Relativistic Jets: Processes Powering Broadband Emission and Locations of Emission Region

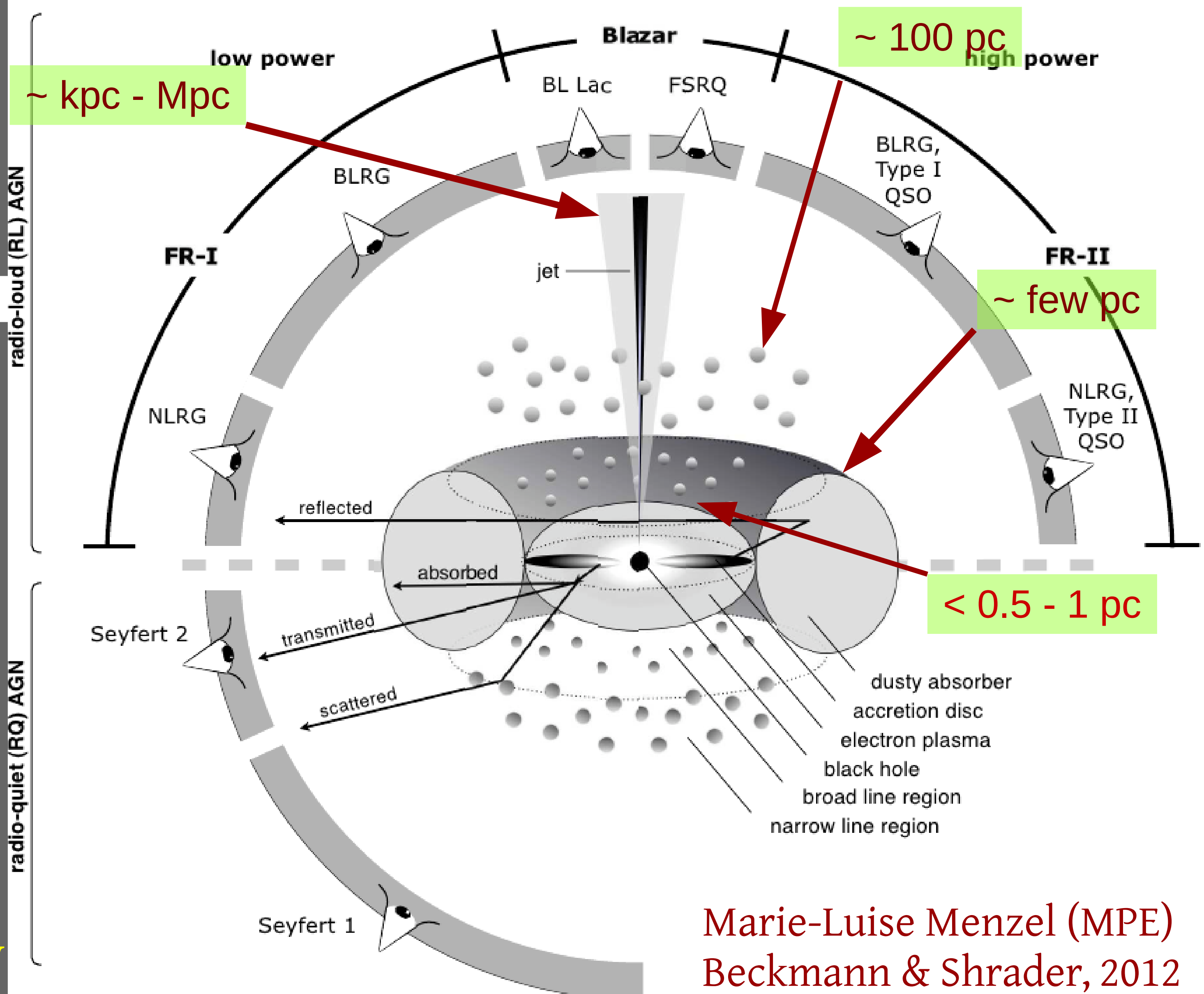
Pankaj Kushwaha
(With: E M de Gouveia Dal Pino, P Wiita, A C Gupta)
Department of Astronomy (IAG-USP)
University of Sao Paulo

AGNs in a Nutshell: Views matters!

☛ AGNs: Galaxies with Optical band luminosity >= 10^{44} erg s^{-1}

- Empirical division on observational properties

- Radio-loudness
- Emission line properties
- Variability
- Radio marphology
- Radiative power



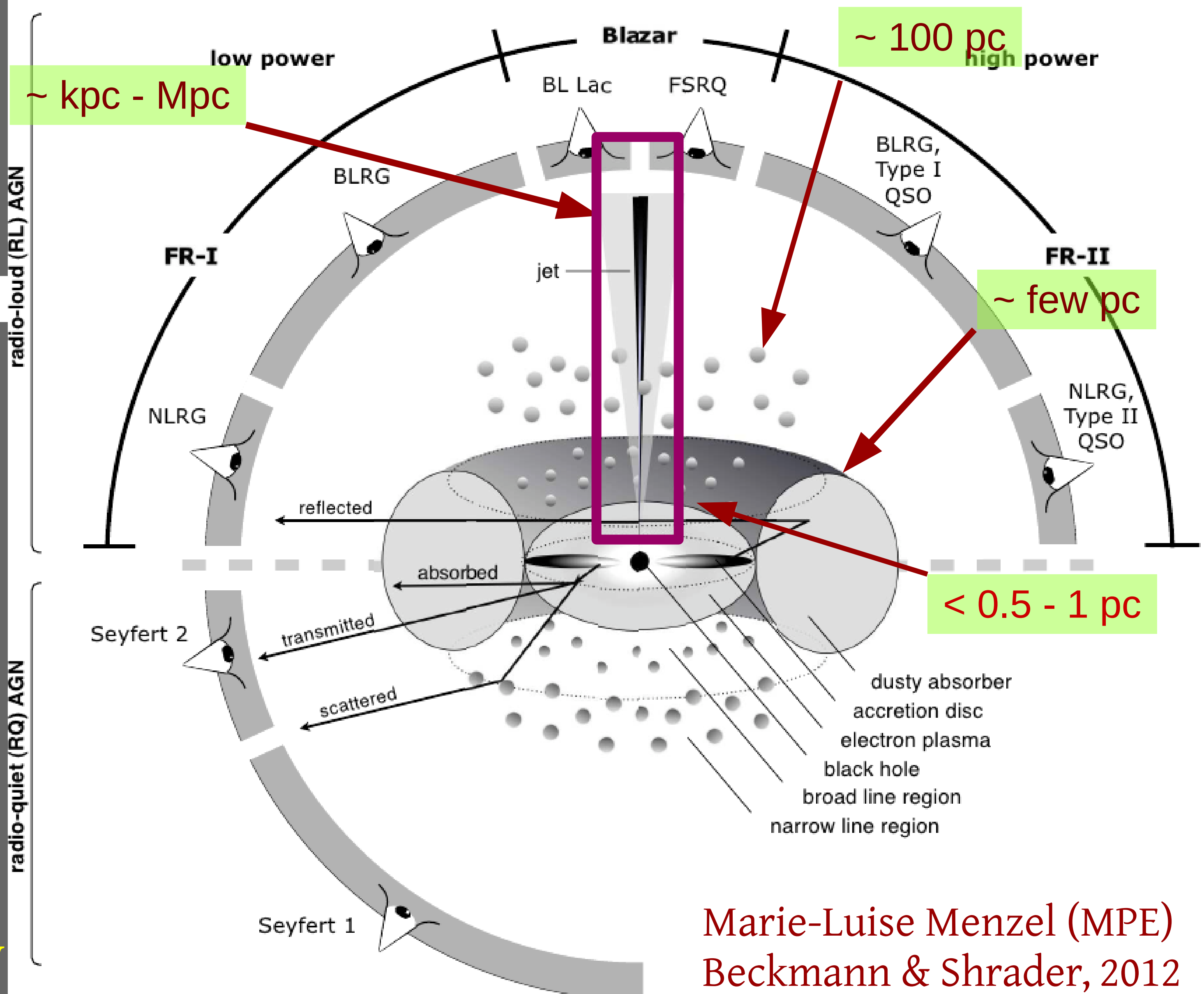
Marie-Luise Menzel (MPE)
Beckmann & Shrader, 2012

AGNs in a Nutshell: Views matters!

☛ AGNs: Galaxies with Optical band luminosity >= 10^{44} erg s^{-1}

- Empirical division on observational properties

- Radio-loudness
- Emission line properties
- Variability
- Radio marphology
- Radiative power

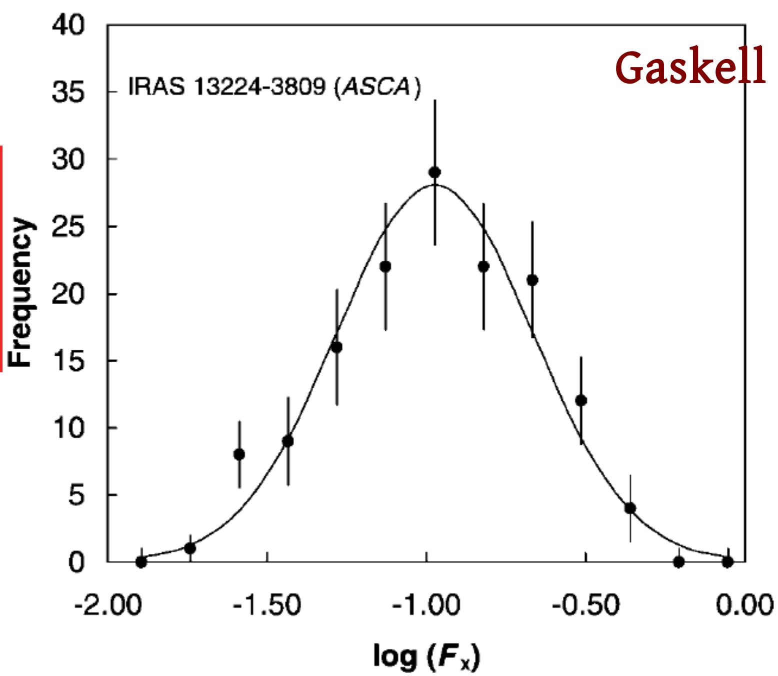


Marie-Luise Menzel (MPE)
Beckmann & Shrader, 2012

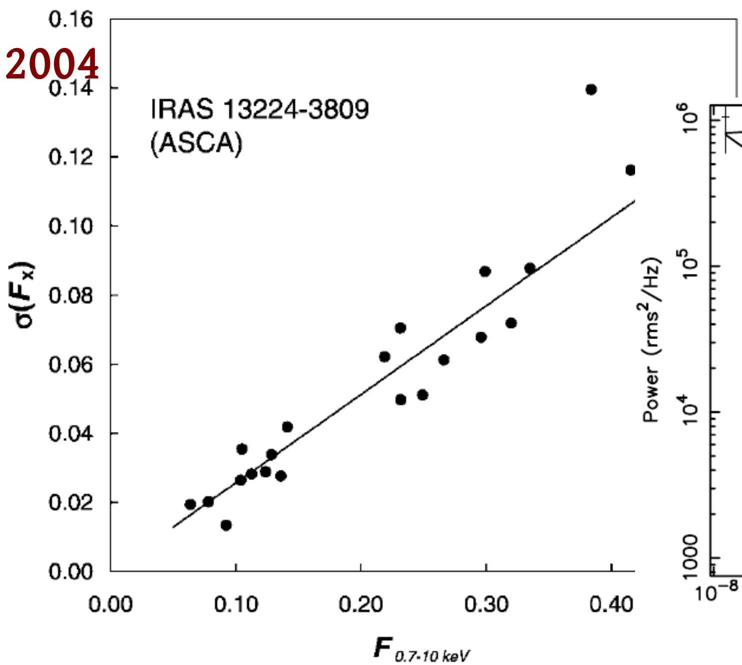
AGNs: High Energy Variability Characteristics

