X-RAY AND OPTICAL STUDIES OF BLAZARS

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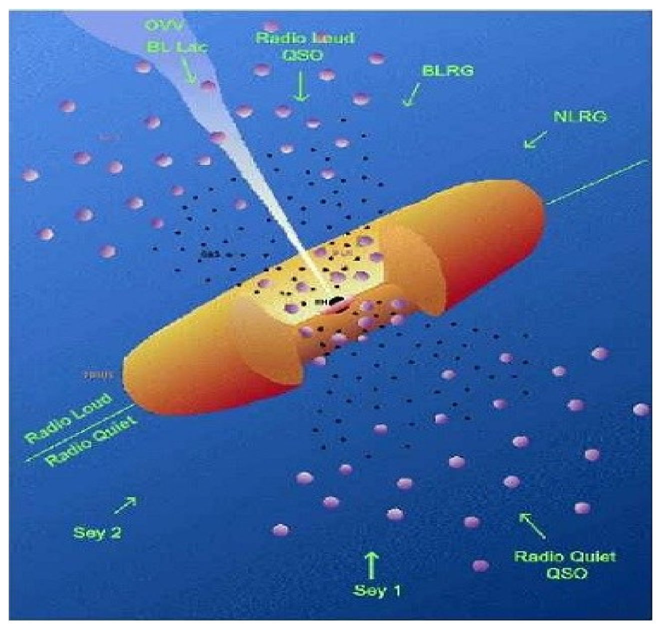


Blazar (A class of AGN)

Properties
- ➔ subclass of radio-loud AGN
- ➔ BL Lacs (Featureless optical spectra) & FSRQs (prominent optical emission lines)
- ➔ Flux Variability (in complete EM)
- ➔ Variable Polarization radio to optical bands
- ➔ Non-thermal radiation (predominantly)
- ➔ Jet axis angle < 10^0

SED of Blazars is a double peaked structure. Classification is as follows:

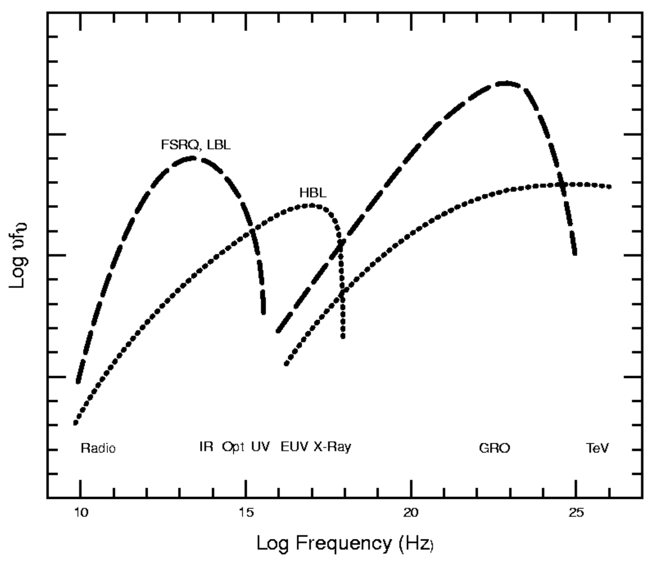
If the first hump peaks at IR/Optical and second hump peaks up to GeV energies, then the blazar is Low energy peaked Blazar (LBL), and if the first hump peaks at UV/X-rays and second hump peaks up to TeV energies, blazar is High-energy Peaked Blazar (HBL).

Emission mechanisms:

Low Energy: Synchrotron Radiation

High Energy: Inverse Compton

Spectral Energy Distribution (SED)



X-ray Intra-day Variability (IDV) and Quasi Periodic Oscillations (QPOs) in Blazars

➢ **We searched for Quasi-Periodic signals and intra-day variability time-scales in the 24 light curves (LCs) of XMM-Newton of blazars.**

➢ **We got 4.6 h QPO and 3.8 cycle in the light curve of the blazar PKS 2155-304 in 0.3 – 10 keV energy range by using SF method. The detected QPO is confirmed by PSD, mhAoV Periodogram, data folding and wavelet methods (Lachowicz et al. 2009).**

