Spectral Energy Distributions of Blazar Substructure

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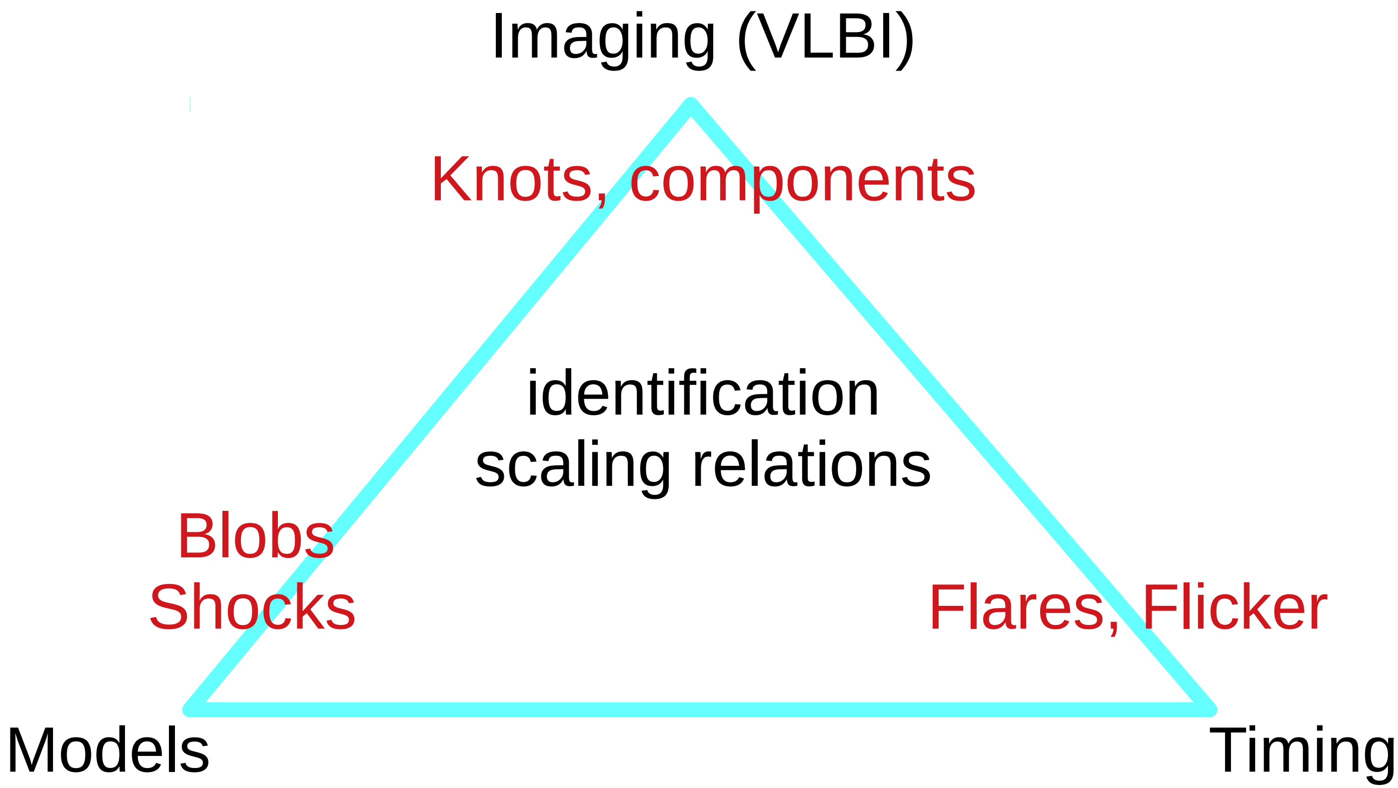
Blazar Jet Substructure



Flares

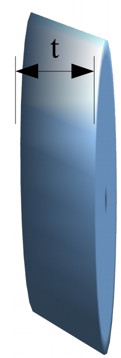
On average flares are peaked and symmetric in time.