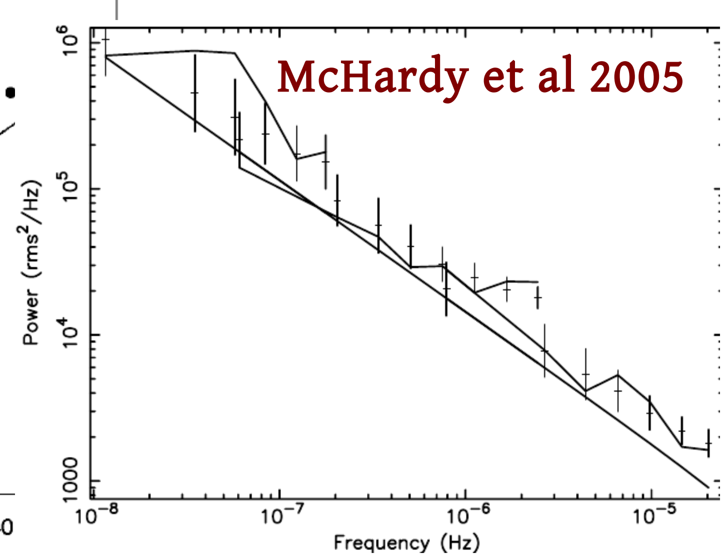
- X-ray emission from AGNs/BXB and other accreting-sources show a lognormal flux histogram with a linear rms-flux relation and a flicker noise power spectral desnity (PSD).

- These characteristics have been attributed to multiplicative fluctuation in the accretion-disk (**Uttley et al. 2005**).



Gaskell 2004



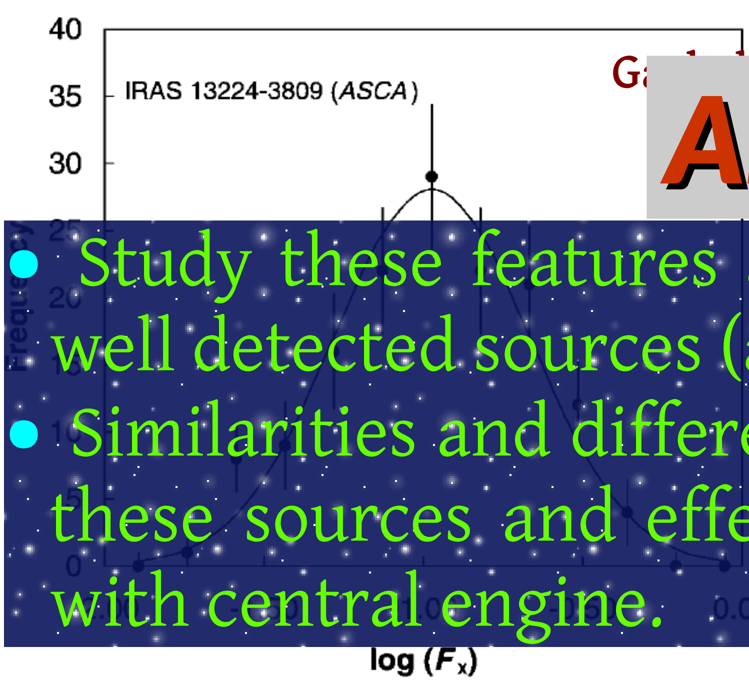


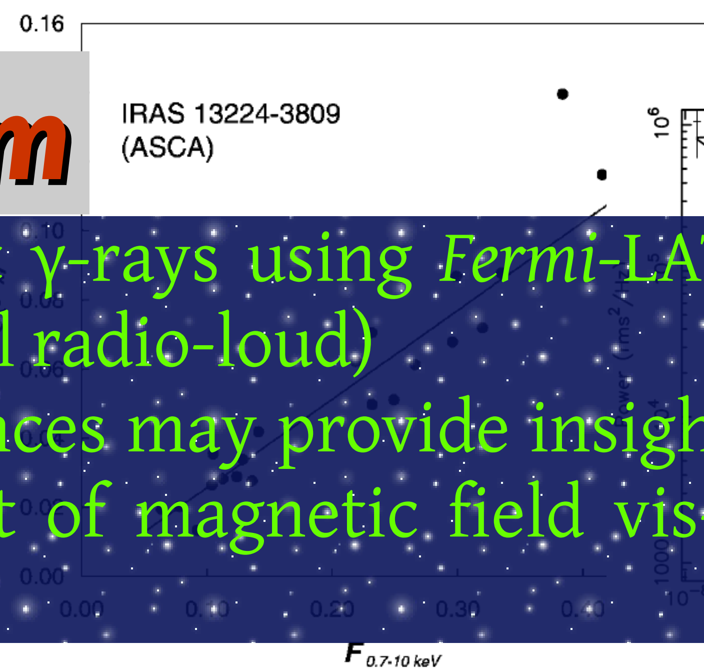
McHardy et al 2005

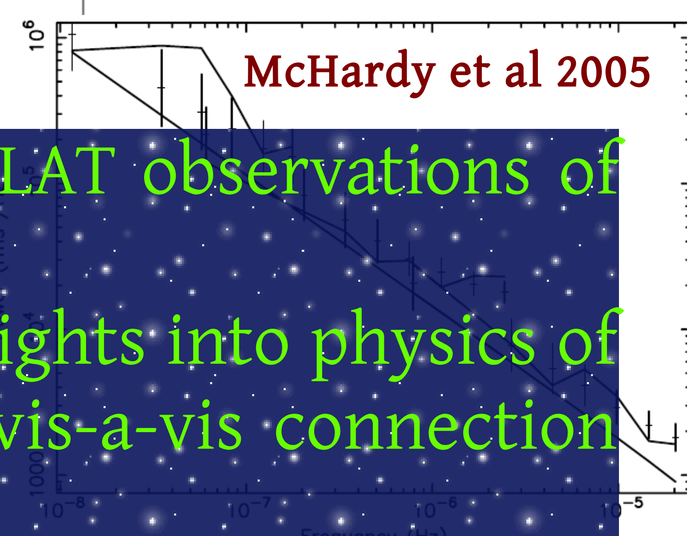
AGNs: High Energy Variability Characteristics

- X-ray emission from AGNs/BXB and other accreting-sources show a lognormal flux histogram with a linear rms-flux relation and a flicked noise power spectral desnity (PSD).

- These characteristics have been attributed to multiplicative fluctuation in the accretion-disk (**Uttley et al. 2005**).





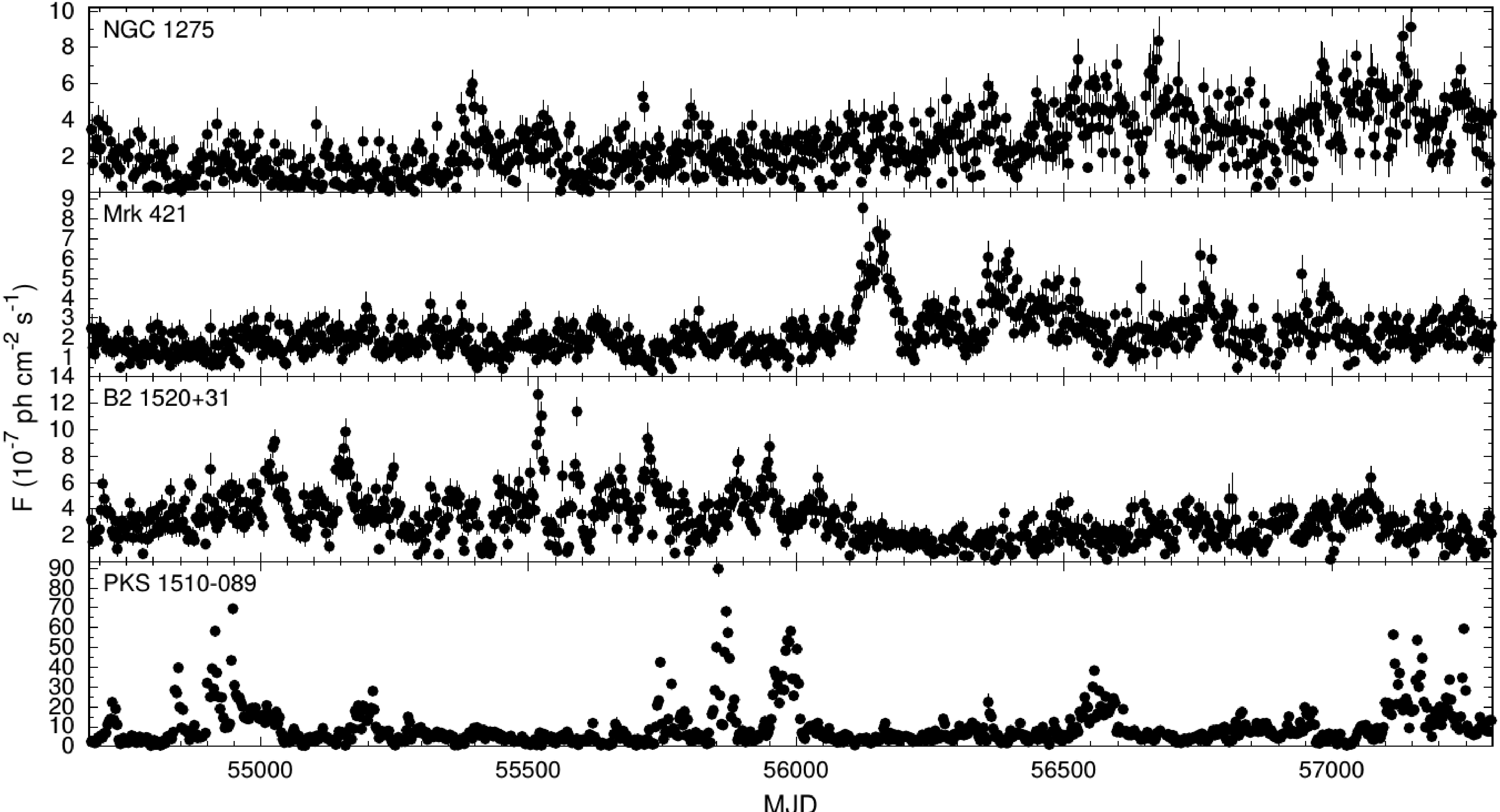


Aim

- Study these features at γ-rays using *Fermi*-LAT observations of well detected sources (all radio-loud)
- Similarities and differences may provide insights into physics of these sources and effect of magnetic field vis-a-vis connection with central engine.

