Optical variability of Blazar 3C66A Long-term study

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Introduction

•Blazars are radio loud AGNs with their relativistic jets pointed close to the line of sight of the observer.

•Blazars show rapid and strong variability spanning the entire electromagnetic spectrum, high and variable polarization from radio to optical regimes, and dominant non thermal emission from radio to high energy $\gamma-$ rays (Urry & Padovani,1995). SED shows two humps: low energy synchrotron and high energy IC. The origin of high energy component is not understood well (Baliyan et al .,2005).

•Time scale of variability range from minutes to years. Variability at time scale ranging from hours to a day is referred to as intra-night variability (IDV) or microvariability; those from days , weeks , and months lead to short-term variability(STV) while variability with timescale of months to several years is considered as long-term variability.

•Variability can serve as a tool to probe location, size, structure and dynamics of the non thermal emitting regions and on the radiation mechanisms.

Aim :

•AGNs are not resolvable by any existing facility. In order to understand the processes behind high energy output and AGN structure, we use variability in blazar 3C66A as a tool.

•Intra-night (IDV) variability is used to estimate the time scales of variability and size of the emission region.

•BL Lacs do not have significant line emission and therefore it is difficult to estimate mass of the central engine. We use variability timescales to infer that.

•Long and short term lc show features which are useful in getting clues to the emission processes.

Statistical tools :

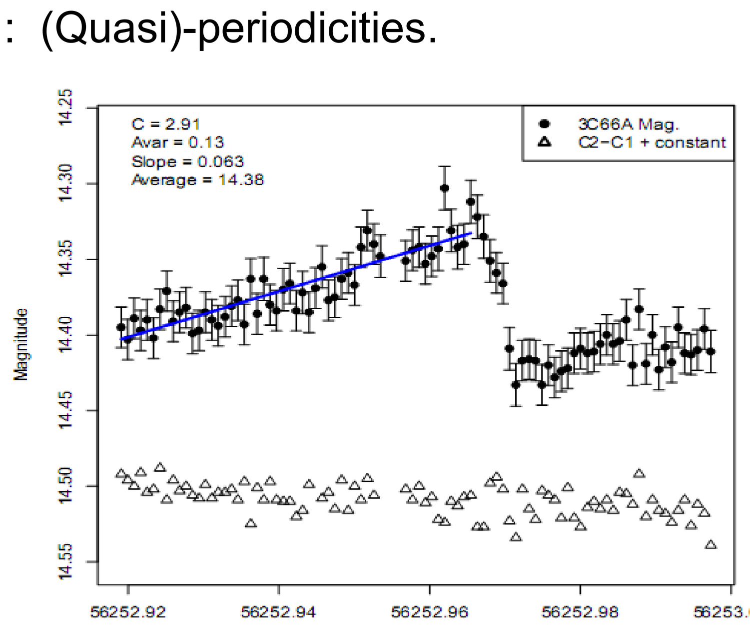
▪C parameter and F- stat estimates, to determine whether or not the source shows significant variability over a night.

▪Visual interpretation of lc to estimate time scales can at best serve as a guestimate and hence the following statistical methods are used to determine the time scales of unevenly sampled data-sets.

▪Structure Function : Useful for time scale of variability and (quasi)-periodicities.

