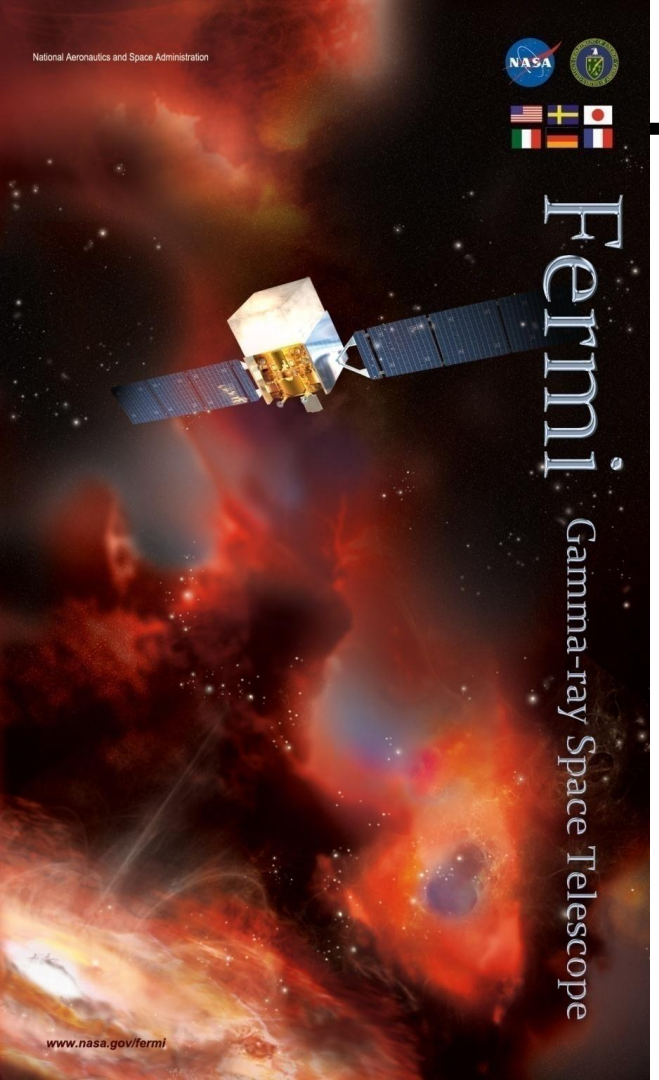

Building a Robust Sample of Fermi-LAT Blazars that Exhibit Periodic gamma-ray Emission

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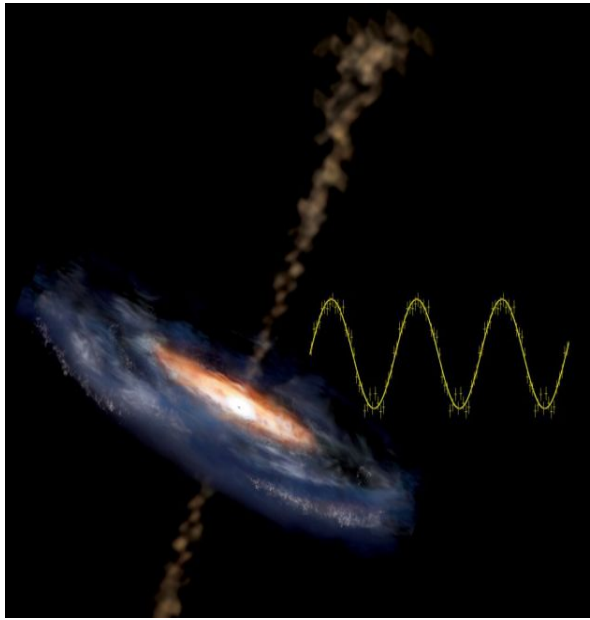
9th Fermi Symposium
4-15-2021

Introduction

- About 10% of AGN → launch highly collimated, relativistic, jets (e.g., Sartori et al. 2019)
    - Pointed towards our line of sight → blazars