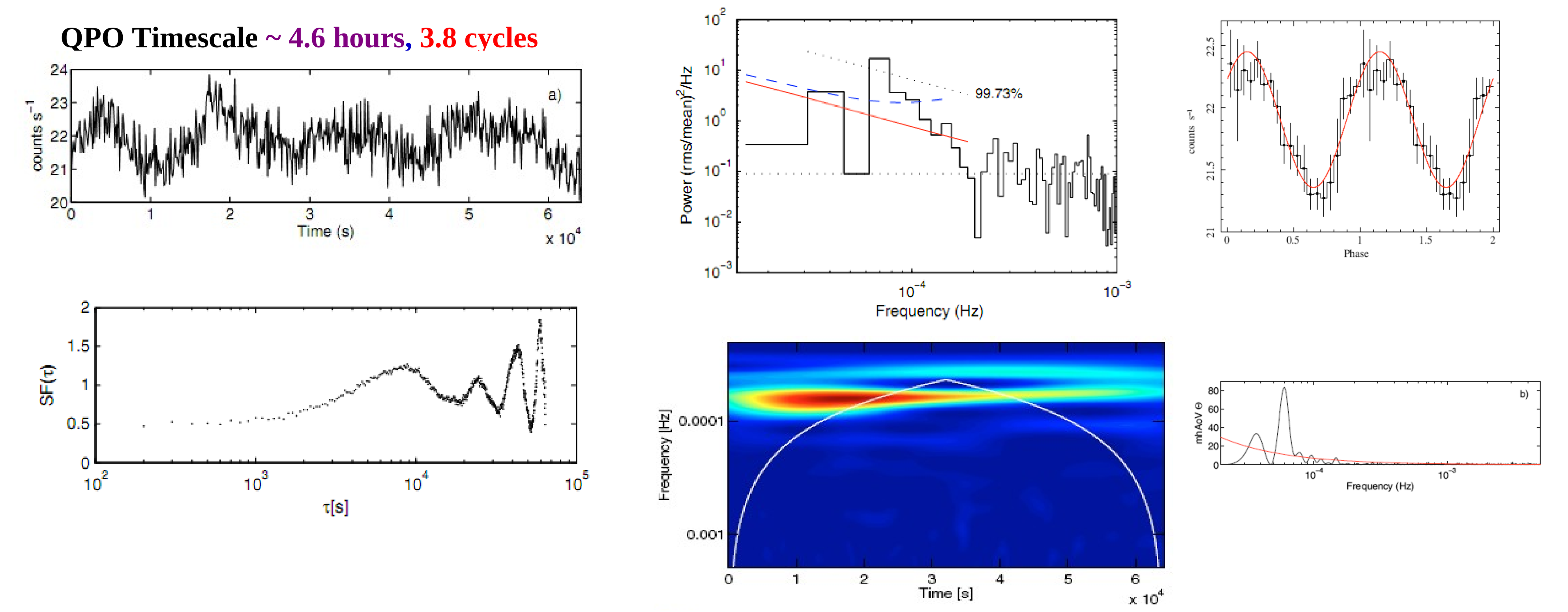
➢ **The QPO timescale give the upper limit of BH mass of the blazar PKS 2155-304: 3.29 * 10^7 M_{sun} (non-rotating BH) & 2.09 * 10^8 M_{sun} (maximally rotating BH).**

➢ **In the remaining 23 LCs we found hints of possible weak QPOs in one LC of ON 231 and PKS 2155—304, but neither is statistically significant. Assuming that the possible weak QPO periods in these blazars are real and are associated with the innermost portions of their accretion disk, we have estimated that their central black hole masses exceed 1. 2* 10^7 M_{sun}.**

