Recent Trends in the Study of Compact Objects (RETCO-II): Theory and Observation
ASI Conference Series, 2015, Vol. 12, pp 101–104
Edited by Indranil Chattopadhyay, Anuj Nandi, Santabrata Das and Samir Mandal

Study of AGNs using Blazar Variability as a tool

K. S. Baliyan[1*], Navpreet Kaur[1,2], Sameer[1], S. Ganesh[1] and S. Chandra[1,3]
[1]*Physical Research Laboratory, Ahmedabad 380009, India*
[2]*Indian Institute of Technology, Gandhinagar 382355, Gujarat*
[3]*Tata Institute of Fundamental Research, Mumbai 400005, India*

Abstract. Matter accretes on the black hole through the disc powering the relativistic jet, which dominates the emission at all wavelengths in blazars. The exact mechanisms responsible for the origin, acceleration and collimation of the jet are not well understood. Since central engine is not resolvable by any existing optical facility, variability in flux can be used as a tool to understand the structure and physical processes in the jet. Blazars show variability in their flux at all frequencies and polarization at radio and optical with time scales ranging from years to minutes and hence are good candidates for such study. Long-term continuous monitoring in all energy bands with high temporal resolution is the key to probe size of emission regions, emission processes and structure of the jet. Some details about the present understanding and the role new facilities might play will be discussed, along with some results on the variability of blazars, in particular, S5 0716+714.

Keywords : galaxies: active – BL Lacertae objects: individual: S5 0716+714 – techniques: photometric – methods:observational, data analysis – radiation mechanism: non-thermal.

1. Introduction

Since blazar jets are launched from the close vicinity of the black hole (Begelman et al. 1984), their study provides a tool to probe the inner regions of the central engine. The jet dominated emission from blazars and the radio/optical polarization are variable at various time scales (Chandra et al. 2011, 2012; Saito et al 2013, and references there-in). While intra-day variations provide clues to the size of the emission region and an estimate of the black hole mass (Chandra et al. 2011), the long-term

*email: baliyan@prl.res.in

trends in the light curves provide information about the structure and dynamics of AGNs (Marscher 2012).

Enormous amount of work has been done to study these sources since their first detection in early 1960's, contributing greatly to our understanding of their nature. However, we still need answers to many questions- how the high energy emission is produced?, how and where the jet is launched? what are the factors keeping it collimated even at Mpc scales? Based on observations, simulations and theoretical models, we have some idea about most of these issues but a clear understanding is lacking. A large number of multi-wavelength campaigns in the era of XMM-Newton, Swift, Fermi and AGILE, supported by ground based facilities in radio, optical and VHE γ-rays have helped immensely in this endeavour. The problem areas are lack of truly simultaneous, long term multi-wavelength observations. At high energies, while Fermi provides continuous monitoring in the 100 MeV- GeV energy range, X-ray all sky monitor mostly detects only brightest blazars. The IR region, where low energy synchrotron peak for FSRQs and LBLs falls, is difficult to access continuously due to lack of facilities (Spitzer, Heschel are rarely devoted to blazar study). In the VHE-γ-ray (TeV) region, cherenkov telescopes are only able to observe flaring blazars while their quiescent phase study is not possible. The situation should improve significantly with newly planned facilities in almost all energy domains (CTA, Astro-H, TMT, ELT, LSST, NuSTAR, ASTROSAT, ALMA, SKA etc). Planned X-ray polarimeters should help distinguish between SSC (synchrotron self Compton) and EC (external Compton) in high energy part of blazar SED.

Mt Abu InfraRed Observatory (MIRO) is monitoring a sample of blazars for last 20 years using 1.2 m (and 0.5m since last two years) telescope mounted with CCDs, optical polarimeter and near infrared array detectors. The main idea is to address micro-variability and long term trends in the light-curves and polarization curves of these sources in order to understand their emission processes and structure of the central engine (Chandra et al. 2011, 2012; Marscher 2012). In this contribution, we report some results on the blazar S5 0716+714, one of the most active source in this sub-class of AGNs.

2. Observations and data analysis

The source S5 0716+714 was observed for 162 nights during November 2005 to December 2012 from MIRO using 1.2m telescope mounted with 1296x1152 pixel LN2 cooled CCD at its Cassegrain focus. Observations are taken keeping at least three standard stars along with target source, in the same image to enable differential photometry. The data for all 162 nights were reduced and analyzed using IRAF and a script which uses WCS tools and Astrometry.net to carry out differential photometry in automated way. The instrumental photometric values for the source and all comparison stars were obtained. The standard values of comparison stars were used to calibrate the source magnitudes.

