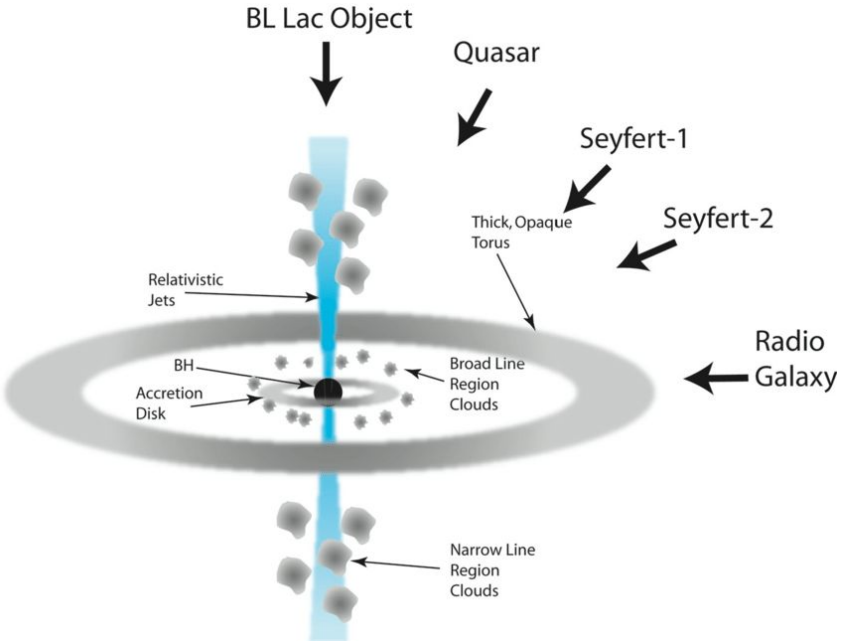
BlaVar: a numerical study of long-term blazar variability

Markos Polkas (National & Kapodistrian University of Athens)

In collaboration with: M. Petropoulou (NKUA), G. Vasilopoulos (Unistra), A. Mastichiadis (NKUA), C. M. Urry (Yale), P. Coppi (Yale), C. Bailyn (Yale)

Blazars

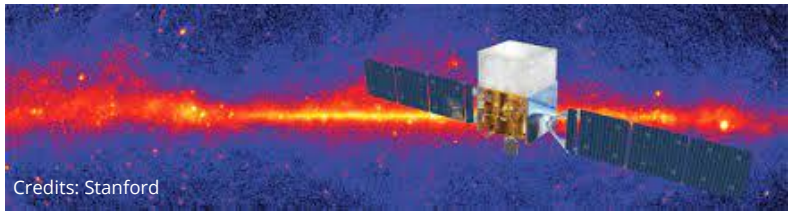


Credits : Biplob Sarkar 2011

- Radio-loud Quasars (very luminous AGNs with strong radio emissions)
- Jet pointing directly at us
- Multiwavelength emission : radio to γ-rays (TeV)
- Dichotomy: Flat Spectrum Radio Quasars (FSRQs) vs BL Lac Objects.

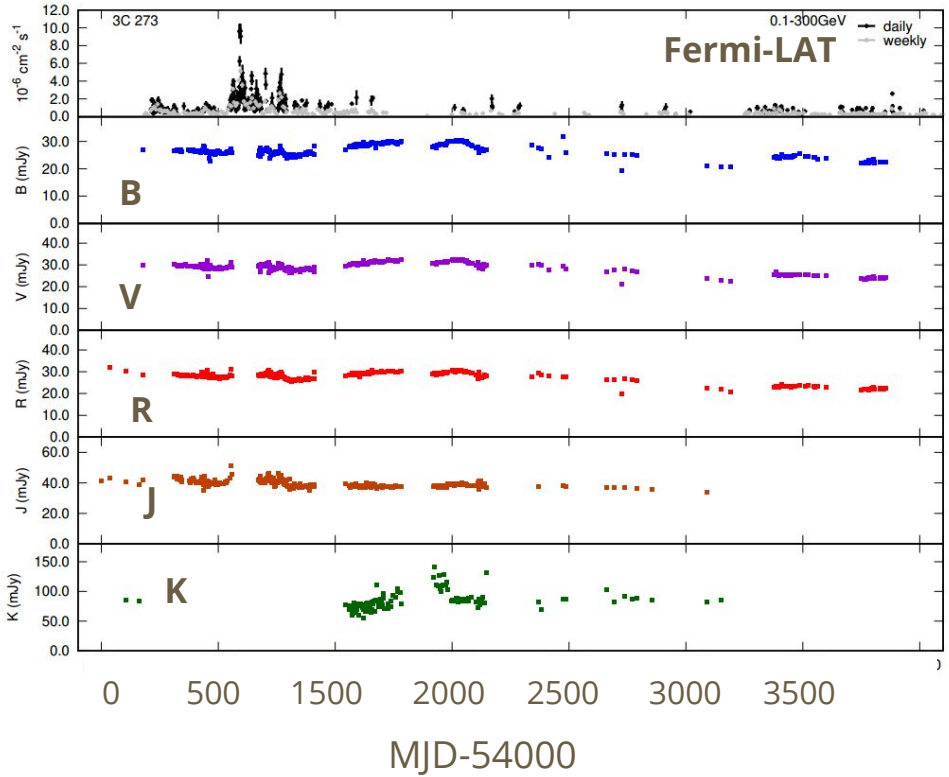
Observations & Motivation

Fermi - LAT : 0.1 - 300 GeV gamma-rays, all-sky monitoring, ~11 yr operation



SMARTS: optical bands (B,V,R,J,H,K)