➢ **We found IDV timescales ranging from 15.7 to 46.8 ks in eight LCs.**

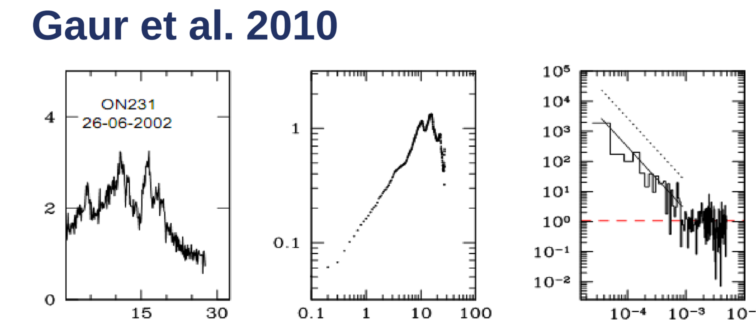
➢ **In 13 LCs any variability timescales were longer than the length of the data.**

QPO Timescale ~ 4.6 hours, 3.8 cycles

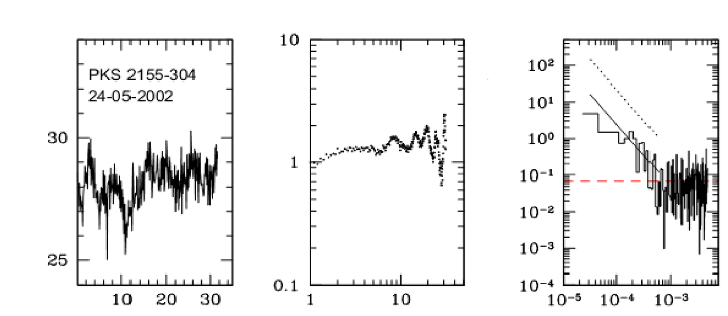


Light curve of PKS 2155—304, its PSD, Data Folding, SF, Wavelet analysis and mhAoV Periodogram

Gaur et al. 2010



LC of blazar On231, SF and PSD



LC of PKS 2155-304, SF and PSD

Optical Studies of Blazars

Anti-correlated Flux and Polarization Variability of BL Lac (Gaur et al. 2014)

❑ **BL Lac is characterized by high degree of optical polarization and rapid flux variability.**

❑ **Basic models explaining the flux and polarization variability in Blazars consist of Shock-in-jet models.**

❑ **In the basic shock-in-jet model because of the strengthened ordering of the magnetic field in the shocked region, we can expect a positive correlation between flux and polarization.**

We discuss about the three main possibilities leading to the anti-correlation between observed flux and polarization of BL Lacertae:

1.Variability arising from the helical jet structures:

If variability arises from helical structures, the observed polarization can be calculated by following Lyutikov et al. 2005: Observed polarization for optically thin synchrotron emission with helical magnetic fields can be calculated using $P = P_{max} \sin^2 \chi'$

Where χ' is the viewing angle in the jet frame and is related to the observed viewing angle χ through the Lorentz transformation $\sin\chi' = \frac{\sin\chi}{\Gamma_b(1-\beta\cos\chi)}$.

By lowering Γ=5.2 and χ=2 , the variations are more towards low polarization values and By increasing Γ =8.8 and χ=6 , the variations are smaller with higher degree of polarization.

But, this model fails to explain the long term variability in the light curve as it is almost flat in Segment 3

2. Transverse shocks in blazars jets:

In the transverse shock model, the observed fractional polarization of the shocked plasma radiation is calculated by Hughes et al. 2005.

$$P \approx \frac{\alpha+1}{\alpha+5/3}\,\frac{(1-k^{-2})\sin^2\chi'}{2-(1-k^{-2})\sin^2\chi'},$$