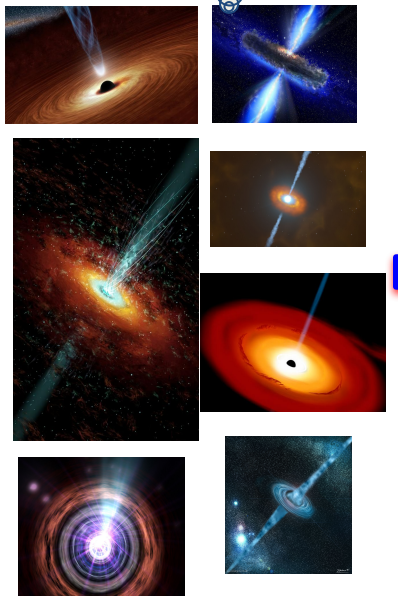
- Blazars: variability in the overall electromagnetic spectrum:
    - Different timescales:
        - Long-term variations → years or months
        - Short variations → days, hours or even minutes.

- Pattern → **Periodicity**
    - Provide information about its astrophysical nature

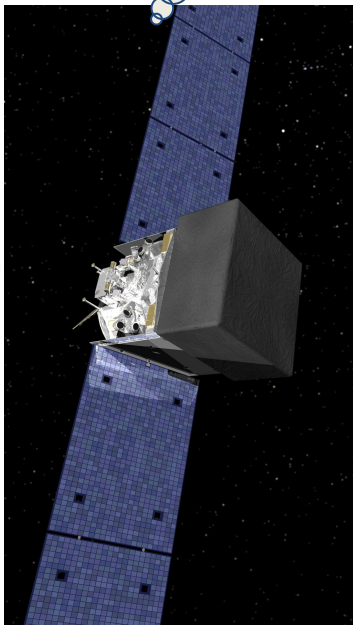


Methodology

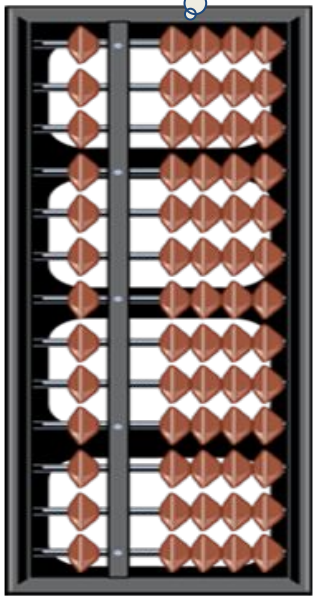
