INVESTIGATING VARIABILITY IN BLAZARS

Quantum Universe Attract Workshop

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DESY/Hamburg University

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Aim of Work

Study of blazar variability

Provides insights into the mechanisms responsible for

- Production and emission of gamma rays
- Properties of the relativistic jets

Understanding the central engine (SMBH)

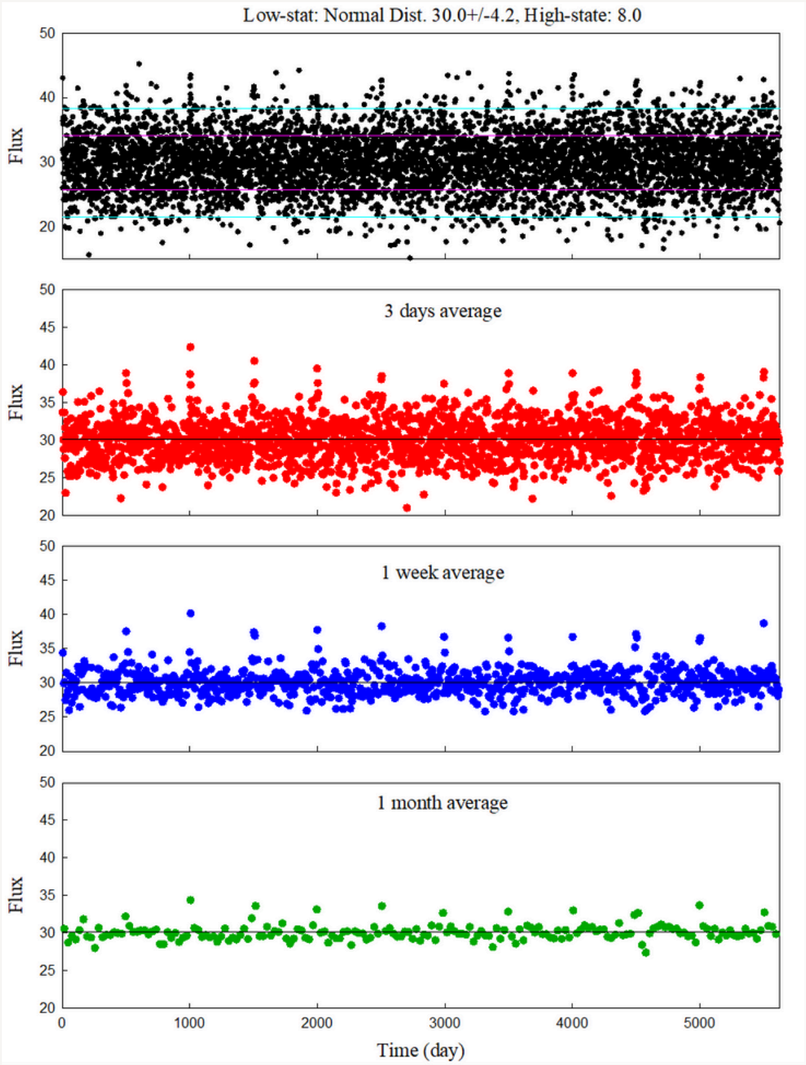
First Study	Second Study
• Selection of BL Lacs & FSRQs • Test for temporal variability using different mathematical methods • Optimization of the best binning • Selection of sources with the highest statistical significance from each class	• Generate the light curve of the final selected sources using Fermi tools • Determine temporal variability/QPOs • Calculation of some physical properties (e.g. mass of SMBH, strength of the magnetic field, separation of the SMBH, etc.)

Simulated Light curves

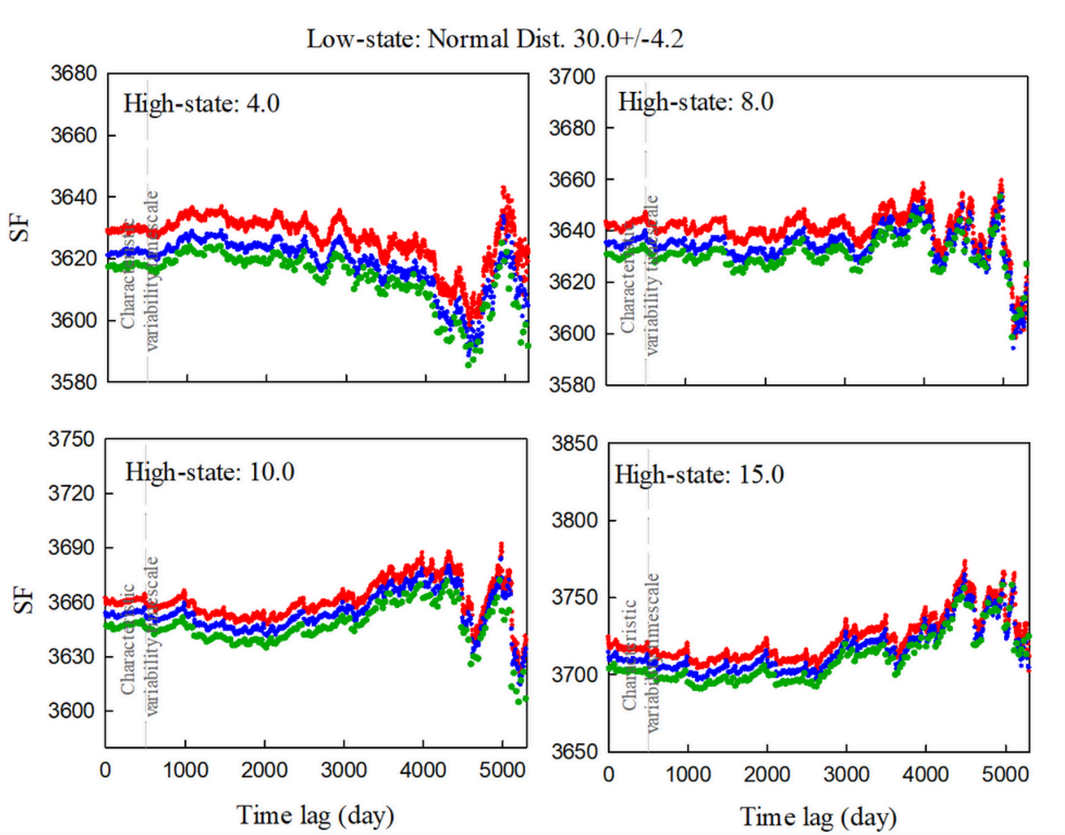
?? The generally used functions for evaluating the time series and extracting the corresponding QPO's period were hardly checked for their optimal conditions as well as their efficiency ??

