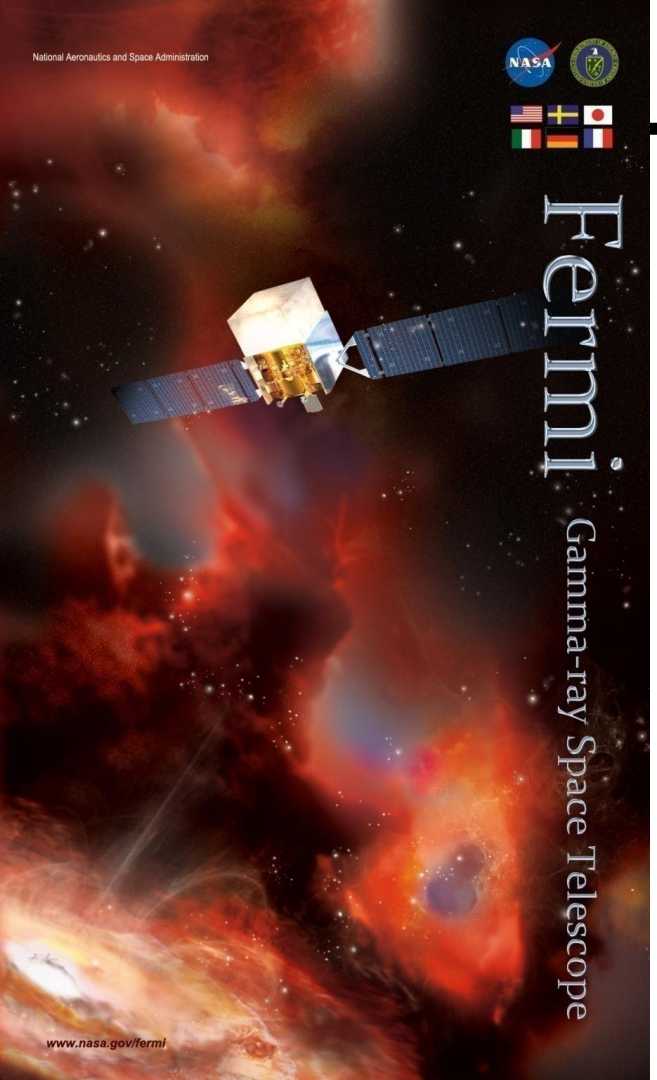

Periodic Variability in gamma-ray Emitting Blazars with Fermi-LAT

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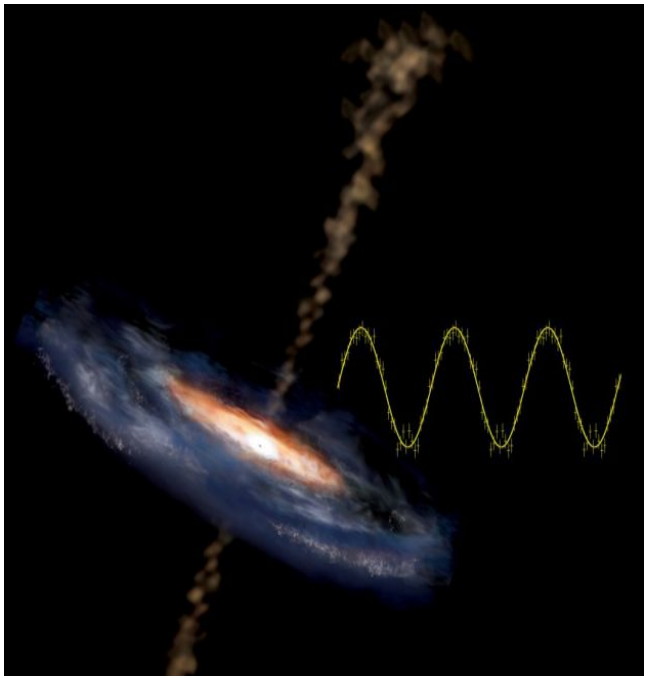
7th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy
7-4-2022

