DETECTION OF QUASIPERIODIC OSCILLATION IN X-RAY LIGHTCURVE OF BLAZAR MRK 501 USING *Swift*/XRT

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Objectives

- To detect the quasi-periodic oscillations(QPOs) in the X-ray light curve of blazar Mrk 501.
- To search for the important information on the location and periodic variations discovered in the blazar lightcurve.

Introduction

Blazars are the subclass of active galactic nuclei (AGN) with emission from the relativistic jets oriented towards the observer and shows the variability in all wavelengths from radio to gamma. The spectral energy distribution (SEDs) of blazars shows the two peaks due to non-thermal emission where first peak is due to synchrotron emission and second peak is due to inverse Compton scattering. Markarian(Mrk) 501 with R.A. : 16 53 52.2 (hh mm ss) and Dec. :+39^{o}45′37′′ is one of the nearest and brightest blazars (z = 0.034) that was first detected at TeV energies by the Whipple Collaboration in 1996. It has been extensively studied in broad range of spectral region with different instrument. We have used *Swift*-XRT to study it. In X-ray astronomy, QPO is the manner in which the X-ray light from an astronomical object flickers about certain frequencies. The QPO phenomenon promises to help astronomers to understand the innermost regions of accretion disks and the masses, radii, and spin periods of white dwarfs, neutron stars, and black holes. So, search for QPOs in the various subclasses of AGNs in different EM bands are very important.

Material and Methods

Lomb-Scargle Periodogram

To search for the possible QPOs in the *Swift*-XRT lightcurve, Lomb-Scargle perio-dogram(LSP) was performed[1]. LSP is considered to be an improved method to compute the periodograms in irregularly sampled data . For an angular frequency ω, the LSP is given as

$$P = \frac{1}{2}\left\{\frac{\left[\sum_i x_i cos\omega(t_i-\tau)\right]^2}{\sum_i \cos^2\omega(t_i-\tau)} + \frac{\left[\sum_i x_i sin\omega(t_i-\tau)\right]^2}{\sum_i \sin^2\omega(t_i-\tau)}\right\},$$

where τ is given by

$$\tan(2\omega\tau) = \frac{\sum_i \sin\omega t_i}{\sum_i \cos\omega t_i}.$$

Epoch Folding

Another method that is used to test the QPOs in x-ray light curve is epoch folding. This method is very useful to find out the accurate period if an approximate period is known. The XRONOS package of HEASOFT FTOOLS has a task named *efsearch*. This methods folds the light curve with large number of periods around the approximate period and finds the best period by χ^2 maximization. Epoch is the reference point with respect to what the light curve is folded. Here we have given 1359 days. We gave the approximate period as 397 days which was obtained by LSP.

Results

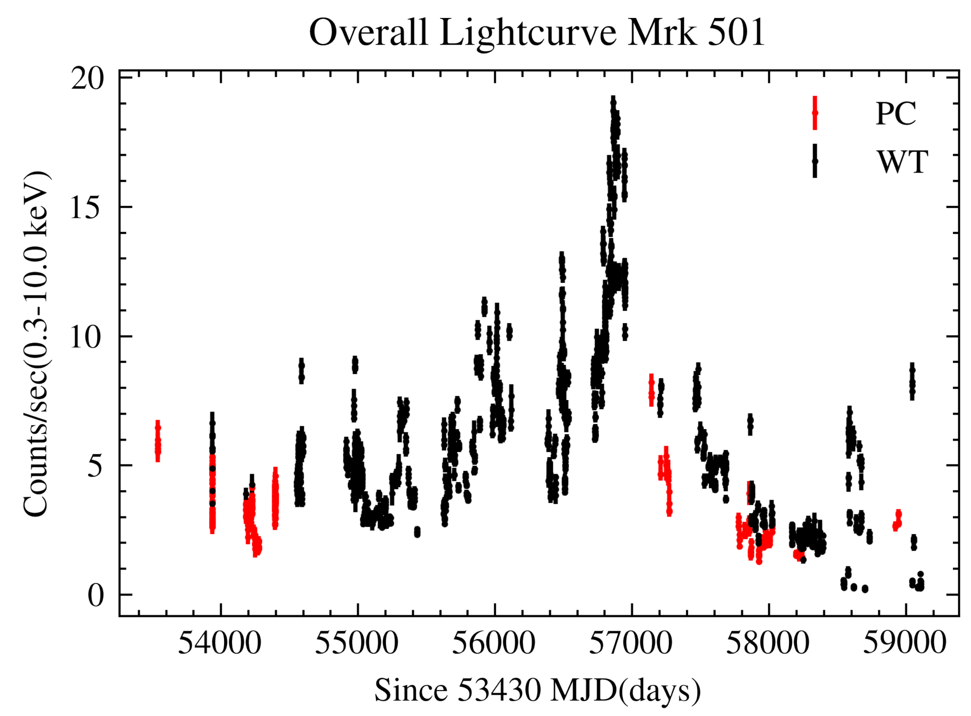

Figure 1: The longterm lightcurve from *Swift*-XRT(0.3-10 keV) observations of the blazar Mrk 501 from the 2005(53539.0 MJD) to 2020(59106.9107529715 MJD) i.e. span of 15 years. The lightcurve clearly show the periodic modulation of the counts with maximum counts/sec around 57000 MJD.

