Multifrequency correlation analysis to constrain the γ-ray emission site in *Fermi*/LAT blazars

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Abstract: We attempt to constrain the γ-ray emission region in blazars by performing cross-correlation analysis using radio, millimetre, optical and γ-ray data. We also compared the start times of the activity at different wavebands for the correlated flares using Bayesian block representation. For our comparison of 37 GHz radio and γ-ray data, this shows that most of the correlated flares at both wavebands start at almost the same time, implying a co-spatial origin of the activity. The correlated sources show more flares and are brighter in every band than the uncorrelated ones.

Aims

- To localise and understand the high-energy emission mechanism in blazars using 37 GHz radio (Metsähovi) and 0.1—200 GeV γ-ray (*Fermi*) observations.
- 55 blazars were selected based on averaged >1 Jy radio flux for the time period, 2008.6—2013.6

Methods

- Individual source time lags and those from stacking were obtained from Discrete correlation function (DCF) of [1].
- The significance of the DCF peak was estimated from mixed source correlations and through cross-correlations of light curves simulated under the assumption of a power-law process ($\nu^{-\alpha}$).
- The Power spectral density slopes of the light curves at every frequency was estimated following [3, 4].
- The active phase in the light curves were characterised by Bayesian Blocks [5].

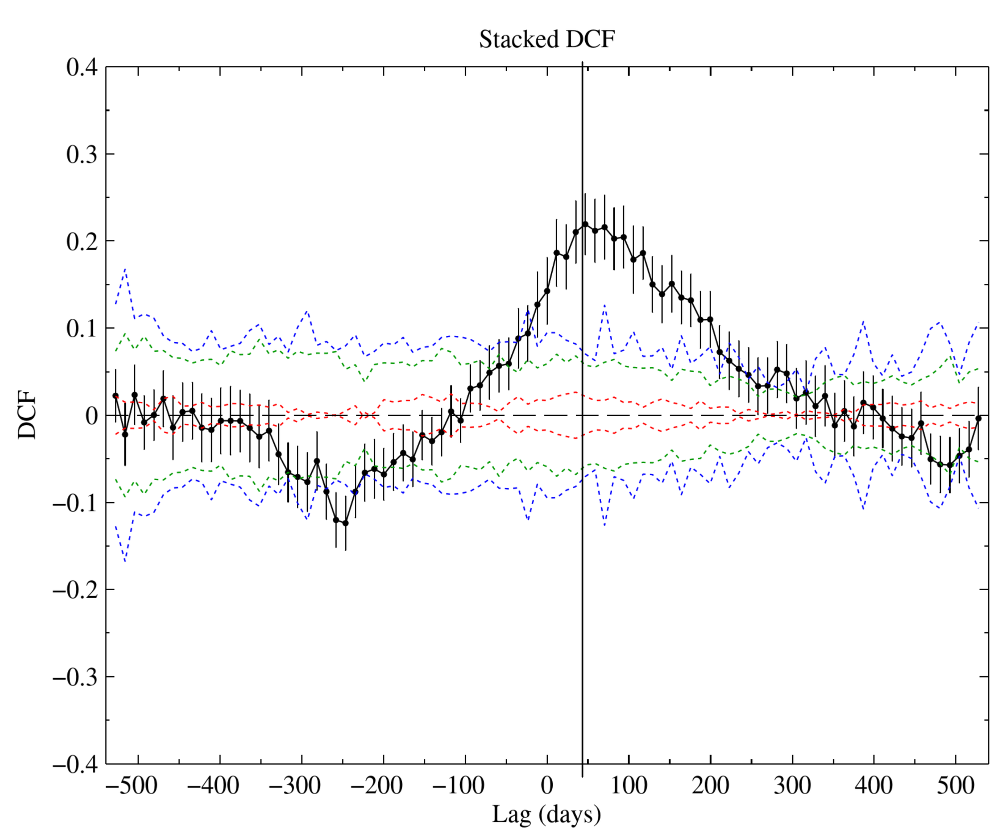

Figure 3: Stacked DCF of 55 blazars in source frame. The γ-ray leads the radio by 47 days. Using the size of the radio core (~0.1 mas) from [2] and the distance travelled by the emission region (~0.08 mas), we constrained the γ-ray emission region within the radio core.

