



# Correlations between X-rays and TeV gamma-rays in HBL Blazars.

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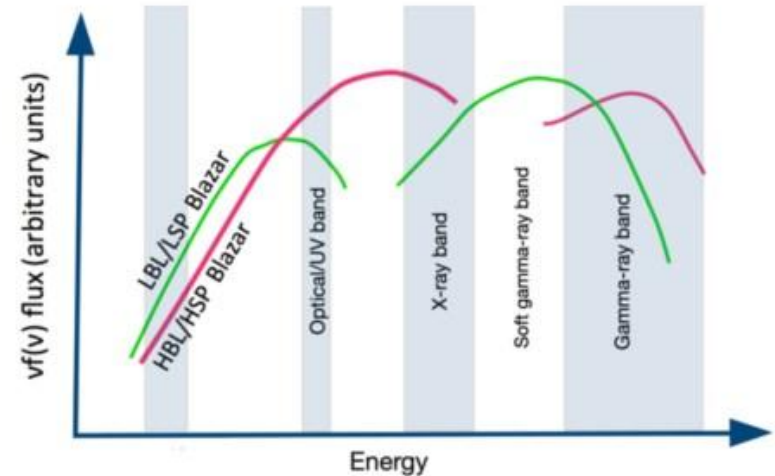
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# State of the art and motivation I

- Blazars exhibits two distinct spectral components.
- High Synchrotron Peaked Blazars (HBL): the majority of the emission is concentrated in X-rays and TeV gamma-rays.
- Low energy component  $\rightarrow$  Synchrotron
- High energy gamma-ray component  $\rightarrow$  ??  
Leptonic SSC or EC  
Hadronic models  
Combinations

Correlations expected



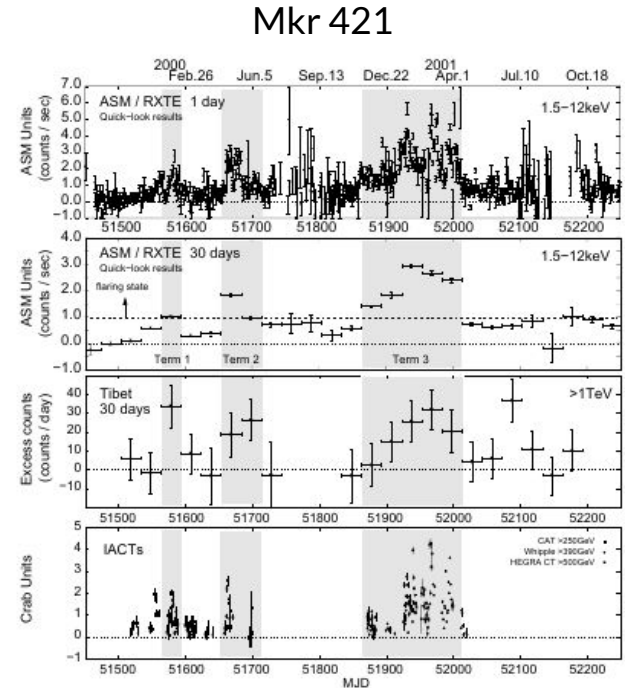
Middei, R. et al. 2022

# State of the art and motivation II

Different correlations reported:  
**linear, quadratic and between.**

- Specific blazar
- Time scale of observations
- Observational campaign

Katarzyński & Walczewska (2010): different correlation indices can be explained by considering a jet with multiple emission zones.



