Deciphering the 2017 soft X-ray flare of OJ 287, a Radio-to-TeV study

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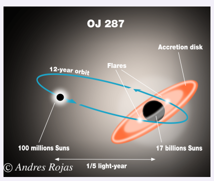
Abstract

Intermediate blazars (Low and Intermediate synchrotron-peaked BL Lacs) are known to present complex multiwavelength SEDs and variabilities, often requiring an interpretation beyond standard one-zone emission models. OJ 287 is the archetype of such a complex blazar. On top of hosting a binary supermassive black hole system, it presents multiple other unusual features like an X-ray extended jet, possible jet precession, complex observed radio jet kinematics, and orphan flares. We focus our attention of such a flare that happened mostly in soft X-ray in Feb 2017. With data in radio-VLBI, optical, UV, X-ray, high-energy and very-high-energy gamma rays; we study the multiwavelength behavior of the source before, during, and after the flare. Based on the discovery of a radio jet ejecta emerging from a region close to the core at the same period, we present a scenario of a compact zone moving through the powerful emission of the core that can accurately depict the multiwavelength SED at different periods.

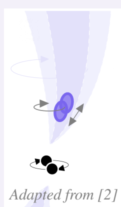
I. OJ 287, The Rosetta stone of Blazars*

- **Binary black hole** [e.g. 9]



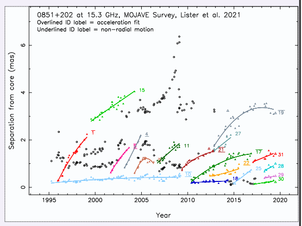
The Feb. 2017 flare does not appear linked to a disk crossing event by the secondary BH.

- **Precessing jet** [1]

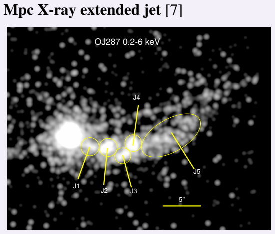


Precession period of 12 years (~ twice the binary period). In dark blue the associated motion of the radio core.

- **Complex radio-VLBI kinematics** [6]



- **Mpc X-ray extended jet** [7]



* Title firstly used by L. O. Takalo (1994)

II. Multiwavelength lightcurves

OJ 287 displayed an exceptional activity during the period 2016 Oct. to 2017 April. We focus our attention on the peak of this activity during February 1-5 2017 that led to its firm detection by VERITAS [8] (orange band). I order to study this event we consider a low state (blue bands) and a post-flare state (gray band). We highlight that the low state is relatively higher than the usual quiescent state of OJ 287 outside this period.

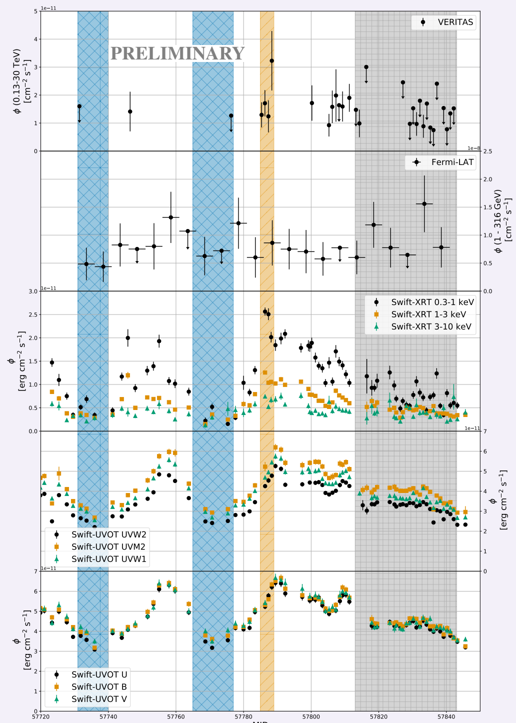


Figure 1: Multiwavelength lightcurve of OJ 287 taken between 2016 November and 2017 April. X-ray fluxes are corrected from the absorption (fixed N_{HI} value [5]). The flare amplitude is observed as maximal in the soft X-ray band.

III. Broadband SED modelling

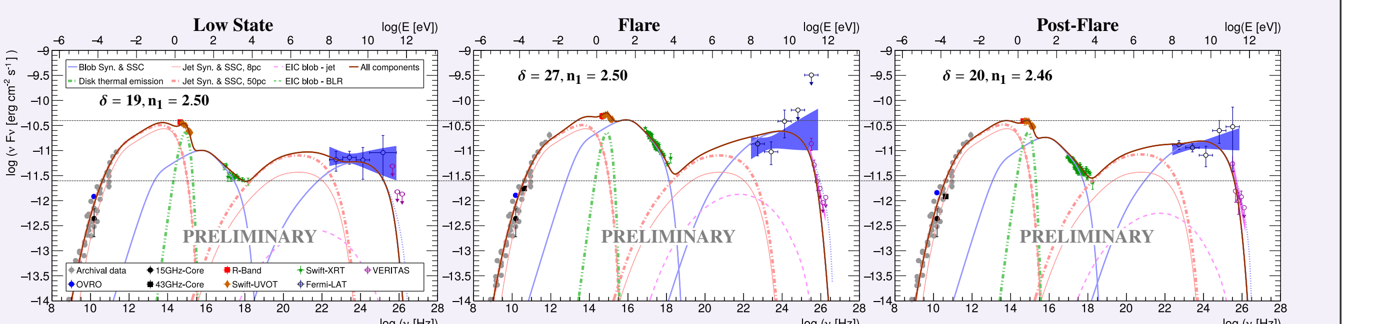


Figure 2: Broadband SED modelling of the 3 activity states shown in Figure 1. We use the multi-zone leptonic model `Bjet` [3] where we consider a compact blob moving through a conical jet and taking into account their radiative interactions. The size of the jet base is adjusted to match the observed radio core extension, with its flux constrained by radio core observations at 22GHz and 43GHz. On the plot are shown the two bob's parameters varying between each state, the Doppler factor δ and the first index n_1 of a broken power law particle distribution.

IV. Discussion - A shock in the core?

The complex flare of OJ 287 in Feb. 2017 with a maximum flux variation observed in soft X-ray can be efficiently described in a multi-zone framework. We consider a compact blob moving though the base of a powerful extended jet (defined as the radio core) responsible of the observed variability. The flare itself can be depicted by an increase of the blob Doppler factor, while the post-flare state is consistent with an hardening of the accelerated particle distribution.

A radio-knot ejection around the time of the flare has also been observed by the VLBA at 3 and 7mm, it is however not clear yet if this event is linked to the radio core or a nearby stationary radio knot (*Lico et al., in prep*).

All these observations point toward a signature of a strong shock at the base of the jet (inside the core or a knot). Indeed a significant variation of the blob Doppler factor is expected when interacting with a recollimation shock, as presented in Figure 3. The harder particle spectrum subsequent to the flare would be a natural outcome of the expected diffuse shock acceleration.

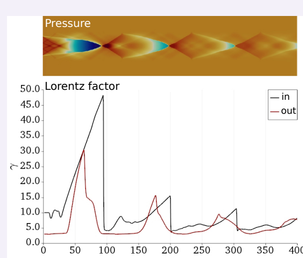


Figure 3: *Top:* 2D pressure profile of a 2-flows jet with a strong first recollimation shock. *Bottom:* associated Lorentz factor of the inner (in) and outer (out) jets. Adapted from [4].

References

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