Recent Trends in the Study of Compact Objects (RETCO-II): Theory and Observation
ASI Conference Series, 2015, Vol. 12, pp 61–64
Edited by Indranil Chattopadhyay, Anuj Nandi, Santabrata Das and Samir Mandal

Optical and GeV flux variations in *Fermi* blazars

C. S. Stalin*
Indian Institute of Astrophysics, Block II, Koramangala, Bangalore 560 034, India

Abstract. A large fraction of γ-ray emitting blazars show correlated flux variations in the optical and γ-ray bands with little or no time lag. However, in a minority of them, uncorrelated optical and γ-ray flux variations are seen. From an analysis of the optical R-band light curves from the Small and Moderate Aperture Research Telescope System (SMARTS) and γ-ray light curves from the Large Area Telescope (LAT) on board the *Fermi Gamma-ray Space Telescope*, we find three sources that show correlated optical and γ-ray flux variations at some epochs and uncorrelated variations at other epochs. These findings pose serious challenges to our current understanding of the various emission processes in the jets of blazars.

Keywords : galaxies: active – quasars: 3FGL J1733.0−1305 – quasars: 3FGL J2147.3−7536 – quasars: 3FGL J2324.7−4040

1. Introduction

Blazars, a class of active galactic nuclei dominate the extragalactic γ-ray sky. They are sources that have their relativistic jets aligned close to the line of sight to the observer (Urry and Padovani 1995). One of the distinctive properties of blazars is that they show flux variations over the entire electromagnetic spectrum. This property can be used as an efficient tool to probe the location of multi-wavelength emission in their relativistic jets. In the leptonic model (Böttcher 2007) of emission from blazar jets, there must be a correlation between flux variations in the low energy (optical) and high energy (γ-ray) bands. Alternatively, in the hadronic emission model (Mücke and Protheroe 2001), correlation between optical and γ-ray flux variations may not be present. Thus, by studying the nature of variations in the optical and γ-ray bands, one can distinguish between leptonic and hadronic models that explain the high energy emission processes happening in the jets of blazars.

*email: stalin@iiap.res.in

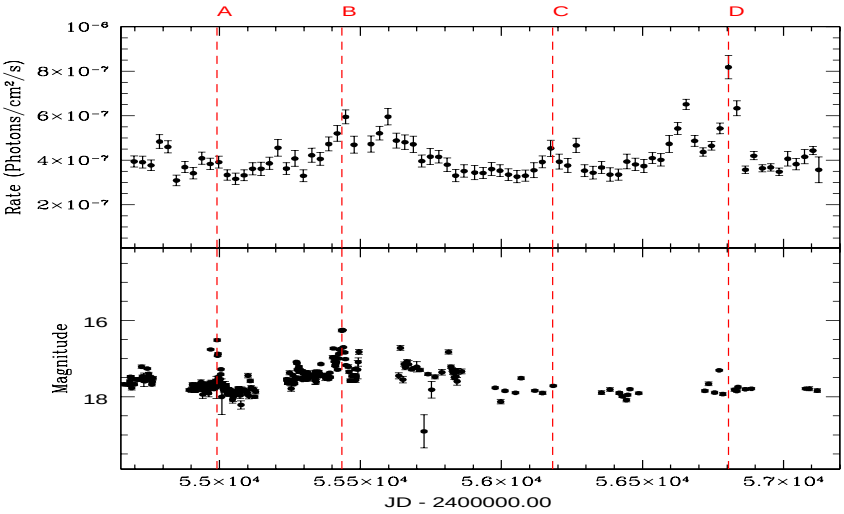

Figure 1. Light curves of 3FGL J1733.0−1305 in the γ-ray (top panel) and optical (bottom panel). Flaring epochs are marked as A, B, C and D.

For most of the blazars studied for multi-wavelength variations, a close correlation is found between the γ-ray and optical flux variations with or without lag (Bonning et al. 2009; Chatterjee et al. 2012; Carnerero et al. 2015; Liao et al. 2014). However, in sources, such as PKS 0208−512 (Chatterjee et al. 2013) and S4 1849+67 (Cohen et al. 2014) there are evidences of optical flares with no corresponding γ-ray flares. Also, there are recent reports of the detection of γ-ray flares with no optical counterparts in sources such as PKS 2142−75 (Dutka et al. 2013), PKS 1510−089 (MacDonald et al. 2015) and PKS 0454−234 (Cohen et al. 2014). Thus, available results on multi-wavelength flux variations in blazars clearly indicate that the relation between their optical and γ-ray flux variations is complex. We present here our results on the search for the presence/absence of correlated optical and γ-ray flux variations in blazars monitored in the SMARTS monitoring program [1] .

2. Sample and Data

Our sample consists of 75 blazars, which includes 35 BL Lacs and 45 flat spectrum radio quasars. For these source we have taken the R-band data from the SMARTS monitoring program and γ-ray data (GeV band) from *Fermi*-LAT [2] spanning about 6.5 years. From a careful inspection of the R-band and γ-ray light curves, we find three sources that show correlated as well as un-correlated variations between the optical

[1] http://www.astro.yale.edu/smarts/fermi/
[2] http://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/ap_lcs.php