Amenomori, M. et al. 2009

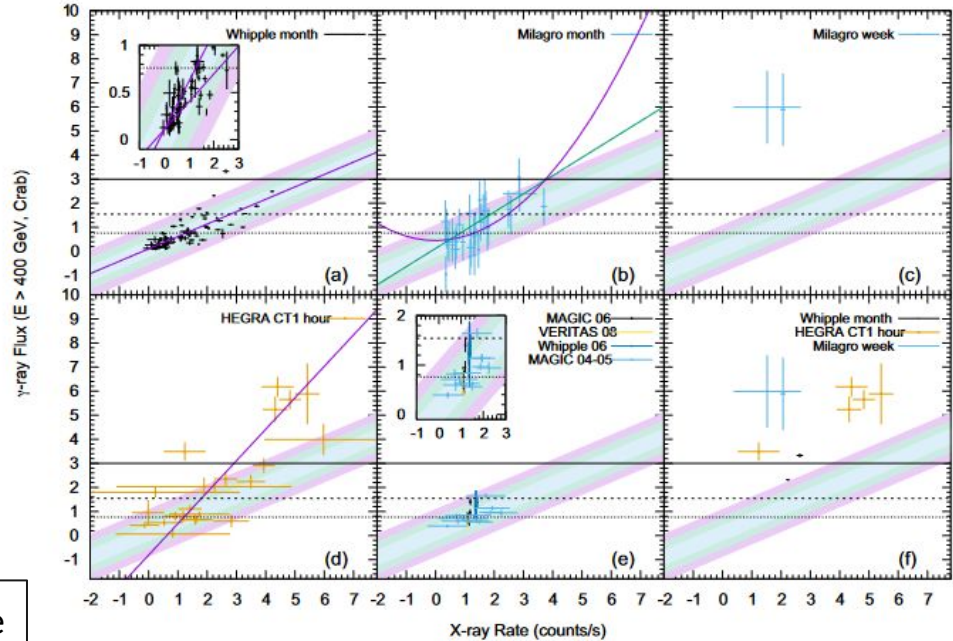
# State of the art and motivation III

González et al. (2019) → Correlation analysis of Mrk 421 (1992-2009):

X-ray data: 2-10 keV

Gamma-ray data: > 400 GeV

- Linear correlation breaks for high gamma ray fluxes
- Correlation consistent with one value of B



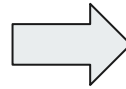
Long-term studies with wider range in fluxes are important to confirm/validate

González, M. M. et al. 2019

# Sample selection

HBL spectral type BL Lacs:

1. Detection threshold  $> 200$  GeV
2. Spectral index  $\sim 2$
3. Redshift  $< 0.15$



14 sources in the TeVCAAt catalog

**4 sources with quasi-simultaneous X-ray and gamma-ray observations**

Source	RA	Dec	Redshift
Mrk 501	$16^h 53^m 52.21^s$	$39.76^\circ$	0.00337
1ES 1959+650	$19^h 59^m 59.85^s$	$65.15^\circ$	0.048
PKS 2155-304	$21^h 58^m 52.06^s$	$-30.22^\circ$	0.117
1ES 2344+514	$23^h 47^m 04.83^s$	$31.70^\circ$	0.044

→ 11 % EBL absorption

# Observations

Quasi-simultaneous data from low to high fluxes

Data homogenization → Integral flux to the predetermined energy threshold

→ X-ray data unified to cgs system

Source	Period yy-yy	Number of campaigns	Instruments	
			X-rays	Gamma-rays
Mrk 501	1997-2013	6	RXTE-PCA Swift-BAT	HEGRA
1ES 1959+650	2002-2016	5	RXTE-PCA Swift-BAT	Whipple, HEGRA MAGIC, VERITAS
PKS 2155-304	2006-2016	4	Swift-XRT Chandra-LETG	HESS
1ES 2344+514	2007-2008	1	RXTE-PCA Swift-XRT	VERITAS

# Statistical method

Bayesian statistical method (D'Agostini 2005):

**Power Law** model to describe the correlation:

$$F_y = b F_x^a$$

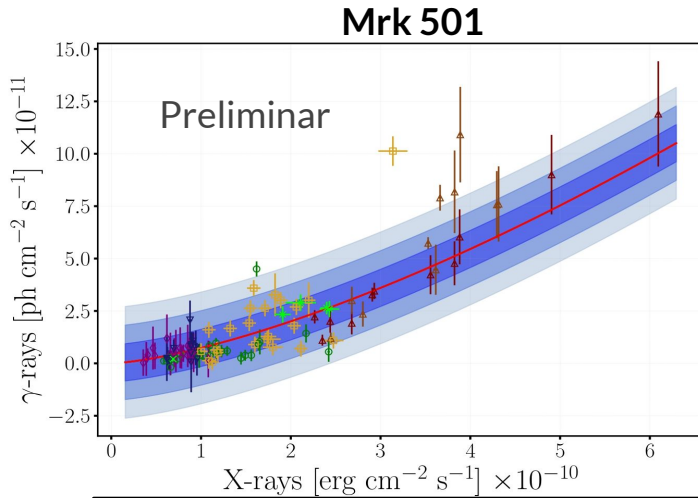
$$L(\omega, \sigma_s; x, \gamma) = \frac{1}{2} \sum \log[\sigma_s^2 + \sigma_\gamma^2 + F_y'^2(x, \omega)\sigma_x^2] + \frac{1}{2} \sum \frac{[\gamma - F_\gamma]^2}{\sigma_s^2 + \sigma_\gamma^2 + F_\gamma'^2(x, \omega)\sigma_x^2}$$