Long-term OIR/γ-ray light curves



The one-zone leptonic model

Parameters of the model

Magnetic field

Electron compactness

Ext. photon compactness

Doppler factor

R (cm)

B (G)

γ_{min}

γ_{max}

p

l_e

l_{ext}

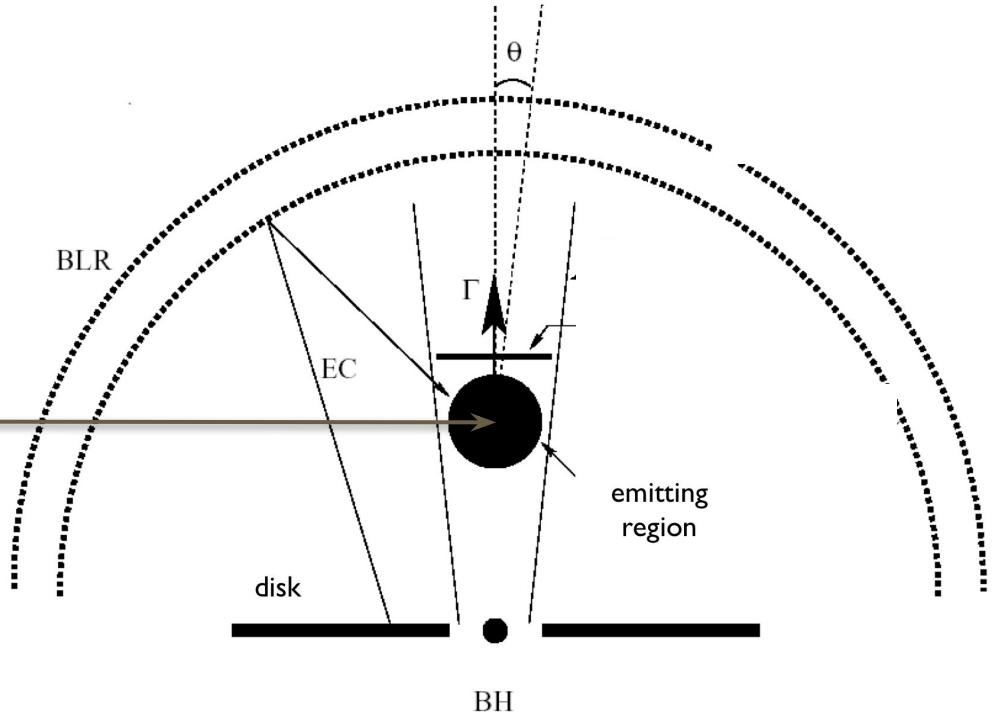
T_{ext} (K)

δ

Γ

θ_{obs} (deg)