$$\Delta t = t_{acc} + t_{cross} + t_{cool} \sim t_{cross}$$

(we have not heard much about particle acceleration & cooling)
(switching B on/off works only in synchrotron regime)

Size is given by crossing time: $\Delta t \geq \varnothing / c$

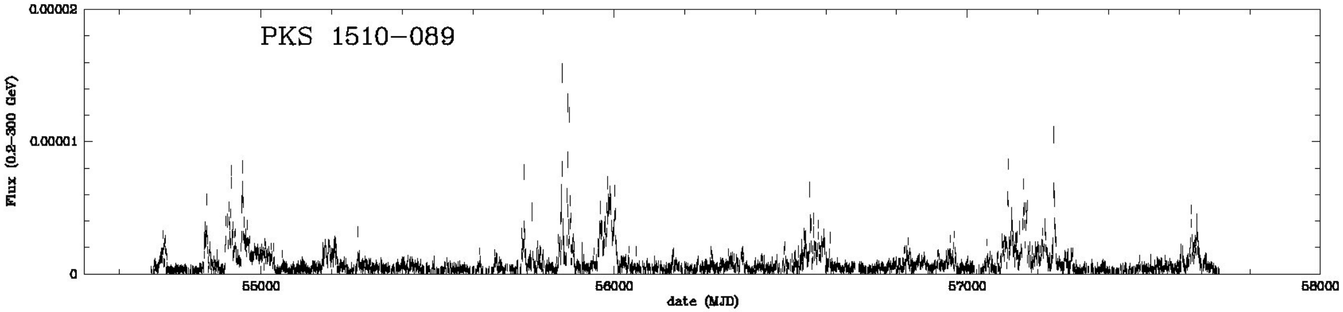
$$[\ \Delta t \sim \Delta\, \Omega / \partial\Theta / \partial t \ \sim \geq \varnothing / c\ ]$$

Assumptions: spherical volumes 

relativistic corrections: $t \rightarrow \mathcal{D} t$

Duty Cycles

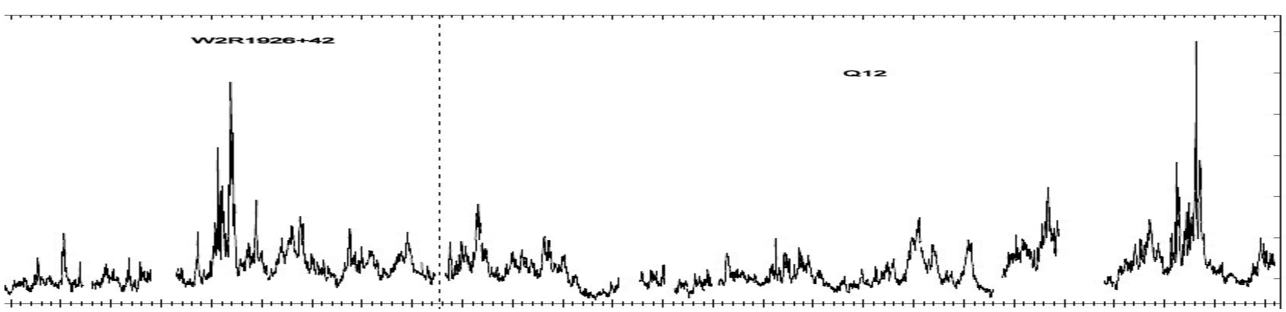
Duty cycle derivations require continuous monitoring.
Within 10yrs > Δ t > 3h [3 10^4] this is provided by *Fermi*-LAT.



