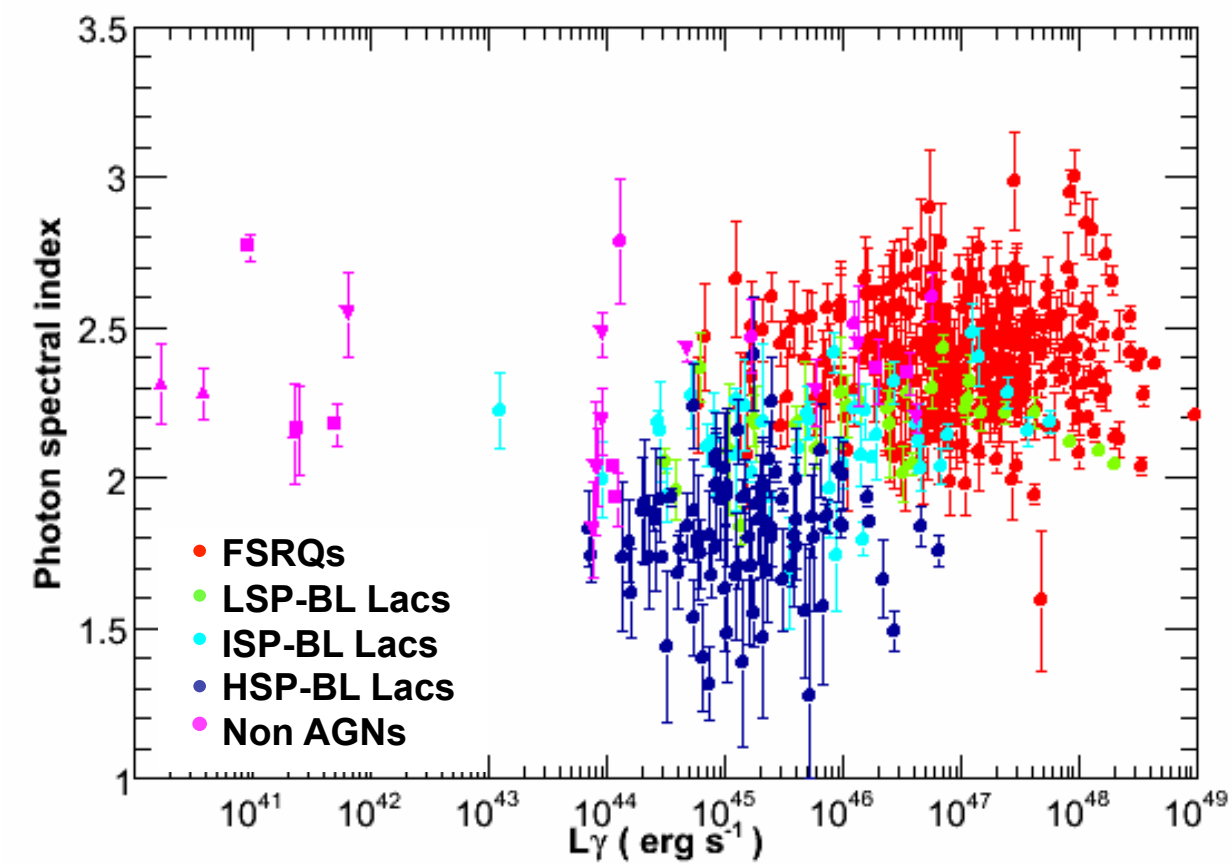


Preliminary



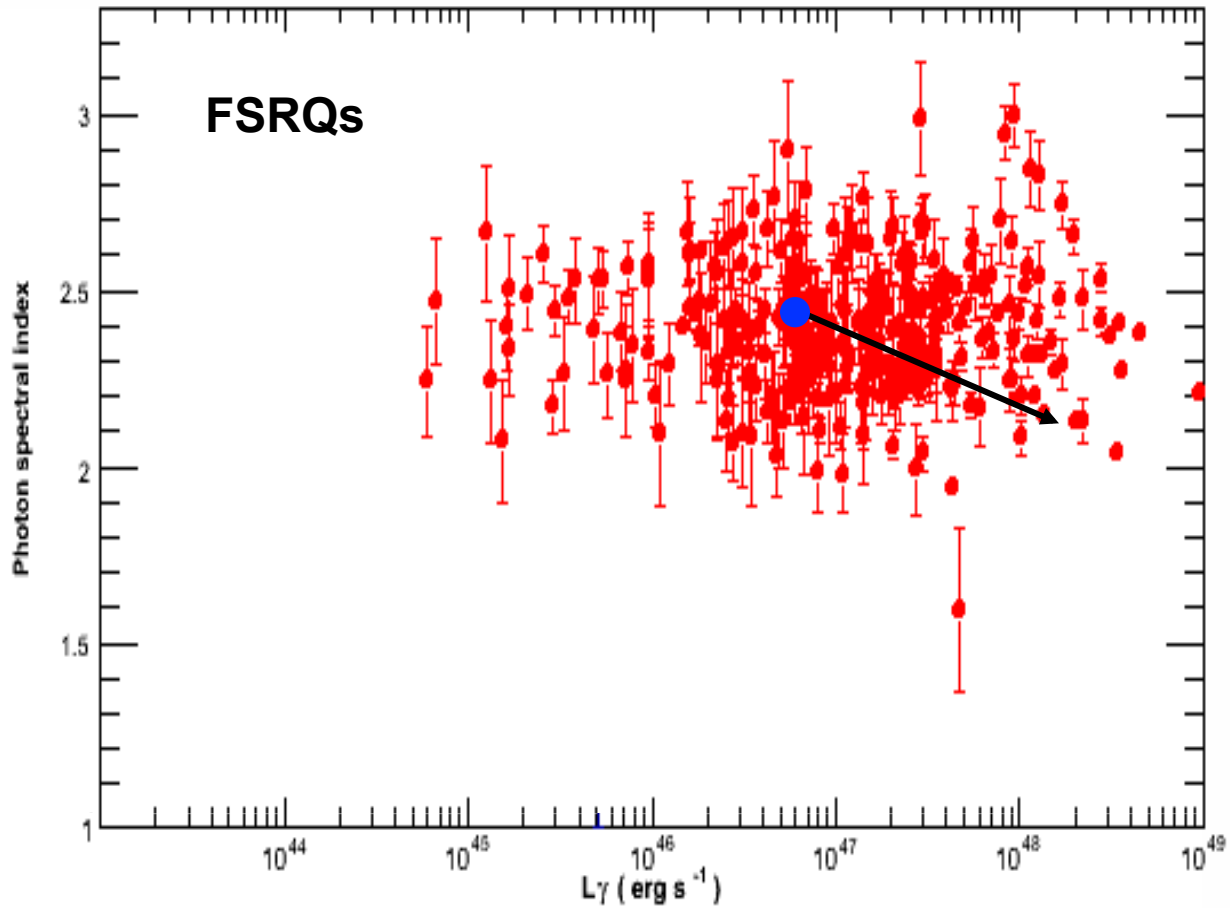
- Indication for different behaviors in FSRQs and BL Lacs
- Slopes cluster at ~ - 0.2 for FSRQs. Why?