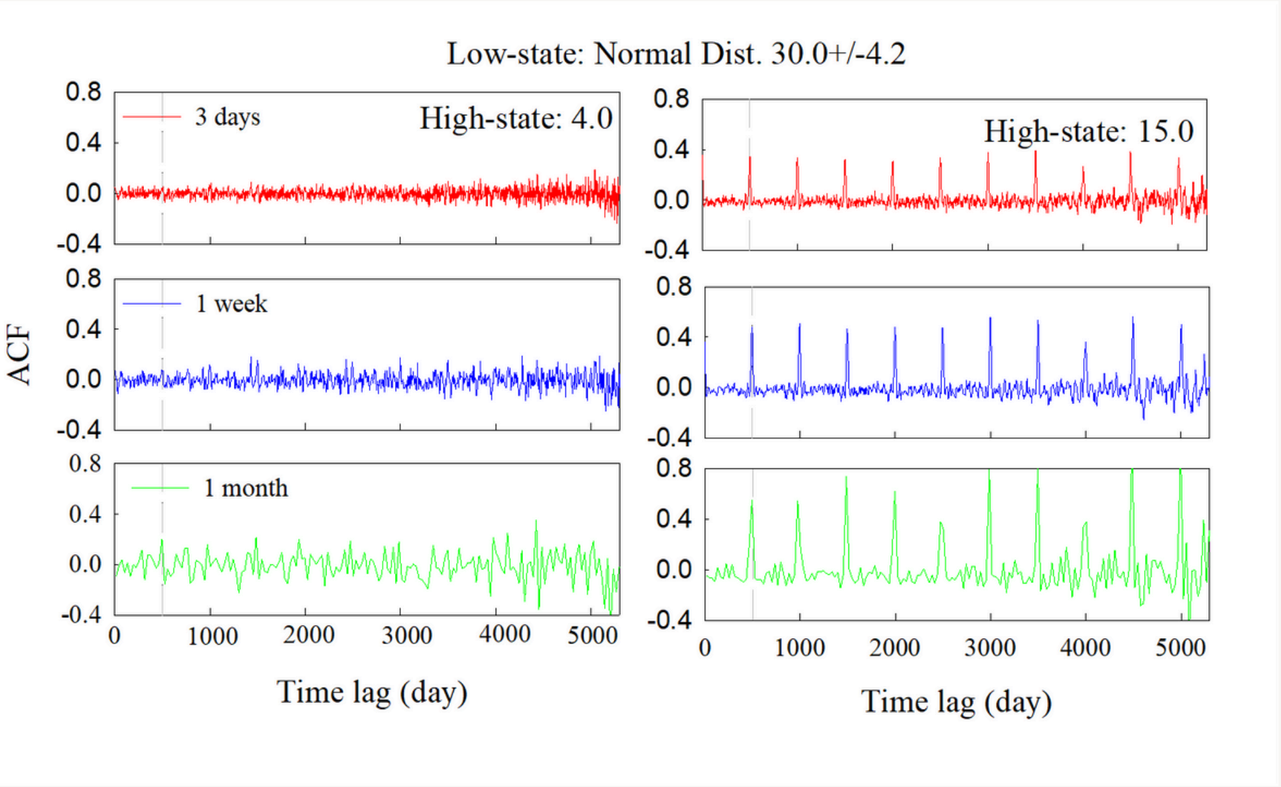
Time series with simple/clear characteristics simulation was initially used:

1. Low-State (Background) and one/two High State (flare) with embedded QPOs.
2. Same period as the Fermi-LAT LC.
3. The HS is assumed to have a constant period throughout the entire LC .
4. To evaluate the effect of the time binning, each simulated LC was averaged every 3 days, 1 week, and 1 month.

