Long-term multi-wavelength analysis Mrk 421 variability

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Introduction and the MWL campaign

- Mrk 421 features bright and persistent activity from radio to TeV.
- Leptonic [1] and hadronic [3, 6] models are considered to explain the spectral energy distribution (SED) of Mrk 421.
- We made use of the long-term (5.5 years) and unbiased TeV light curve from FACT, a 3.8 m IACT located at La Palma [2].
- The multi-wavelength light curves for nine instruments span from December 14, 2012 to April 18, 2018 (from MJD 56275 to 58226).

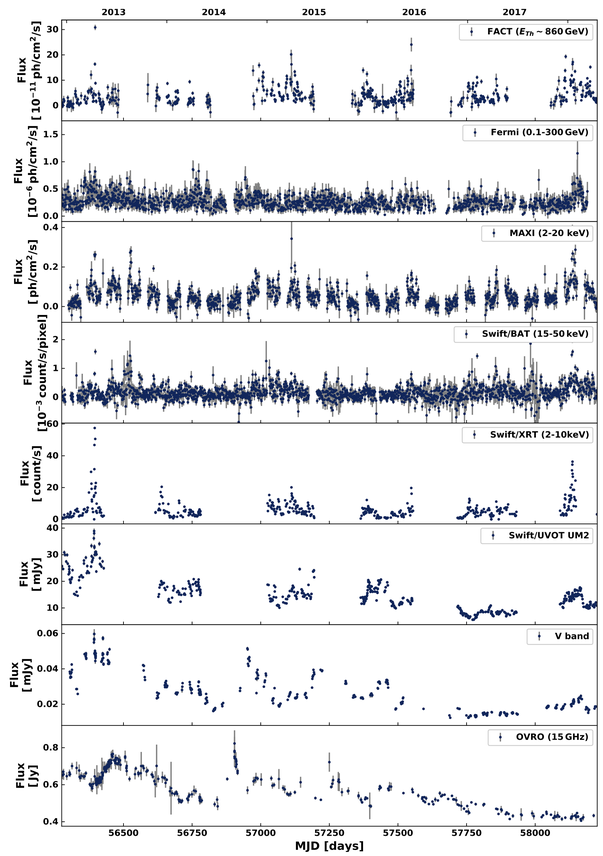

Fig. 1: Long-term light curves of Mrk 421. From top to bottom: FACT (E_{Th} ~860 GeV), Fermi 100–300 GeV, MAXI 2–20 keV, Swift/BAT 15–50 keV, Swift/XRT 2–10 keV, UM2 Swift/UVOT, V-band and 15 GHz OVRO radio telescope.

Variability, correlations and response analysis

- Lowest $F_{var} = 0.15$ and highest 1.33 are found in radio and X-rays (Swift/BAT), respectively.
- F_{var} drops for GeV to 0.34 and increases to 0.92 for FACT in TeV.
- TeV and X-rays are strongly correlated without significant time-lag, combined lag between the two is (-0.16 ± 0.58) days (1σ). Correlation between TeV and GeV was not found.
- All 22 identified TeV flares were also found in the X-rays. Distribution of delays between the flares peaks at between 7.5 and 30 days.

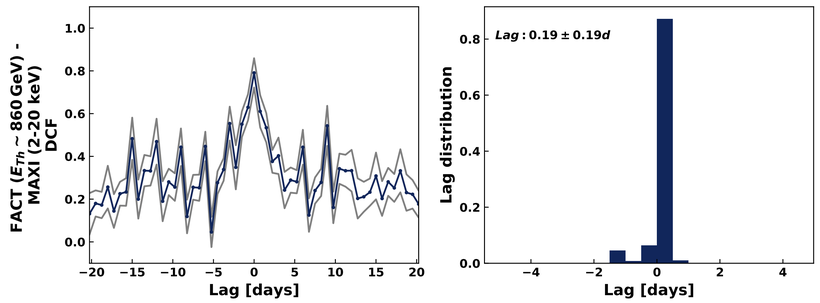

Fig. 2: DCF cross-correlations of TeV (FACT) and X-rays (MAXI) light curves. Left: DCF values as a function of time lag. Gray lines denote the 1σ uncertainties. Right: lag distribution for the DCF 80% centroid value.