Gamma-ray luminosity vs photon index



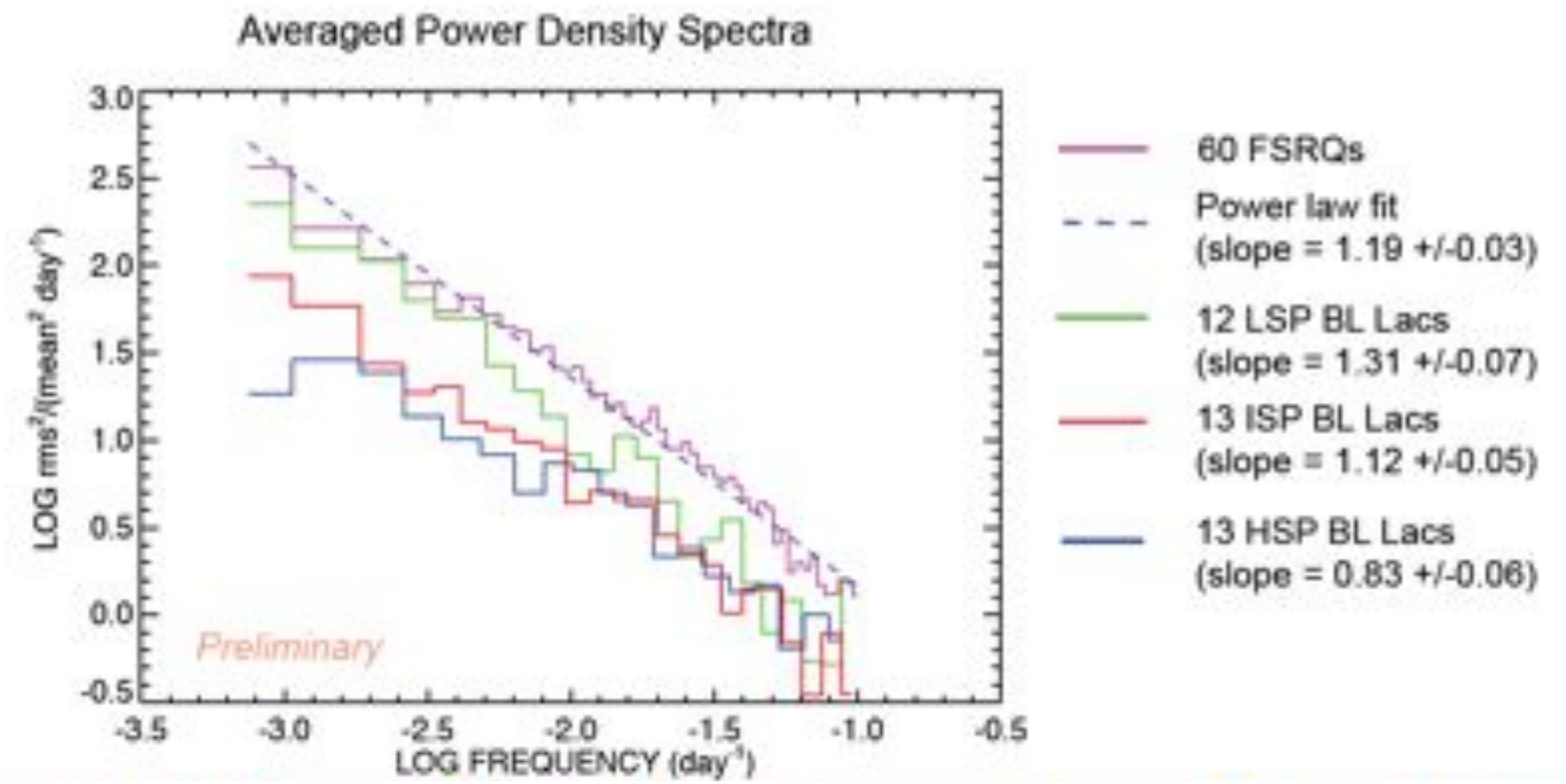
Gamma-ray luminosity and photon index averaged over 2 years

Gamma-ray luminosity vs photon index



slope= -0.2
luminosity x30

Power Density Spectra



Produced with 5-day light curves
No persistent breaks found in PDS of individual sources

See poster 8.2 by S. Larsson

Summary

- Adaptive-binning method offers some interesting features

-Well suited for cross-correlation functions

-Both lowest and highest detectable fluxes assessed for the sample sources

-Cumulative flux distributions look different for the blazar classes

- Shortest rise and decay times are similar in magnitude and evolve with different classes

-Moderate spectral variability indicative of a « harder-when-brighter » effect present for most FSRQs (slope ~0.2), while BL Lacs don't show a uniform behavior

-PDS confirm 2LAC findings with a trend to flatter distribution as the synchrotron peak moves to higher frequencies