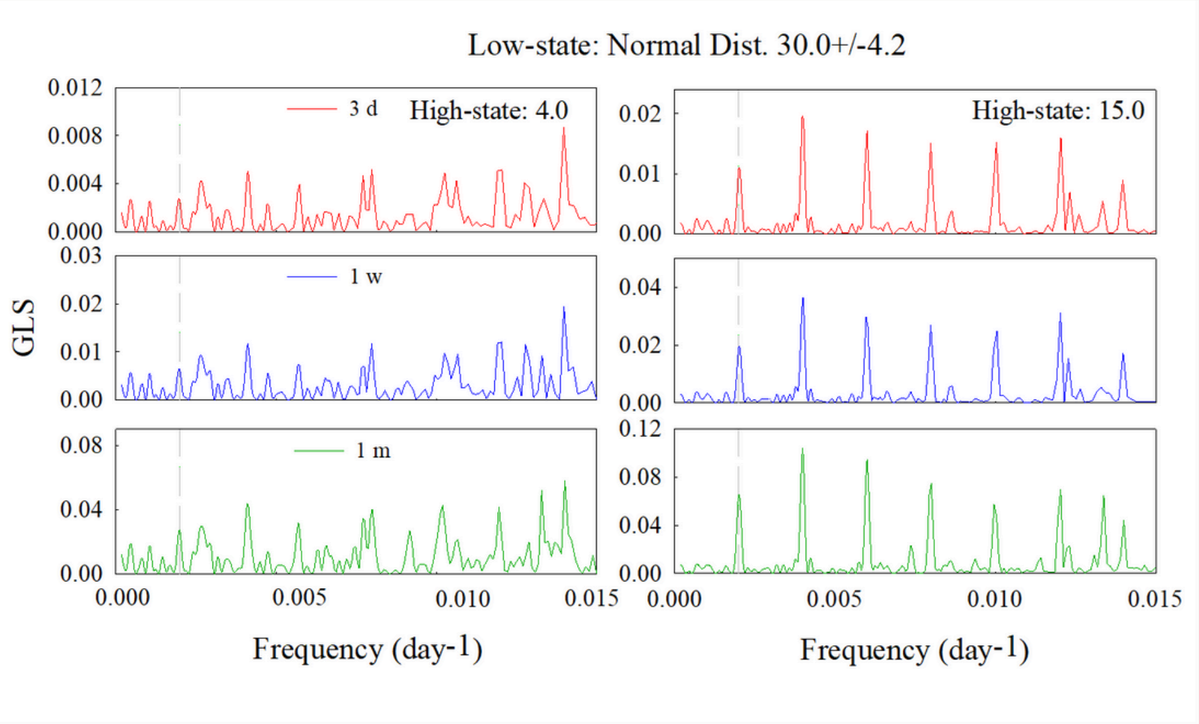


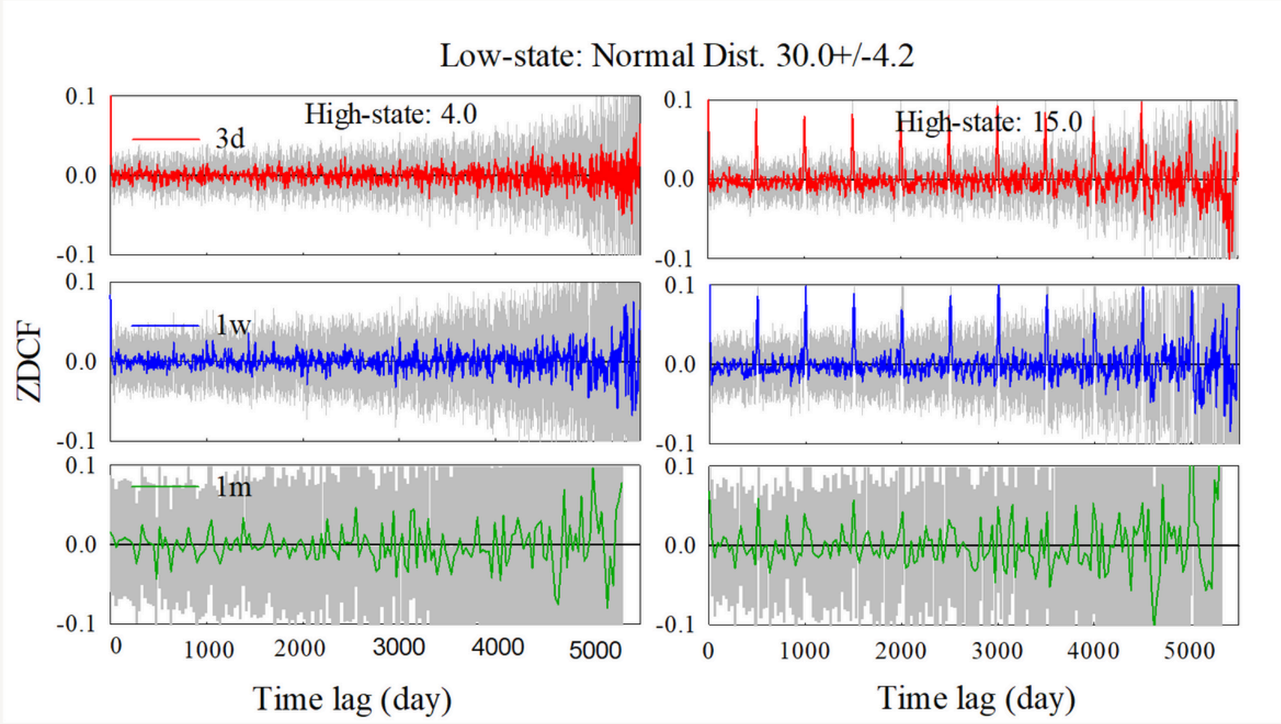
SF and ACF Simulation Results





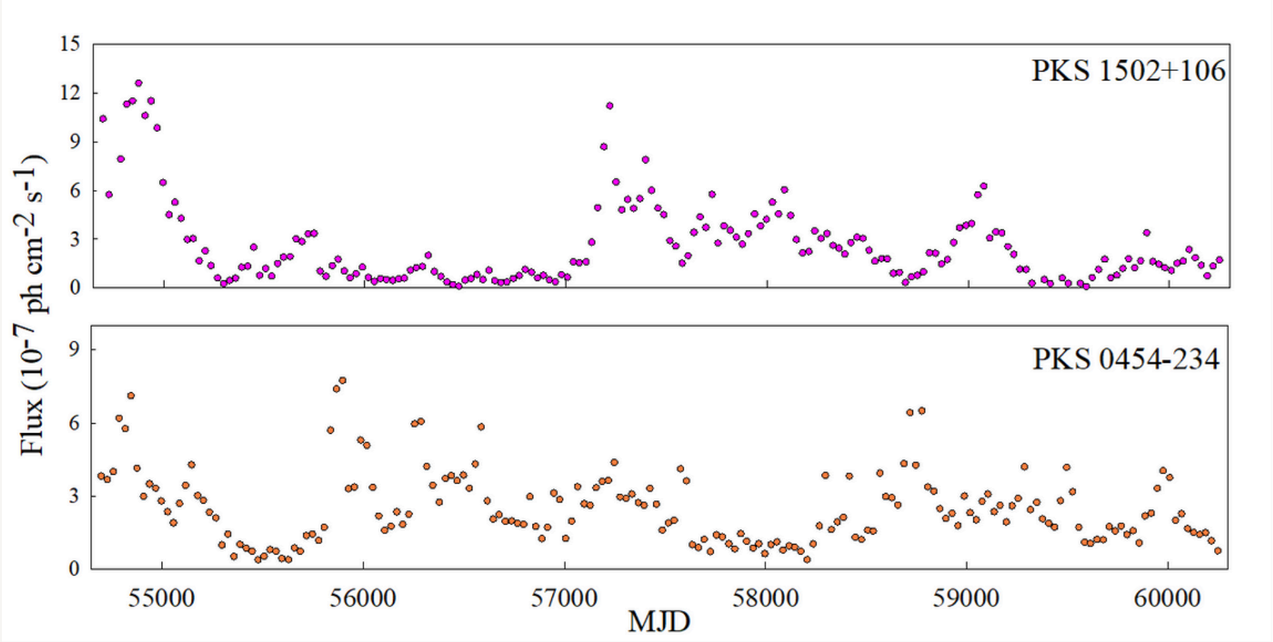
GLS and ZDCF Simulation Results





Fermi-LAT Repository Light Curves