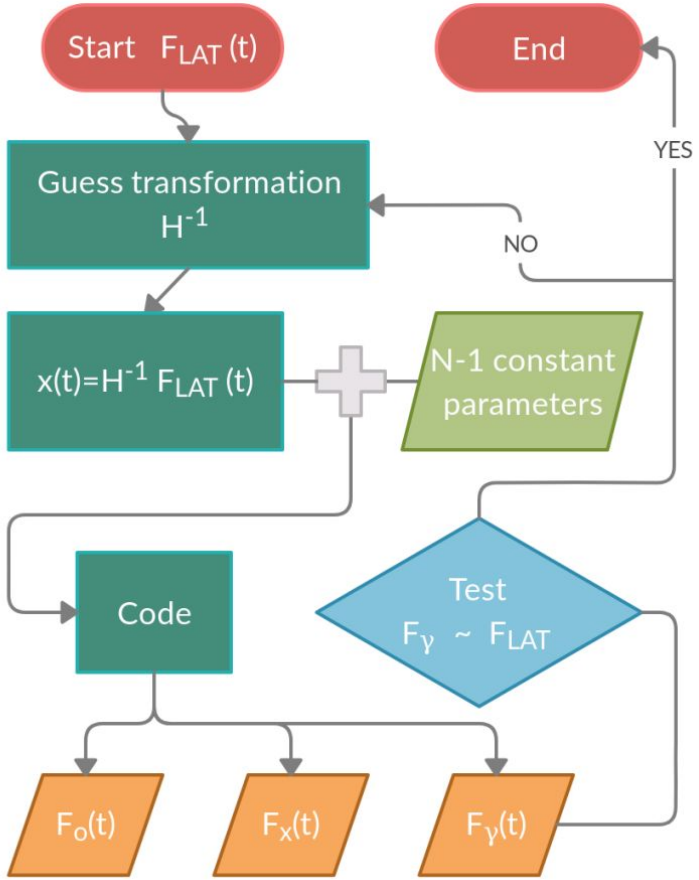
$t_{esc} = R/c$



Credits: Tramacere 2011

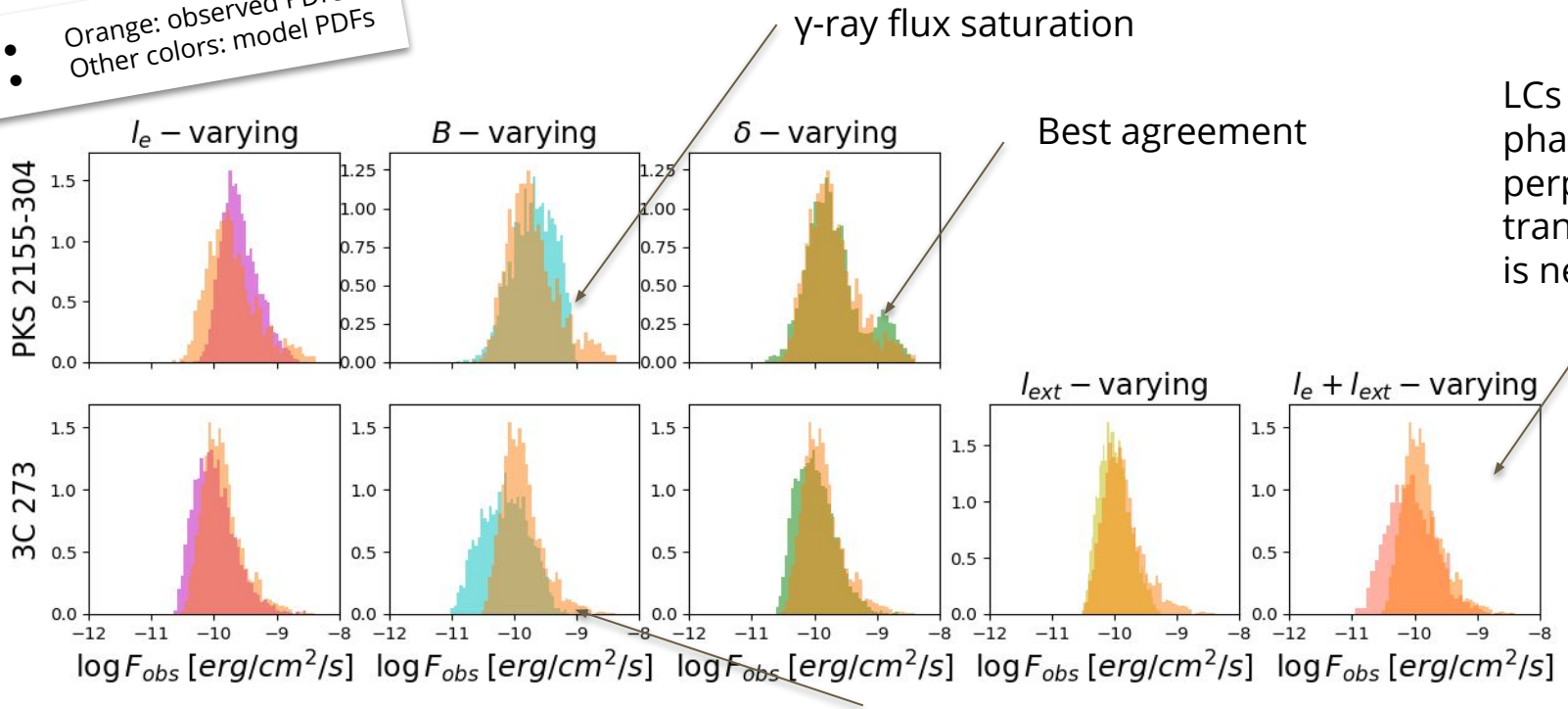
Our method

$$x(t_j) = x_0 \left(\frac{\tilde{F}_{\mathrm{LAT}}(t_j)}{\langle \tilde{F}_{\mathrm{LAT}}(t_j) \rangle} \right)^{1/\sigma_\gamma}$$