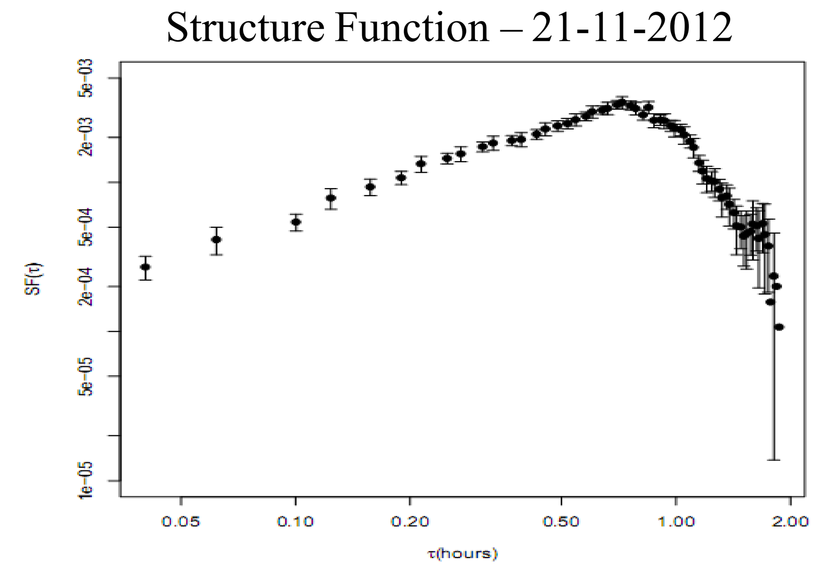
▪L-S periodogram : To determine (Quasi)–periodicities in a data-set.

▪DCF : (Quasi)-periodicities.



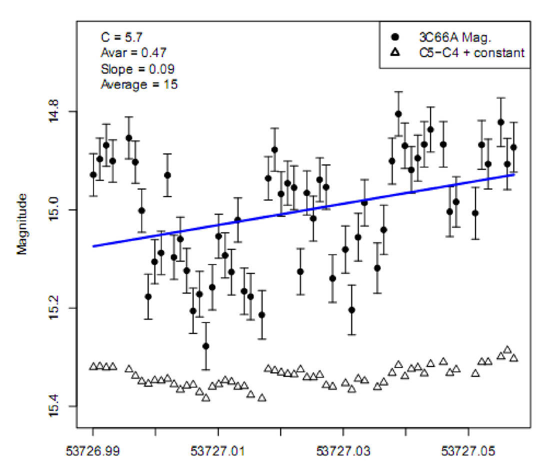
IDV for 3C66A on 2012 November 21 (MJD 56252.92), variability is determined by the C parameter , $\sigma_{BL-C}/\sigma_{C1-C} > 2.57$

Structure Function – 21-11-2012



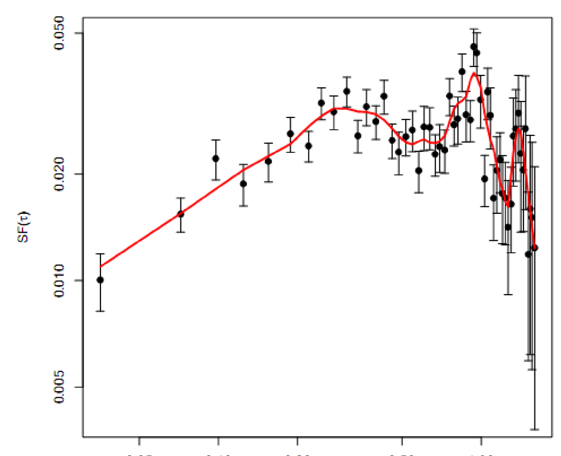
Structure function for 2012 November 21 (MJD 56252.92), the plateau corresponds to the time scale of variability ~ 43 min

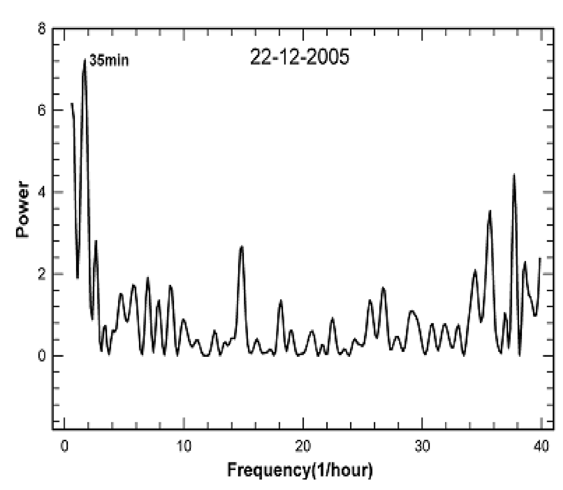
(Quasi)-periodic oscillations



IDV on 2005 December 22 (MJD 53726.99), qualifies as a variable night, seems to show (quasi)-periodic oscillations.