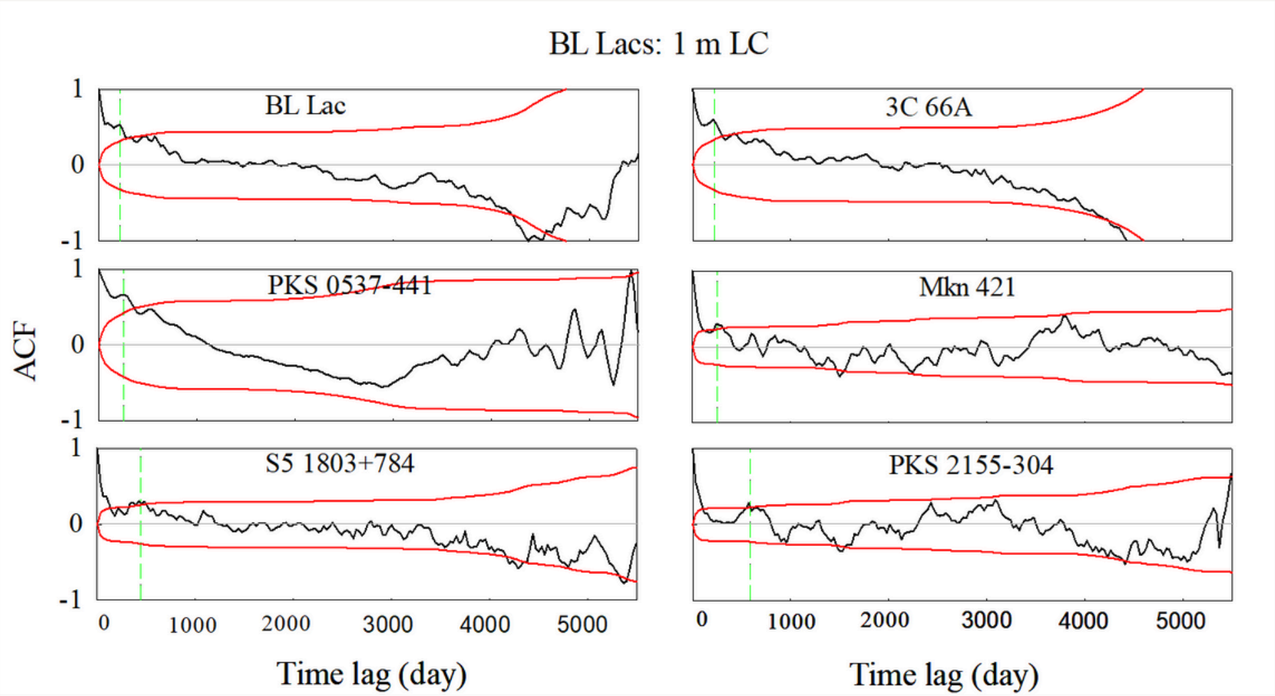
- The Fermi-LAT repository is a public, continually updated database
- Fermi fourth catalog-data release 4 (4FGL-DR4)
- 20 sources: 10 BL Lacs and 10 FSRQs