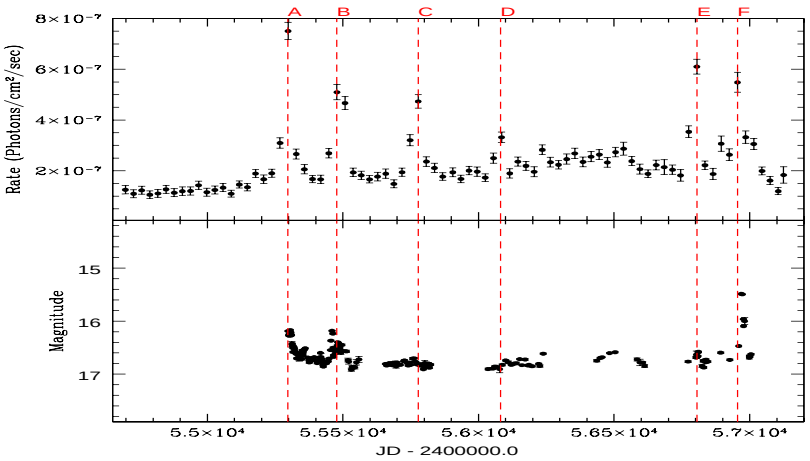

Figure 2. The γ-ray (top panel) and optical (bottom panel) light curves of 3FGL J2147.3−7536

and γ-rays. The optical and γ-ray light curves of these three sources are shown in Figures 1 to 3.

3. Results

3FGL J1733.0−1305: The optical and γ-ray light curves for this source are shown in Fig. 1. Based on either the optical or the γ-ray flares, four epochs denoted as A, B, C and D have been identified from visual inspection. During epoch A, there is an optical flare without the corresponding γ-ray flare. During epoch B, both optical and γ-ray emissions show correlated variations. During epochs C and D, γ-ray emission has flared, but the optical emission has not shown any noticeable flux variation.

3FGL J2147.3−7536: In this source, depending on the presence of either an optical or γ-ray flare, a total of six epochs have been identified visually as marked by A, B, C, D, E and F in Fig. 2. During epochs A, B and F, both optical and γ-rays show flaring behaviour at the same time. During epochs C, D and E, there are γ-ray flares with no counterparts in the optical band.

3FGL J2324.7−4040: The source has remained non-variable in the optical band as can be seen in Fig. 3. A large γ-ray flare is seen around JD 2456565 (shown by vertical line), however, during that epoch the optical emission is nearly stable.

4. Summary

The analysis of the optical and γ-ray variability of the three blazars presented here is a clear pointer that blazars exhibit complex variability patterns. These limited observations indicate that in a single source it is possible to witness the following variability behaviours (i) correlated optical and γ-ray flares, (ii) optical flare with no correspond-

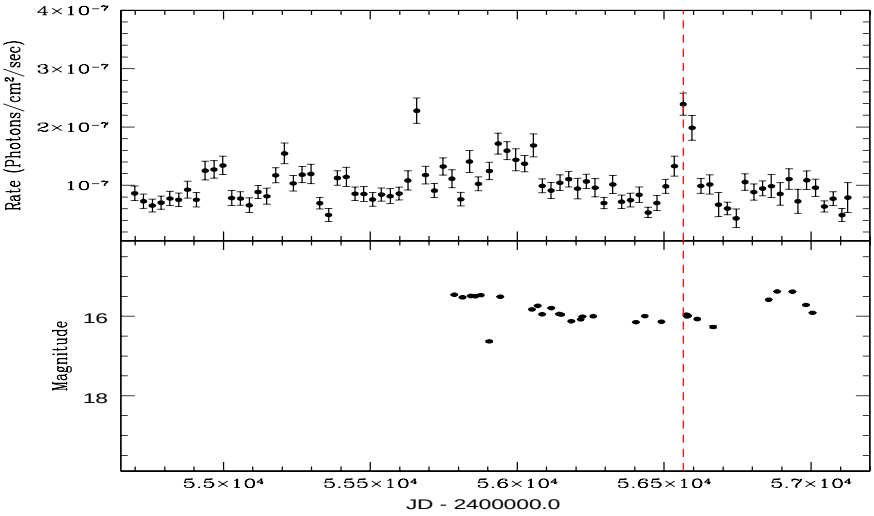

Figure 3. Light curves of 3FGL J2324.7−4040 in the γ-ray (top) and optical (bottom).

ing γ-ray flare and (iii) γ-ray flare with no optical counterparts. The correlated optical and γ-ray variations can be explained in the leptonic scenario wherein the same population of relativistic electrons is responsible for the optical and γ-ray radiation via synchrotron and inverse Compton processes respectively. The observed uncorrelated optical and γ-ray flux variations from blazar jets might be due to enhancement of B-field (Chatterjee et al. 2012), hadronic processes contributing to the γ-ray emission etc. Though these models could explain the variability patterns shown by blazars at different epochs in isolation, new theoretical models are needed to explain in totality the varied variability patterns shown by a single blazar at different epochs of time.

References

Bonning E. W., Bailyn C., Urry C. M., et al., 2009, ApJL, 697, L81
Böttcher M., 2007, Ap&SS, 309, 95
Carnerero M. I., Raiteri C. M., Villata M., et al., 2015, MNRAS, 450, 2677
Chatterjee R., Bailyn C. D., Bonning E. W., et al., 2012, ApJ, 749, 191
Chatterjee R., Fossati G., Urry C. M., et al., 2013, ApJL, 763, L11
Cohen D. P., Romani R. W., Filippenko A. V., et al., 2014, ApJ, 797, 137
Dutka M. S., Ojha R., Pottschmidt K., et al., 2013, ApJ, 779, 174
Liao N. H., Bai J. M., Liu H. T., et al., 2014, ApJ, 783, 83
MacDonald N. R., Marscher A. P., Jorstad S. G., Joshi M., 2015, ApJ, 804, 111
Mücke A., Protheroe R. J., 2001, Astroparticle Physics, 15, 121
Urry C. M., Padovani P., 1995, PASP, 107, 803