GAMMA-RAY SOURCES



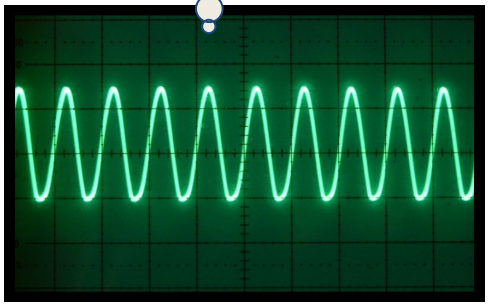
FERMI-LAT OBSERVATIONS



SYSTEMATIC SEARCH

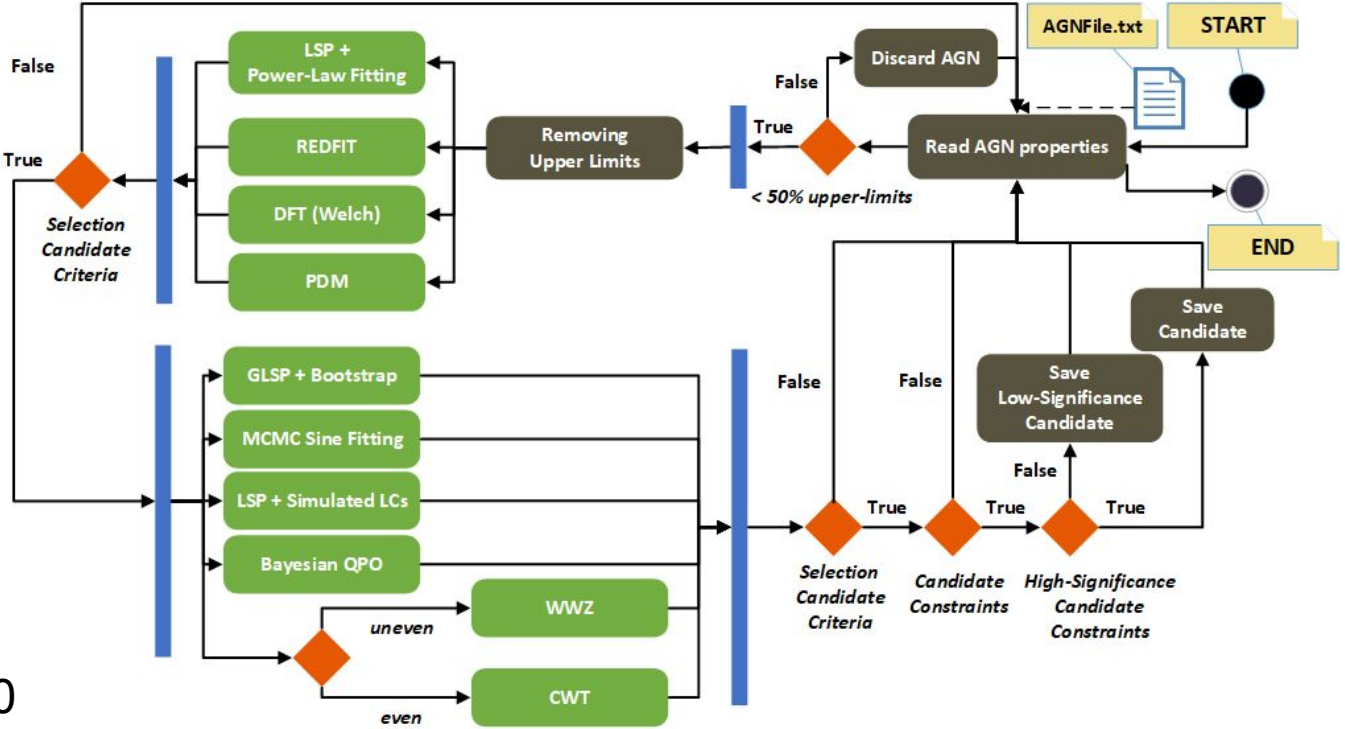


LONG-TERM (YEARS) PERIODICITY



Previous Results

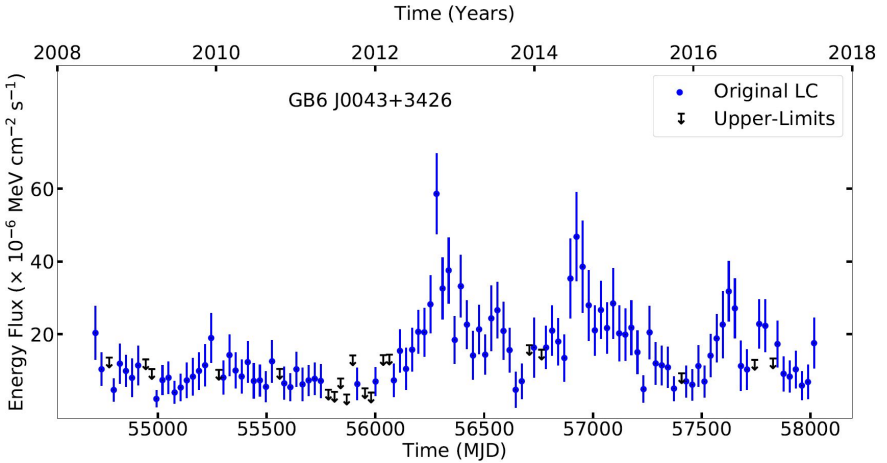
- 3FGL+2FHL+3FHL blazars
- Telescope time: Aug. 2008-Sep. 2017
- Data Reduction: Flux integrated ≥1 GeV 28-days binning
- Methods: Periodicity detection: 10 Significance estimation: 4