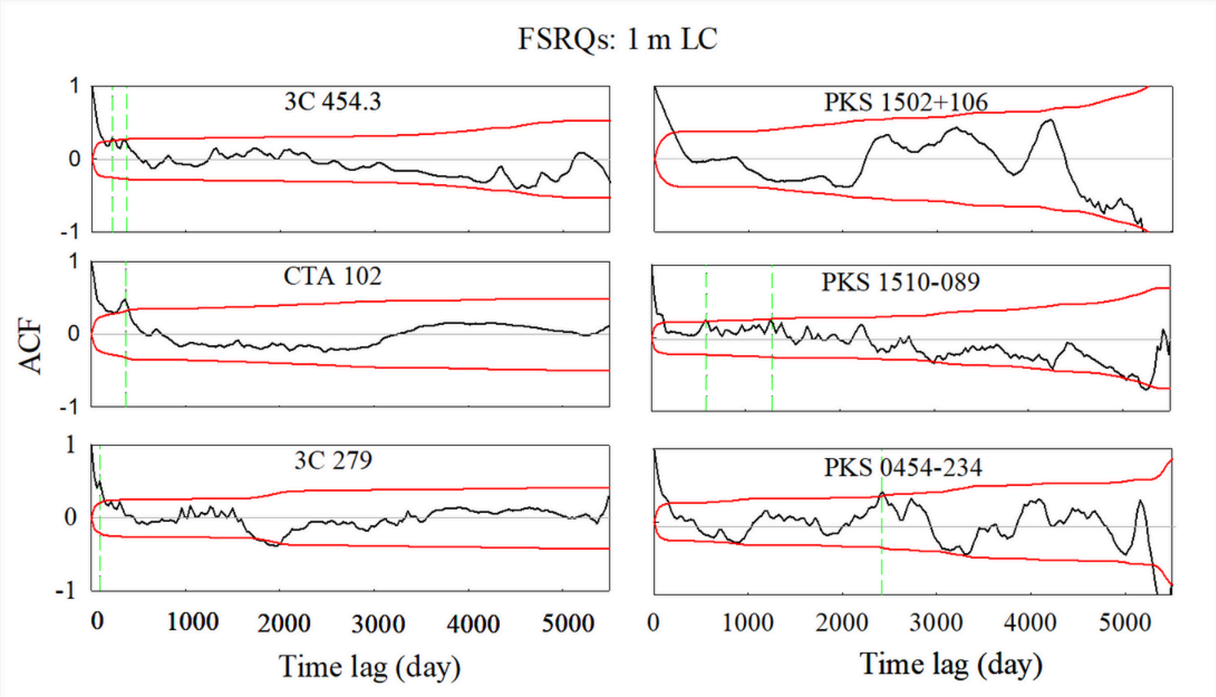


Selection criteria:

1. Fermi-LAT catalog: BL Lacs and FSRQs sources with highest variability index
2. Observational gaps of no more than 20%, 10%, and 5% for 3-d, 1-w, and 1-m LCs, respectively.
3. The minimum detection significance of LCs' bins of 2σ (TS
4. Free photon index was used for all 20 sources except for : PKS 2155-304, 3C 66A, and Mkn 421, as well as PKS 1424-418.