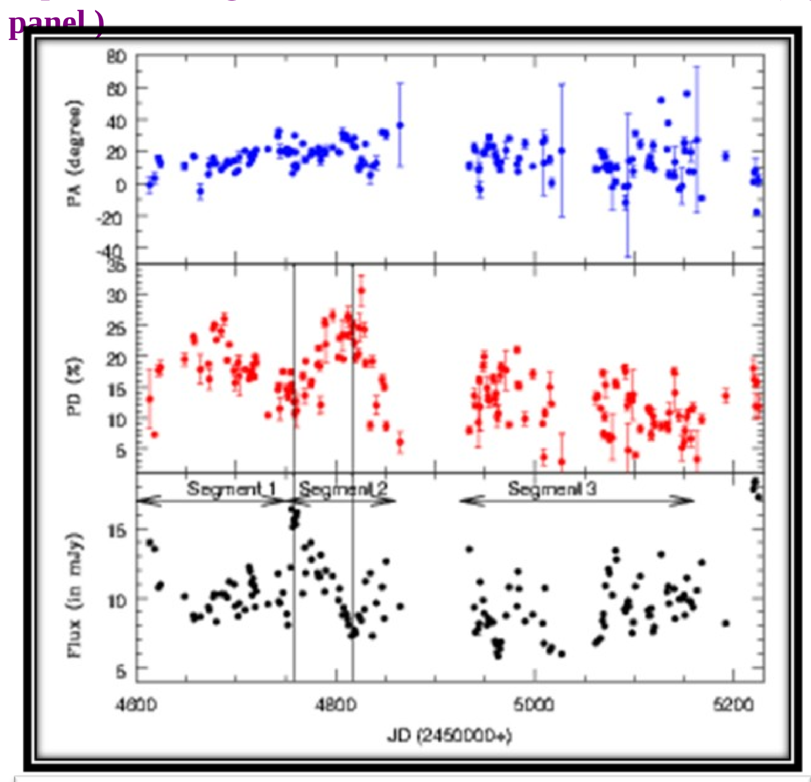
Where (α+1)/(α+5/3) is the synchrotron polarization factor due to a relativistic electron population with particle distribution dN/dE ∝E^{-p}.

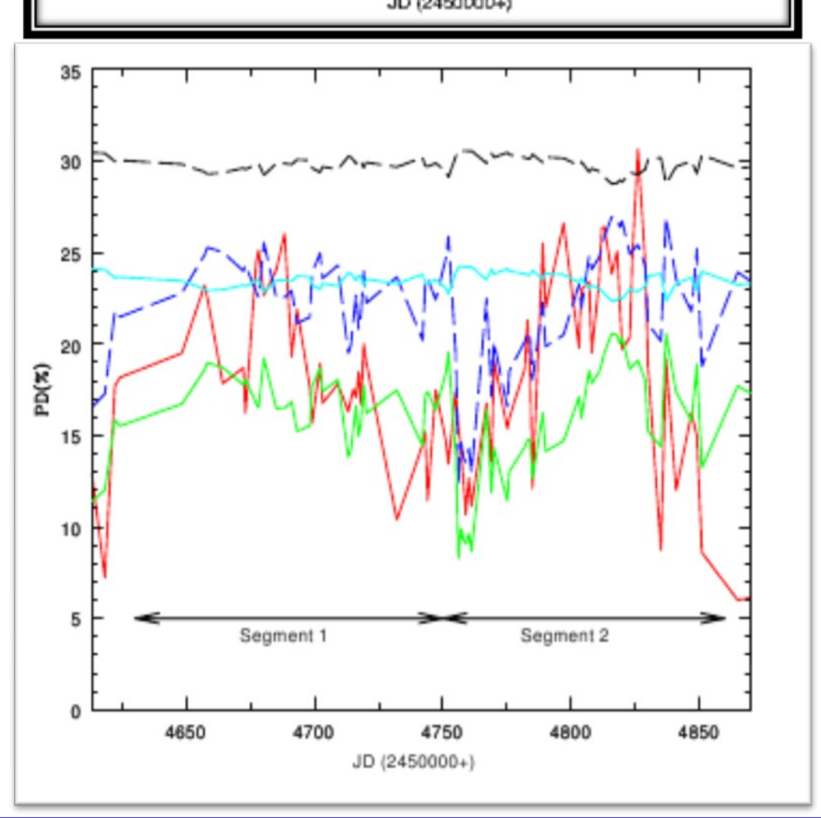
K is the degree of compression of the shock wave. Varying values of Γ or χ would increase the variations at lower PD values, with the opposite being the case for the higher values of Γ or χ.

This model well reproduces the observed polarization in all of the three segments.