Probability Density Function (PDF) of γ-ray fluxes

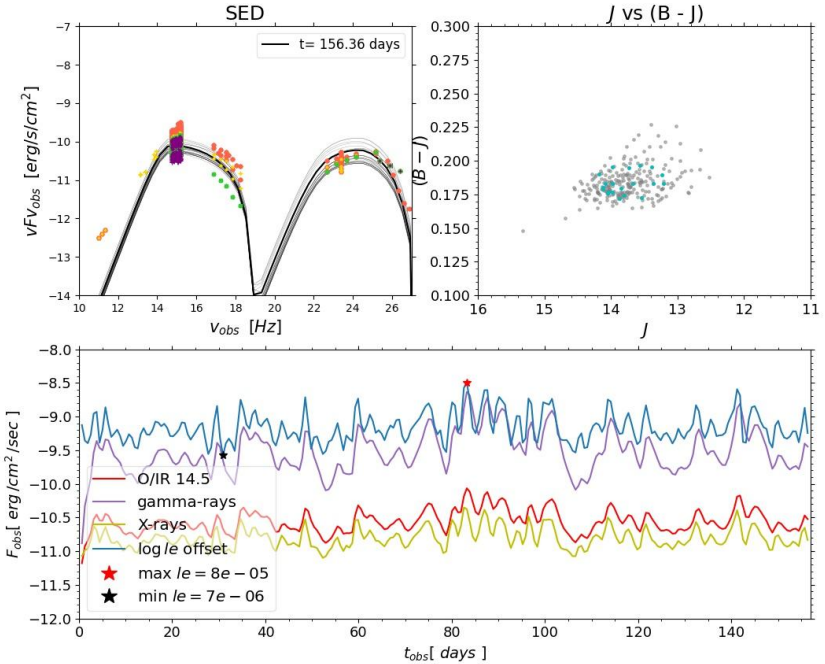
- Orange: observed PDFs
- Other colors: model PDFs



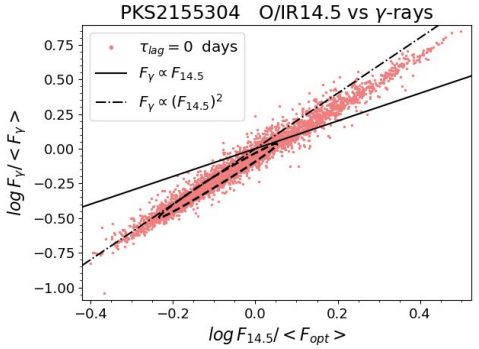
Crucial: different cooling regimes ⇢ sensitive to the selection of the steady state parameters

BL Lac PKS 2155-304 : le(t) simulation

Scarce spectral changes / color variations



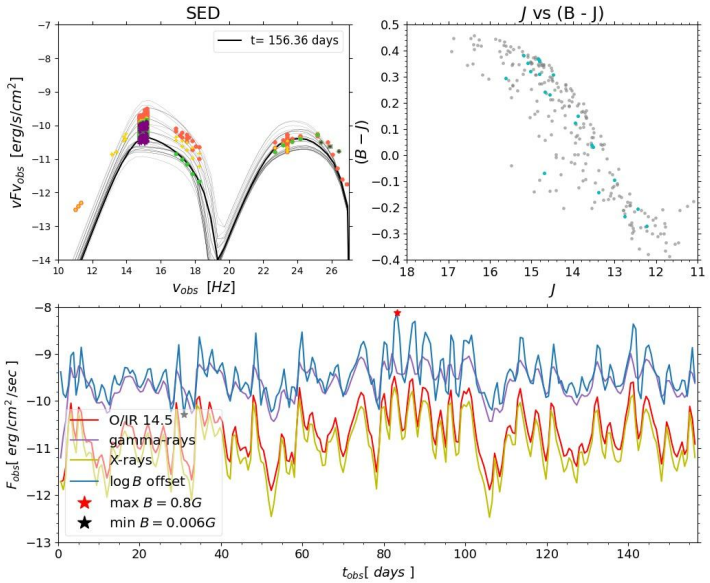
- Red: OIR
- Orange: X-rays (2-10 keV)
- Purple: γ-rays (0.1-300 GeV)



Strong correlation between all bands at all epochs it is <u>not</u> observed

BL Lac PKS 2155-304 : B(t) simulation

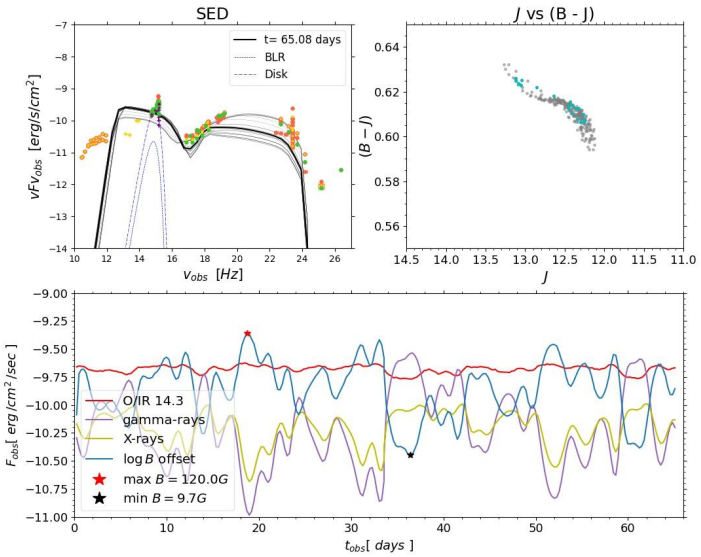
Magnetic field variations always produce spectral changes