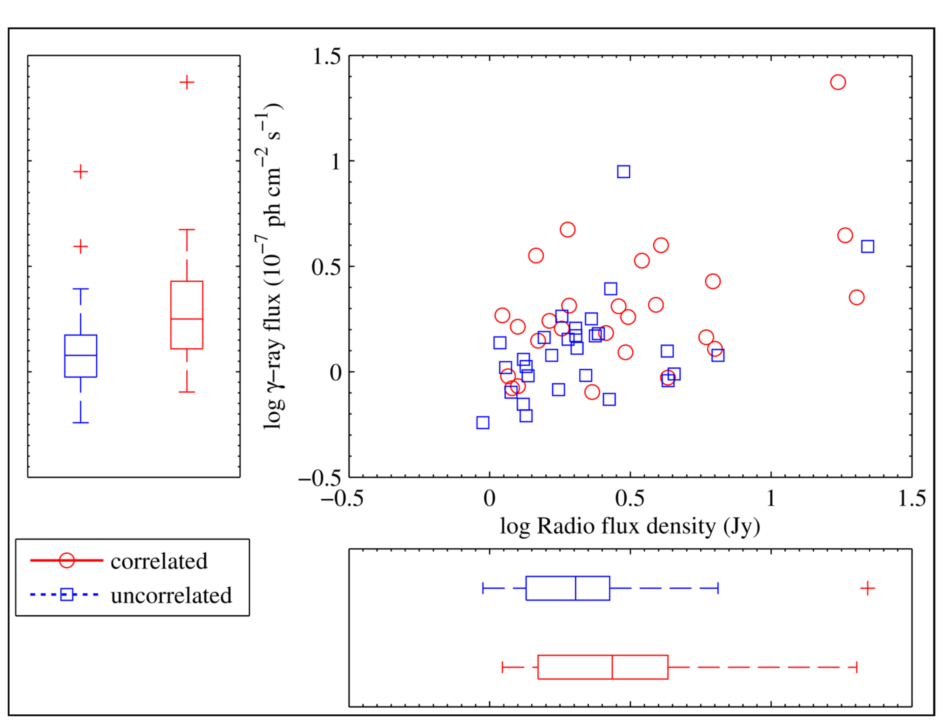

Figure 4: Average flux of all sources showing that the correlated sources are on average brighter than the uncorrelated ones.

References:

[1] Edelson R. A., Krolik J. H., 1988, ApJ, 333, 646
[2] Jorstad S.G. et al., 2001, ApJS, 134, 181
[3] Max-Moerbeck W. et al., 2014, MNRAS, 445, 437
[4] Ramakrishnan V. et al., 2015, MNRAS submitted
[5] Scargle J. D. et al.. 2013, ApJ, 764, 167