3. Existence of two emission components: Slowly varying component contributing to global jet region and short lived variable components with different polarization directions called local emission region. When coupled with the shock wave model, this model offers a simple explanation for the observed anti-correlation between the long-term polarization and flux, which appears to depend on the bulk Lorentz factor for any given range of viewing angles.

V pass-band Light Curve, PD and PA of BL Lacertae (right panel)





Red plot shows the observed polarization curve; dashed black and blue plots shows the polarization behaviour predicted by the helical jet model ; the green and cyan color shows the polarization behaviour predicted by the transverse shock model.

Gaur et al. 2012

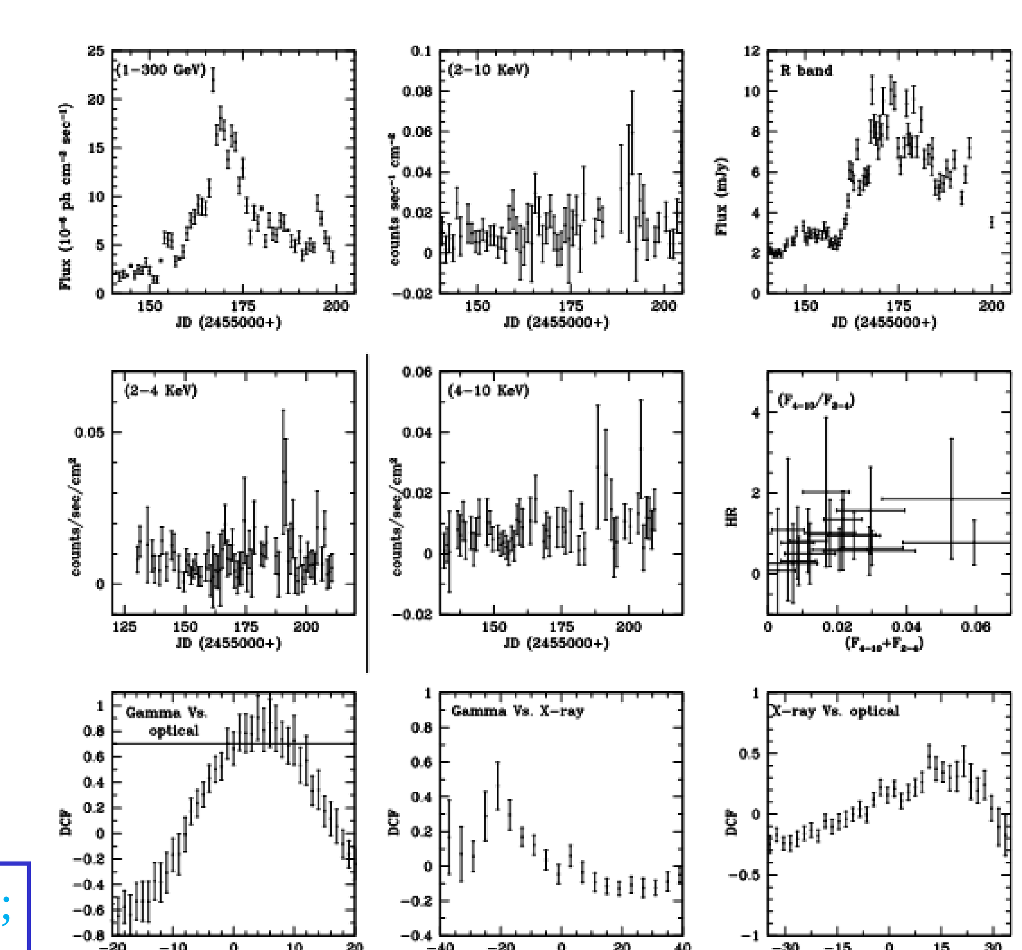
Correlated Variability of 3C 454.3

➢ **We observed the blazar 3C 454.3 during the high state in 2009-2010.**

➢ **We cross correlate the variability in gamma, X-ray and optical bands.**

➢ **We found strong correlation (greater than 99% significance) between optical and gamma rays whereas X-rays were not correlated with either.**

➢ **This supports the external Compton model.**



Gamma, X-ray and optical LCs of 3C 454.3.

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