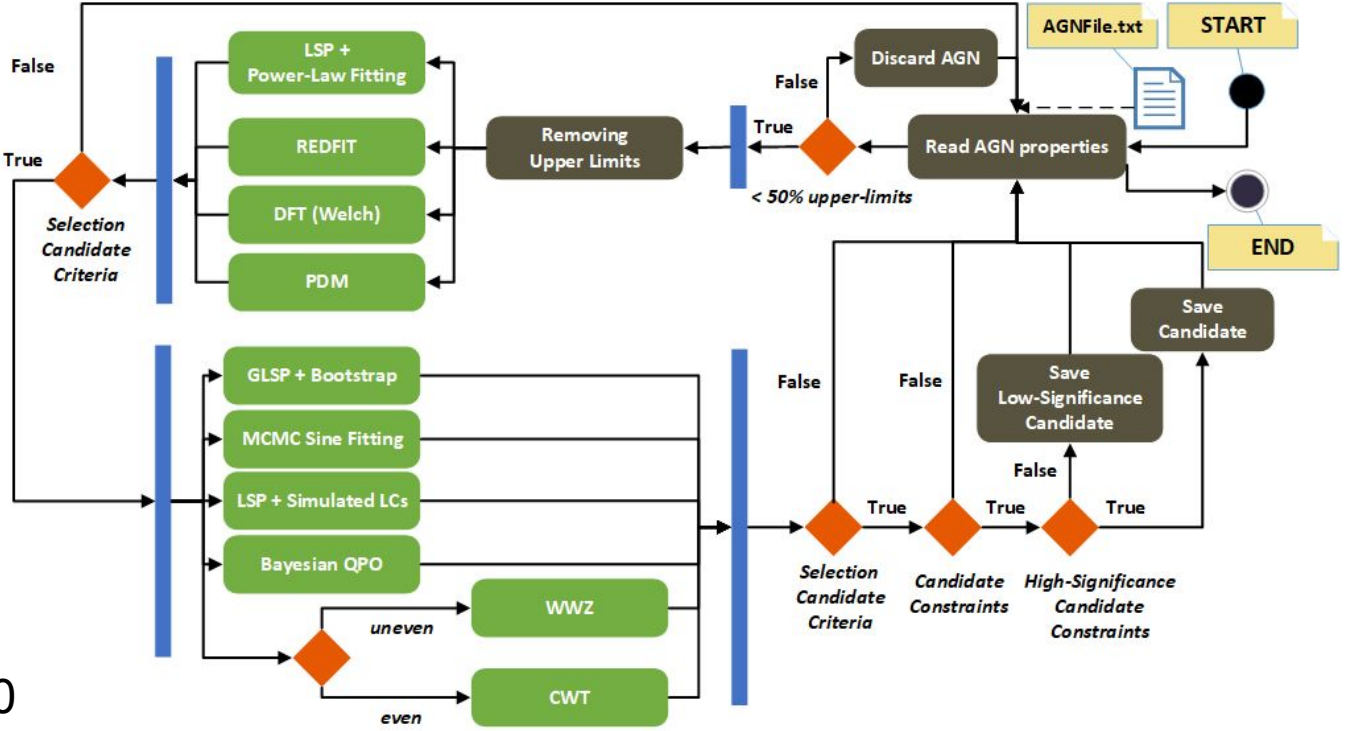
Introduction

- Blazars: variability in the overall electromagnetic spectrum:
  - Different timescales:
    - Long-term variations
    - Short variations
- Pattern → **Periodicity**
- Astrophysical nature: single or a binary SMBH
- Find a sample with γ-ray periodic-emission



