

Exploring the variability properties of gamma-ray emission from blazars

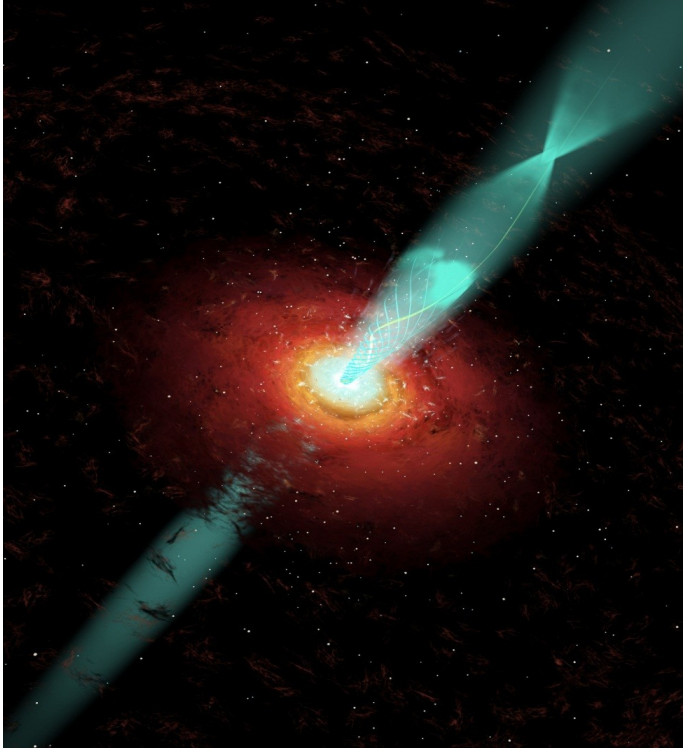


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Motivation

- In the hadronic scenario gamma rays from the blazar could be the result of pion decay. In such case, study of gamma ray emission could be an excellent probe to the UHECR
- Using Hillas Energy relation, the size of the accelerator that accelerate particles to 100 EeV is of order of kpc-Mpc. In such context, blazar jets are promising avenues to the production of UHECR. The Mpc scale radio jets provides most favorable conditions to the acceleration of the non-thermal particles to the highest energies.
- Detection of quasi-periodic oscillation could investigate the nature of space-time under extreme gravity conditions such as around fast rotating (binary) supermassive black holes.

What are Blazars?



- Characterized by high amplitude rapid variability, high optical and radio polarization, non-thermal multi-frequency (from radio to gamma-ray) variable flux

Doppler Factor

$$\delta = \gamma^{-1} (1 - \beta \cos \theta)^{-1} \text{ where } \beta = v/c, \text{ frequency } \nu = \delta \nu'$$