Average duty cycle depends on S/N.
< ~ 10%

Jankowsky, SW, Mohammed, 2017

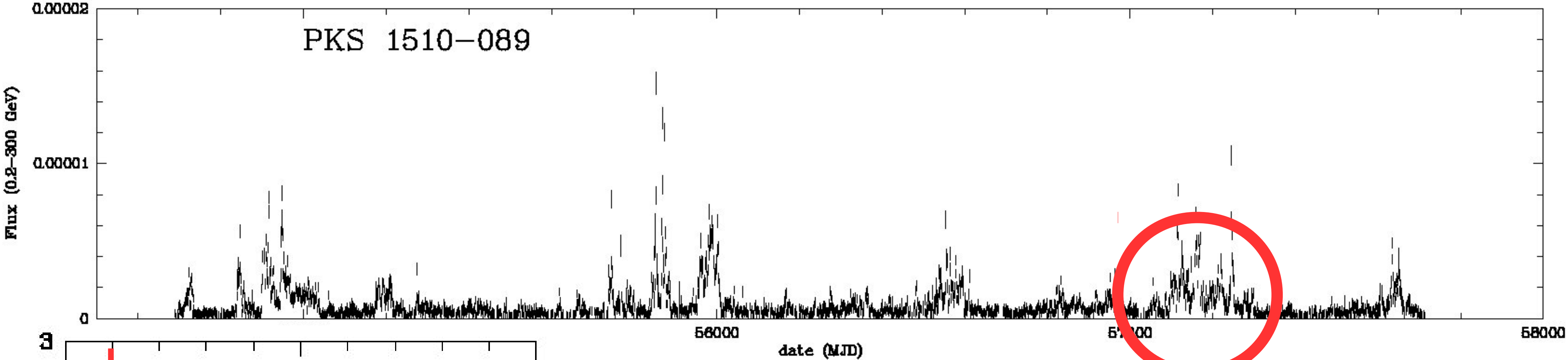
Very few other options for equally broad coverage
(Kepler (few sources) 180d > Δ t > 1 min [3 10^5].

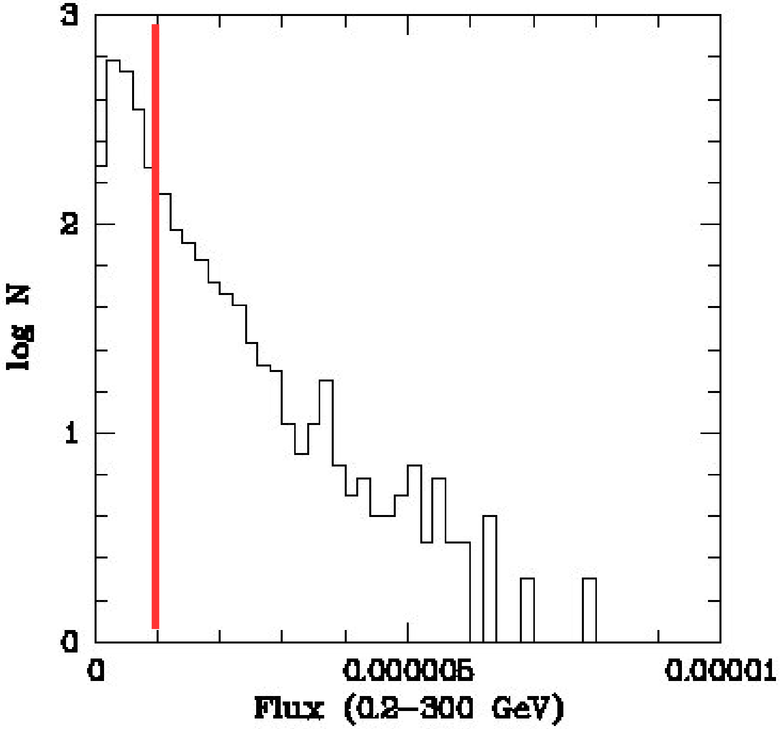


S/N limited
< ~ 10%

Edelson et al., 2013

Duty Cycle





Flux goes down to base
Bias: Faint → long flares

Bright (well sampled) Blazars:
Baseline well defined
Duty cycle: 3 sigma deviations
Lower limit (fainter flares)

Duty Cycles

In most sources well sampled lightcurves
are not saturated for most of the time.
Flares overlap, but sources are mostly at well-defined baseline.

→ base level identified (few sources have high dynamic range).

Even γ - brightest Blazars are not always detected in 1d binning.