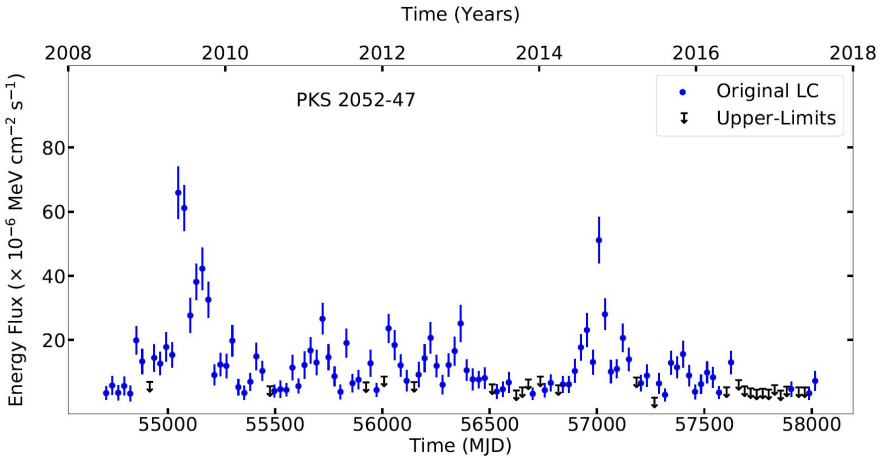


Peñil et al. 2020

Previous Results

- 11 High-significance candidates (4σ in 4 methods)
  - 9 New detection
- 13 Low-significance candidates (4σ in 3 methods)
  - 9 New detections
- 6 objects previously reported in the literature:
  - 5 with the same period
  - S5 0716+ 714





Gamma-Ray Data

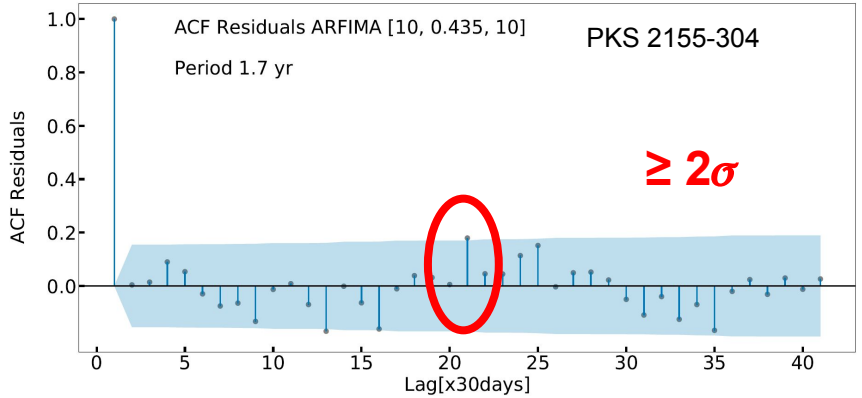
- 24 periodicity candidates from previous work Peñil et al., 2020

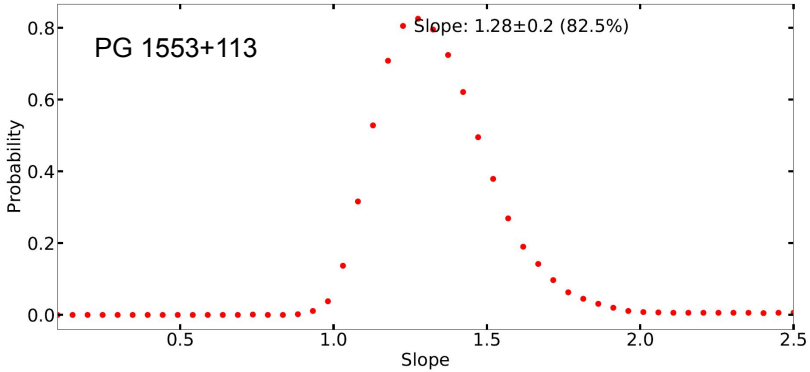
- Light Curves
  - Telescope time: August 2008-December 2020
  - Extended with 3 extra years → total of 12 years