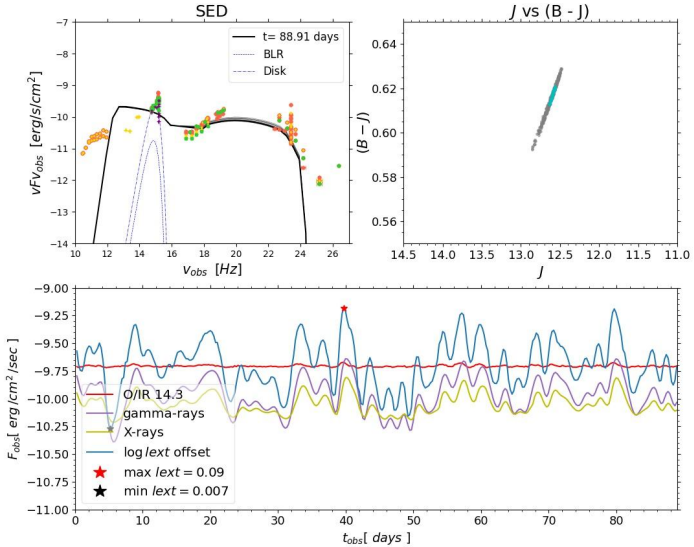
color changes <u>not</u> observed

FSRQ 3C 273: Time-dependent cooling

Magnetic field: B(t)



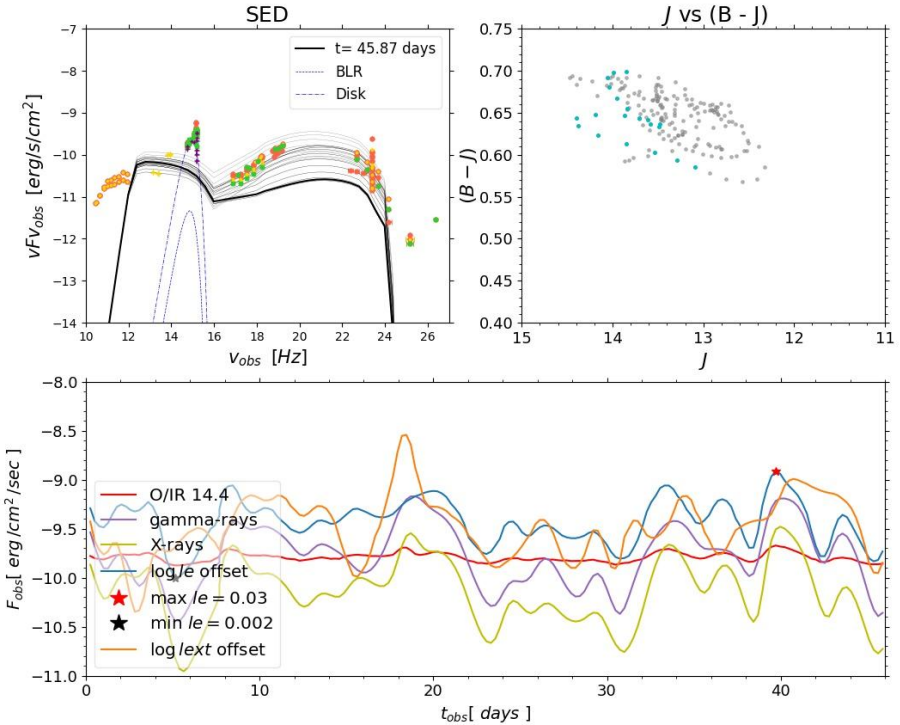
External Photon field: lext(t)