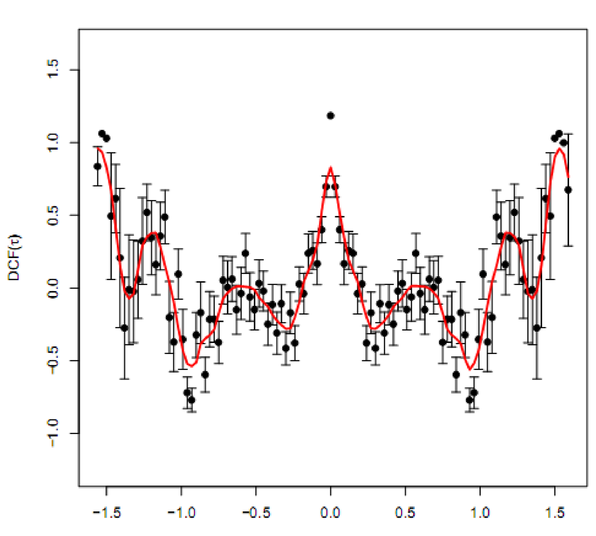
The structure function of the lc reveals 35min quasi periodic rapid variations.



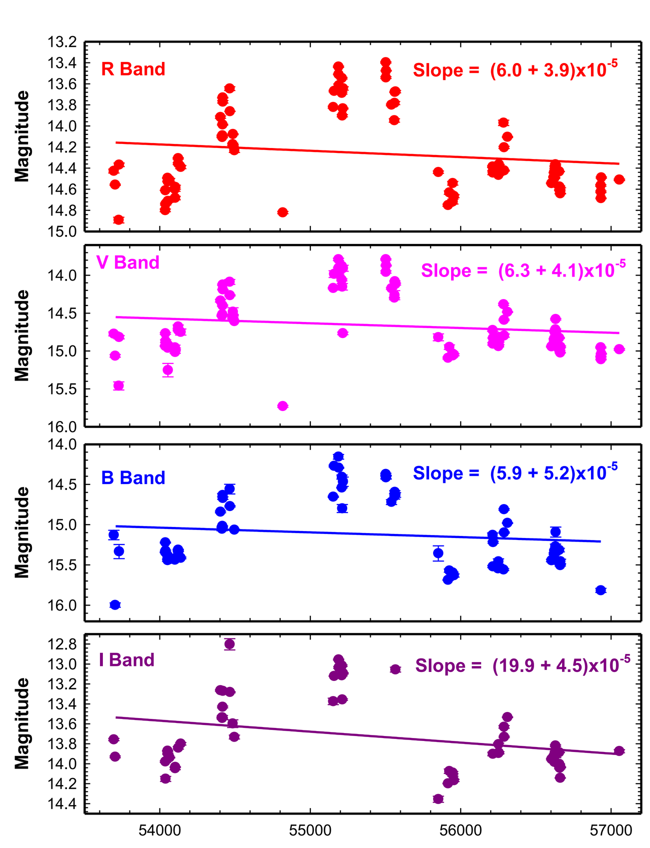


Lomb-Scargle periodogram confirms the rapid variation periodicity as 35 min.

Discrete correlation function also confirms the rapid variation periodicity as 35 min.