1d – 100d binning results in dynamic range < 100

In most sources duty cycle < 10%
(Selection biases: Most of the time: Duty Cycle < 10%)

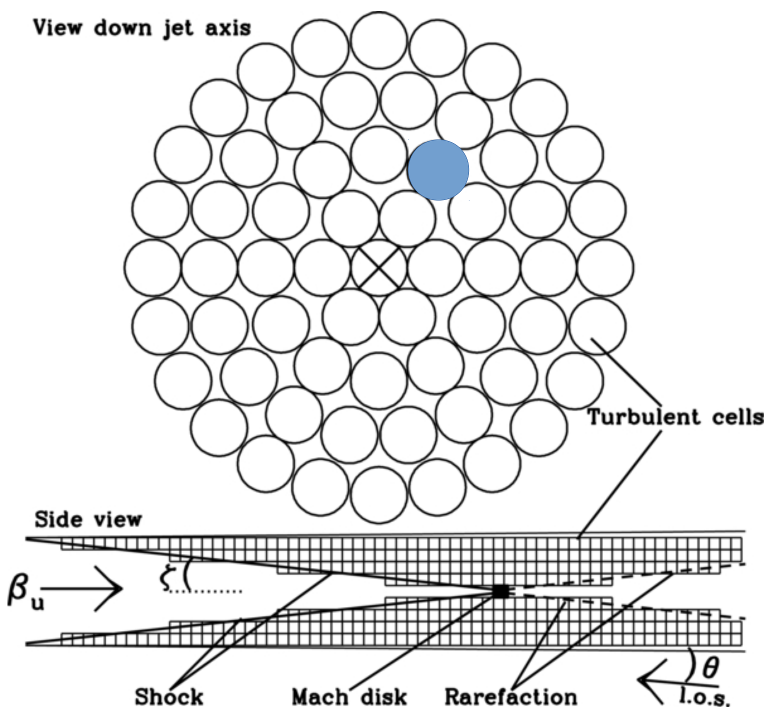
Caveats: adaptive binning finds higher fractions of total time in states significantly brighter than minimum level (MC).

Duty Cycles

For a large fraction of the total time the is only one (or no) flare.

Most flares are fast (10^5-10^6 sec) → Most flaring regions are small.

Spherical regions are much smaller than the jet diameter



Diameter of order few pc ?
(beyond BLR)

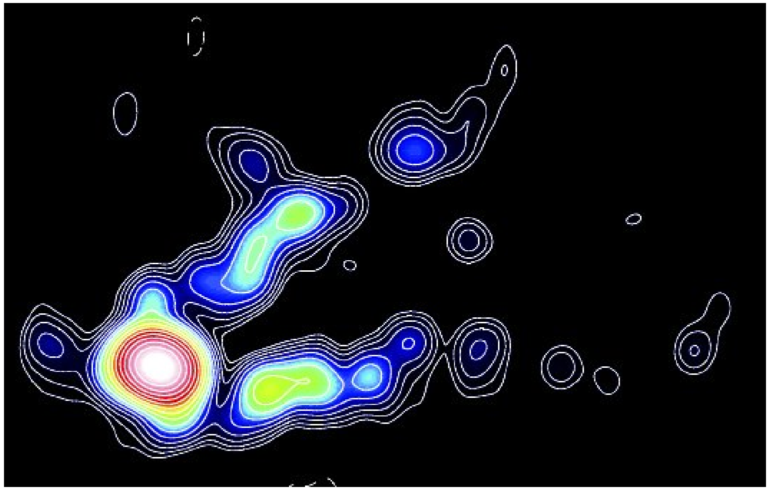
→ Projected filling factor is very small (10^{-4} – 10^{-2} for $\mathcal{D}$ ~ 10)

Marscher: ApJ 780,87 2014

Filling Factor

Volume filling factor depends on width of ‘gamma-sphere‘ from which gamma - flares can originate.