Previous Results

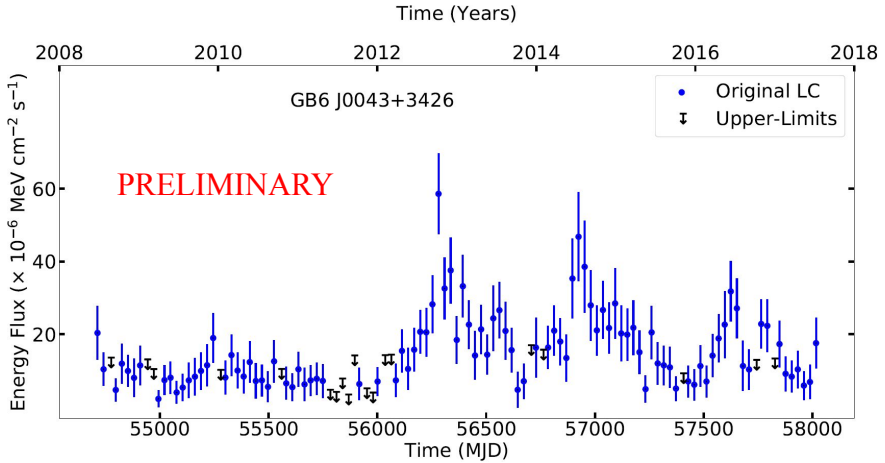
- 3FGL+2FHL+3FHL blazars (351)
- Telescope time: Aug. 2008-Sep. 2017
- Data Reduction: Flux integrated ≥1 GeV 28-days binning
- Methods: Periodicity detection: 10 Significance estimation: 4

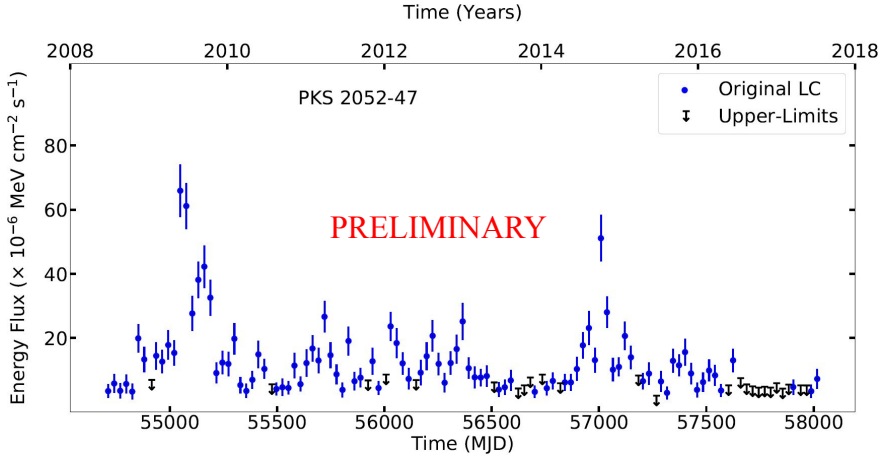


Peñil et al. 2020

Previous Results

- 11 High-significance candidates (≥4σ)
  - 9 New detections
- 13 Low-significance candidates (>2.5σ)
  - 9 New detections
- 6 objects previously reported in the literature:
  - 5 with the same period
  - S5 0716+ 714 (2.9 yr)
- False-positive detection rate: 1 detection





