GeV-radio correlation in Markarian 421

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Abstract

Markarian 421 is a high-synchrotron-peaked blazar showing relentless variability across the electromagnetic spectrum from radio to gamma-rays. We use over 7-years of radio and GeV observations to study the correlation and connected variability in radio and GeV bands. Radio data was obtained in a 15GHz band by the OVRO 40-m radio telescope, and GeV data is from Fermi Large Area Telescope. To determine the location of the gamma-ray emission regions in Mrk 421 we correlate GeV and radio light curves. We found that GeV light curve varies independently and accurately leads the variations observed in radio. Using a fast-rise-slow-decay profile derived for shock propagation within a conical jet, we manage to reproduce the radio light curve from GeV variations. The profile rise time is comparable with the Fermi-LAT binning the decay time is about 7.6 days. The best-fit value for the response profile also features a 44 days delay between the GeV and radio, which is compatible with the wide lag range obtained from the correlation. Such a delay corresponds to 10^{17} cm/c, which is comparable with the apparent light crossing time of the Mrk 421 radio core. Generally, the observed variability matches the predictions of the leptonic models and suggests that the physical conditions vary in the jet. The emitting region moving downstream the jet, while the environment becomes first transparent to gamma rays and later to the radio.

Introduction and data

- Mrk 421 is a bright and close ($z = 0.0031$) high-frequency-peaked blazar variable from radio to the TeVs. As a source of high-energy gamma-rays Mrk 421 was identified by the Whipple IACT [6].
- The spectral energy distribution (SED) of Mrk 421 can be reproduced using different emission models, e.g.: leptonic one-zone synchrotron self-Compton model (SSC) [1], hadronic model [4].
- Mrk 421 was a target of many multi-wavelength (MWL) campaigns from radio to the very-high energy gamma-rays [e.g. 1, 3].
- During the long-term multi-year observations, Mrk 421 has the highest variability in the X-rays and TeVs [3]. Emission in X-rays and TeVs is highly correlated with close to zero days lag [3, 2].
- Seven-years period from late 2010 to mid 2018 was considered, Mrk 421 found in both low and high activity states. We used day-binned *Fermi*-LAT light curve in the $100\,\mathrm{MeV} < E < 300\,\mathrm{GeV}$ energy range, and 15 GHz radio light curve.

Variability and correlations

- During the considered period the fractional variability dependency of the frequency has a two-hump shape, peaking in the X-rays and TeVs, with F_{var} of 1.4 and 1.02. The lowest variability was found in the radio and GeV band, F_{var} of 0.18 and 0.4, respectively [3].
- Strong and wide correlations were found between GeV and radio variations [3, 5] with gamma-rays variability leading by 40-50 days.
- Radio light curve can be obtained from GeV variability by convolving with a fast-rise-slow-decay profile: $t_{rise} < 3\,\mathrm{days}$, $t_{decay} = 7.64\,\mathrm{days}$, $t_{delay} = 44.1\,\mathrm{days}$ [9]. Goodness of fit for the obtained synthetic light curve using best-fit profile is $\chi^2/\nu = 422/281 = 1.5$.

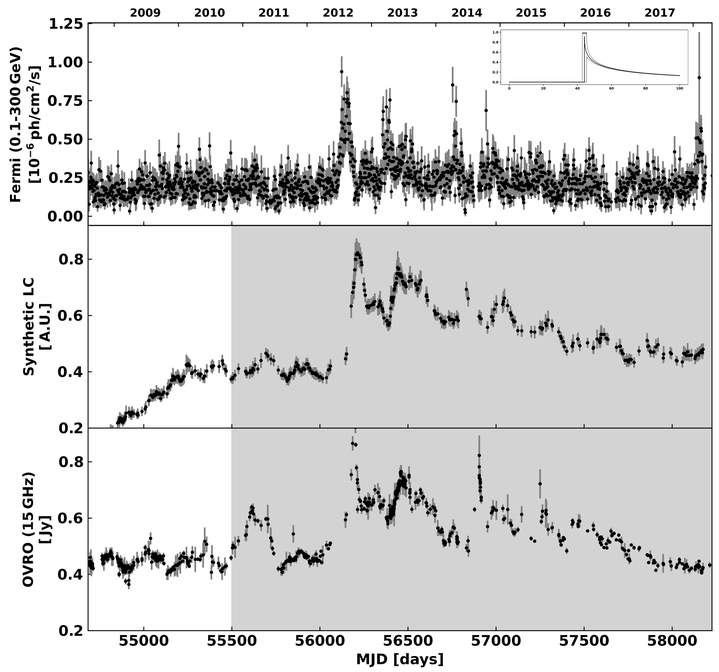

Fig. 1: A synthetic radio light curve (middle) derived from the *Fermi*-LAT light curve (top). The best-fit GeV to radio response profile (top right) was obtained for the time range highlighted in grey by comparing the synthetic and original radio light curves (bottom).

Conclusions

- The fractional variability dependency on frequency has a two-hump shape, with the lowest variability in the radio and GeV band, and highest in the X-rays and TeVs. Using long-term observations data we were able to confirm that this is an internal property of Mrk 421 and it doesn't depend on the current state of the blazar.
- The radio emission can be reproduced by convolving the GeV light curve with a delayed asymmetric response (a fast-rise-slow-decay response profile with a delay of ∼44 days). This is an indication of the leptonic synchrotron emission dominating the low energy emission component.
- Taking into account the points above and the variability time scales in different bands for the same period [3], the leptonic scenario is compatible with the correlation and the delay between GeV and radio variabilities. Such a delay, which has been observed also in 3C 273 and S5 0716+714, could be related to an evolution of the physical conditions when shocks move along the jet.

References and acknowledgements

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