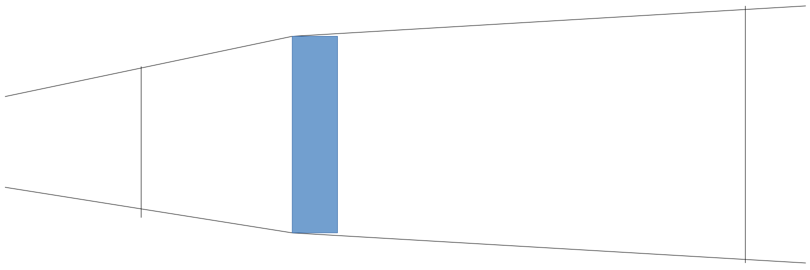
(Would be identical to the volume that includes substructure emitting synchrotron flares only in SSC models)



What is the radial range within jets that contains substructure which give rise to flares?

M87, GMVA

Filling Factor



Flare rate corresponds to all active subregions along the line of sight.

R_{min}: base of the jet? core?
R_{max}: collimation region?
Jet-diameter throughout this radial range?

Volume filling factor: 10^{-2} (thin transition region) – 10^{-9} (kpc jet)

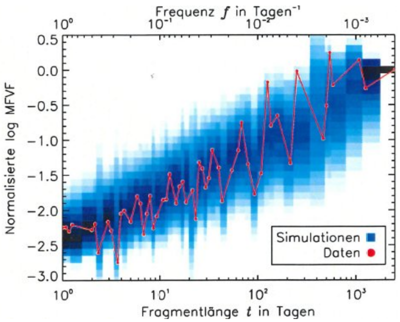
High contrast in radiation energy density (origin of baseline flux?)

Topology

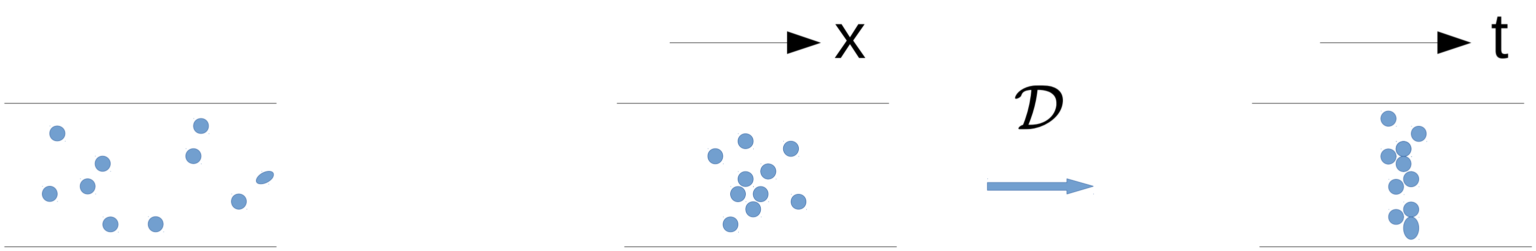
20% (+/- factor 4) of time-averaged flux from 10^{-2} – 10^{-9} of volume.

High contrast in radiation energy density
(Doppler factor helps only to a limited extend, Doppler crisis)

Low filling factor → individual regions contribute.
How does this fit to log-normality of flux distribution?



Multiplicative processes → lognormal flux distribution.



Power Density Spectrum

Two-point correlation function
Fourier transform of power spectrum of flares – not of flux points.