Fermi-LAT Bright AGNs: Long term light curve

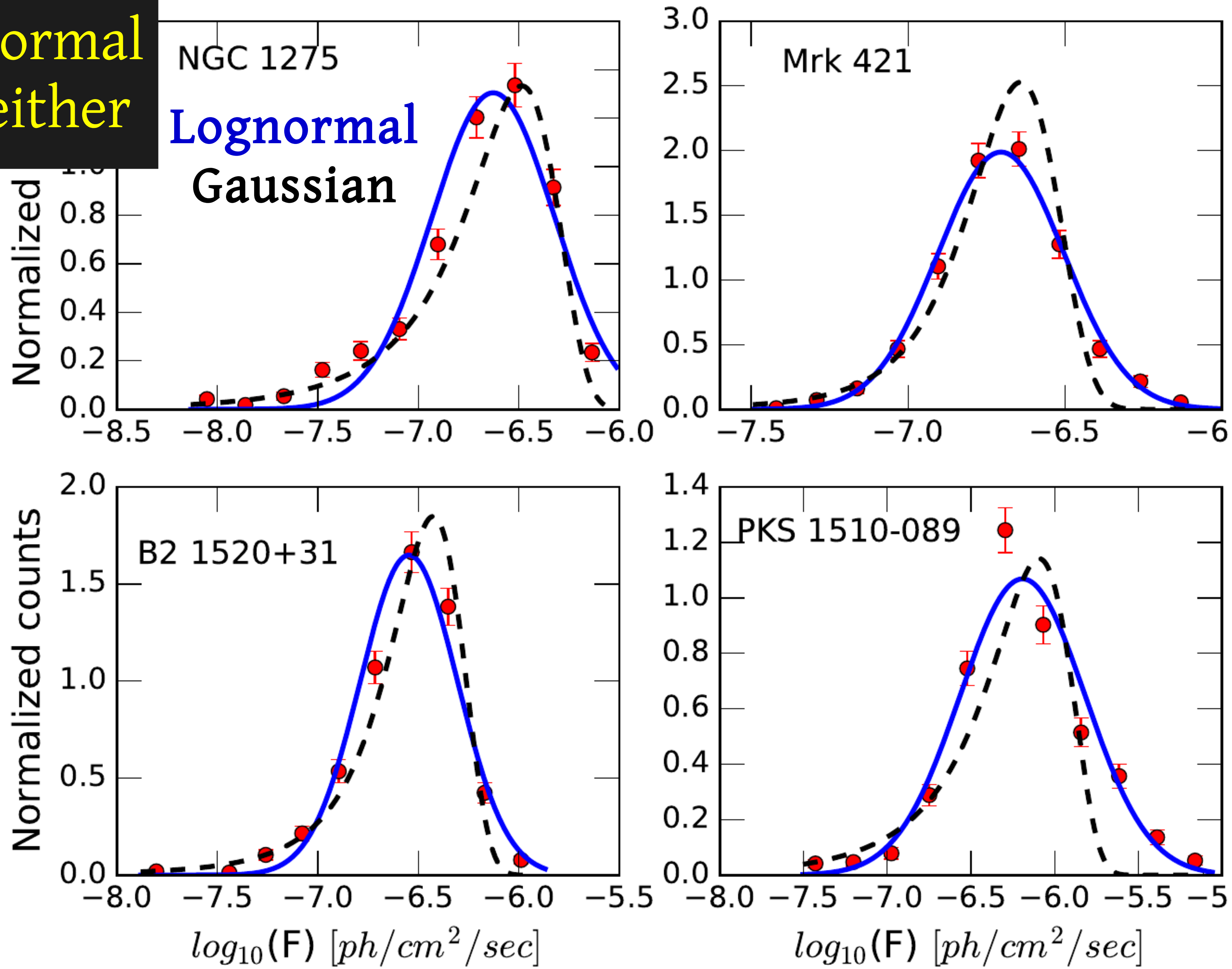
- *Fermi*-LAT (0.1 – 300 GeV) light curves with 3d binning.
- Compromise between physics goal and limitations with data.



Kushwaha et al 2017, ApJ in press

Fermi-LAT Bright AGNs: Histograms

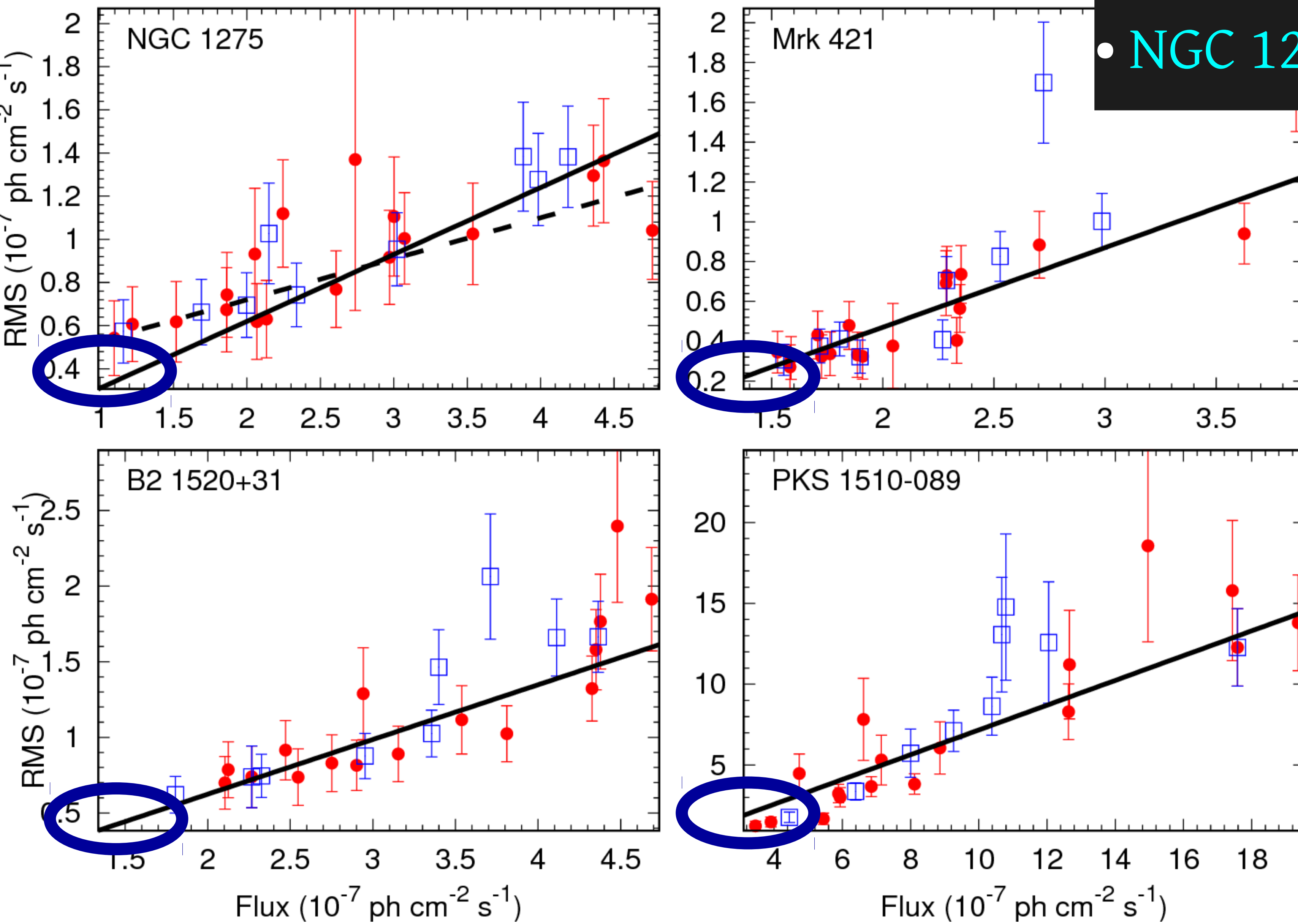
- Blazars: lognormal
- NGC 1275: Neither



