Exploring the Nature of the 2016 Gamma-Ray Emission in the Blazar 1749+096

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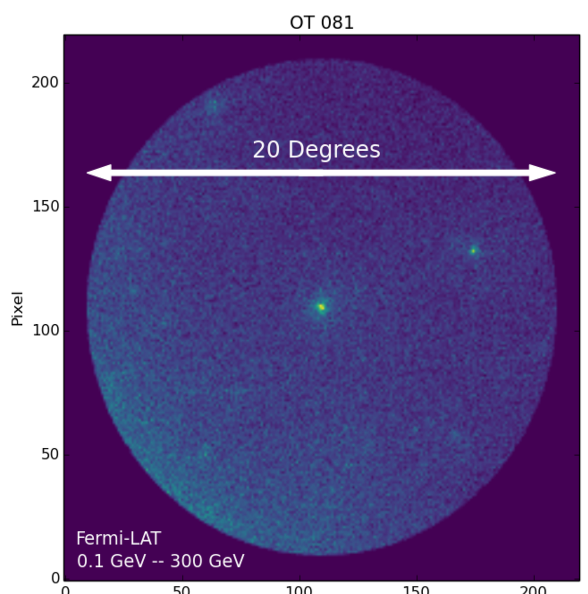
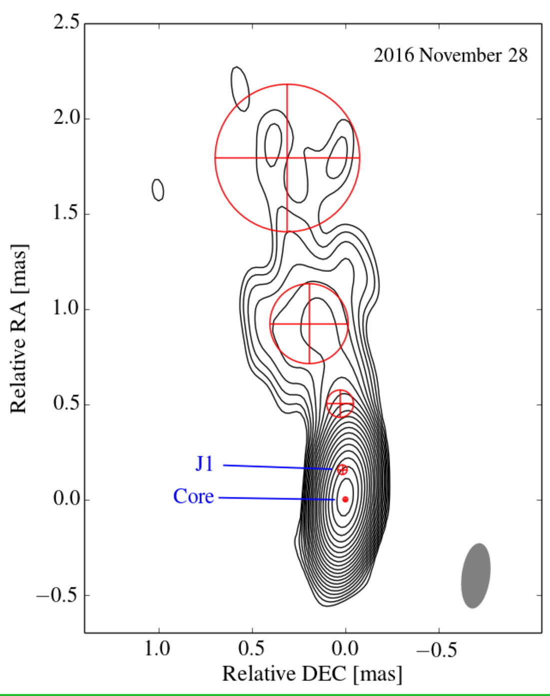
Recent Fermi-Large Area Telescope light curves indicate an active γ-ray state spanning about five months from 2016 June to 2016 October in the BL Lac object 1749+096 (OT 081). During this period, we find two notable γ-ray events: an exceptionally strong outburst followed by a significant enhancement (local peak). In this study, we analyze multi-waveband light curves (radio, optical, X-ray, and γ-ray) plus very long baseline interferometry (VLBI) data to investigate the nature of the γ-ray events. The γ-ray outburst coincides with flux maxima at longer wavelengths. We find a spectral hardening of the γ-ray photon index during the γ-ray outburst. The photon index shows a transition from a softer-when-brighter to a harder-when-brighter trend at around 1.8 x 10^{-7} ph cm^{-2} s^{-1}. We see indication that both the γ-ray outburst and the subsequent enhancement precede the propagation of a polarized knot in a region near the VLBI core. We conclude that both γ-ray events are caused by the propagation of a disturbance in the mm-wave core.

Scientific Background

More than 70 % of γ-ray sources in the sky are now identified as Blazar. It is generally supposed that blazars radiate the γ-ray emission in their relativistic jet [9]. However, the physical processes and the origin of the γ-rays in the jets are still a matter of debate [5]. In this study, we explore these questions in the blazar 1749+096 with the data: KVN, OVRO, and VLBA (radio) / ASAS-SN (optical) / Swift-XRT (X-ray) / Fermi-LAT (γ-ray).