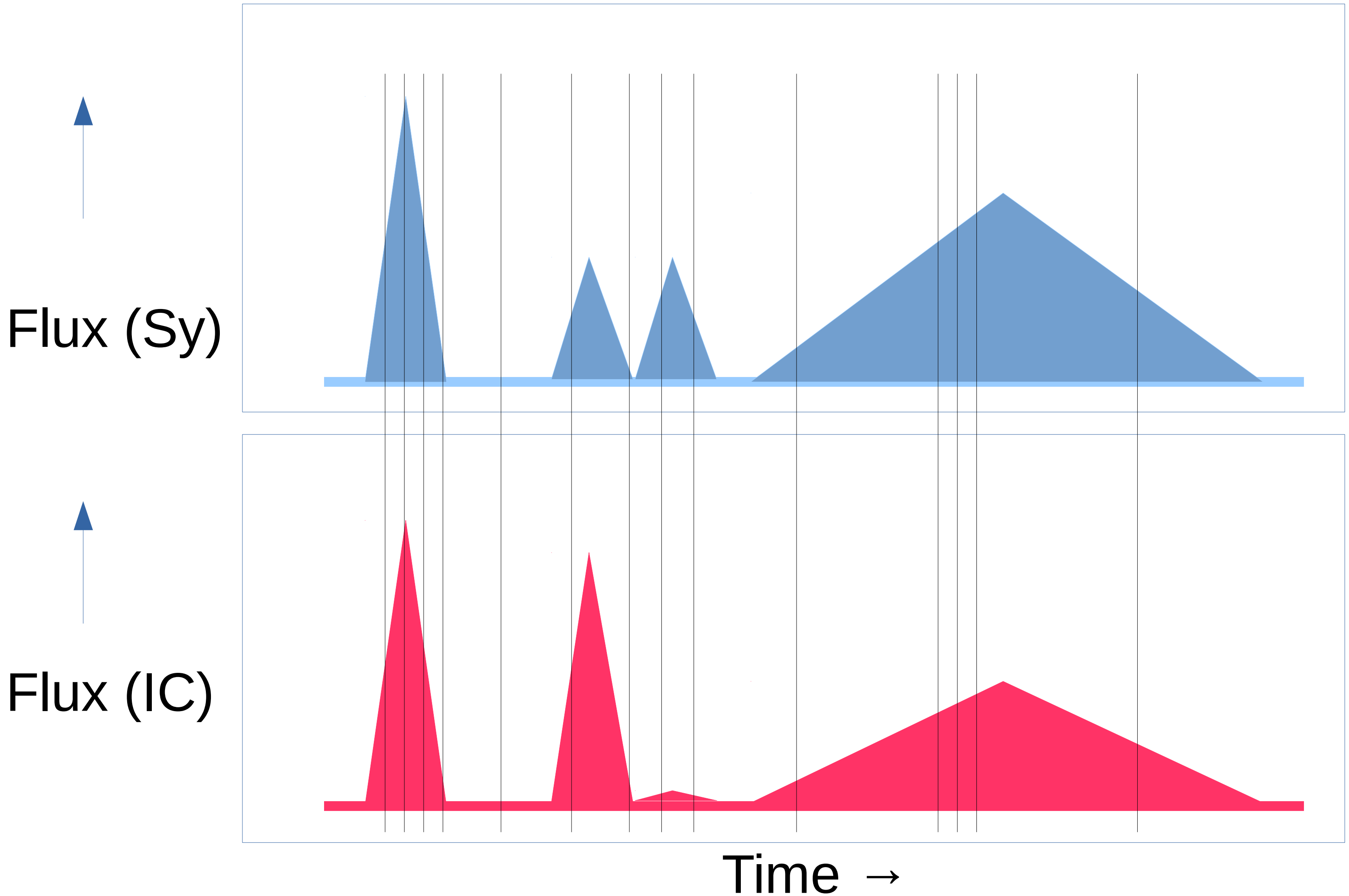
Resolving blended flares (e.g. Luigi Pacciani).

Temporally resolved flares introduce multiple samples of the same flare in flux power spectra →
flux power spectra steeper than spectra of flare number density.

High-frequency end of spatial correlation function →
Stratification of subregions.

How different are individual subregions?