Kushwaha et al 2017, ApJ in press

Fermi-LAT Bright AGNs: RMS-Flux relation

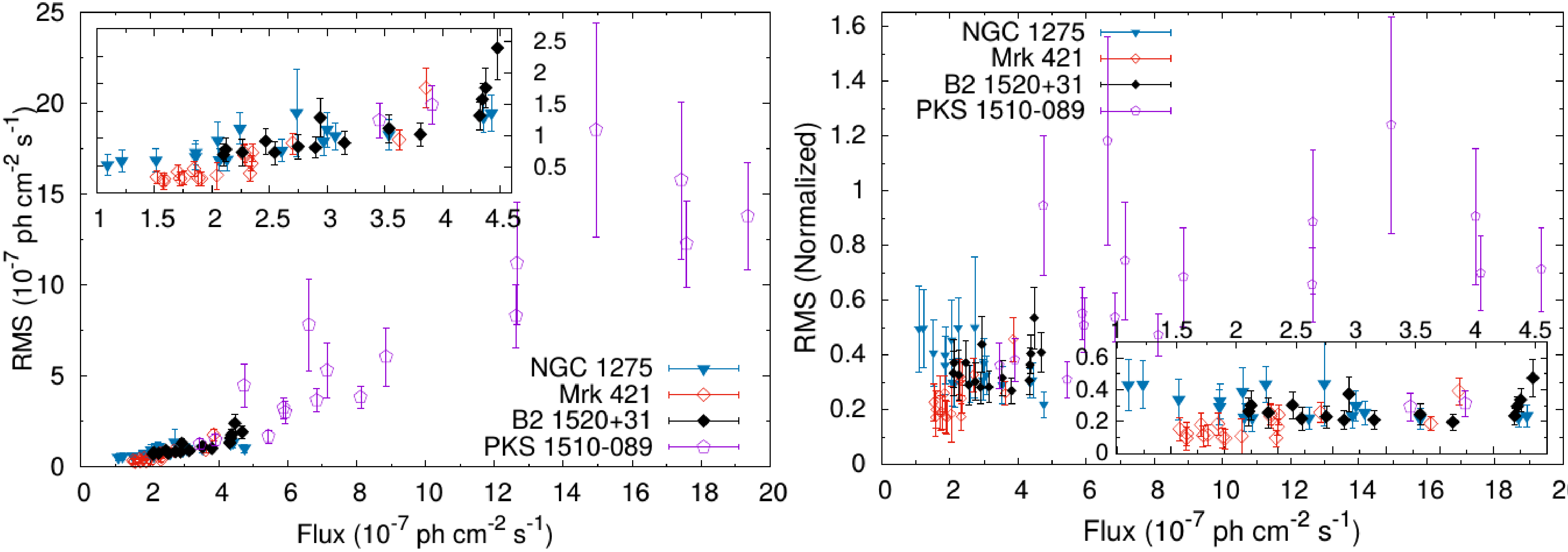
- Blazars: +ive offset
- NGC 1275: Zero



Kushwaha et al 2017, ApJ in press

Fermi-LAT Bright AGNs: RMS-Flux relation

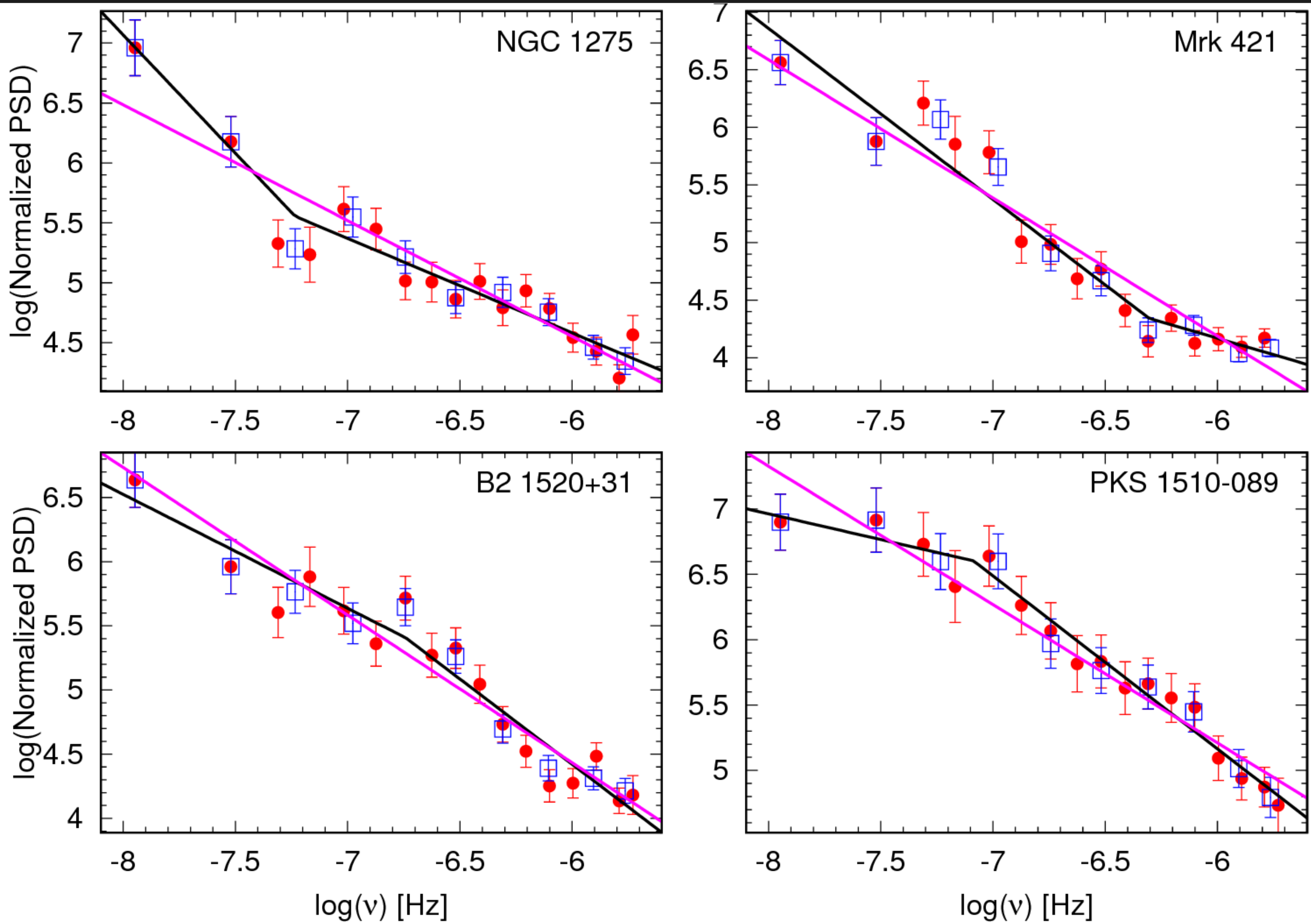
- Blazars: +ive offset
- NGC 1275: Zero



Kushwaha et al 2017, ApJ in press

Fermi-LAT Bright AGNs: PSD

- Powerlaw PSDs (slope ~ -1) with hints of break



Kushwaha et al 2017, ApJ in press

Minijets-in-a-jet Model

Pareto distributions, power-law flux histogram with a linear rms-flux relations. A special class of it follow generalized CLT

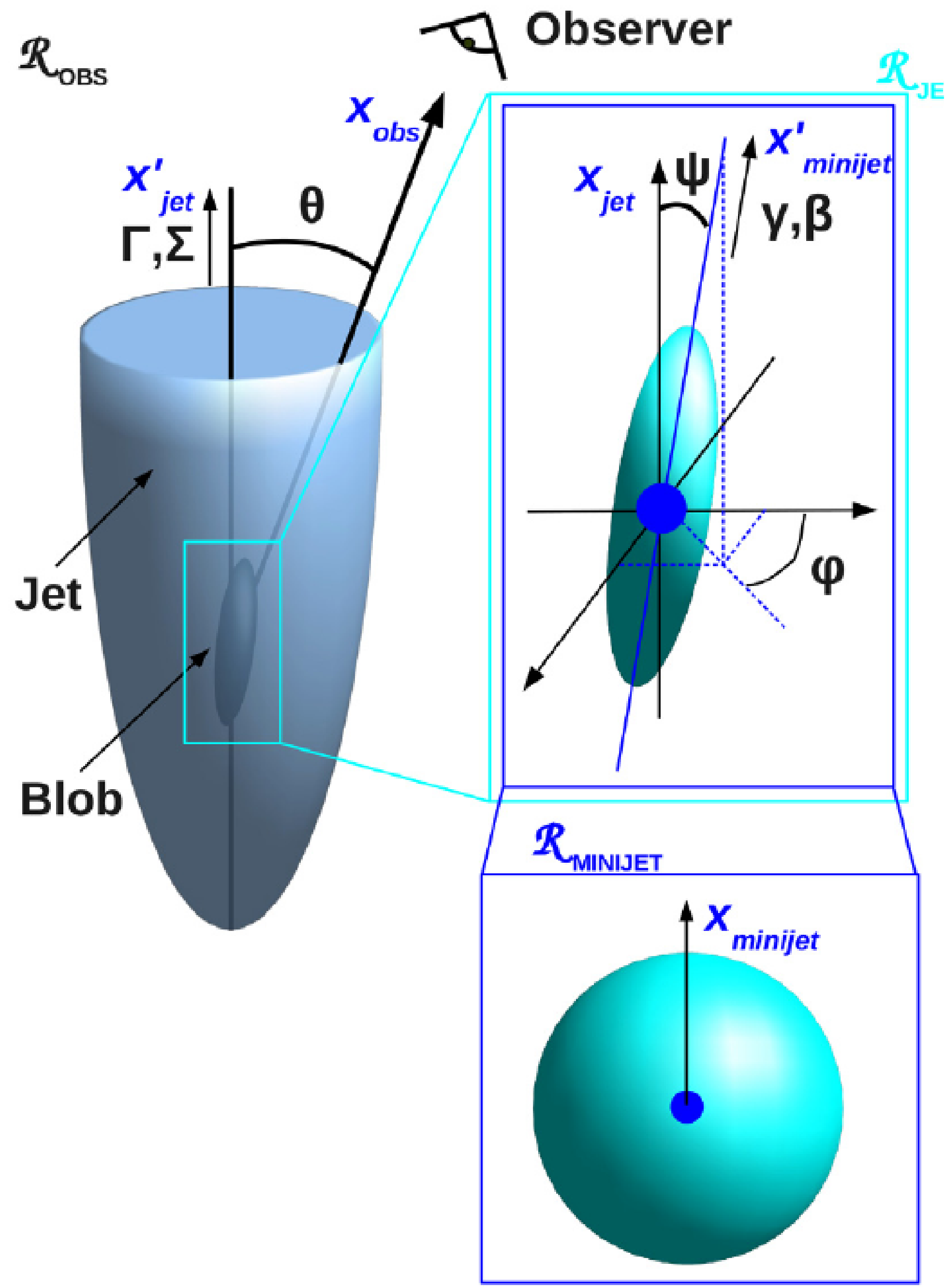
$$f_Y(y) = \frac{\alpha}{y^{1+\alpha}} \quad \text{for } y > 1$$

Randomly oriented minijet in a jet

$$f_{\mathcal{I}}(I_N) = \left|\frac{\partial g^{-1}(I_N)}{\partial I}\right| f_C\left(g^{-1}(I_N)\right),$$

$$\text{where } g^{-1}(x) = \frac{1}{\beta} \times \left(1 - \frac{1+\Sigma}{2} \times \frac{1}{2\gamma^2} \times x^{-\frac{1}{3+s}}\right)$$

$$f_{\mathcal{I}}(I_N) = \frac{1+\Sigma}{2\beta} \times \frac{1}{4\gamma^2(3+s)} \times \frac{1}{I_N^{1+\frac{1}{3+s}}}$$



Biteau & Giebels 2012

Minijets-in-a-jet Model

Pareto distributions, power-law flux histogram with a linear rms-flux relations. A special class of it follow generalized CLT