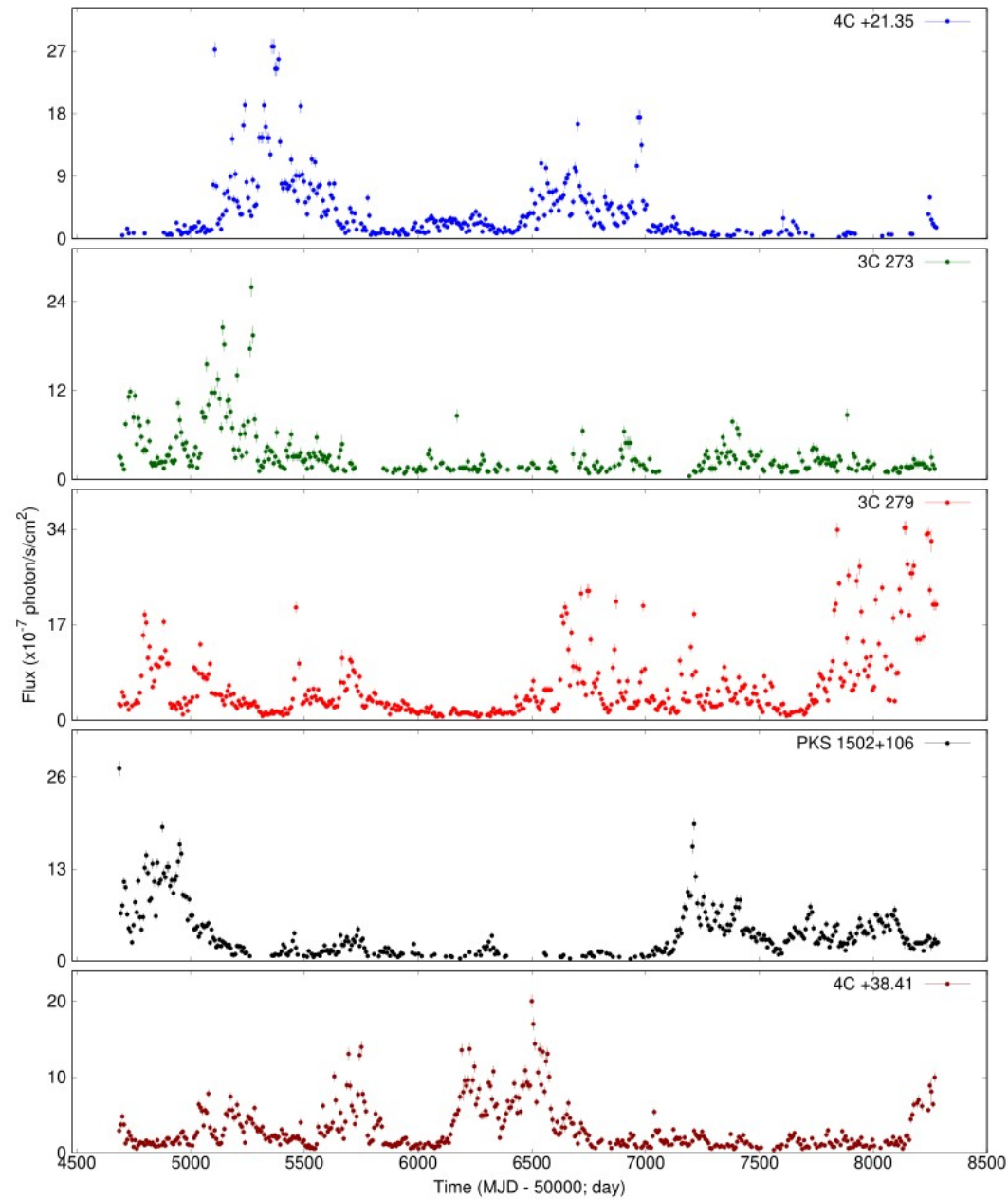
- Blazars are a subset of active galactic nuclei (AGN), with relativistic jets oriented at small angles to the line of sight of the observer.