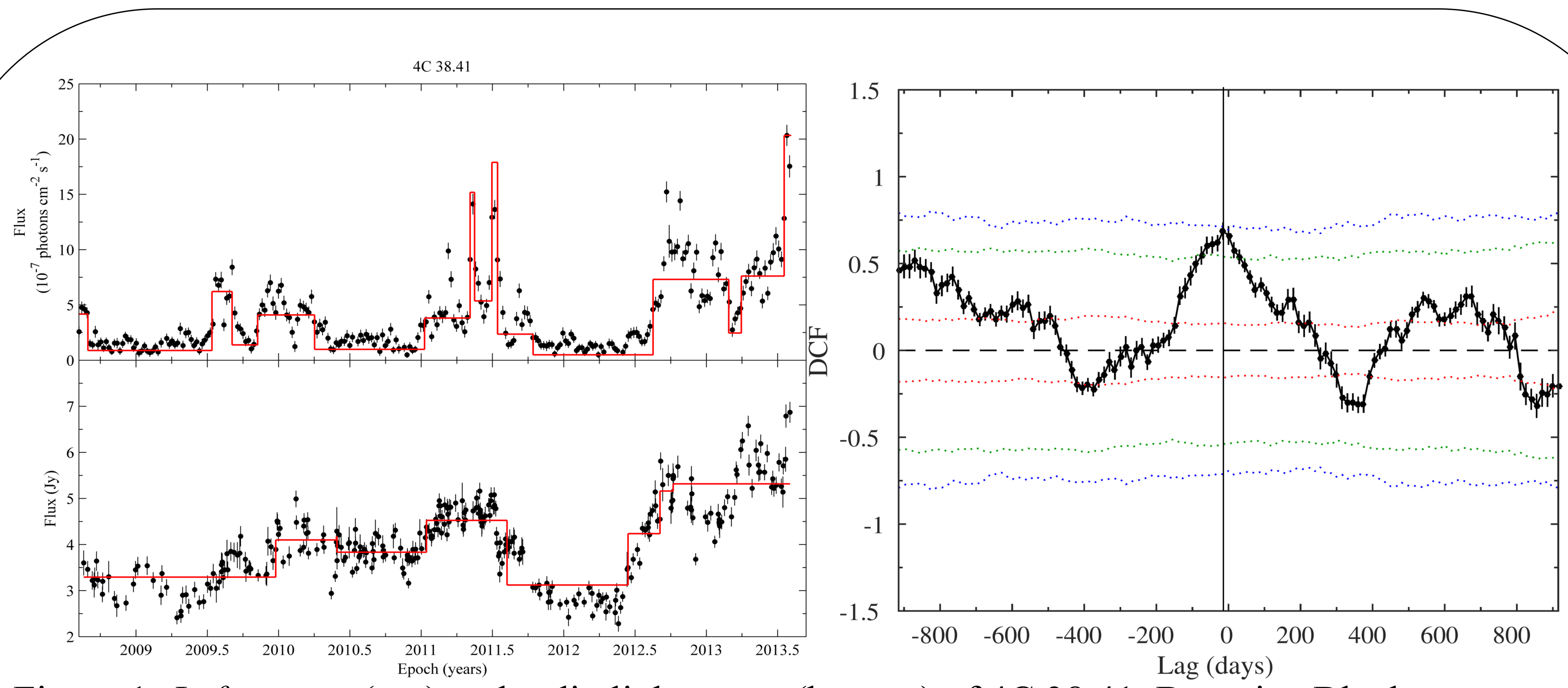

Figure 1: *Left*—γ-ray (top) and radio light curve (bottom) of 4C 38.41. Bayesian Block representation is plotted in red line. *Right*—DCF between the radio and γ-ray light curves. The significance levels (1, 2 & 3σ) are denoted by dotted red, green and blue lines. The DCF peak shows that the radio leads the γ-ray by 15 days.