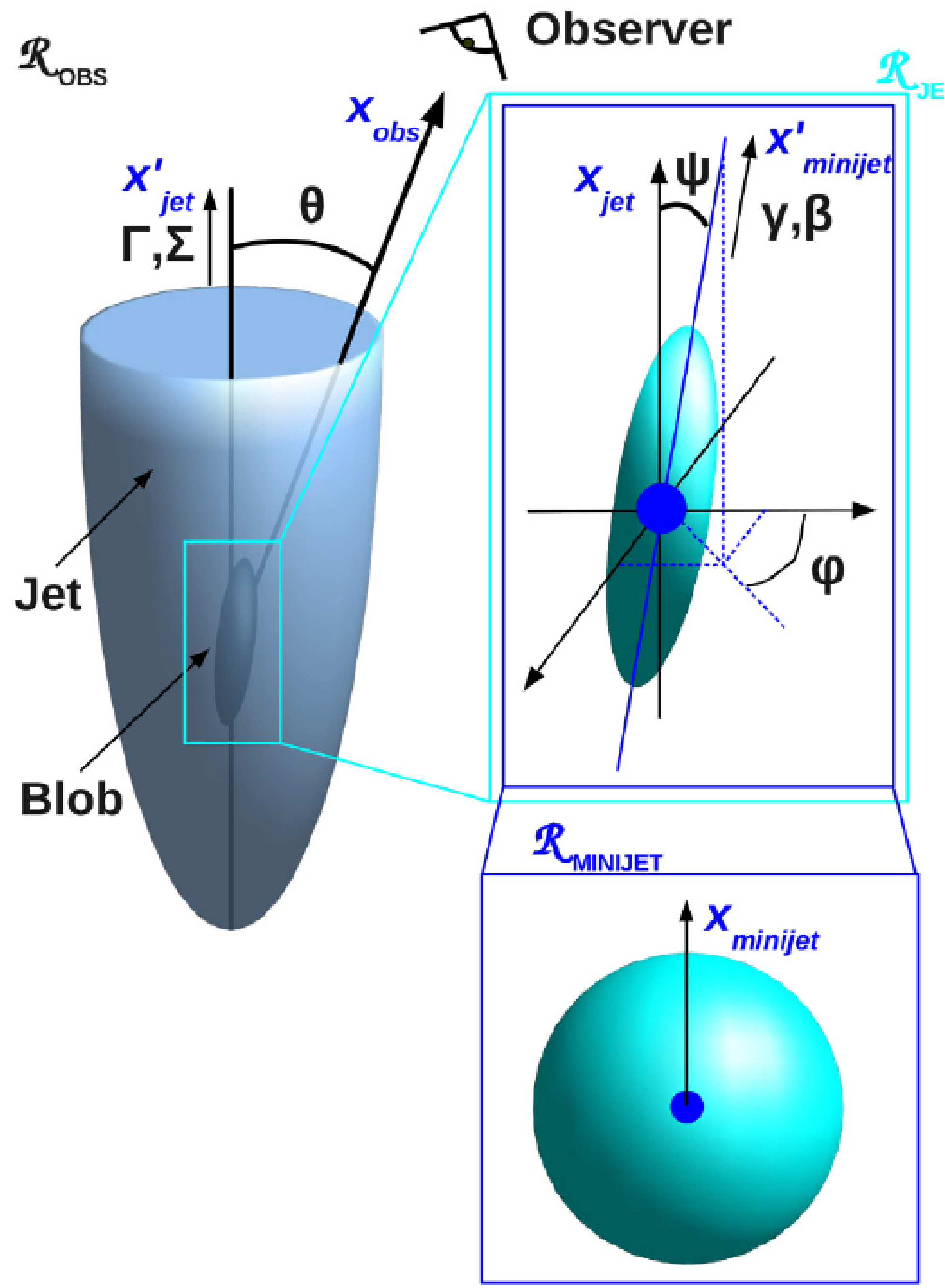
$$f_Y(y) = \frac{\alpha}{y^{1+\alpha}} \quad \text{for } y > 1$$

Randomly oriented minijet in a jet

$$f_{\mathcal{I}}(I_N) = \left|\frac{\partial g^{-1}(I_N)}{\partial I}\right| f_C\left(g^{-1}(I_N)\right),$$

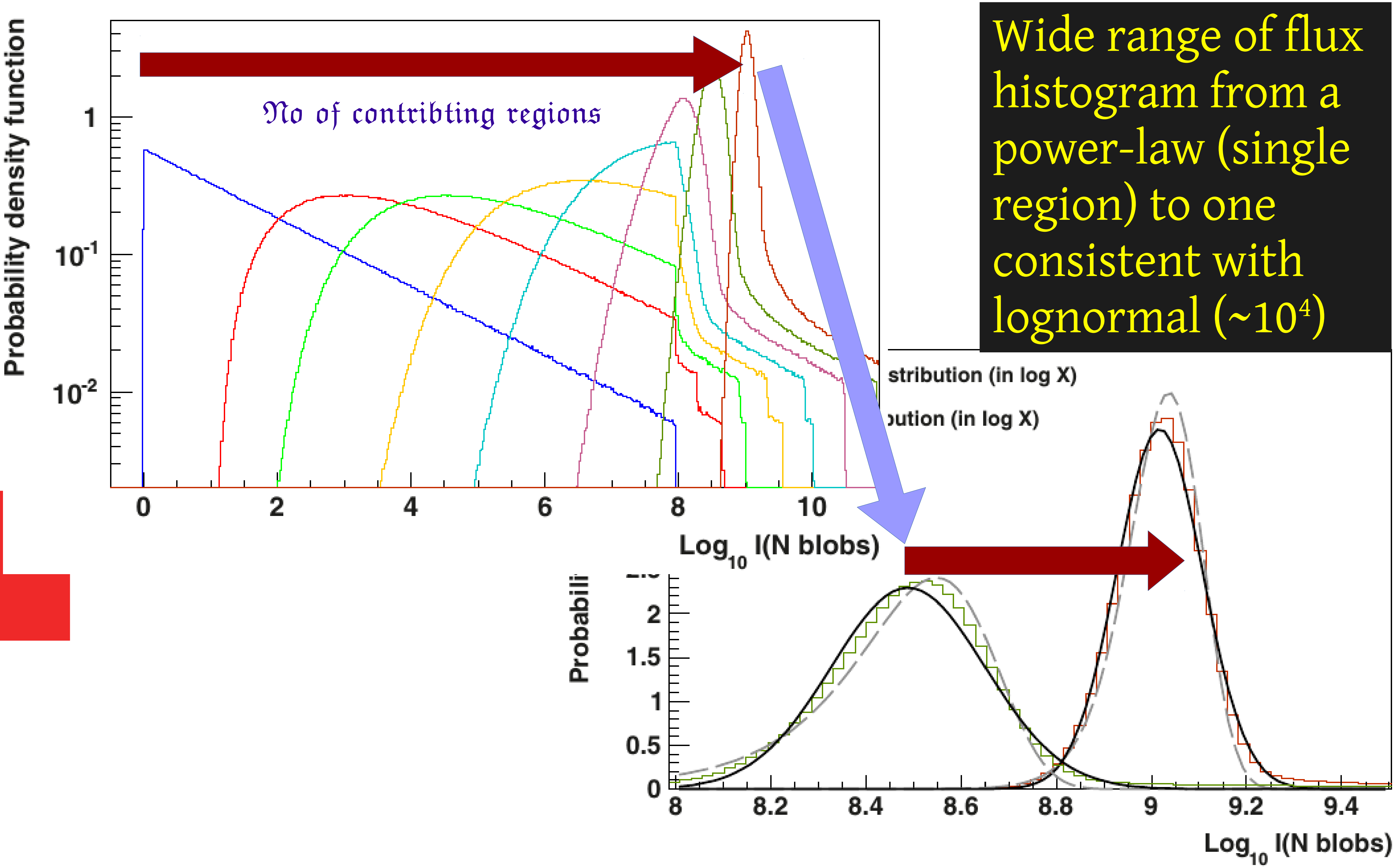
$$\text{where } g^{-1}(x) = \frac{1}{\beta} \times \left(1 - \frac{1+\Sigma}{2} \times \frac{1}{2\gamma^2} \times x^{-\frac{1}{3+s}}\right)$$

$$f_{\mathcal{I}}(I_N) = \frac{1+\Sigma}{2\beta} \times \frac{1}{4\gamma^2(3+s)} \times \frac{1}{I_N^{1+\frac{1}{3+s}}}$$



Biteau & Giebels 2012

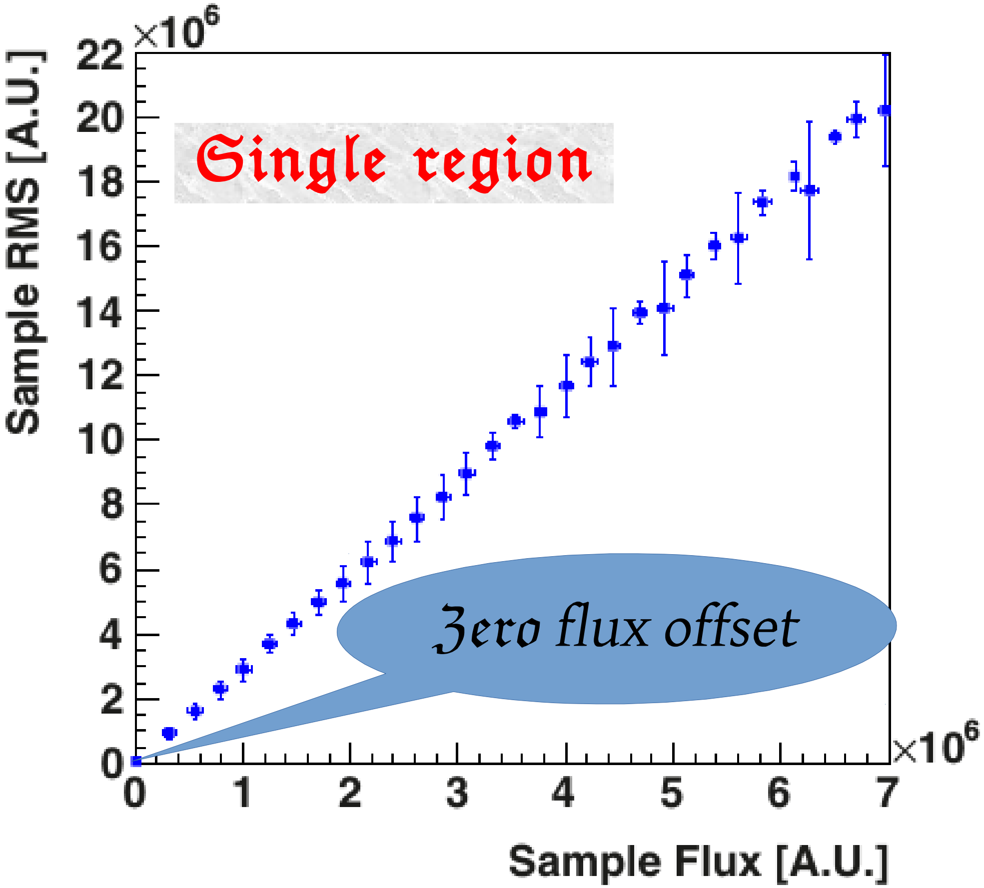
Minijets-in-a-jet Model: Histogram evolution