$$\theta \sim 5^\circ$$

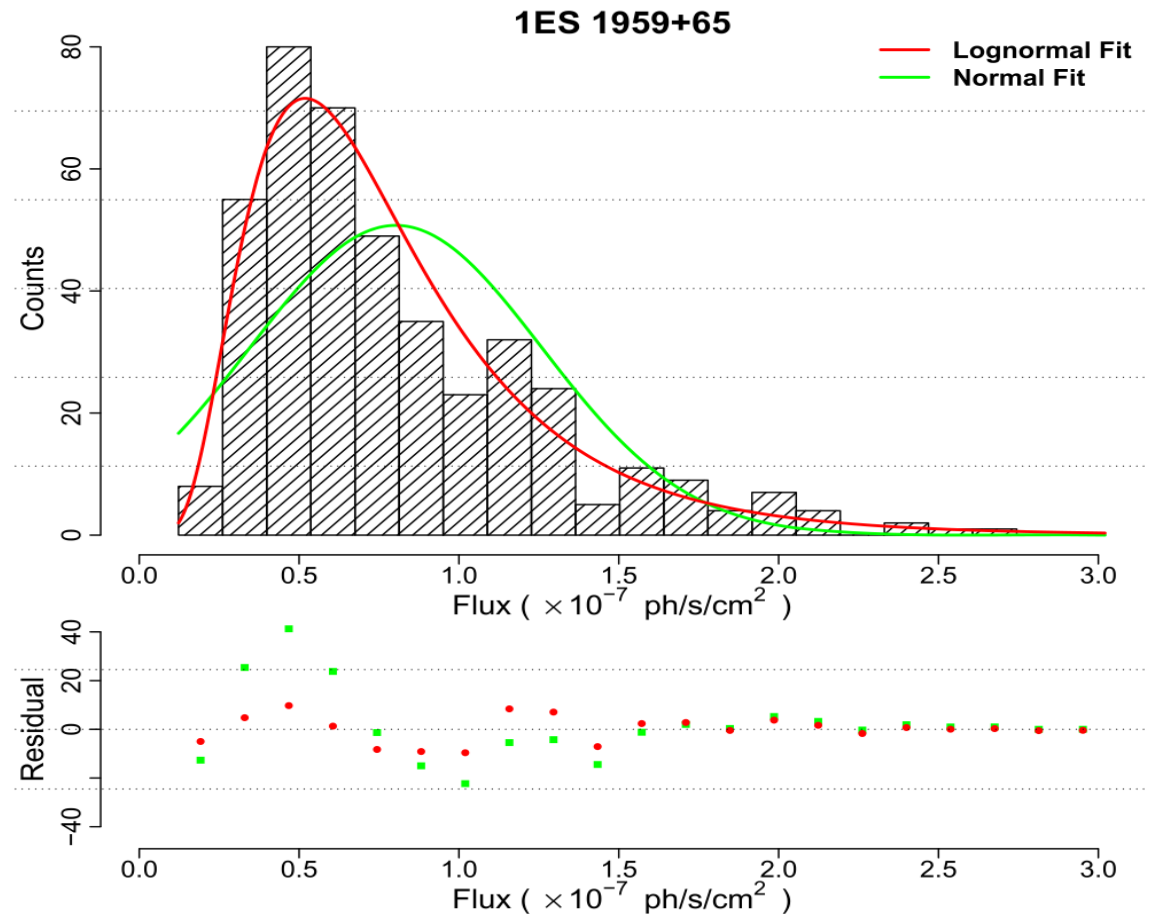
blazar

Decade-long Fermi/LAT (0.1-300 GeV) blazar