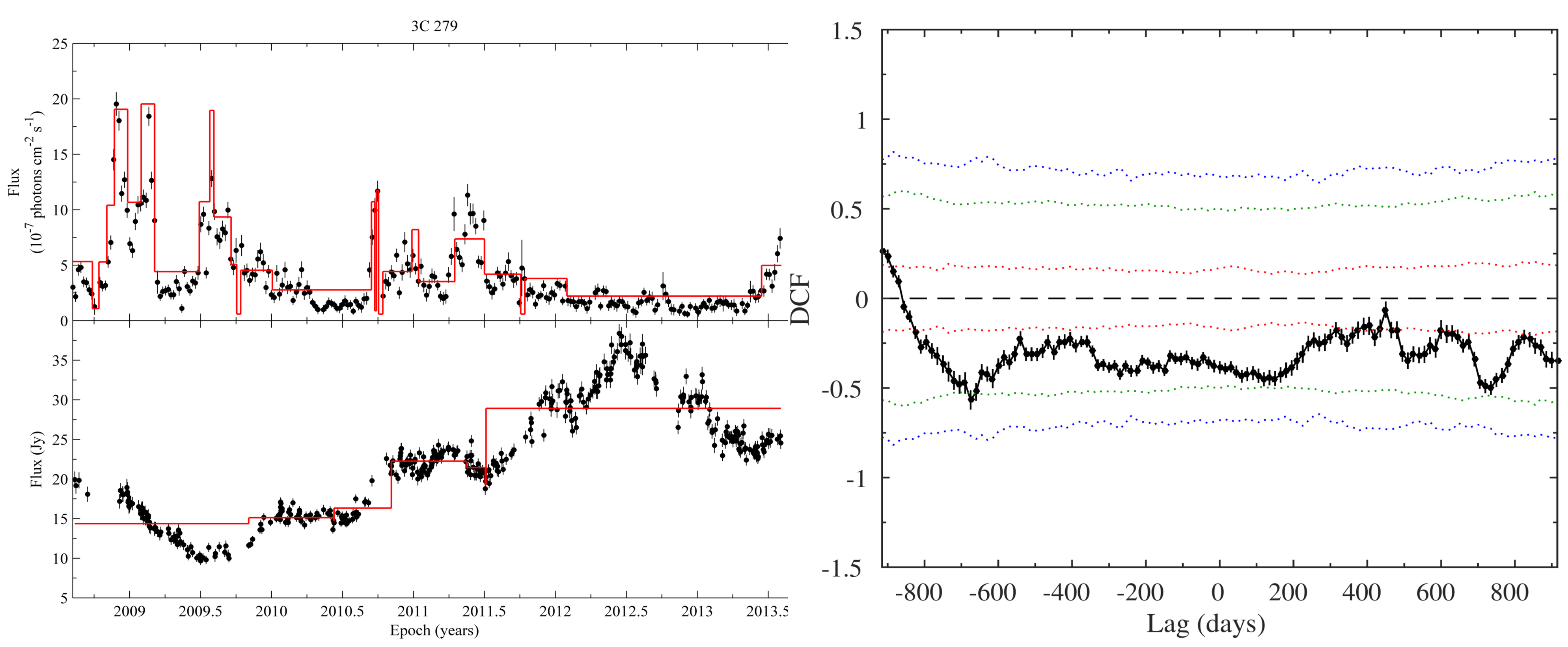

Figure 2: *Left*—γ-ray (top) and radio light curve (bottom) of 3C 279. *Right*—DCF between the radio and γ-ray light curves. The rapid variability in the γ rays has no counterpart in the radio and/or the variations in radio are superimposed resulting in the lack of significant correlation in this source.