Synchrotron and ICS flux are anti-correlated

observed color trend

FSRQ 3C273: Combining le(t) with lext(t) variations

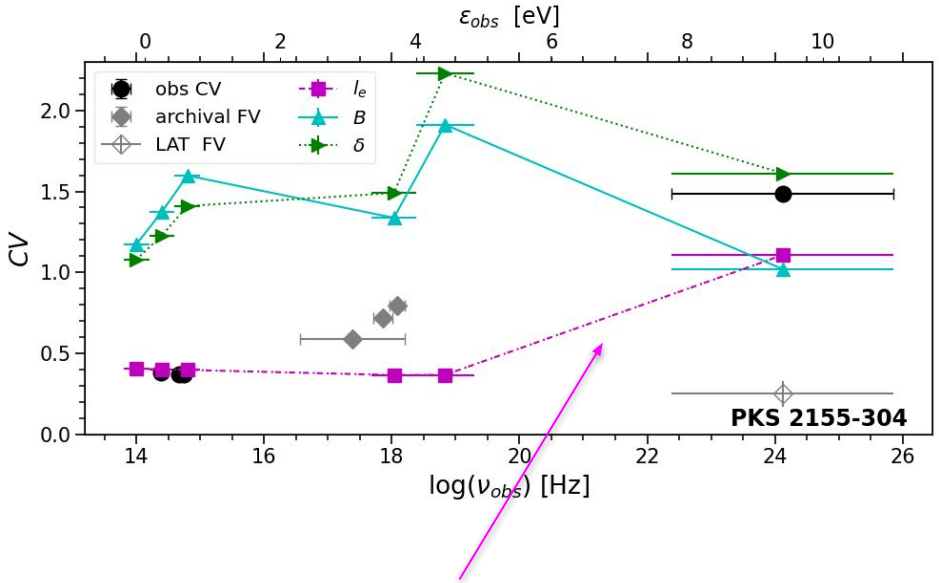


chaotic behavior

le variations are more important when introduced along with variations in external photon field luminosity.