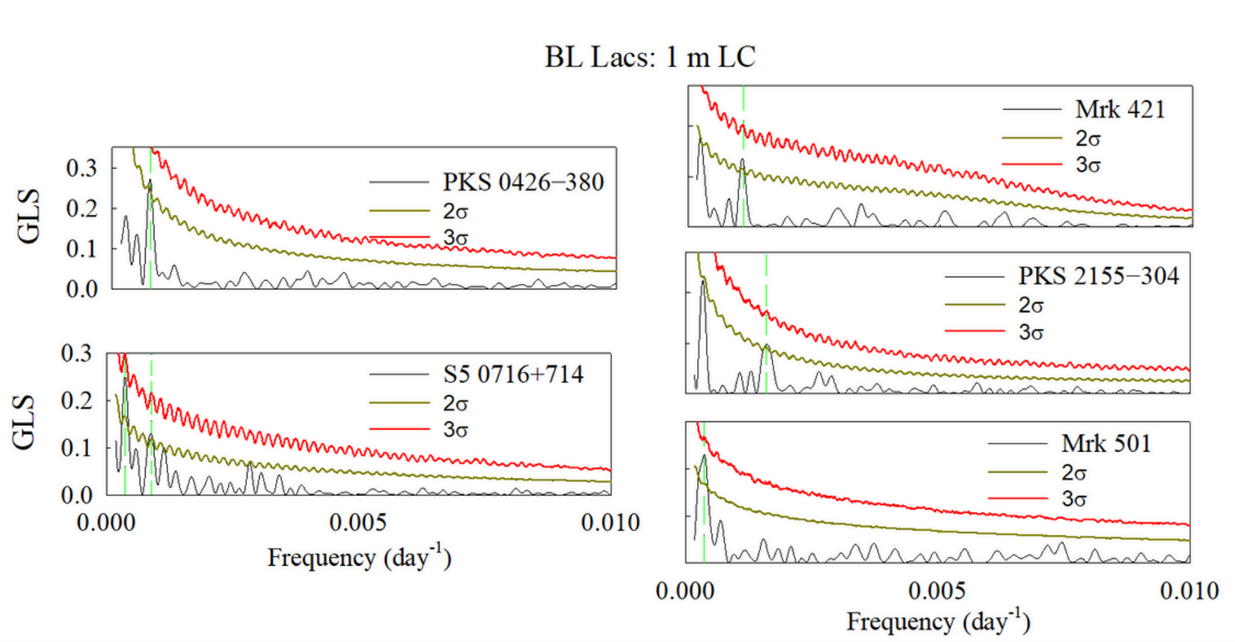
ACF Fermi-LAT Results

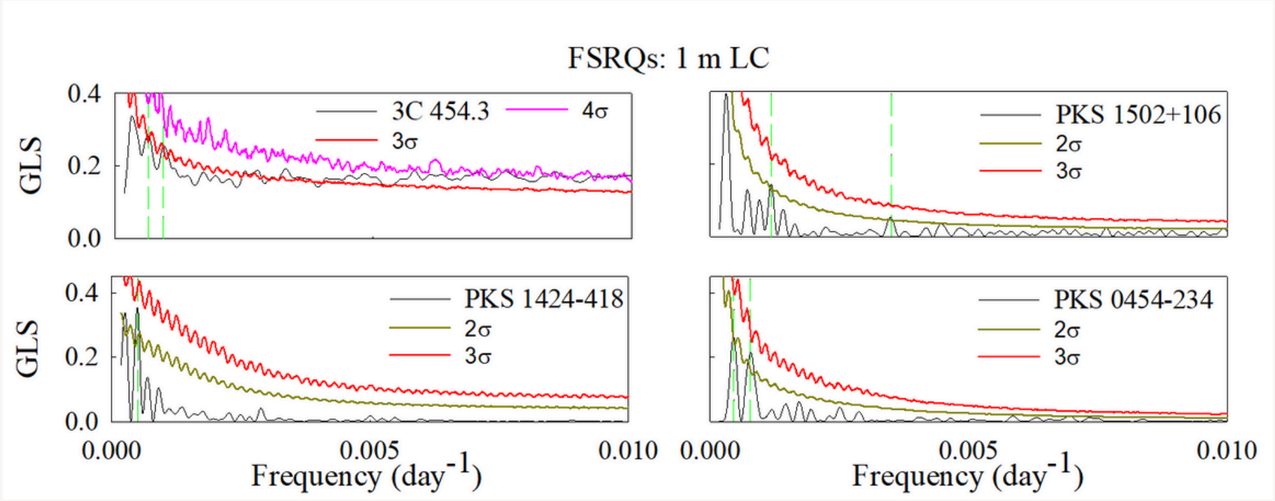




- BL Lacs: no strong periods, most values less than 2 years.
- FSRQs: On the contrary, relatively short (≤1 yr), moderate (1.6 and 3.5 yr), and long (6.8yr) timescales