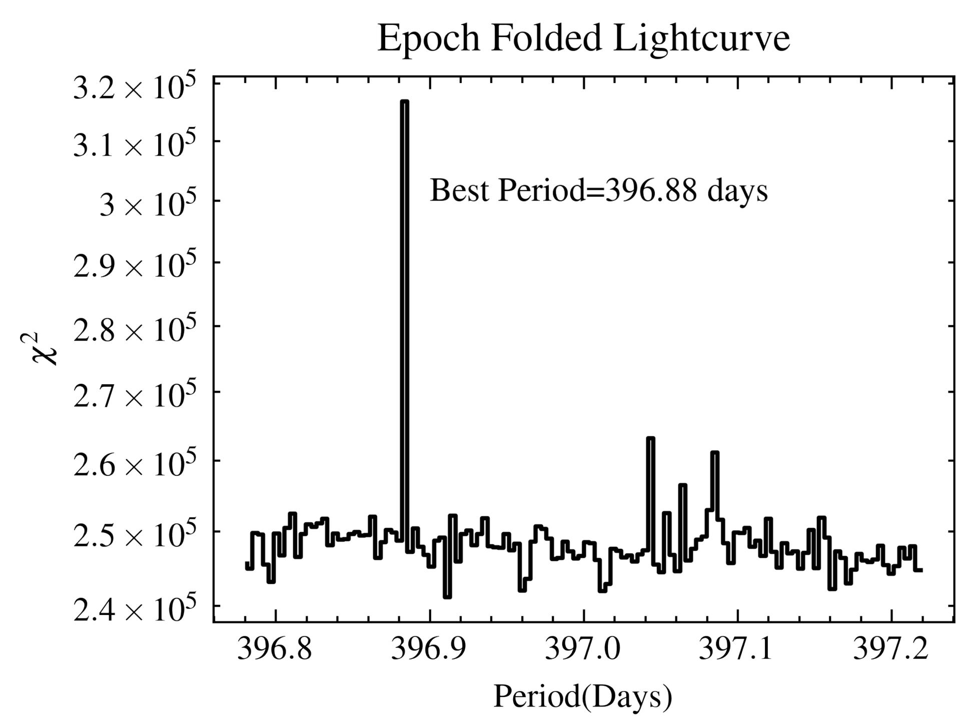

Figure 2: The plot of χ^2 vs. period(s). The plot clearly shows the best period of 396.88 days i.e. ~397 days using the epoch folding method.