light curves



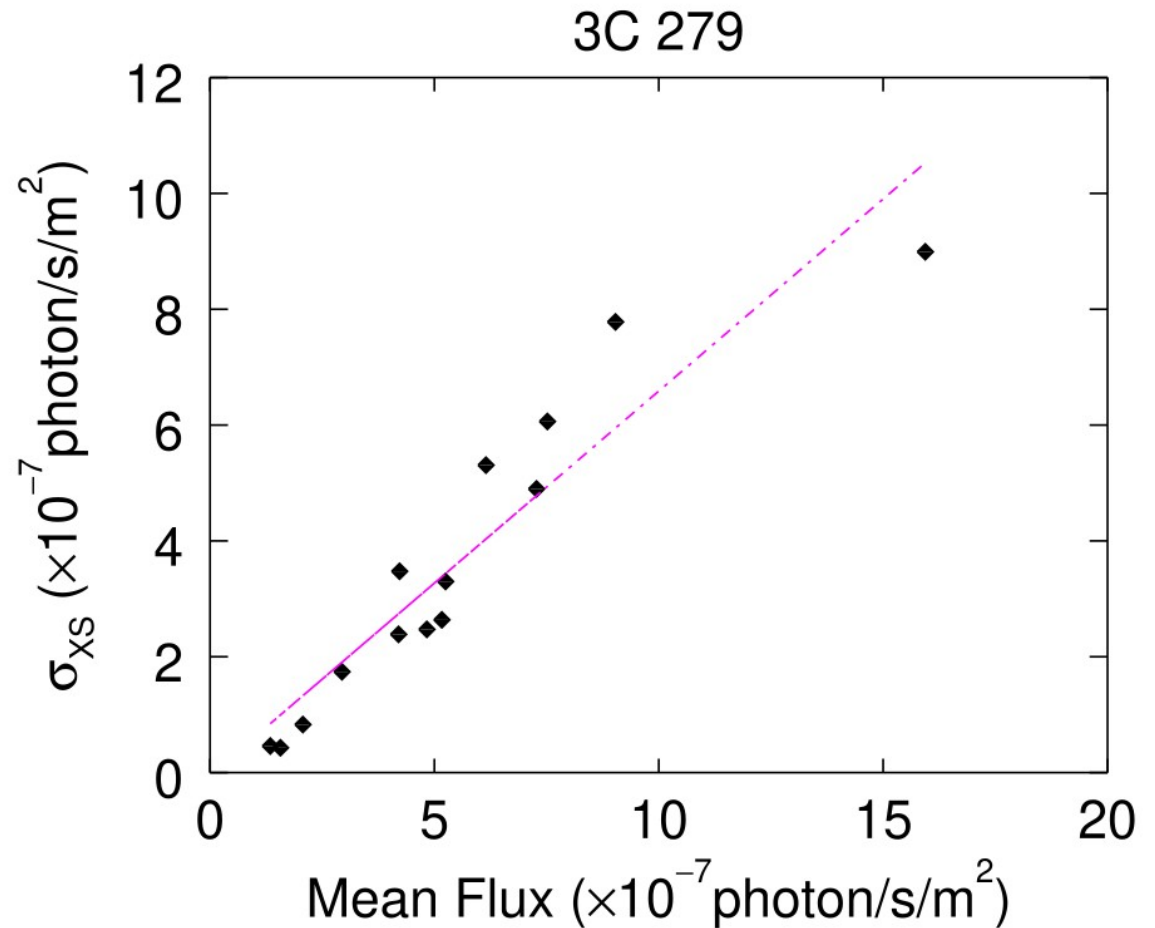
Flux distribution: probability distribution function