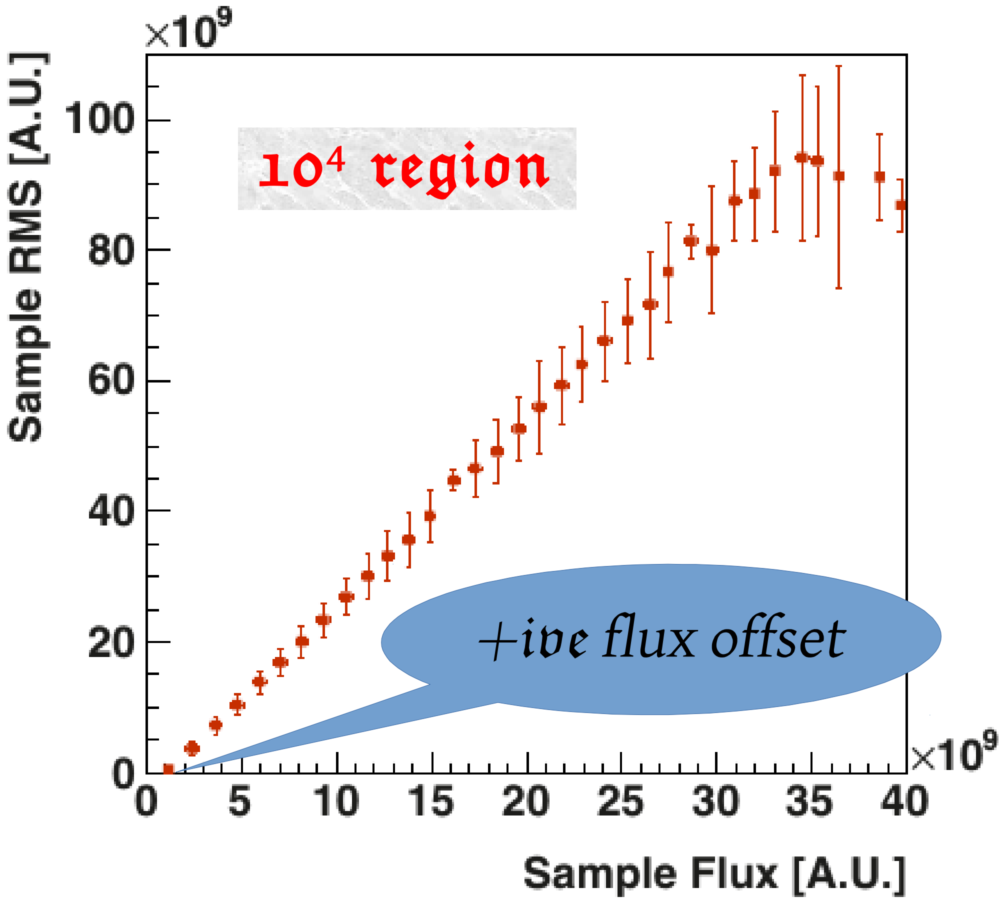


Wide range of flux histogram from a power-law (single region) to one consistent with lognormal (~10^4)

Biteau & Giebels 2012

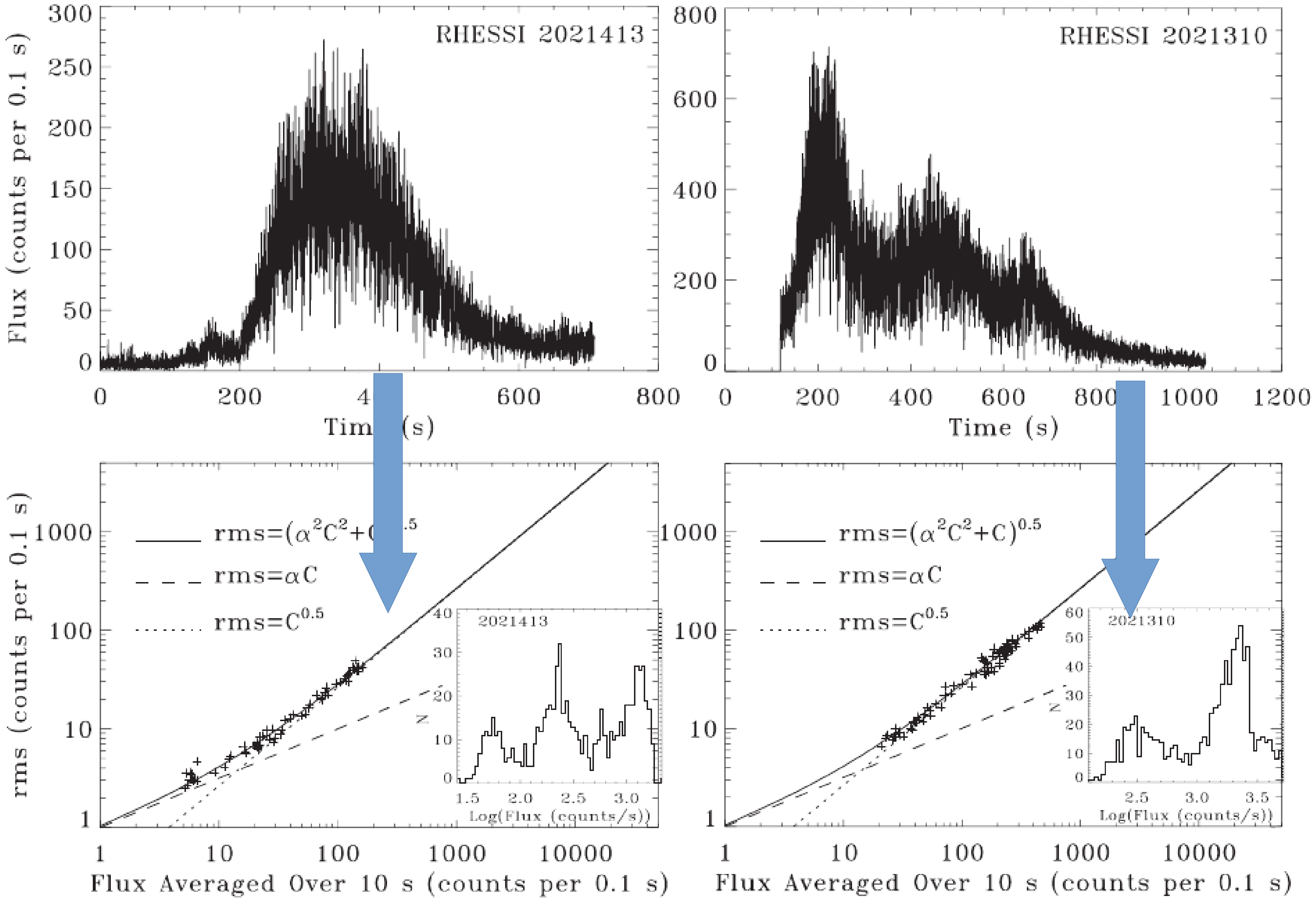
Minijets-in-a-jet Model: RMS-Flux Relation