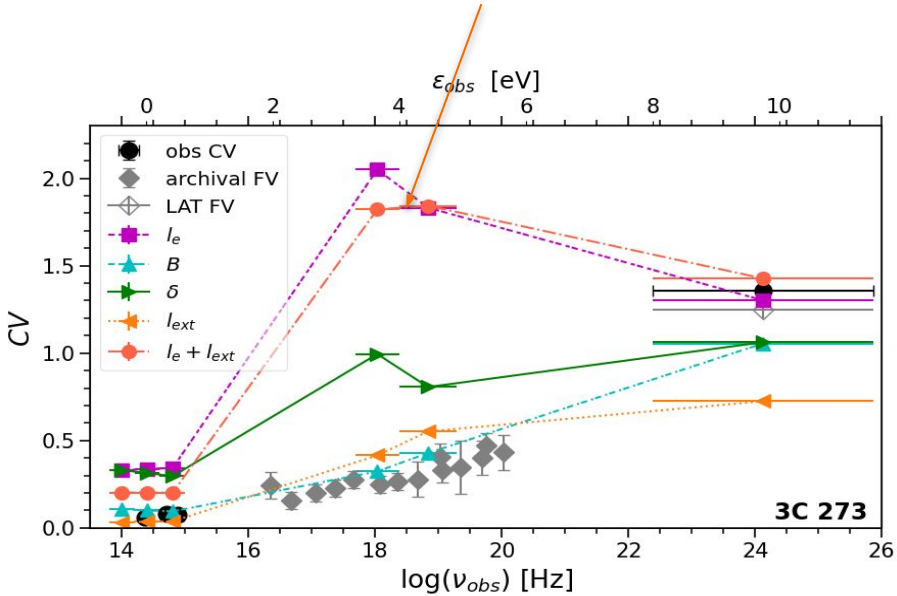
gamma-rays do not trace changes in BLR

Coefficient of Variance and Fractional Variabilities

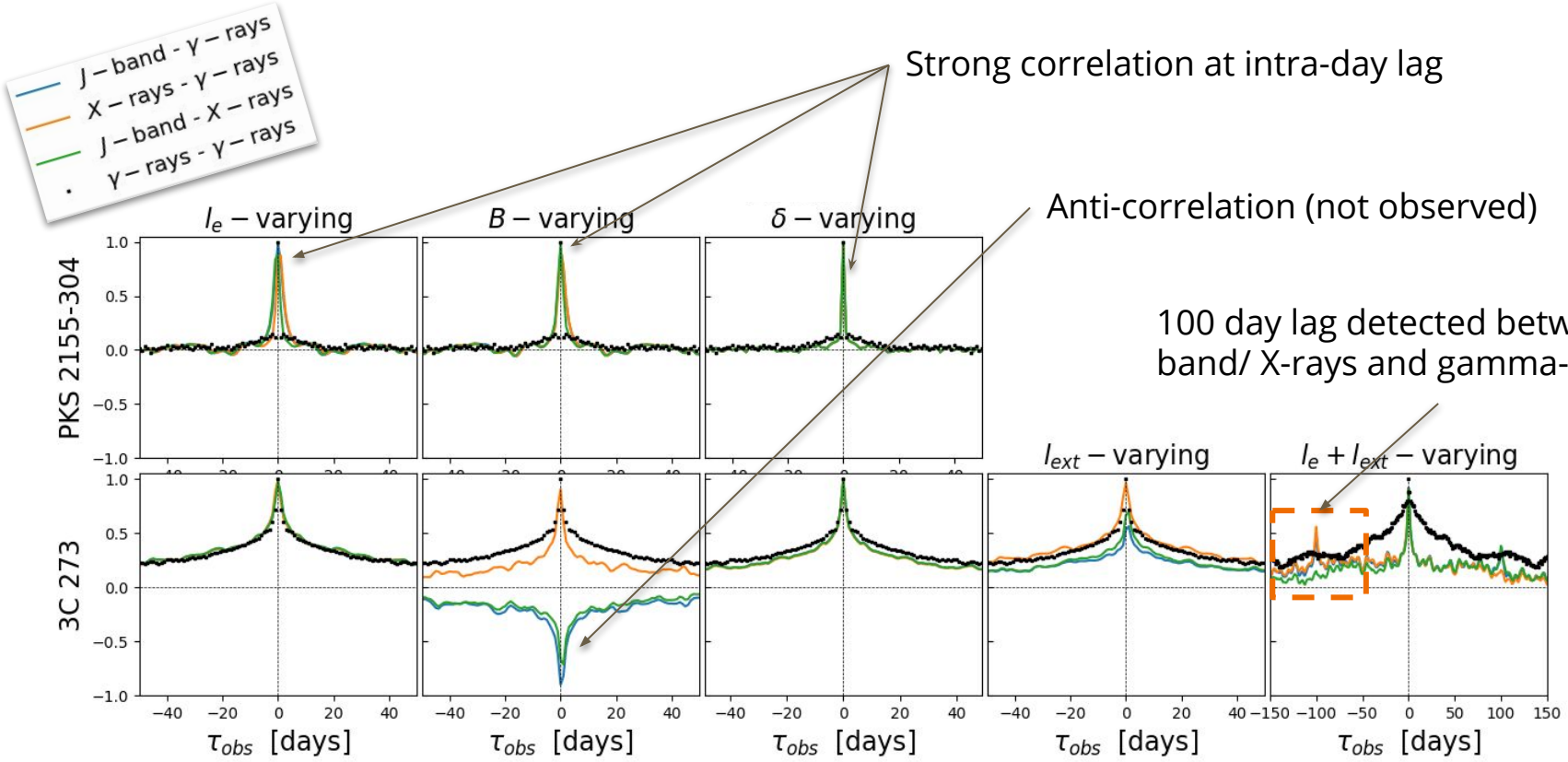


- Underpredicts variability in X-rays and γ-rays
- Captures the general trend with frequency

- Overpredicts variability in X-rays
- Captures the variability in OIR/γ-rays



Discrete Correlation Function (DCF)



Conclusions & Future Work

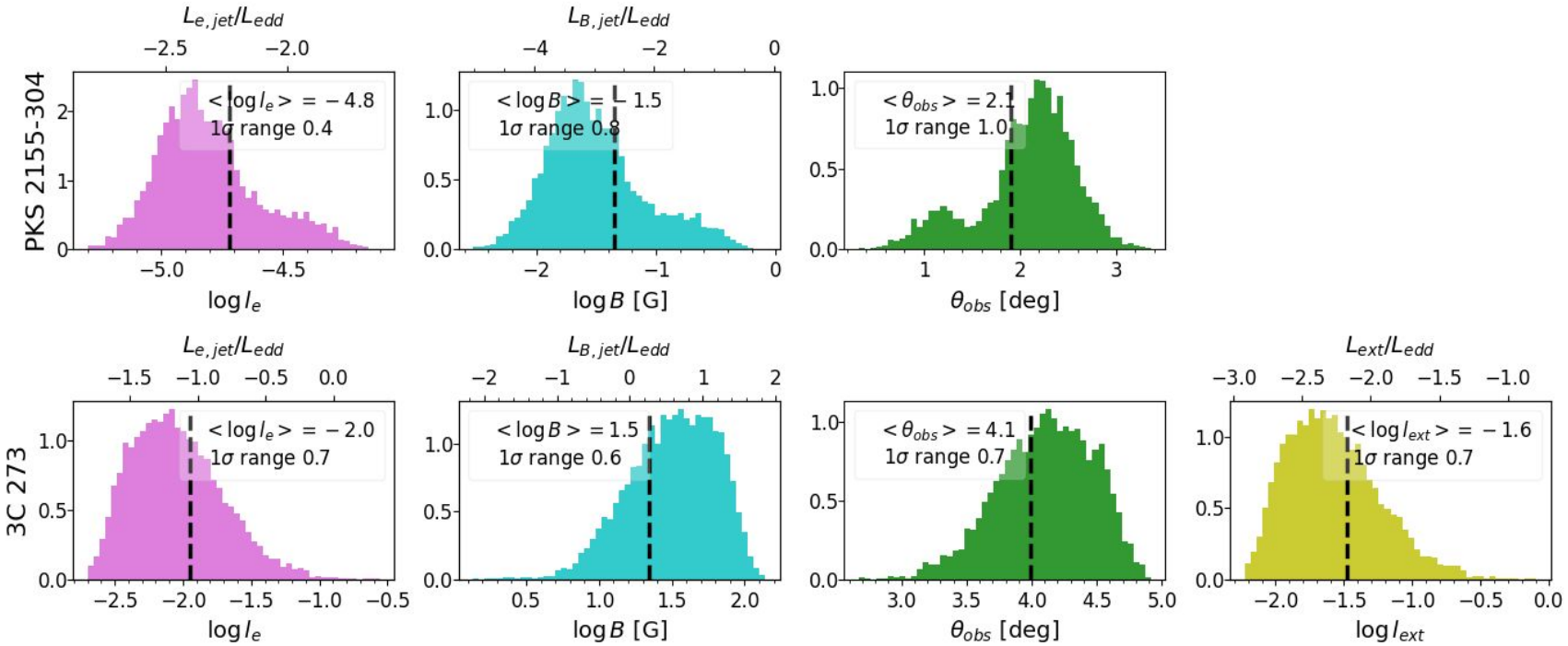
- ❖ Single parameter variations are highly unlikely to describe all the long-term timing properties of any blazar.
- ❖ Non-zero time lags can be produced but an indirect second zone (distant source of external photons)
- ❖ One-zone steady-state models can be put into test via timing analysis of long-term variability for individual blazars