- Presence of log-normal PDF suggests possible multiplicative processes driving the observed variability, as opposed to the independent shot-noise like processes.
- Observed positively skewed heavy tail of the Log-normal PDF could a key to the production of UHECR, that distribution of the accelerate particle might follow similar PDF.



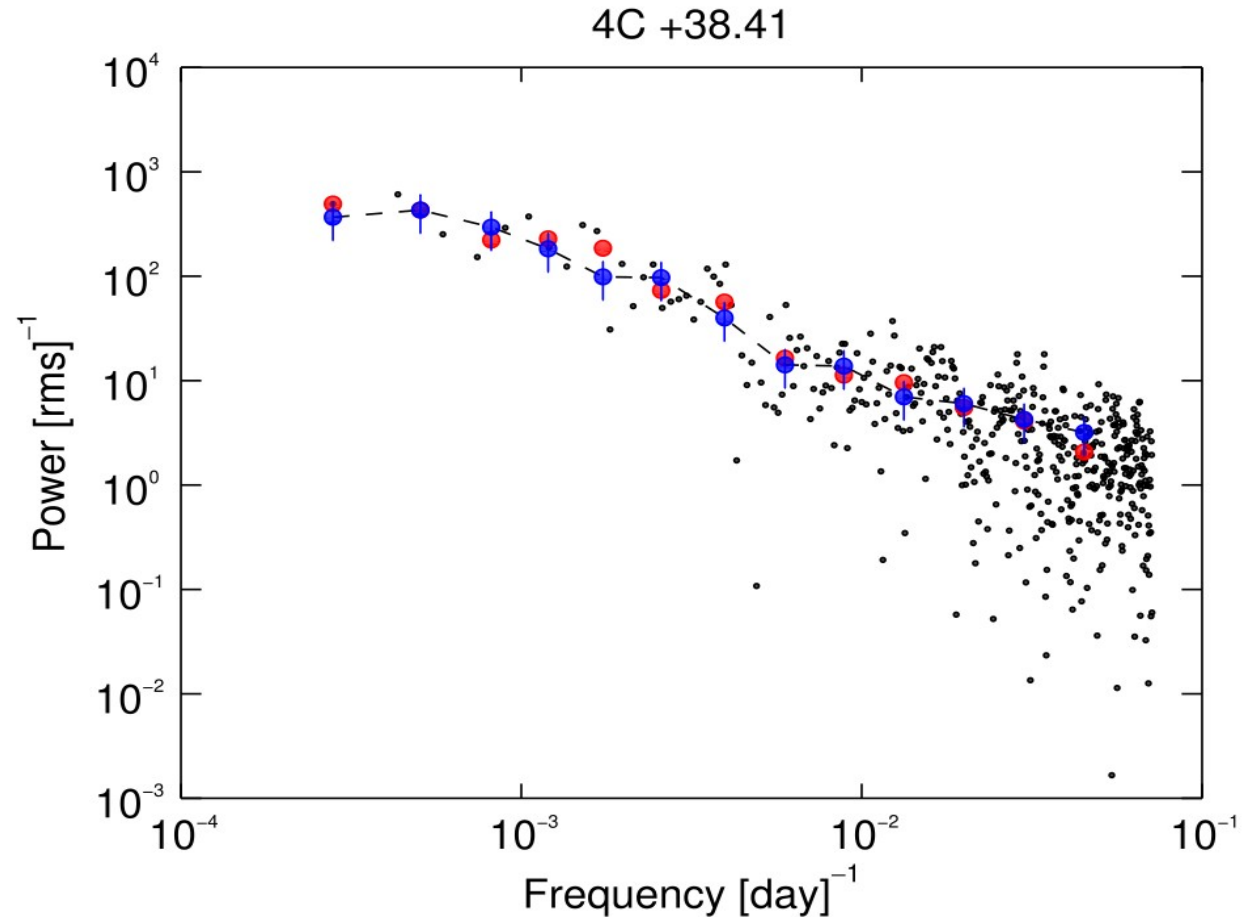
Linear RMS-Flux relation

- In the current models of blazar, the observed linear RMS-flux relation is best explained in terms of the longer timescales accretion rates at the larger radii of disk modulating the shorter timescale instabilities close to the central engines.
- This is a possible indication of the strong disk-jet connection, in the sense that the disk modulations are imprinted in the observed flux variability from the jets.



Power spectral density: flicker noise, long memory processes

- The power spectral density slopes of the gamma-ray light curve turn out to be near 1, indicating the presence of flicker noise ($P \propto 1/f$).
- The analysis points to the presence of long-memory processes at work, in confirmation with the observed log-normal PDF and linear RMS-flux relation