New Periodicity Study

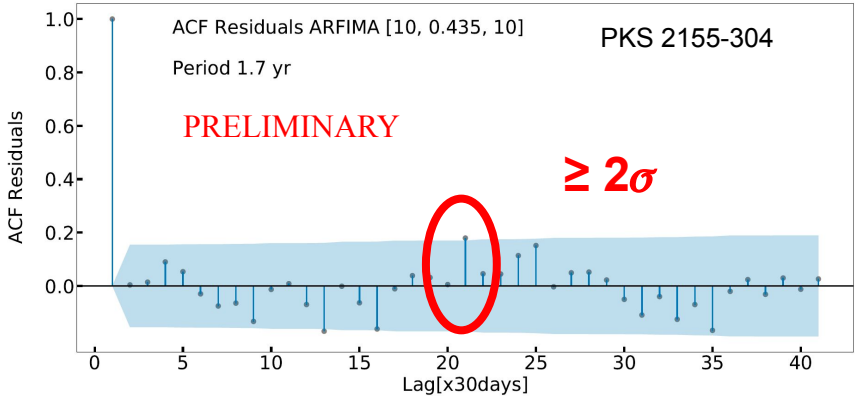
- 24 periodicity candidates from previous work Peñil et al., 2020

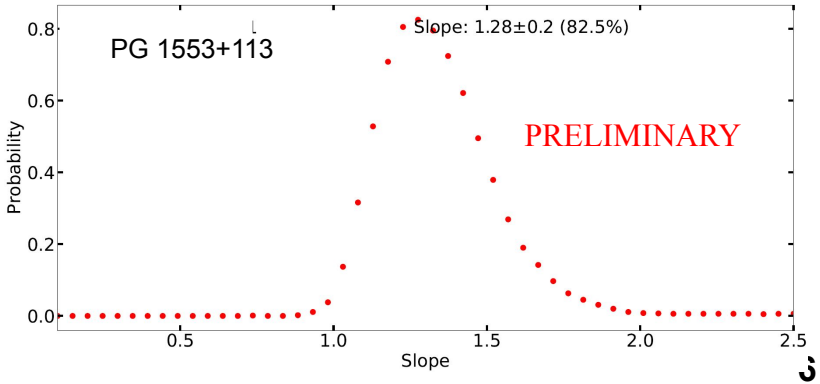
- Light curves:
  - Telescope time: August 2008-December 2020
  - Extended with 3 extra years → total of 12 years

- Data reduction:
  - Flux integrated ≥100 MeV (Reduction of upper-limits)
  - 28-days binning