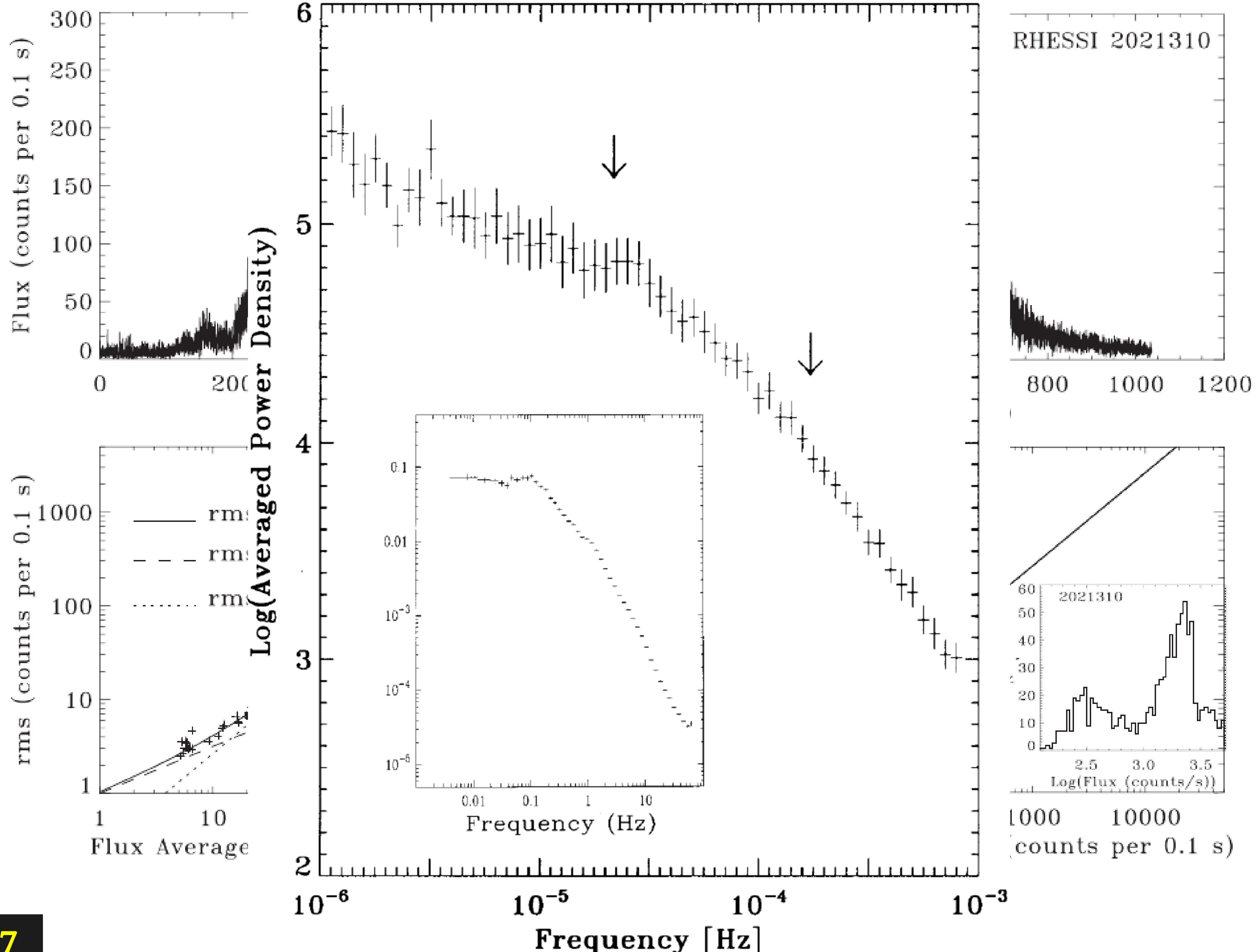
Biteau & Giebels 2012

Statistical Characteristics: Solar X-ray Emission



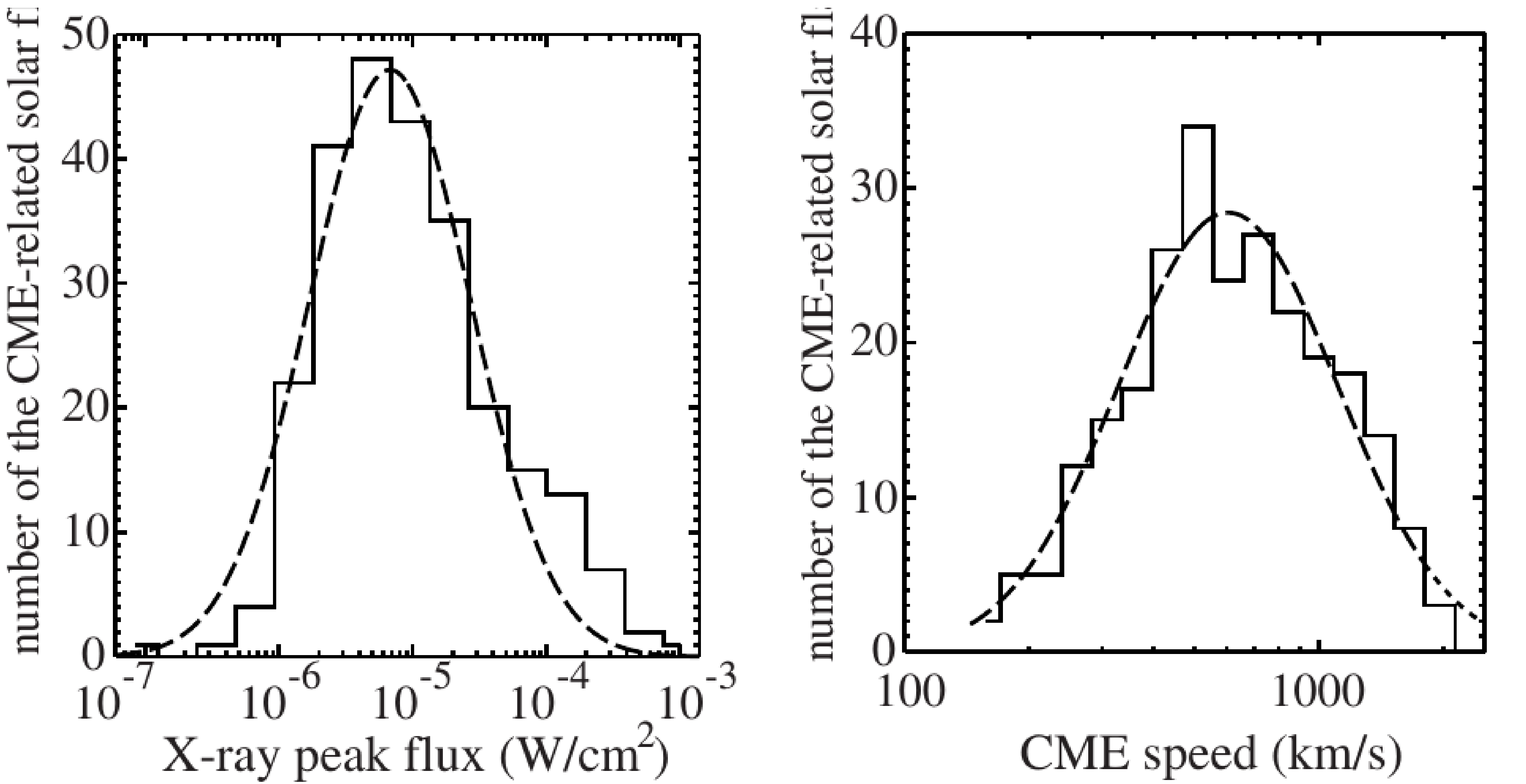
Zhang 2007

Statistical Characteristics: Solar X-ray Emission



Zhang 2007

Statistical Characteristics: Solar CMEs



Zhang 2007

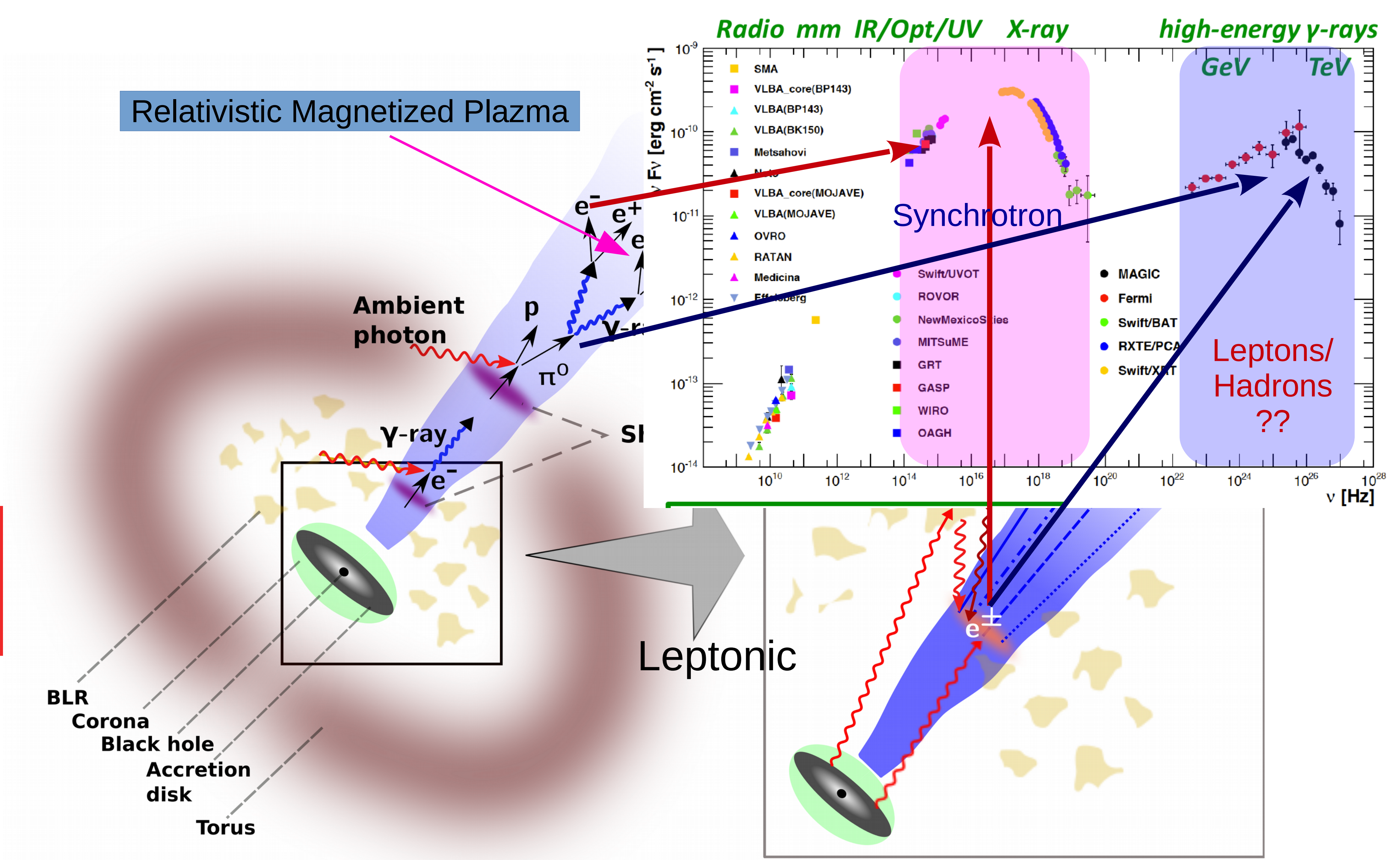
Summary

- Skewed/lognormal flux histograms with a linear rms-flux relation and shot noise PSD
- Studied feature are broadly consistent with the statistical features of the magentic-reconnection based minijets-in-a-jet model with random orientation.
- Statisitical features are also consistent with Solar X-ray emission and CMEs properties.
- Results favor magnetic-reconnection process for powering the jet, with trigger may reflect the imprint of fluctiation in the accretion-disk, or jet dynamics, and/or imprint of corona.

PART – II

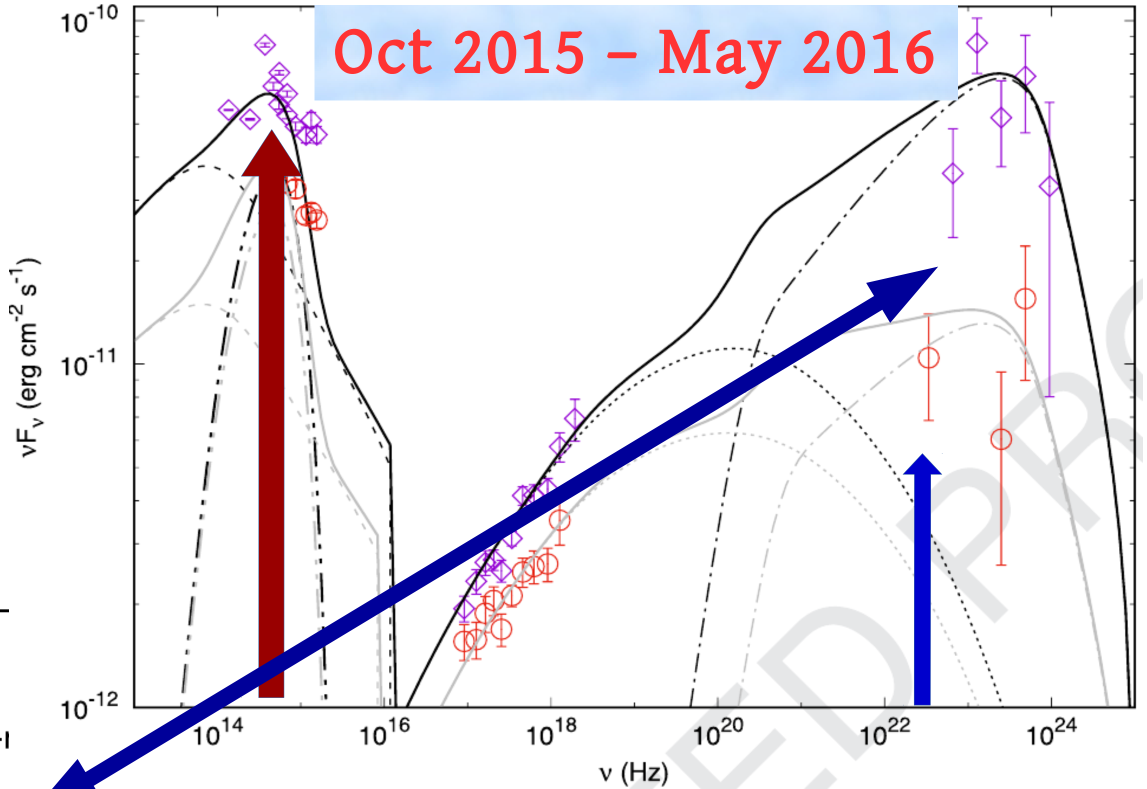
High Energy Emission and Dissipation of Magnetic energy to kinetic