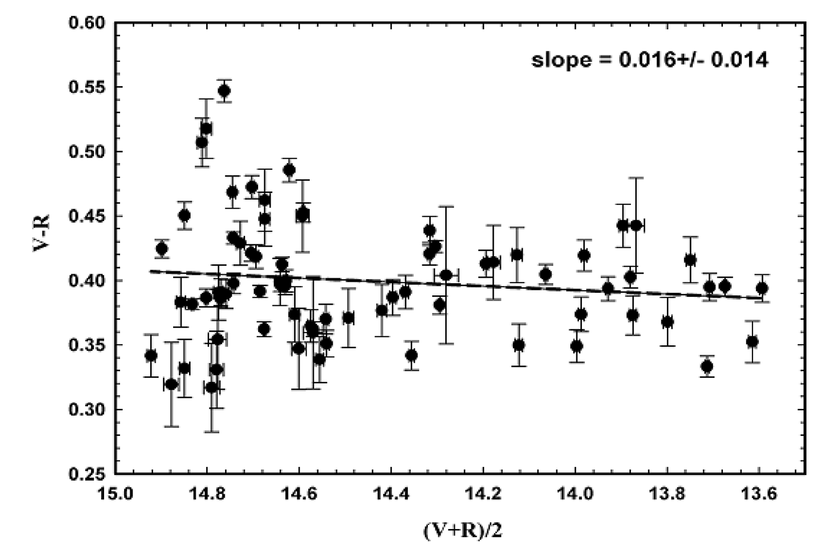


Day Averaged Long-term trend



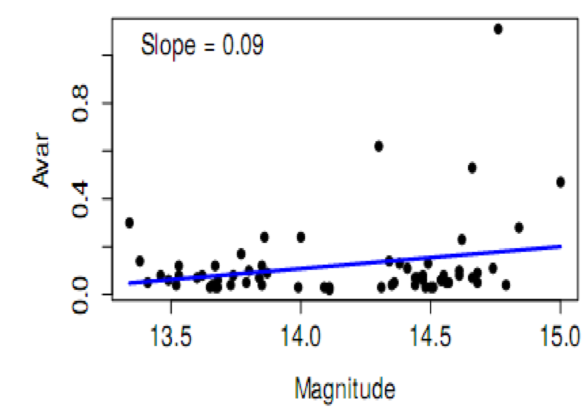
Long-term brightness light-curve of 3C66A in R band for the duration 2005 November – 2015 February , shows a mild decaying trend superimposed by a number of flares. Our observations show that the BL Lac Object 3C66A was brightest with a magnitude of 12.8 on 2010 October 18 (MJD 55488.04 and faintest with a magnitude of 15.4 on 2009 November 22 (MJD 55157.01) in R Band.

Spectral behaviour of 3C66A



Color information is important as it can help discriminate among various physical processes responsible for the variation.Using the observed data from MIRO in R,V bands from 2005 November to 2015 February each nights averaged color is determined.3C66A shows a mild bluer-when-brighter trend.

Amplitude of variability vs. Brightness state



Variability amplitude in different phases of brightness vs. Average brightness for the night. Shows a counter-intuitive correlation : "more variability when fainter". However, more study is needed to confirm this trend.

Estimation of SMBH parameters

Considering the minimal variability timescale estimated above as the time required by the light to cross the emitting volume, one can set an upper bound to the emission region size, R

$$R \geq \frac{c\,\delta\,\Delta t_{min}}{1+z}$$

We have estimated the minimal variability time scale from the structure function analysis of IDV on 2012 November 21 (MJD 56252.92) to be Δt_{min}~43 min , δ = 15 (Lanzetta et al. (1993)) , the size of the emission region is 8.1 x10^{14} cm.

The mass of the central black hole assuming that the minimum variability timescale manifests by the orbital time-scale near the innermost stable orbit around the black hole (Xie et al. (2002))

$$M = \frac{1.62\times10^{4}\,\delta\,\Delta t_{min}}{1+z} M_{sun}$$

Here , δ is the doppler factor , z is the cosmological red-shift. The derived mass of the SMBH is 4.3 x 10^8 M_{sun}

Conclusion

•A slowly decreasing trend in average brightness and a mild bluer-when-brighter trends are seen, supportive of a shock-in-jet scenario.

•Duty cycle for intra-night variability is very low about 17% as compared to other Bl Lacs- eg. S5 0714.

•Shortest time results in estimate of the emission size: 8.1x10^{14}cm and mass of central object: 4.3x$10^8 M_{sun}$

•QPOs are detected in lc's of at least two nights, asymmetric profiles rule out geometric mechanism. The random variations indicate to turbulence in the jet plasma as the source of variation.

References

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