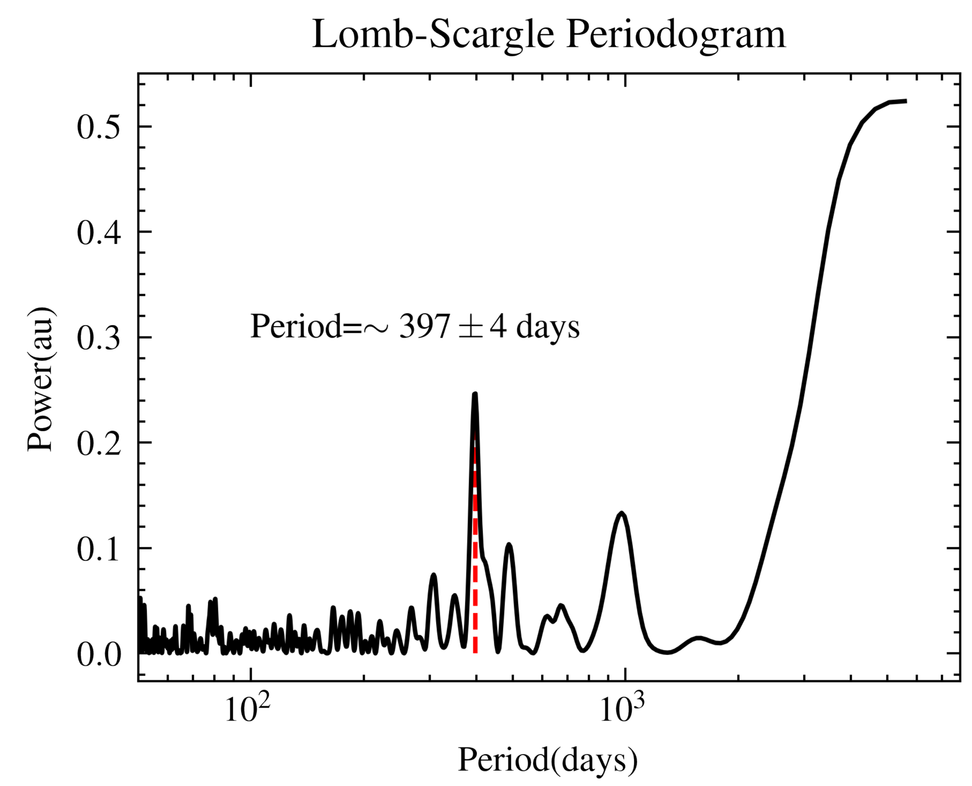

Figure 3: Lomb-Scargle periodogram(LSP) of ~15 year long observation of blazar Mrk 501. It can be seen that in the periodogram a distinct peak stands out around the timescale of 397±4 days. This suggests the presence of a strong periodic signal in a year-like timescale. The uncertainties in the period were estimated by taking the FWHM of the most prominent peak i.e. at power of 0.24.

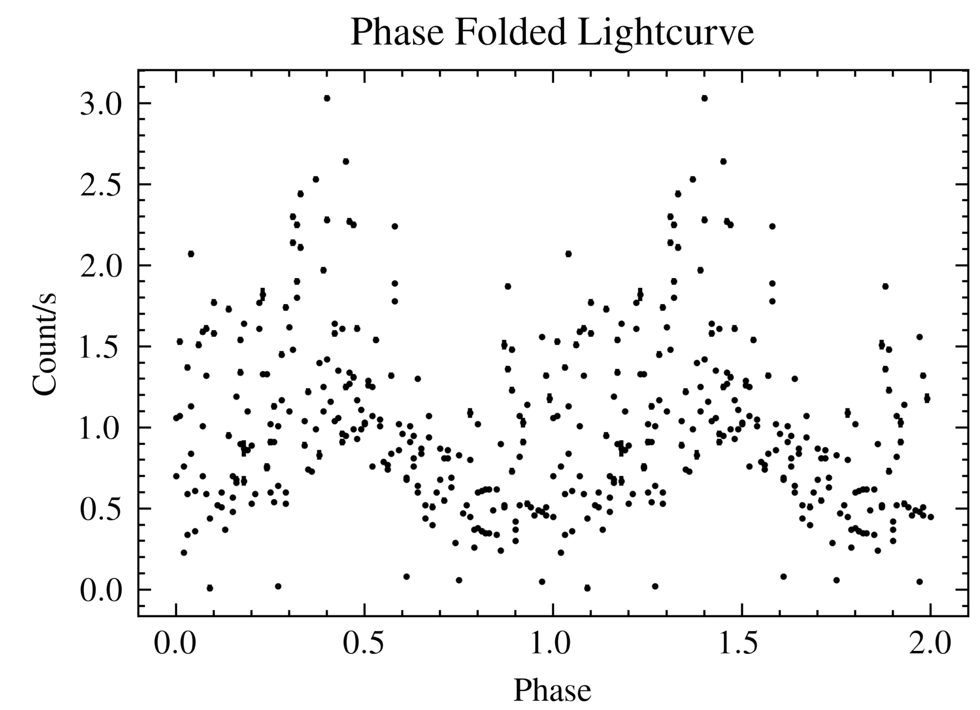

Figure 4: The phase folded light curve showing the two complete cycles with the period folded on 397 days given by the epoch folding method.

Conclusion

QPOs can be caused by binary black hole systems in blazars, instabilities in the accretion disk, relativistic motion of emission zones along the helical path of magnetized jets, and so on. Although all of the aforementioned factors can cause QPOs, we can infer that QPOs in Mrk 501 are caused by the binary black hole system and relativistic motion of emission areas along the helical path of magnetized jets because there are QPOs on year-long time-frame.

References

[1] Gopal Bhatta. Study of periodic signals from blazars. In *Multidisciplinary Digital Publishing Institute Proceedings*, volume 17, page 15, 2019.

Future Research

Other scenarios can cause QPOs, but without multi-frequency time series analysis and group debate, the source of the observed x-ray QPOs will remain a mystery. Other well-established methods for detecting QPOs, such as the discrete auto-correlation function, the weighted wavelet z-transform, etc, can be tried in the future.

Acknowledgements

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