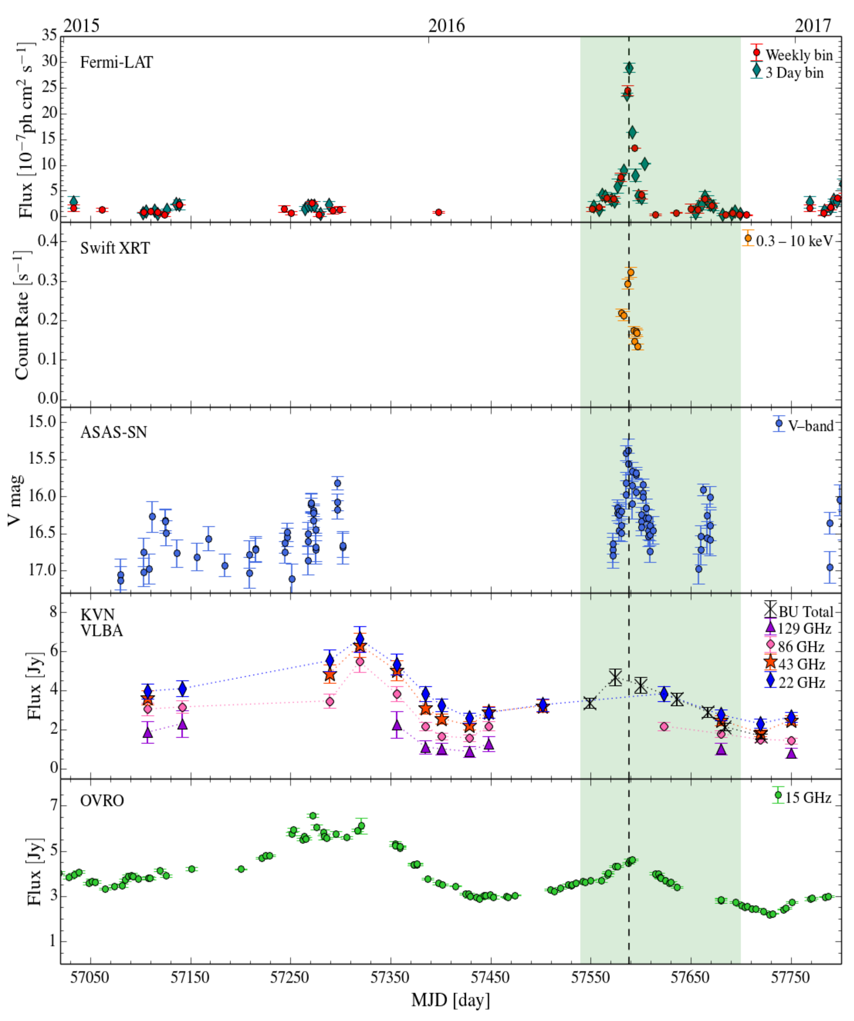
Left: γ-ray sky centering on the BL Lac object 1749+096 (RA: 267.89 & DEC: 9.65 in degrees) observed by the LAT at 0.1 - 300 GeV.

Right: Parsec-scale radio jet image of 1749+096 observed by the VLBA at 43 GHz (monitored by Boston University group; BU).

Variability of 1749+096 in 2016

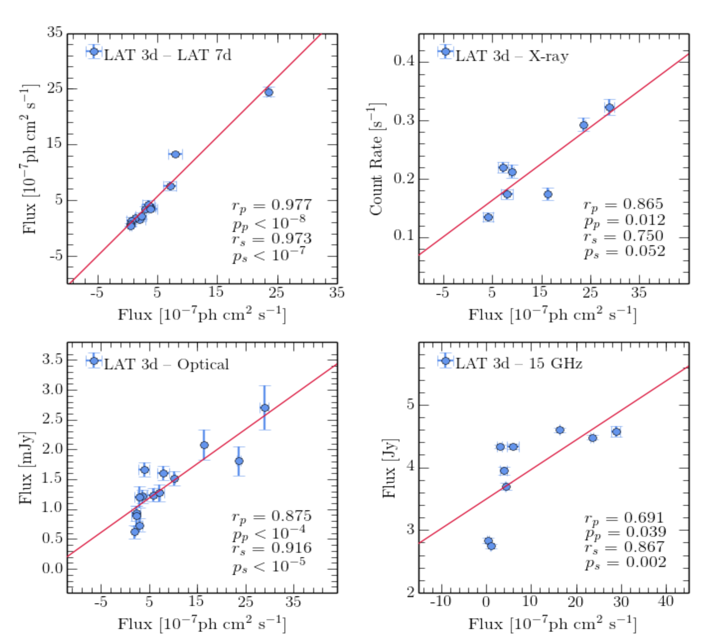
The BL Lac object 1749+096 (OT 081; z~0.32) is a flat spectrum compact radio source [8], known to have Doppler factor of ~17.7 and viewing angle of ~2.5°. 1749+096 was flaring at γ-rays (0.1 - 300 GeV) in the mid-2016 (June to October).