- Data reduction:
  - Flux integrated ≥100 MeV
  - 28-days binning

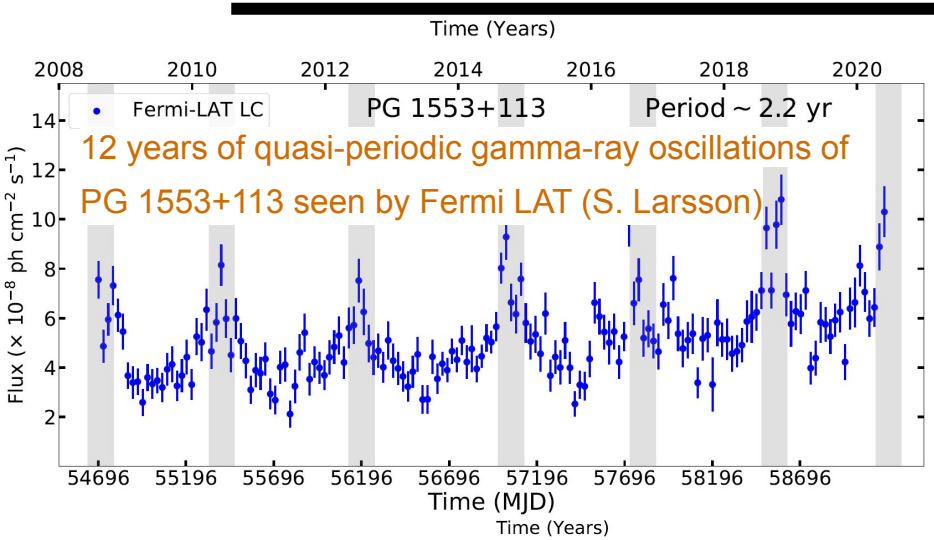
Extended Pipeline

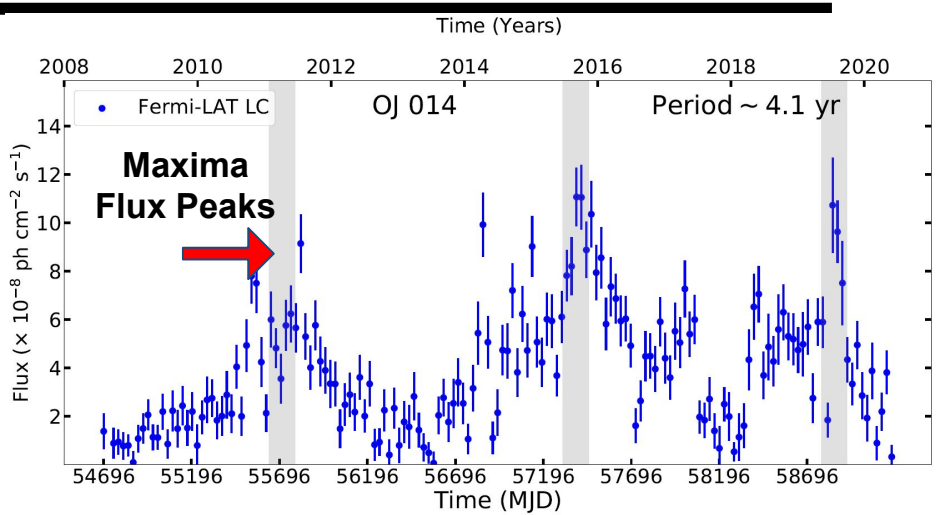
- Uncertainty is given by the Full Width Half Maximum (FWHM)
- ARIMA/ARFIMA analysis
- Power Spectral Density (periodogram)
  → Power-law fitting:
  - $y = a*f^{-\beta}$
  - Power Spectrum Response method (Uttley et al. 2002)
  - Range [0.8-1.3]
- Flux Distribution:
  - Shapiro-Wilk Test & MLE
  - Log-Normal & Normal