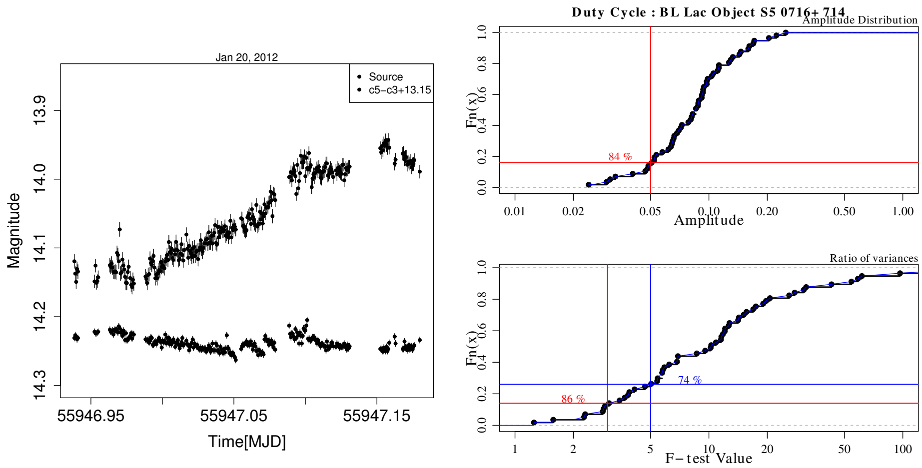

Figure 1. Left: Intra-night variation in R-band on 2012 January 20 for S5 0716+714. Right: Duty cycle of variation: Amplitude of variation (top panel) and F-value (bottom panel) are plotted against fractional number of nights.

3. Results and Discussion

3.1 Intra-night variations

In order to investigate intra-day variability in S5 0716+714, nights for which source was monitored for two hours or more, were selected. The data on these 56 nights were put to statistical tests to determine whether the source showed significant (at better than 90% confidence level) variability during a night. The light curve of one such night is shown in Figure 1 (Left), where source brightness increases by 0.19 mag in R-band on a time scale of 4.56 Hrs. Such fast variation in the source flux can be used to obtain an upper limit on the size of the emission region (R$\leq c.\delta.\Delta_t/(1+z)$, where δ is Doppler factor, Δ_t, the time scale and z is the redshift) using light travel time arguments. The emission region size is 3.78x10^{15} cm. The source intra-night variations indicate to a very high duty cycle (86% at 90% confidence level). The shapes of IDV light-curves are quite different indicating to variability due to turbulence, nonetheless, all these show that source is very active with significant amplitude of variation. The duty cycle for the variation is shown in Figure 1(right panel) using extent of the amplitude of variation (Heidt and Wagner 1996) and F-test, which uses ratio of variances in the light curves of source and comparison stars.

3.2 Long-term behaviour

To understand the long term behaviour of the source, we used data for all 162 nights in all the observed bands during the 7-year period. The light-curves, as shown in Figure 2, consist of a large number of outbursts at all wavelength bands. Though the data sampling for I, R, V, and B is not uniform and there are large gaps in the data in all bands, trend of the outbursts appears similar. It is evident from the Figure 2 that average brightness of the source shows a slow decrease with time during 2005 - 2012 period. Nesci et al (2005) have discussed the historical trend for the source from 1971 to 2003 and stated that source showed an increasing brightness trend during 1995 - 2003. In a recent study, Wierzcholska and Siejkowski (2015) show X-ray

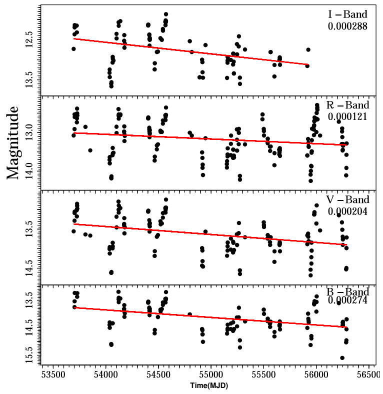

Figure 2. Light curves for S5 0716+714 in I, R, V and B bands for the duration of 2005 November to 2012 December. Fitted line shows average level of brightness.

light-curve for the period 2005 - 2015 using Swift data which, interestingly, follows the similar trend as our optical light-curves. The viewing angle is known to be increasing since 2004. It perhaps indicates to the precession of the jet about its axis. The source also shows mild bluer when brighter trend, indicative of the shock-in-jet scenario (Chandra et al. 2011; Marscher 2012) in which a shock moves down the jet encountering local inhomogeneities or density enhancements. More such studies are needed at all possible wavelengths to arrive at any conclusion.

4. Conclusions

Here we used long-term monitoring of a source to infer emission processes for intra-night and long term variations. The upper limit to the size of emission region is estimated as 3.78×10^{15} cm. The source shows high (86%) duty cycle of variation. The increasing and decreasing brightness trends are suggestive of the precession of the relativistic jet, affecting viewing angle and source brightness. Upcoming new facilities should strengthen our understanding of these sources with more sensitive detectors and longer periods of simultaneous monitoring.

References

Begelman M. C., Blandford R. D., Rees M. J., 1984, Rev. Mod. Phys., 56, 255

Chandra S., Baliyan K. S., Ganesh S., Joshi U. C., 2011, ApJ, 731, 118

Chandra S., Baliyan K. S., Ganesh S., Joshi U. C., 2012, ApJ, 746, 92

Heidt J., Wagner S. J., 1996, A&A, 305, 42

Marscher A. P., 2012, Int. Jour. Mod. Phys.: Conf. Series, 8, 151

Marscher A. P., Gear F., Travis J. P., 1984, in Valtaoja and Valtonen, eds, Variability of Blazars, Cambridge Univ. Press, Cambridge, p 85

Nesci R., et al., 2005, AJ, 130, 1466

Saito S., et al., 2013, ApJ, 766, L11

Wierzcholska A., Siejkowski H., 2015, MNRAS, 452, L11