Scalings and Durations

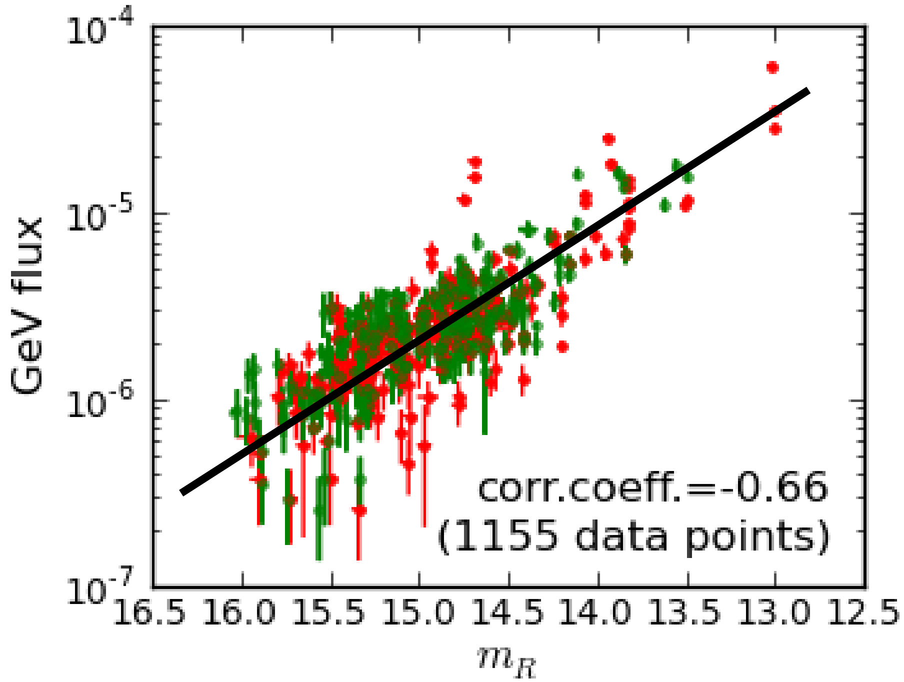


SEDs of Substructure

How similar are different subregions in the same source?

Insufficient sampling to derive full SEDs.