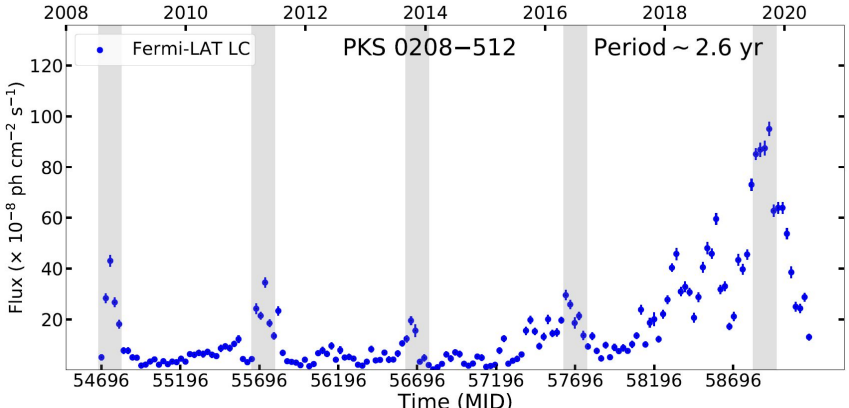




Results: 6 Blazars $\geq 5\sigma$ periodicity detection



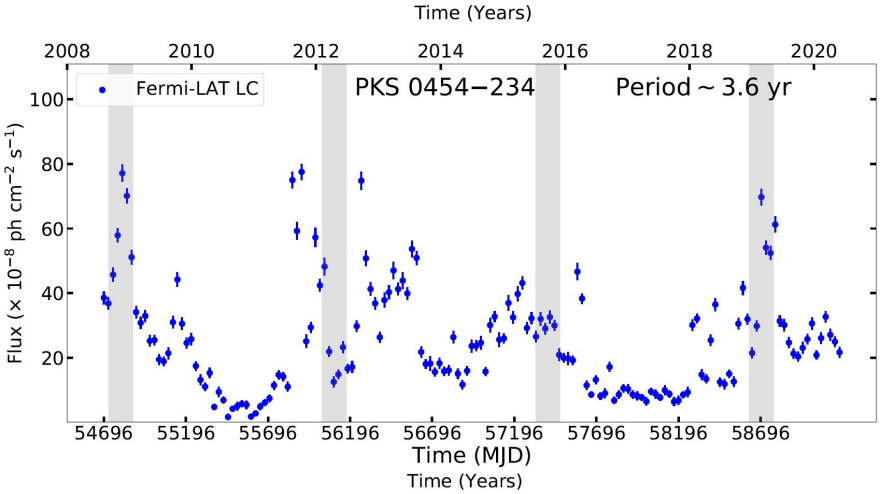


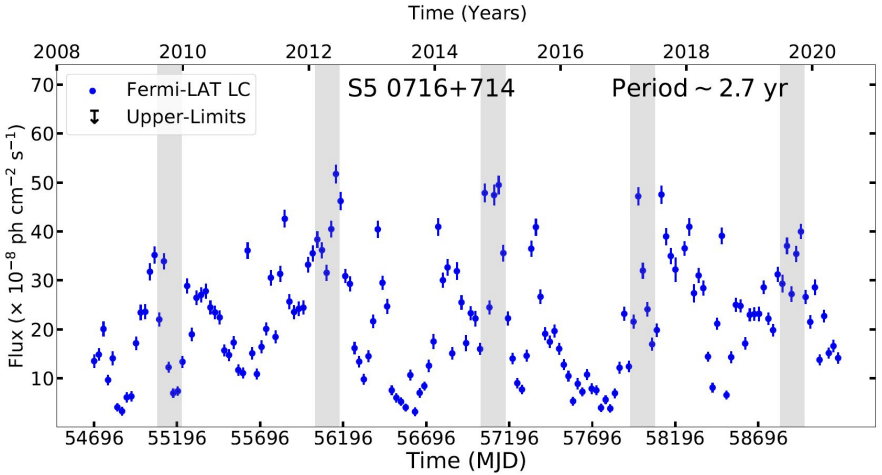


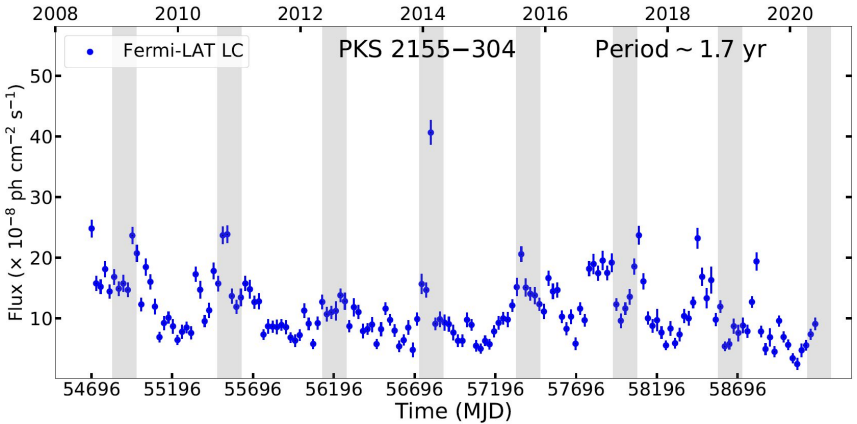
≥5σ periodicity detection criterium → 5σ in average