GLS Fermi-LAT Results

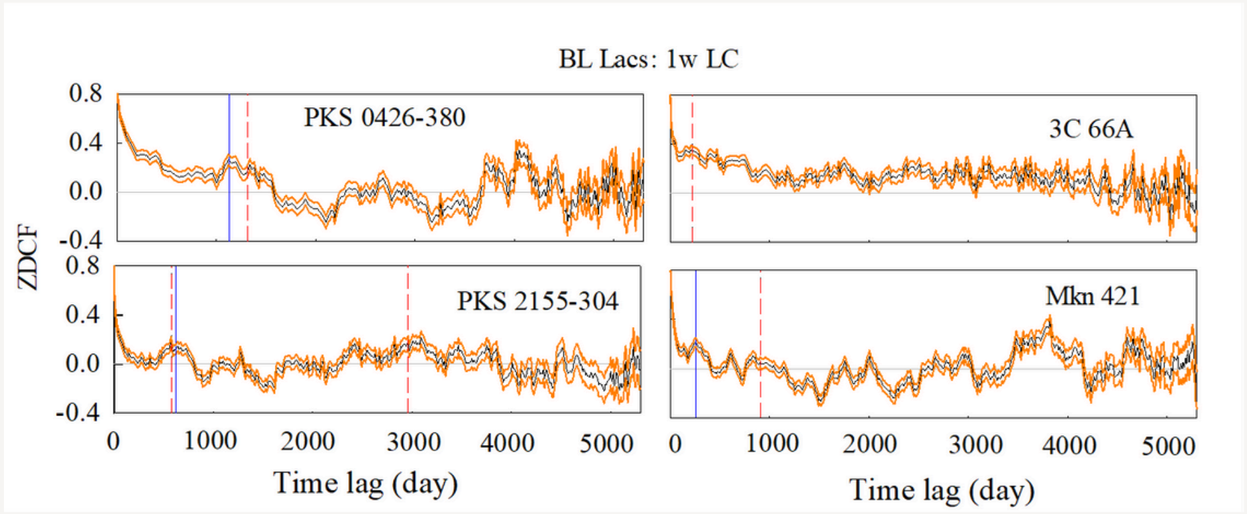


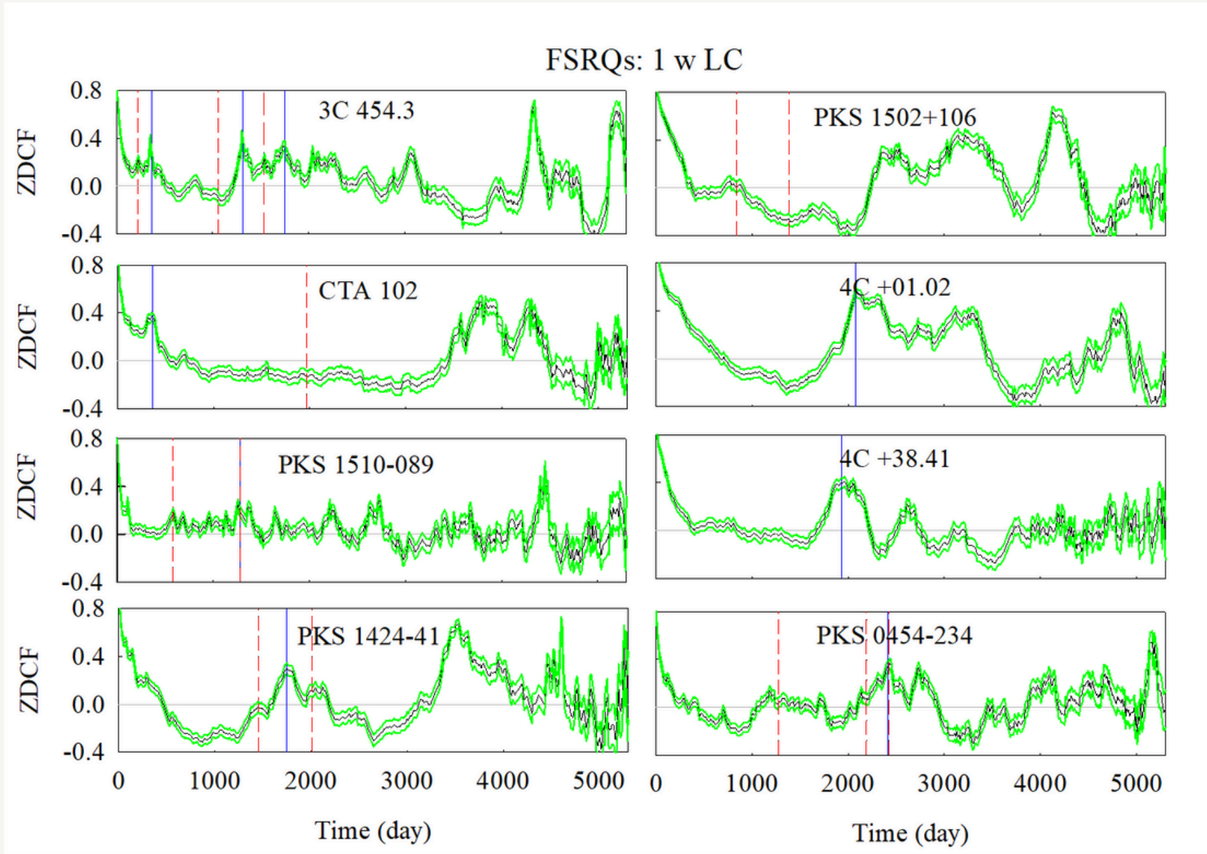


- Significance estimation for GLS' periods: simulating LCs using Emmanoulopoulos method.
- Two BL Lacs showed QPOs with long periods, S5 0716+714 (7.5 yr and 2.4σ) and Mkn 501 (8.0 yr and 2.7σ); first time observed.
- FSRQs GLS showed moderate and long QPOs.
- The result obtained for PKS 1502+106 LC suggested two unreported periods at 0.8 yr and 2.3 yr, both at 2.2σ.

ZDCF Fermi-LAT Results

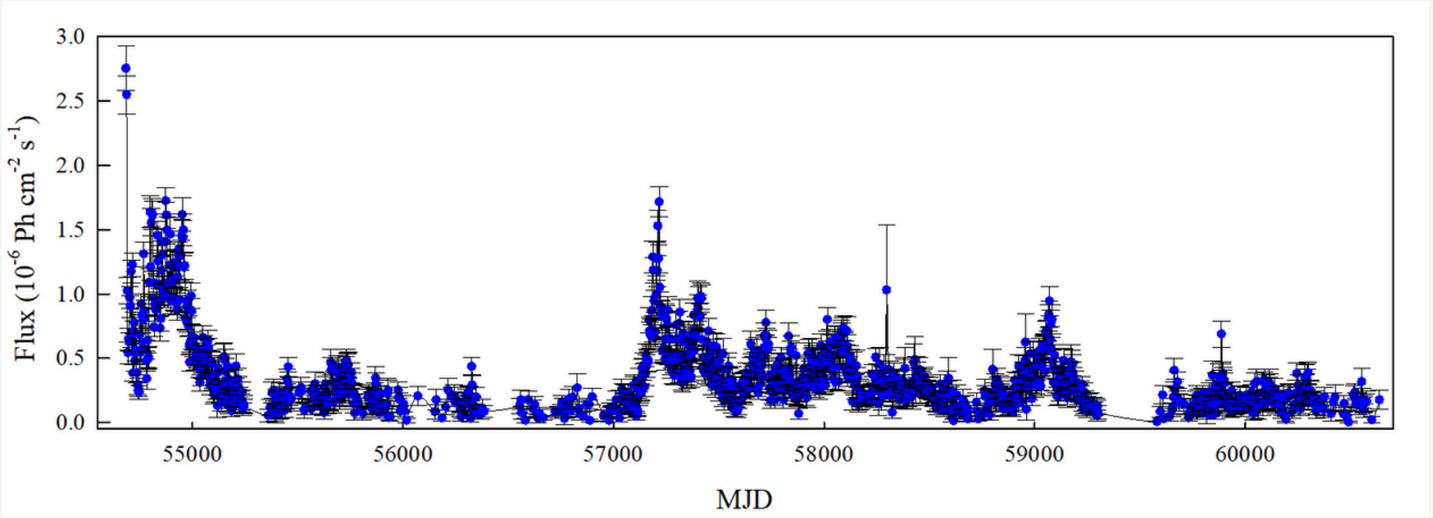
- The results of ZDCF show that 7 out of 10 BL Lacs have no observed periods.