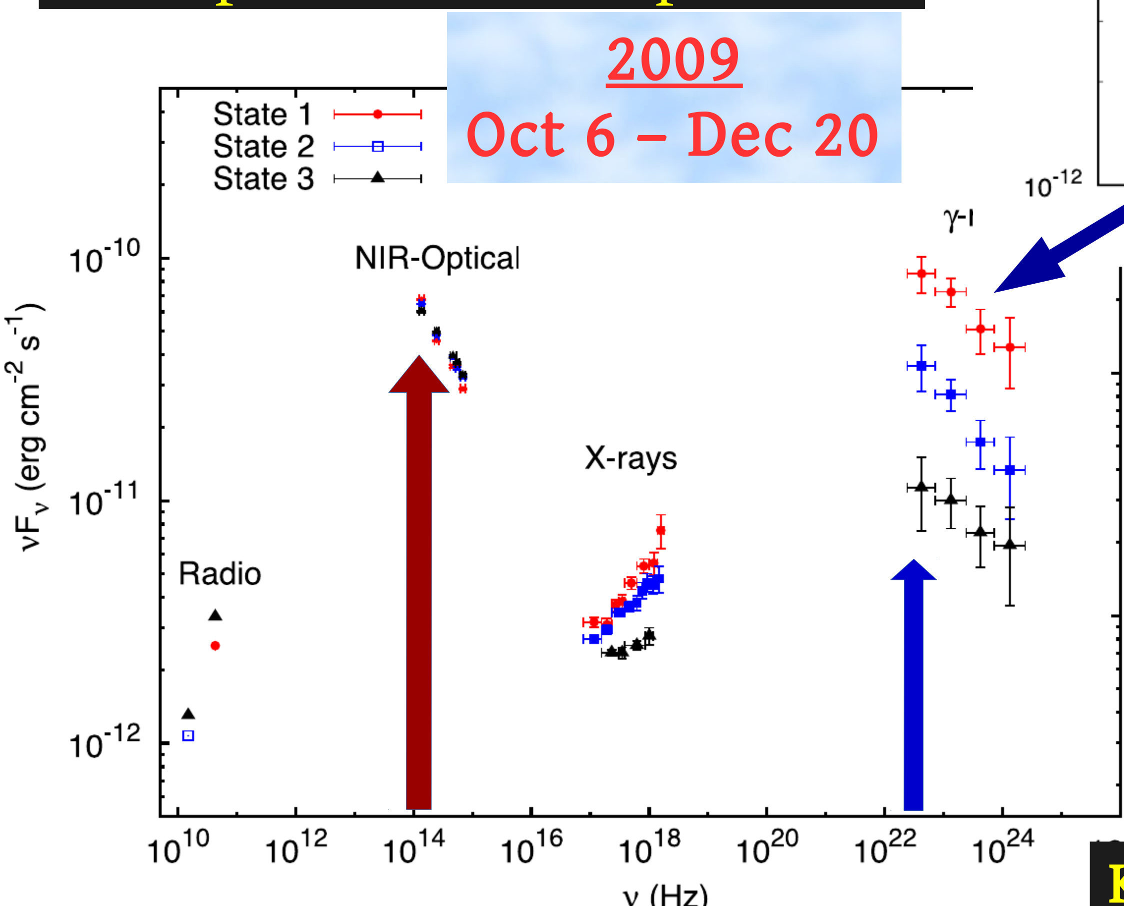
Relativistic Jets: Non-thermal emission

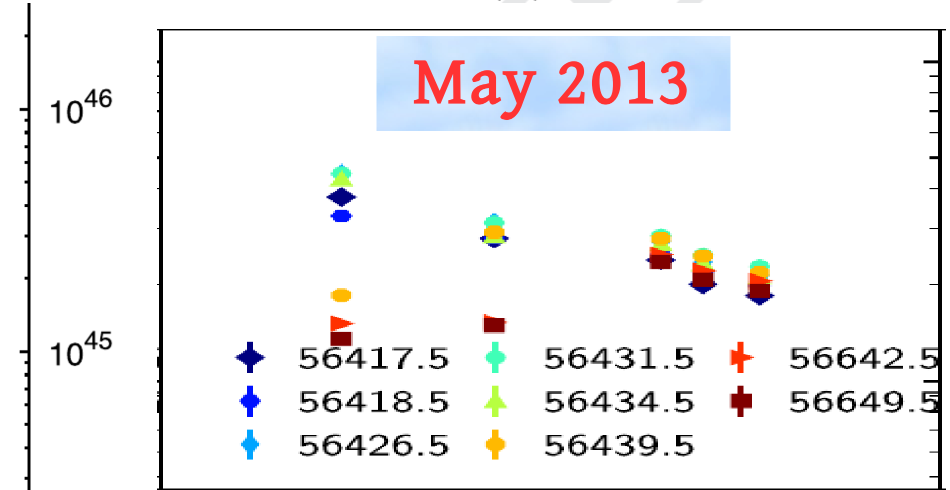


OJ 287: SED evolution

- Potential binary SMBH system
- Change in γ-ray spectra with change in the appearance of new component in IR-optical



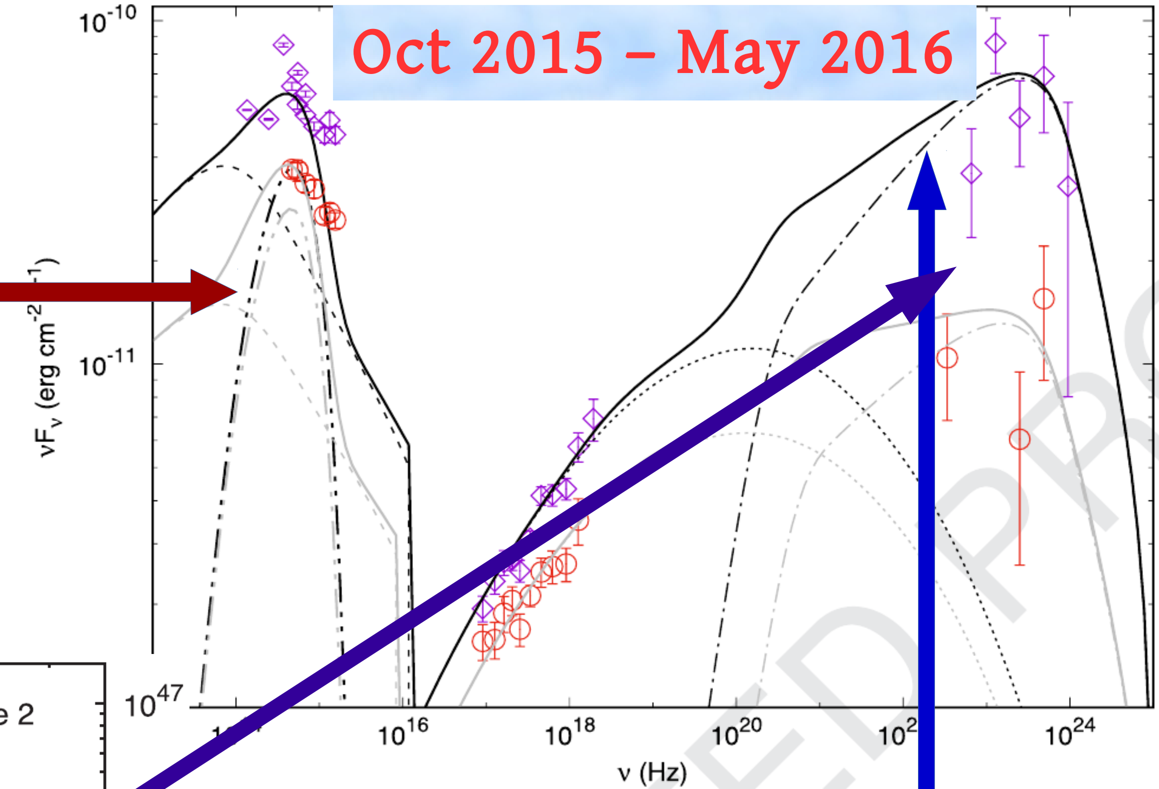




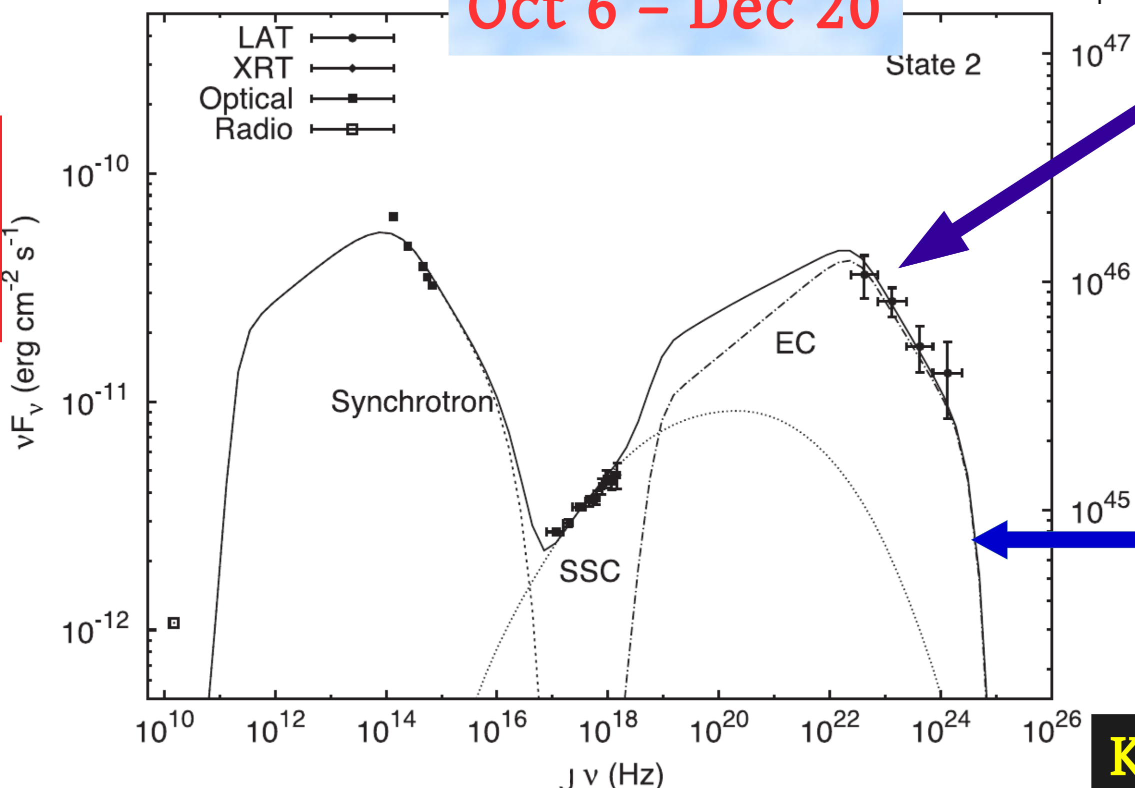
Kushwaha et al 2017, MNRAS in press

OJ 287: SED evolution

Accretion disk
1.8 x 10^{10} M_o



2009
Oct 6 – Dec 20



Inverse-Compton
Broad Line emiss

Inverse-Compton
Infra-red emiss

Kushwaha et al 2017, MNRAS in press

Conclusions

- Gamma-ray emission statistical features suggest magnetic reconnection as the most promising process for broadband non-thermal emission.
- The broad similarity reflect that magnetic reconnection may be result of imprint of fluctiation in the accretion-disk, or jet dynamics, and/or imprint of corona.
- The change of γ-ray spectra with the appearance of accretion-disk emission along with broad line regions favors emission at sub-parsec scales.
- This sub-parsec origin of emission suggest that a significant fraction of magentic energy is been transferred to non-thermal particles between 1000-10000 R_g.

Conclusions

- Gamma-ray emission statistical features suggest magnetic reconnection as the most promising process for broadband non-thermal emission.
- The broad similarity reflect that magnetic reconnection may be result of imprint of fluctiation in the accretion-disk, or jet dynamics, and/or imprint of corona.
- The change of γ-ray spectra with the appearance of accretion-disk emission along with broad line regions favors emission at sub-parsec scales.
- This sub-parsec origin of emission suggest that a significant fraction of magentic energy is been transferred to non-thermal particles between 1000-10000 R_g.

Thanks