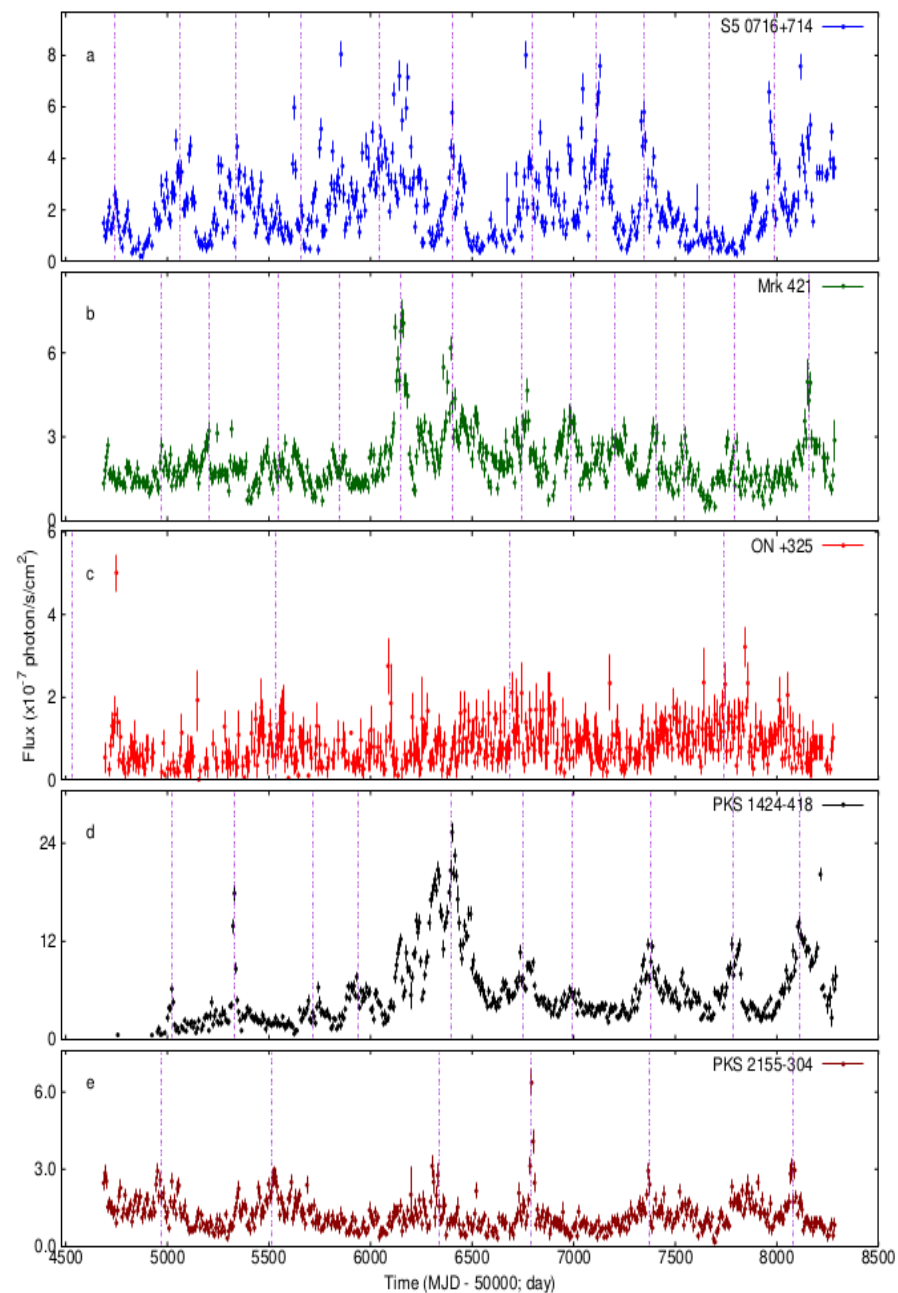
Gamma-ray QPOs in blazars

Study of decade-long light curves of the 20 gamma-ray bright blazars in the energy band of 100 MeV-300 GeV

List of the Blazars in the Sample That Show Significant QPO in the γ -Ray Light Curves

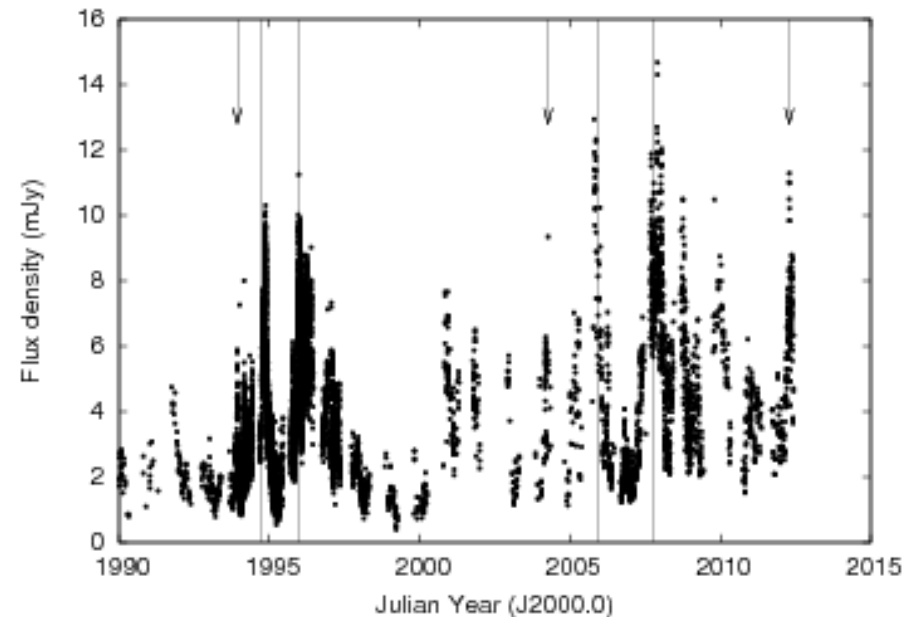
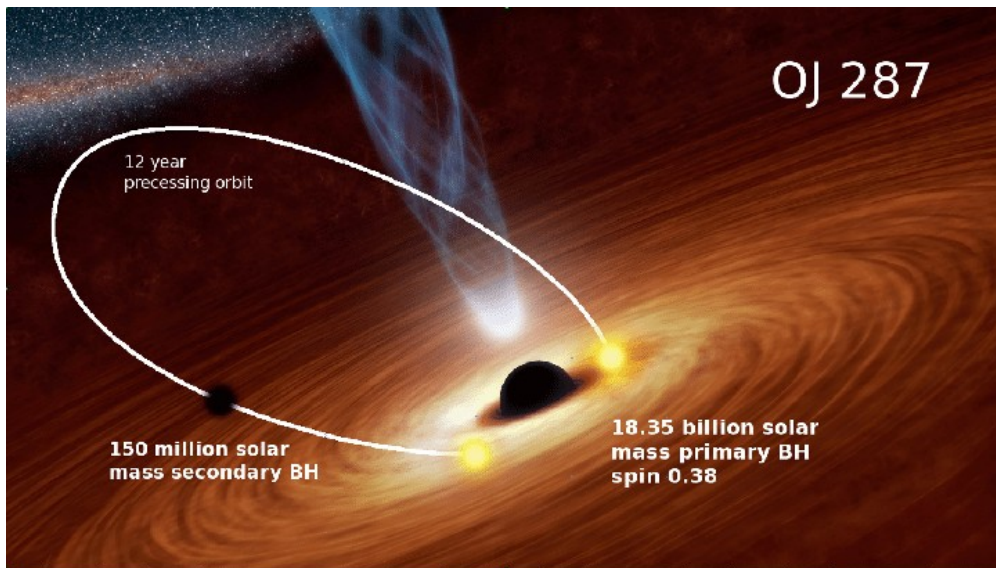
Source (1)	LSP		WWZ			Global Sig. (%) (7)
	Period (days) (2)	Local Sig. (%) (3)	Global Sig. (%) (4)	Period (days) (5)	Local Sig. (%) (6)	
SS 716+714	346 \pm 23	99.97	99.96	349 \pm 27	99.982	99.980
Mrk 421	285 \pm 27	99.99	99.97	287 \pm 32	99.997	99.993
PKS 2155-304	610 \pm 51	99.9994	99.99841	617 \pm 53	99.995	99.9981
PKS 1424-418	353 \pm 21	99.98	99.95	349 \pm 24	99.985	99.981
ON +325	1086 \pm 63	99.9986	99.9968	1081 \pm 67	99.987	99.983