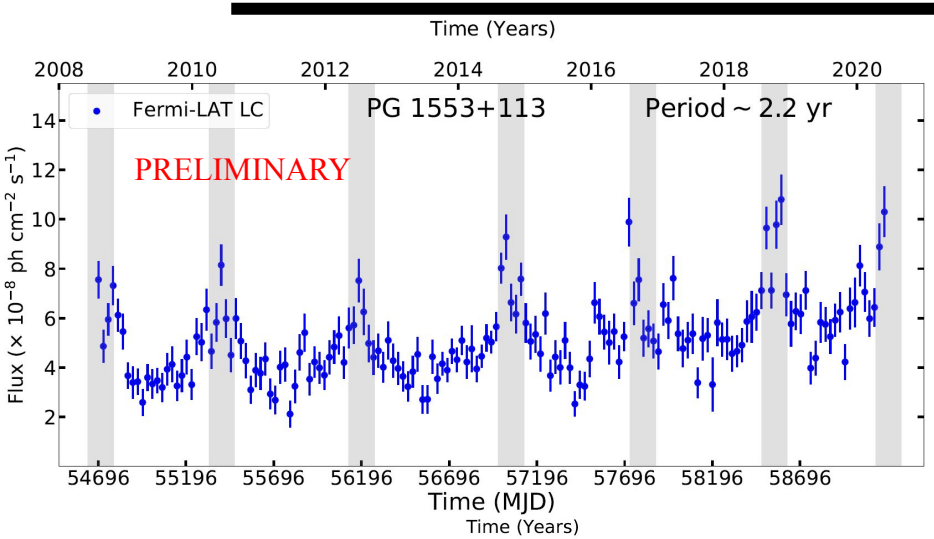
Extended Pipeline

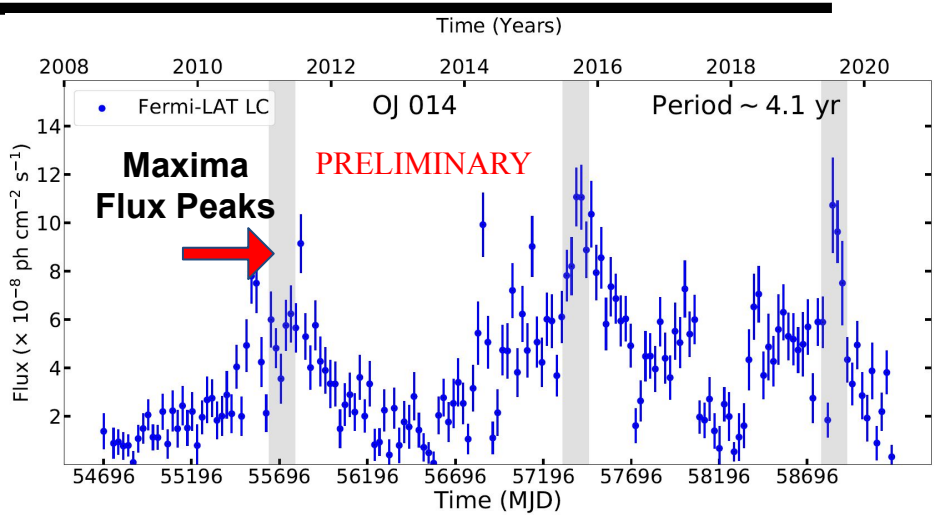
- Full Width Half Maximum (FWHM)
- ARIMA/ARFIMA analysis
  - Robust against stochastic noise (Feigelson et al., 2018)
- Power Spectral Index (β):
  - Power Spectrum Response method (Uttley et al. 2002)
- Flux Distribution:
  - Log-Normal & Normal
  - Shapiro-Wilk Test & MLE