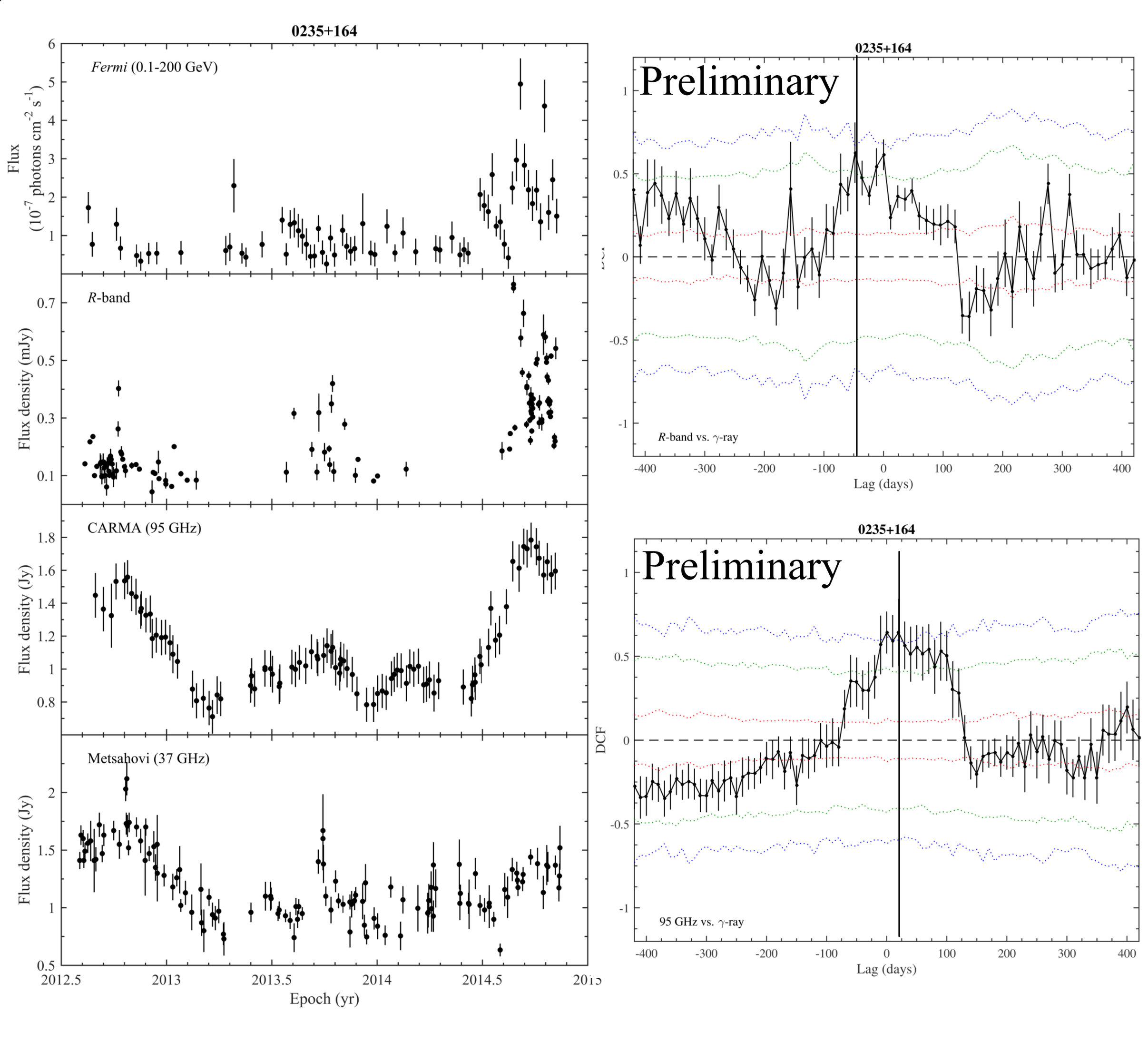

Figure 5: *Left*—Multifrequency light curves of 0235+164 from γ rays to radio (top to bottom). *Right*—Cross-correlation between *R*-band and γ-ray (top) & 95 GHz and γ-ray (bottom). The time lags in either case are 28 and 27 days, respectively, with the γ rays lagging in the former and leading in the latter case.

Work in progress

- Cross-correlations of 15 blazars using observations at 37 GHz (Metsähovi), 95 GHz (CARMA), *R*-band (Tuorla blazar monitoring programme) & 0.1—200 GeV (*Fermi*), for the time interval, 2012.6—2014.9.
- Sources with optical data showed significant correlation with near-zero time lag with γ rays (see Figure 5).
- The correlations between the radio and high-energy bands were significant only in few sources, as the results were affected by the short time-span of the observations.
- Within the radio band, all sources were correlated with a shorter delay.