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Supermassive binary black hole system

12 year periodicity in OJ 287

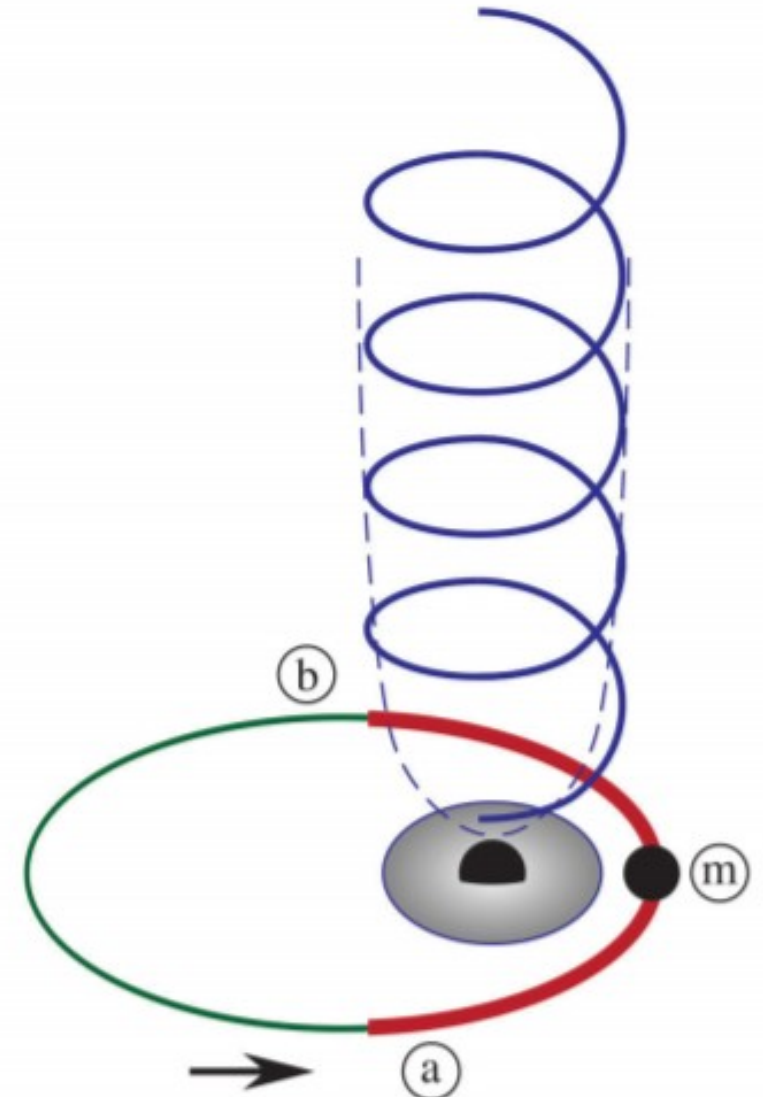
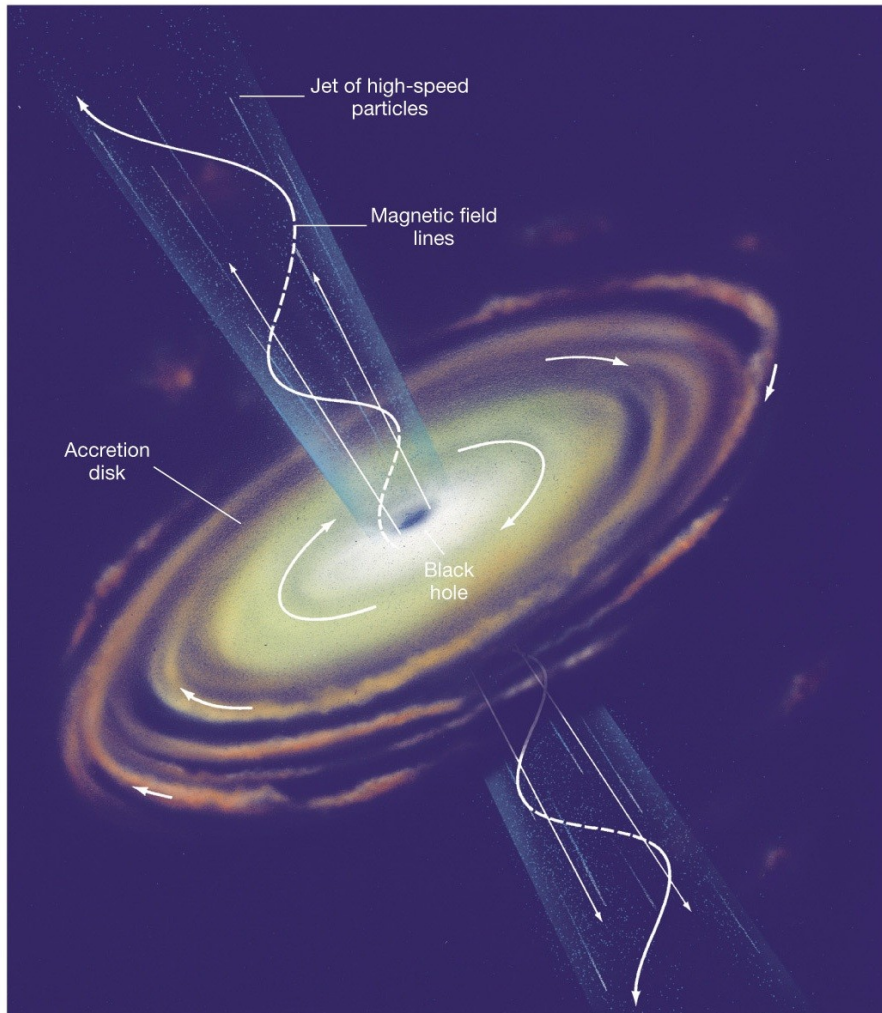


Keplerian period for mass ratio=0.1

$$\tau_k = 0.36 \left(\frac{M}{10^9 M_\odot} \right)^{-1/2} \left(\frac{a}{r_g} \right)^{3/2} \text{ days,}$$

Motion along Helical magnetic fields of the jets

Emission regions moving along helical magnetic field show periodicity



Tavani et al. 2017

Summary and Conclusions

- A detailed time series analysis of 20 powerful blazar was carried out using the observations from Fermi/LAT gamma-ray telescope
- Blazar are found to be highly variable in decade long timescales
- The properties of the variability include log-normal PDF, linear RMS-flux relation and presence of year timescale QPOs.
- These properties suggest that the variability is correlated over large spatial and temporal timescales through multiplicative process and strong disk-jet connection.
- QPOs could make an excellent probe to the innermost regions of AGN including the extreme physical conditions near the supermassive black hole.