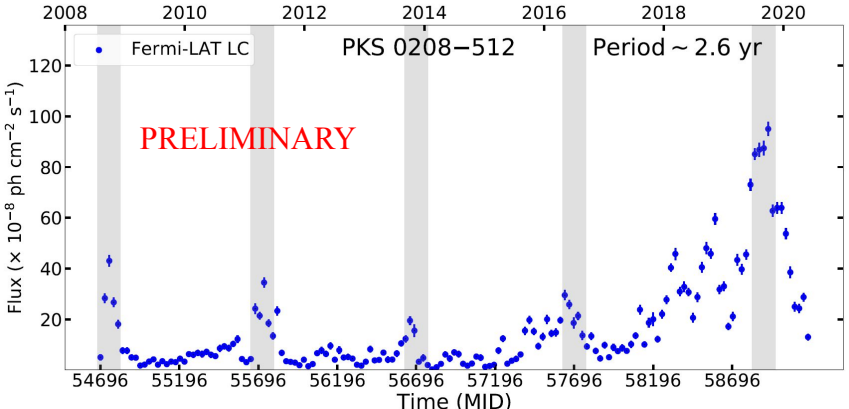




Results: 6 Blazars $\geq 5\sigma$ (local) periodicity detection



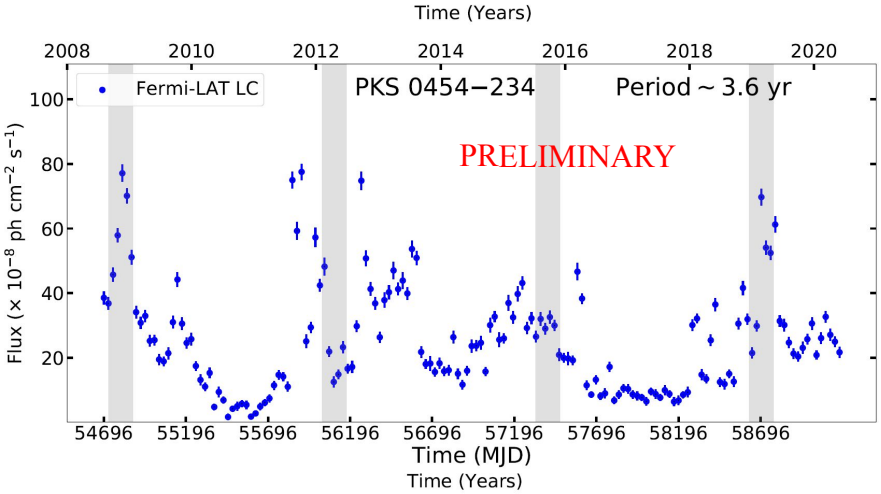


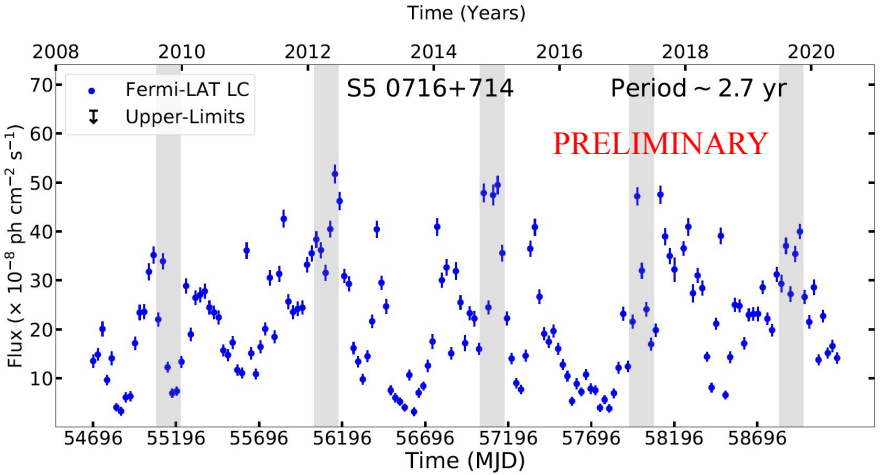


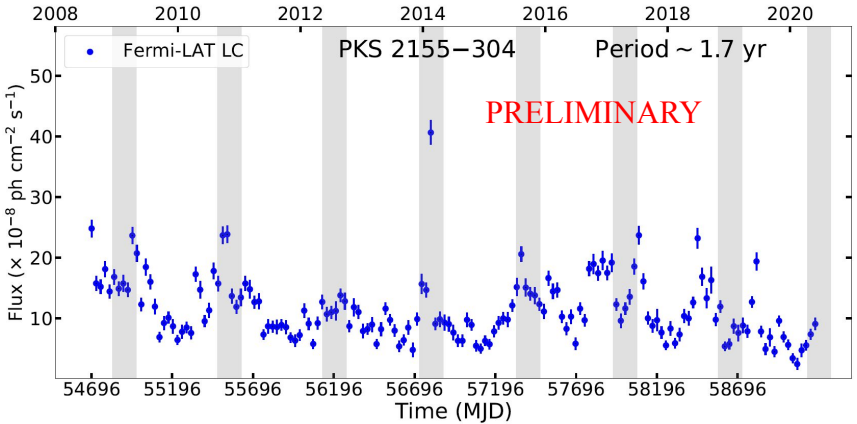
$\geq 5\sigma$ (local) periodicity detection

Peñil et al. 2020: >4σ, >3.5σ, >3σ respectively

Results: 6 Blazars ≥5σ (local) periodicity detection







4FGL Source Name	RAJ2000	DecJ2000	Type	Redshift	Association Name	Period (yr)
J0210.7−5101	32.68952	−51.01695	fsrq	1.003	PKS 0208−512	2.6
J0457.0−2324	74.26096	−23.41384	fsrq	1.003	PKS 0454−234	3.6
J0721.9+7120	110.48882	71.34127	bll	0.127	S5 0716+714	2.7
J0811.3+0146	122.86418	1.77344	bll	1.148	OJ 014	4.1
J1555.7+1111	238.93169	11.18768	bll	0.36	PG 1553+113	2.2
J2158.8−3013	329.71409	−30.22556	bll	0.116	PKS 2155−304	1.7