- A strong outburst (2016 July 19) and a local peak (2016 October 2) at γ-rays.
- The γ-ray outburst coincides with flux maxima at longer wavelengths.
- Positive correlations between γ-ray and longer wavelengths during the period.



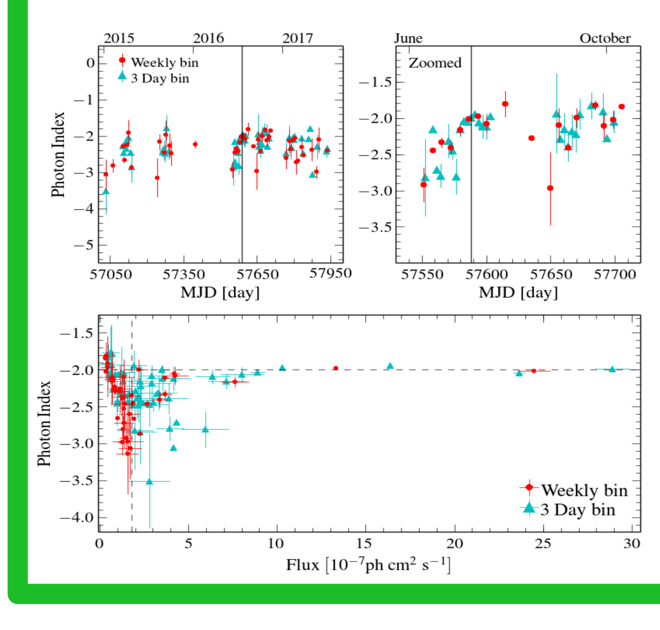
Left: Multi-waveband light curves. Green shaded region indicates the γ-rays flaring period (2016 June to 2016 October).

Right: Linear correlations (Pearson & Spearman) of the emissions during the period.



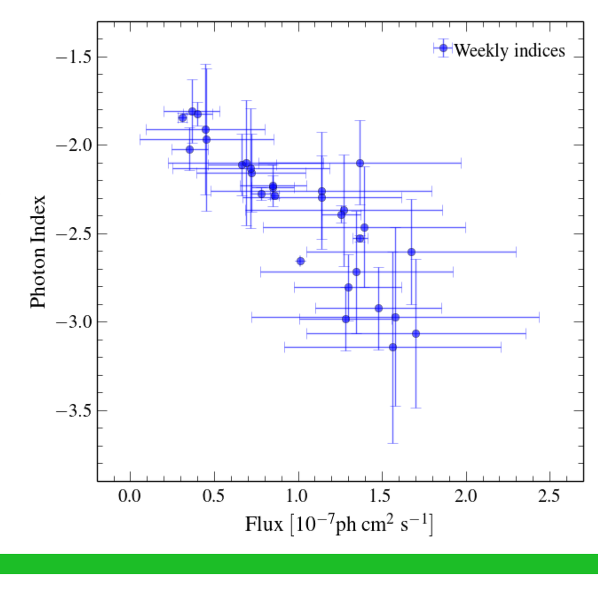
Properties of the γ-rays

- A clear spectral hardening before the outburst which is rare in BL Lac objects.
- Softer-when-brighter trend up to 1.7 x 10^{-7} ph cm^{-2} s^{-1} with r_P ~ −0.86.