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

Results: 6 Blazars ≥5σ periodicity detection





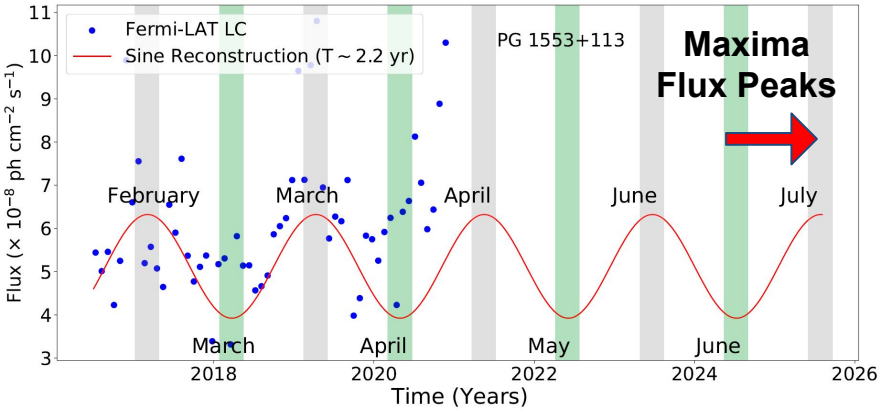


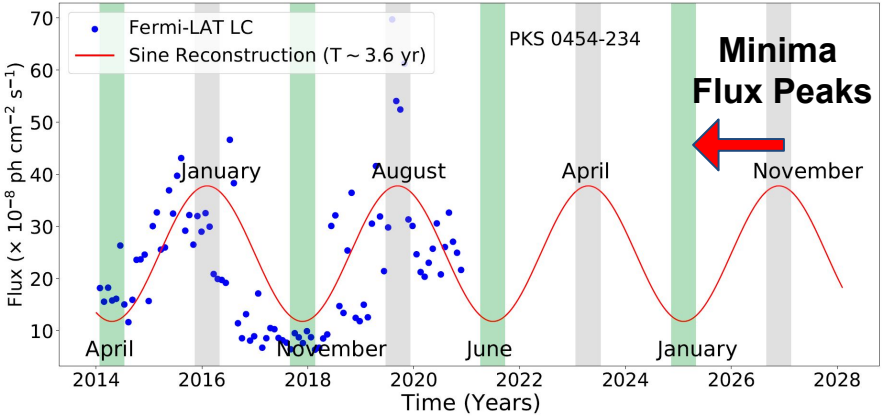
4FGL Source Name	RAJ2000	DecJ2000	Type	Redshift	Association Name	Period (yr)
J0210.7−5101	32.68952	−51.01695	fsrq	1.003	PKS 0208−512	2.6
J0457.0−2324	74.26096	−23.41384	fsrq	1.003	PKS 0454−234	3.6
J0721.9+7120	110.48882	71.34127	bll	0.127	S5 0716+714	2.7
J0811.3+0146	122.86418	1.77344	bll	1.148	OJ 014	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

Predicting the Future

- Predict the future:
  - 15 objects have a high/low emission state during this year