- Strong and wide correlation found between GeV and optical, GeV and radio.
- GeV to radio fast-rise-slow-decay response profile has $t_{rise} < 3$, $t_{fall} = 7.62$ and $t_{delay} = 44$ days.
- Radio light curve can be reproduced ($\chi^2_\nu = 1.5$) except fast radio flare near MJD 56897.

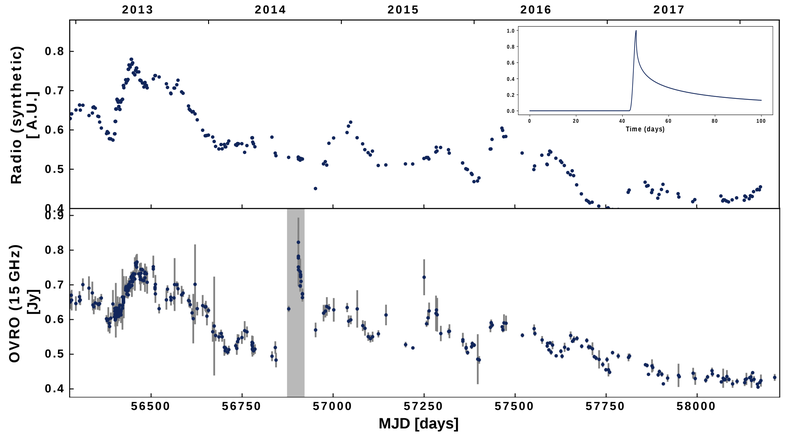

Fig. 3: Synthetic radio light curve (top) derived from Fermi LAT light curve and OVRO 15 GHz radio light curve (bottom). Best-fit GeV to radio response profile assuming shock propagation in a conical jet (top right).

Conclusions

- GeV and radio correlation indicates synchrotron process dominating low energy emission.
- 44 days delay in the GeV to radio response profile suggests emission region moving outwards and becoming first transparent in GeV, later in radio.
- The fractional variability of Mrk 421, and the correlated TeV and X-ray emission, indicate that the main source of variability of both bands is a synchronous change of the cutoff energies.
- No significant lag between TeV and X-rays suggests that both emissions are driven by the same physical parameter consistent with leptonic emission scenario.
- Observed variability cannot be explained by hadronic and leptono-hadronic models due to short variability in X-rays and no TeV and X-ray lag, respectively.

References

[1] A. A. Abdo et al. "Fermi Large Area Telescope Observations of Markarian 421: The Missing Piece of its Spectral Energy Distribution". In: 736, 131 (2011), p. 131.

[2] H. Anderhub et al. "Design and operation of FACT - the first G-APD Cherenkov telescope". In: *Journal of Instrumentation* 8, P06008 (2013), P06008.

[3] M. Cerruti et al. "A hadronic origin for ultra-high-frequency-peaked BL Lac objects". In: 448 (2015), pp. 910–927.

[4] N. Gehrels and Swift Team. "The Swift γ-ray burst mission". In: *New Astronomy Reviews* 48 (2004), pp. 431–435.

[5] M. Matsuoka et al. "The MAXI Mission on the ISS: Science and Instruments for Monitoring All-Sky X-Ray Images". In: 61 (2009), pp. 999–1010.

[6] A. Mücke and R. J. Protheroe. "A proton synchrotron blazar model for flaring in Markarian 501". In: *Astroparticle Physics* 15 (2001), pp. 121–136.

[7] J. L. Richards et al. "Blazars in the Fermi Era: The OVRO 40 m Telescope Monitoring Program". In: 194, 29 (2011), p. 29.

[8] P. S. Smith et al. "Coordinated Fermi/Optical Monitoring of Blazars and the Great 2009 September Gamma-ray Flare of 3C 454.3". In: *2009 Fermi Symposium, eConf Proceedings*, C091122 (2009).

Acknowledgements

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