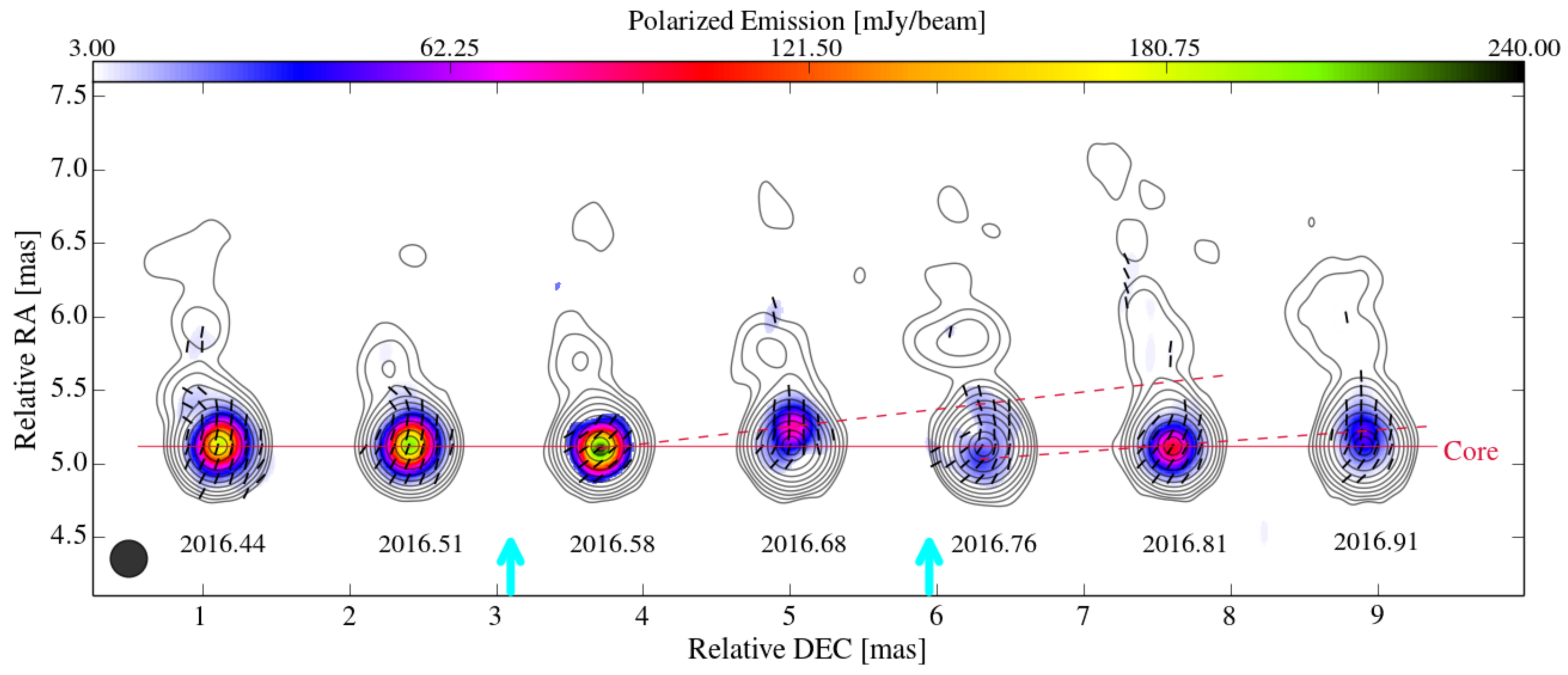
Left: Evolution of the photon index Γ, defined as dN/dE ∝ $E^{+Γ}$. The vertical line indicates the γ-ray outburst.

Right: The photon index (weekly bin) as function of γ-ray flux.