Band-wise matching on most complete data sets: optical – γ rays



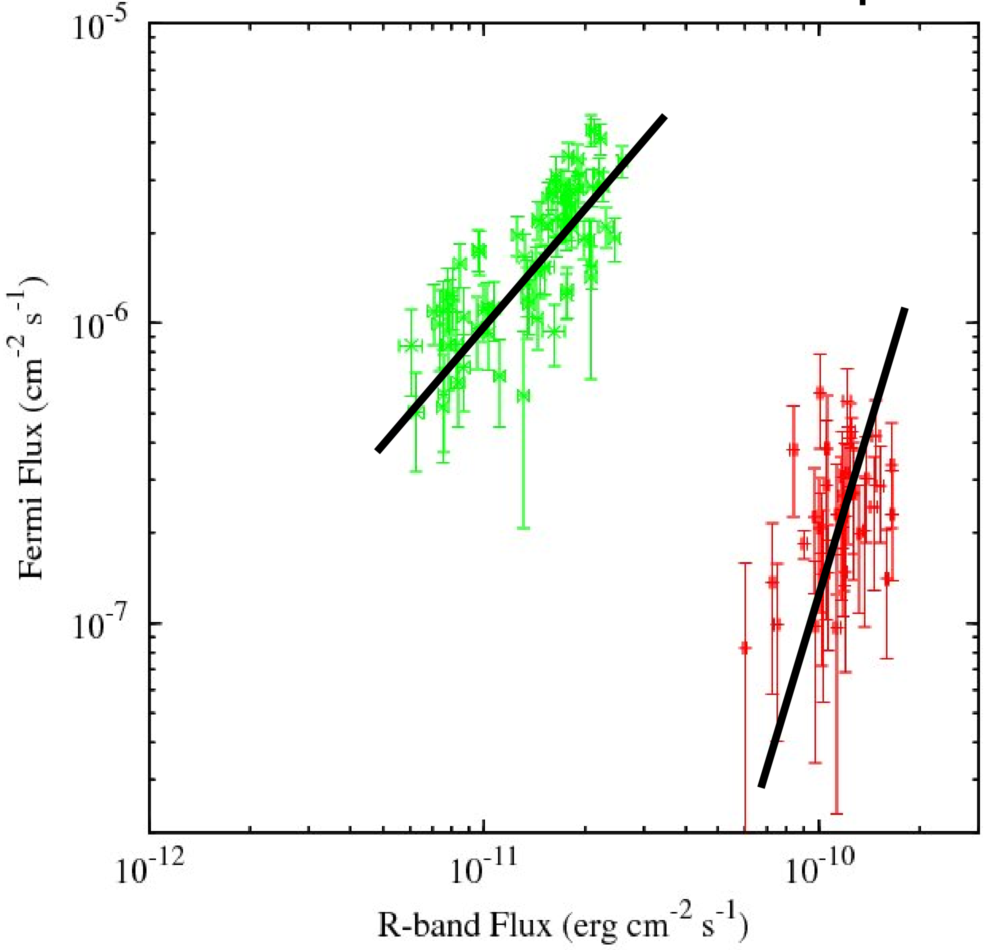
see also Valeri Larionov

Simultaneous 1 day bins
Significant scatter beyond errors
Scatter increases with # flares

Hauser, SW, 2013

F_{GeV} – F_{eV} Relations

100 sources with > 100 samples: We confirm early results from Wagner et al., 2012



Significant correlation
Significant real scatter
Slopes in range 0.3 – 3.2

3C454.3 and **PKS 2155-304**

Individual flares differ from average trends.

In preparation:
scatter due to IDV

F_{GeV} – F_{eV} Relations

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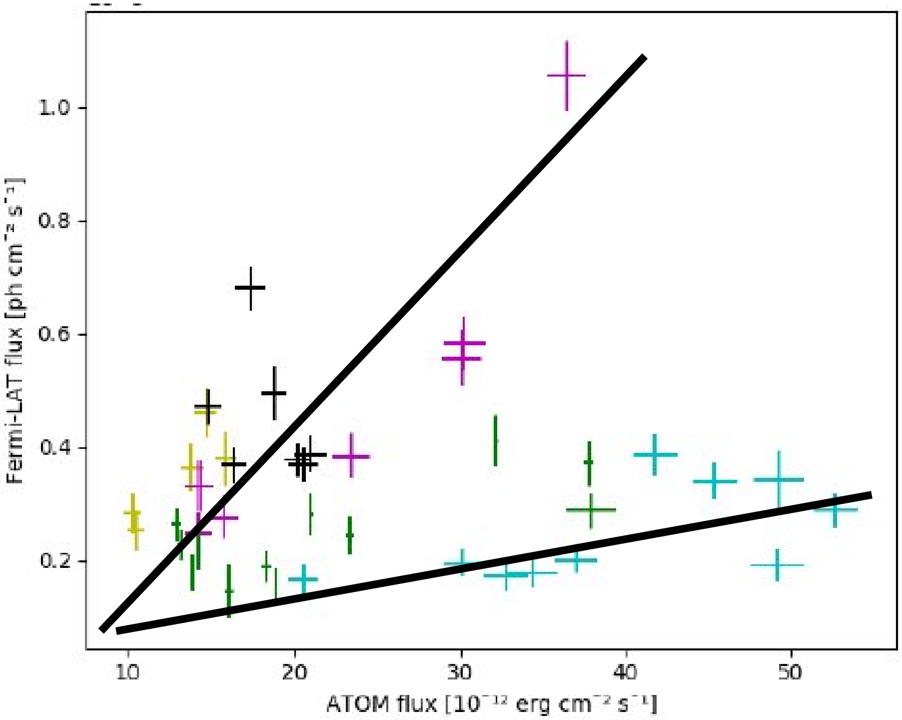
PKS 1510-089



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Summary

Well resolved, high density light curves in the bands sampling the high-energy end of synchrotron and IC-branch (optical, γ-rays) show low to moderate flare duty cycles.

Most of the time there is one or no flare from regions with radii much smaller than the local jet diameter.

Flaring knots have low filling factor and high contrast in radiation energy density.

Topological distribution requires yet more data and radial profiles

SED of substructure reveals diversity throughout source sample.