- Maximum Likelihood estimation.
- Takes into account an inherent unknown data scattering ( $\sigma_s$ )

$\omega$  is the set of free parameters ( $b, \mathbf{a}$ ).

# Results I

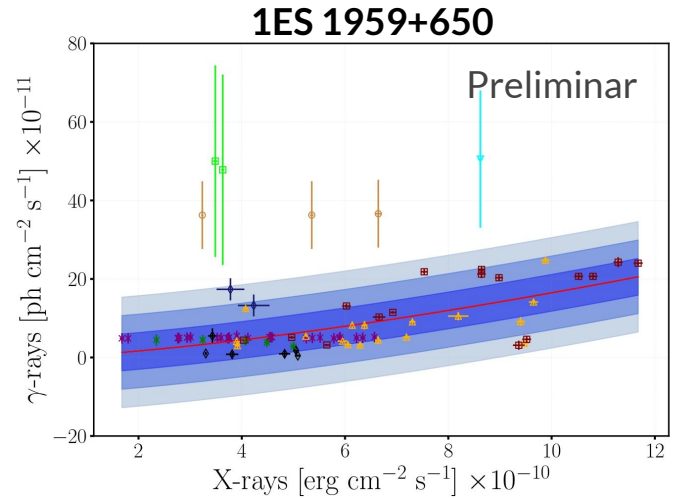


→ 6 campaigns: low to high states

$$\alpha = 1.45 \pm 0.01$$

$$b = 0.74 \pm 0.09$$

$$\sigma_s = (8.89 \pm 0.89) \times 10^{-12}$$



→ 5 campaigns: low to high states

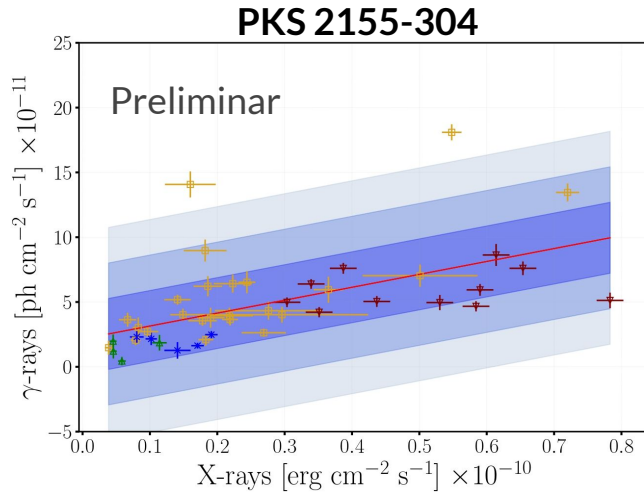
$$\alpha = 1.43 \pm 0.22$$

$$b = 0.62 \pm 0.03$$

$$\sigma_s = (4.69 \pm 0.45) \times 10^{-11}$$



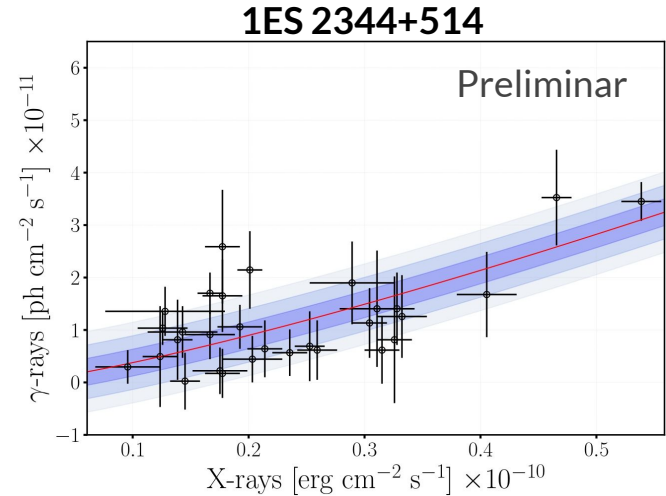
# Results I



→ 4 campaigns: low to high states

Linear correlation

$$\sigma_s = (2.74 \pm 0.32) \times 10^{-11}$$



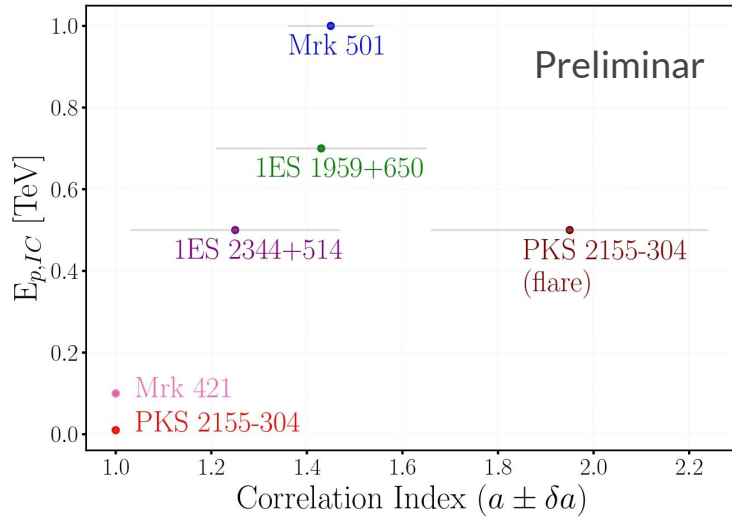
→ 1 campaign: low to high states

$$\alpha = 1.25 \pm 0.22$$

$$b = 6.72 \pm 1.69$$

$$\sigma_s = (2.56 \pm 1.63) \times 10^{-11}$$

# Results II



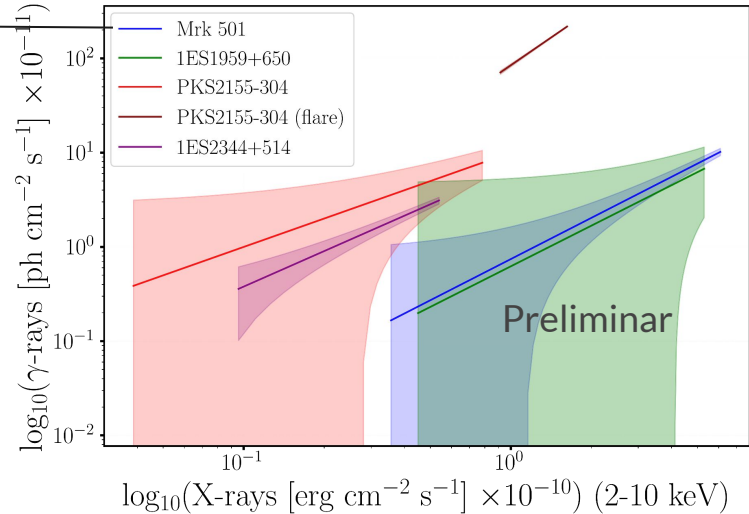
Possible relation between the high energy peak of the SED and the correlation index.

- Smaller IC peak: Linear correlation.
- PKS 2155-304 exceptional flare: Unusual behavior ??

# Results III

From correlations: Possible distinct populations of blazars

- Shaded region  $1\sigma_s$  deviation.
- All sources exhibit similar gamma ray flux (but the flare)
- Mrk 501 and 1ES 1959+650 less efficient in higher energies



# Summary and work to do...



- Overall the average correlations of these sources are consistent with indices values between 1 and 2, as previous work reported.
- An apparent pattern appears between the high energy SED peak and the correlation index seems to appear (further work is needed).
- These studies can contribute to ponderate the contribution of different radiative processes in blazar's emission.

**Thank you!**

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# Grazie!

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