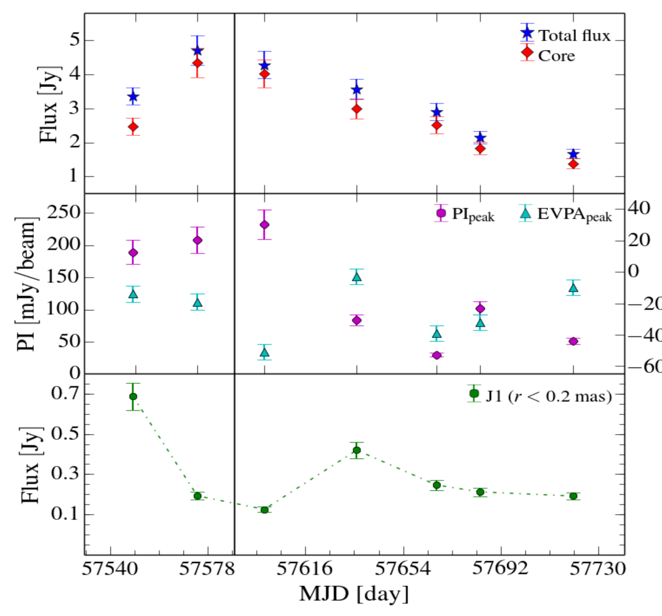


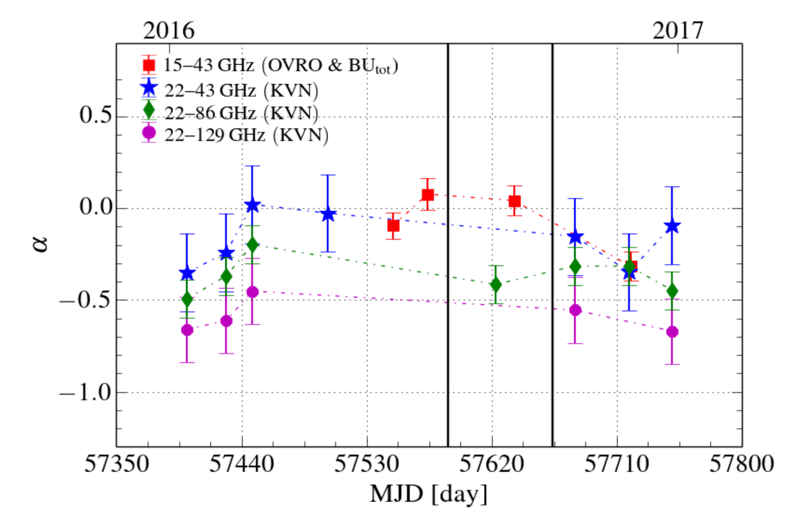
Activity of the Radio Jet

- Evolution of the jet around the time of the two γ-ray events in 2016. (June 11, July 5, July 31, September 5, October 6, October 23, and November 28)
- A polarized knot propagating from the BU core was detected in both cases.
- The highest PI of ~230 mJ & an EVPA rotation by ~32 in 2016 July 31.



Top: VLBA (BU) maps of 1749+096 at 43 GHz. Linearly polarized flux (colour scale) and electric vector position angle (EVPA; black line segments) plotted over total intensity structure (contours). The cyan arrows represent the two γ-ray events: the outburst in 2016 July and the enhancement in 2016 October. The size of the restored beam is 0.25 x 0.25 mas (*bottom-left*), contour levels increase by factors of two from 0.25 % to 64 %, plus 85 % of the total intensity peak.





Left: Flux evolution of the core & total flux (*top*) and the jet component J1 which is quasi-stationary (*bottom*). Polarized intensity and EVPA of the polarized knot (*middle*). The vertical line indicates the γ-ray outburst. **Right:** Pairwise spectral indices α ($S_\nu \propto \nu^\alpha$) of 1749+096 at radio wavelengths observed in 2016. Here, the two γ-ray events are indicated by two vertical lines.

Conclusions & References

We suggest the parsec-scale scenario that a moving disturbance causes the γ-ray events as it passes through the mm-wave core [2]. We summarize our observational results as follow.

- For the γ-ray outburst, a same emitting region is expected.
  - → The outbursts at mm-wave to γ-rays are considered to be simultaneous [3].
  - → Possible exception might be the peak of OVRO (around 5 days delayed).
- The connection between the γ-ray outburst and a growing shock.
  - → The clear spectral hardening indicates shock acceleration [6].
  - → The abundant polarized emission can be explained by growing shock [7].
- We find a softer-when-brighter trend at γ-rays with r_P ~ −0.86.
  - → A transition point is assumed to be around ~1.8 x 10^{-7} ph cm^{-2} s^{-1}.
  - → Still unclear the physical mechanisms behind it [1].
- The passage of a propagating disturbance through the mm-wave core.
  - → The ejection of a polarized knot preceding the γ-ray events.
  - → The changes in PI & EVPA: a propagating oblique shock in a blazar jet? [4].
  - → The timing of the γ-ray outburst and total intensity of the core and the J1.
- The γ-ray enhancement: smaller Doppler factor and energization?
  - → Probably, similar processes to the γ-ray outburst with the polarized knot.
  - → But, do not show any notable clues (e.g., counterparts at longer wavelengths).

Ref. :

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