- ➔ More detailed thermal components for accurate color variations
- ➔ Weighted two parameters variations -> More complex analytical transformation to describe gamma-rays
- ➔ Sample of highly resolved sources with polarimetry (where the emission site is localized) to test models.

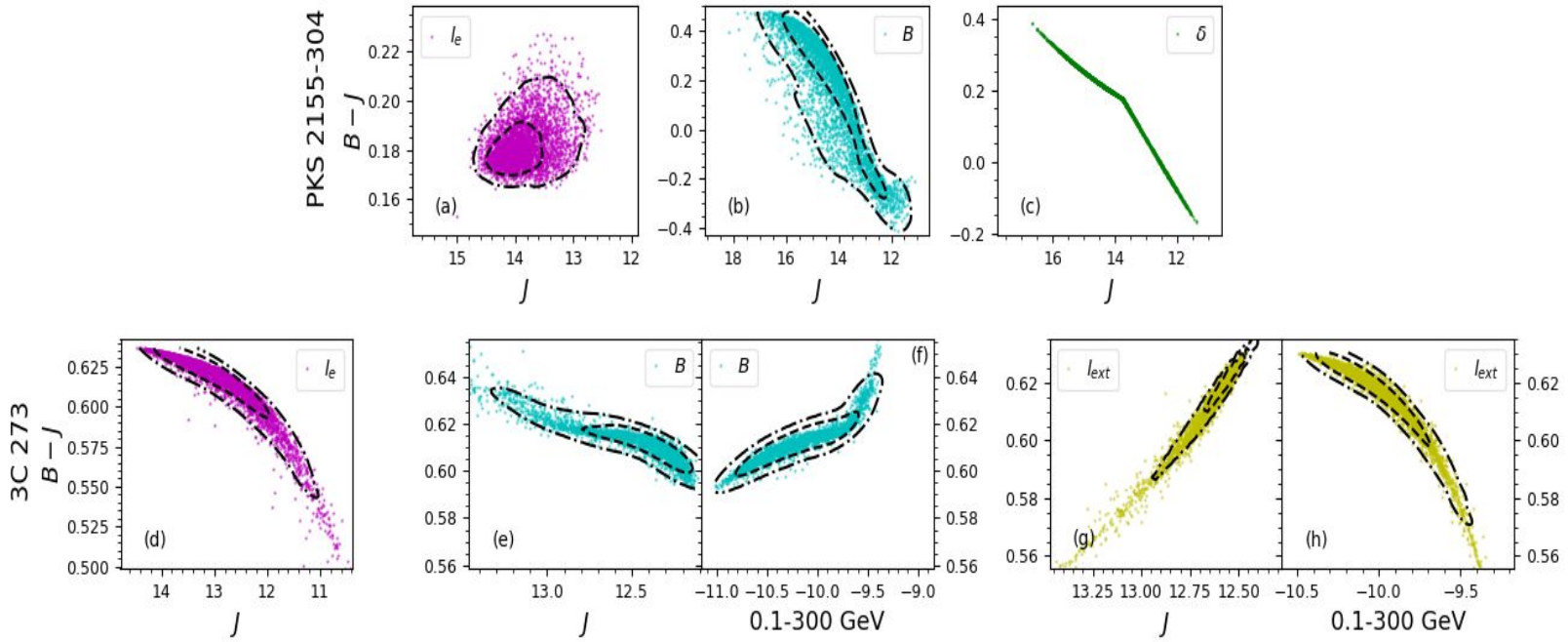
THANK YOU, for your attention!

Backup Slides

Distributions of Parameter Values



Color-Magnitude Diagrams



Summary Table

		γ-ray PDFs	FV/CV			DCF	$B-J$ vs. J-band	$B-J$ vs. γ-rays
			OIR	X-rays	γ-rays	(J-band vs. γ-rays)		
		(1)	(2)			(3)	(4)	(5)
PKS 2155-304	l_e	?	✓	↘	↘	✗	✓	✓
	B	?	↗	↗	↘	✗	✗	✗
	δ	✓	↗	↗	✓	?	✗	✗
3C 273	l_e	✓	↗	↗	✓	✗	✗	✗
	B	✗	✓	✓	↘	✗	?	✓
	δ	✓	↗	↘	↘	✗	✗	✗
	l_{ext}	✓	✓	✓	↘	?	✓	✗
	$l_e + l_{ext}$	✗	✓	↗	✓	?	✗	✗