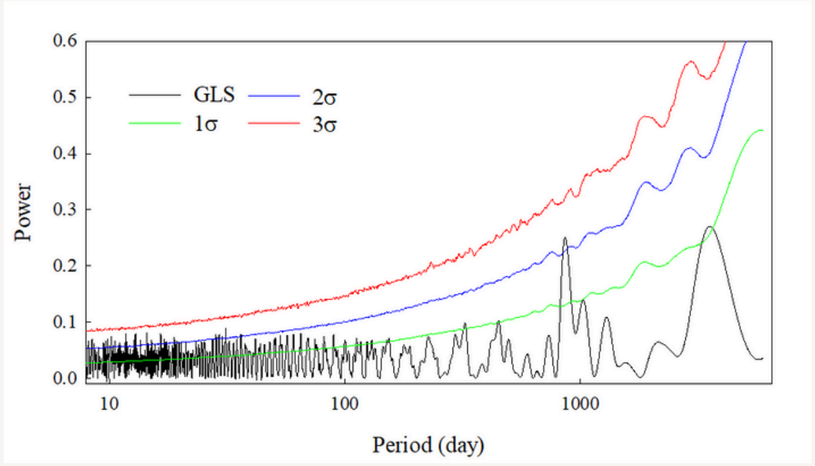


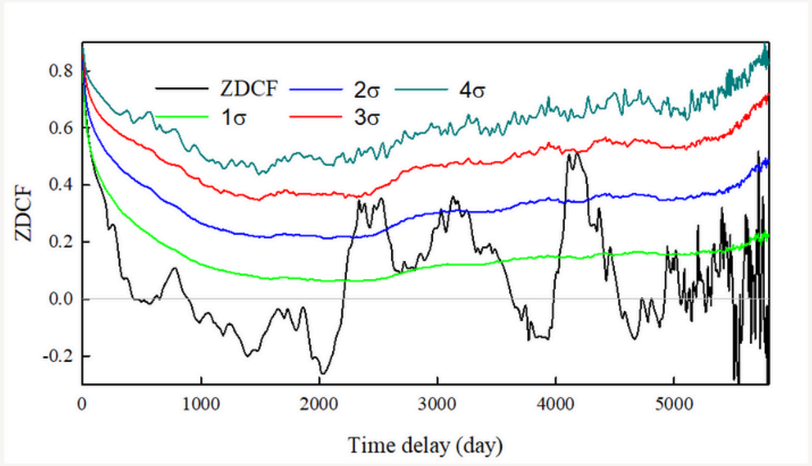


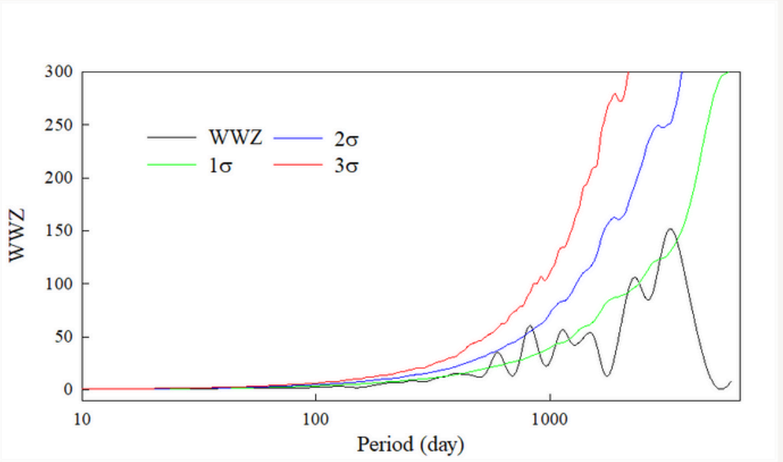
- Near agreement between the three approaches occurred for **PKS 0454-234 (6.0-6.8 yr)** along with a similar reported result.

PKS 1502+106


Flux (10^{-6} Ph cm^{-2} s^{-1})
MJD


GLS
2σ
1σ
3σ
Power
Period (day)


ZDCF
2σ
4σ
1σ
3σ
ZDCF
Time delay (day)


WWZ
2σ
1σ
3σ
WWZ
Period (day)

Summary and Conclusion

- The QPO period of the HS can only be obtained if its amplitude is higher than the standard deviation of LS, regardless of the value of the standard deviation.
- The ACF, GLS, and ZDCF yield similar findings.
- The SF is not a dependable method for variability search.
- LC with a 1-m average has the most statistically significant.

Recommendations

- Implement 1-m binned LCs.
- Utilize both GLS and ACF for low frequency, while ZDCF for identifying the highest frequency.
- ZDCF was further implemented on the 1-w data, as supported by the simulation.