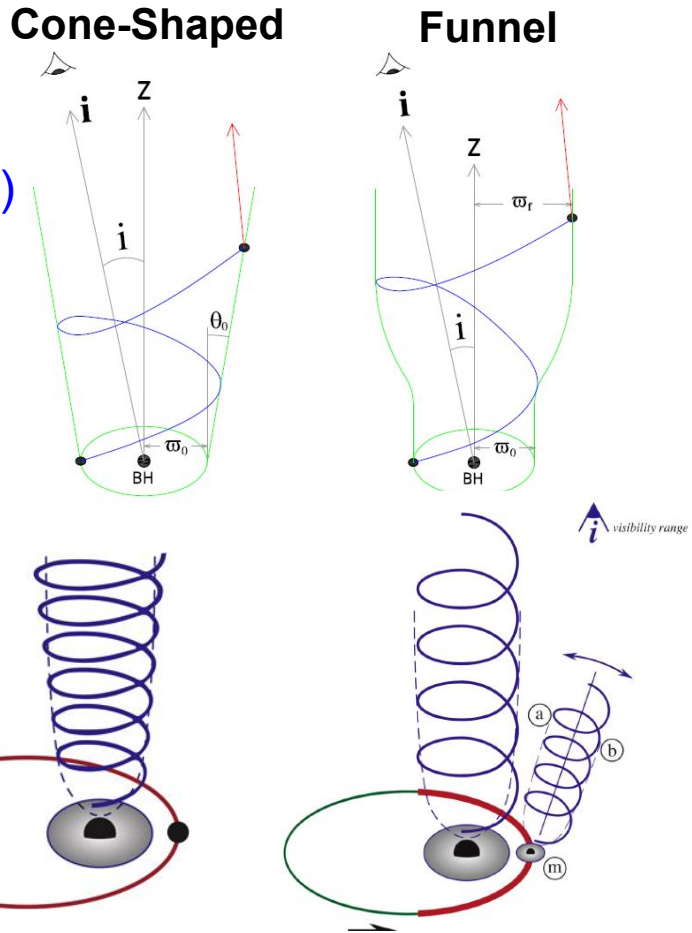
- Strategy to optimize Cherenkov telescopes observations

- Controversy → LCs compatible with red noise:
  - Red noise → stochastic → **<u>not predictable</u>**
  - Yang et al., 2020 claims compatible with red noise

Physical Interpretation

- Single SMBH:
  - Lighthouse effects in jets
    (e.g. Camenzind and Krockenberger 1992)
  - Density inhomogeneities in jets
    (Mohan and Mangalam, 2015)

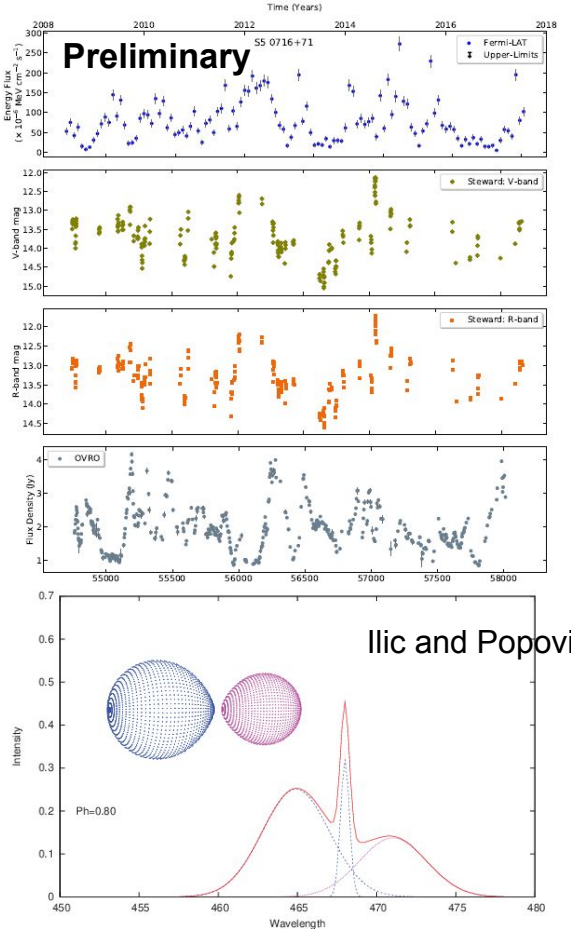
- Binary SMBH
  - PG 1553+113:
    - Perturbed Jet
      (Cavaliere, A., et al., 2017)
    - Double jets
      (Tavani, M., et al., 2018)



Ongoing and Future Work

- Multiwavelength Analysis (Emission Origin)
  - Periodicity
  - Cross-correlation

- Spectroscopy (Binary-SMBH):
  - Emission lines:
    - Hβ–[OIII] region, Hα, [MgII]
  - Velocity offset
  - Lines shape



Conclusions

- We find 6 blazars with periodicity detected with ≥ 5σ
- We also find hints of periodicity for 12 blazars
- Estimating the future behavior of the periodicity candidates:
  - 15 blazars to be evaluated over this year
- Multiwavelength Analysis and spectroscopy
- Any questions: ppenil@clemson.edu