Peñil et al. 2020: >2.5σ, >2.5σ, >3σ, respectively

Results

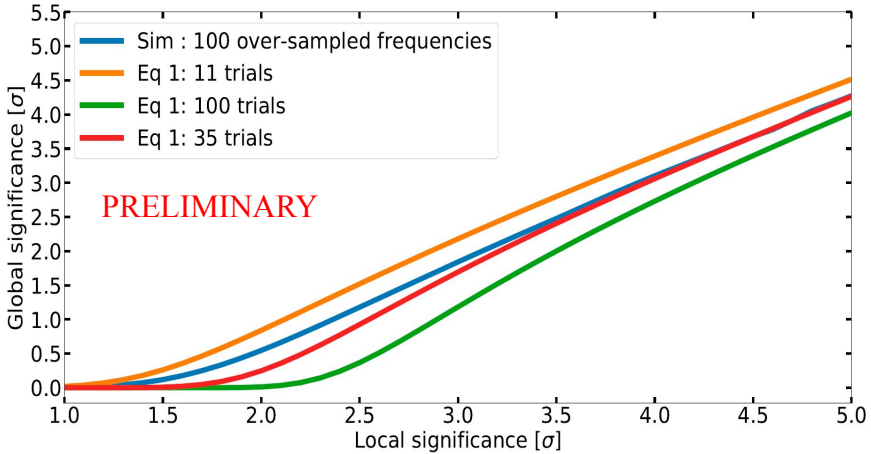
- Genuine periodicity: larger number of cycles, increase the significance (Vaughan, et al. 2015)
  - 14 blazars increase their significance
  - 4 blazars same significance
  - 6 blazars decrease their significance

- Power Spectral Index:
  - β=[0.9-1.5]
  - Jet modulations are likely coupled to the disk modulations (e.g, Abdo, et al. 2010)

- Flux Distribution:
  - Log-normal distribution
  - Fluctuations in the accretion disk to produce an aggregate multiplicative effect transmitted to the jet (e.g., Shah, et al., 2018)

Global Significance

- Local Significance (pipeline techniques)
- Look-elsewhere effect:
  - $P_{Global}=1-(1-P_{Local})^N$
  - N: trial factor
- N =$N_{blazars}$*indep. frequencies:
  - $N_{blazars}$: 351
- Indep. frequencies:
  - Bottom-limit: 11 (# points in LC, samples/year)
  - Upper-limit: 100 (# frequencies in the periodograms)
  - Monte-Carlo simulations → indep. frequencies=35
  - **$5\sigma \rightarrow 3.5\sigma$**



Statistical Corrections

- Calibrated the significance of the methods:
  - Calculate the number of Xσ detections with artificial LCs
  - LCs with same PSD and PDF (Emmanoulopoulos, D., et al. 2013)
    - $\Delta\sigma$ = [8%-15%]
  - LCs based on a power-law [β-Δ, β, β+Δ] (Timmer and Koenig, 1995)
    - $\Delta\sigma$ = [9%-25%]

- Evaluation of the method's detection against the noise:
  - Sinusoidal signal:
    - Different periods [1.5-4.5] yrs
  - Contaminated with noise :
    - white, pink, red
  - Methods more robust against pink\red noise: detection in [25%-65%]

Conclusions & Future Work

- We confirm the evidence of periodicity in 18 blazars:
  - We find 6 blazars with periodicity detected with 3.5σ (global significance)

- **Future Work**:
  - Multiwavelength and cross-correlation study of the 24 blazars
  - New periodicity analysis of all blazars in 4FGL catalogue: ~3000 blazars