Blazar Variability from Plasmoids in Relativistic Reconnection

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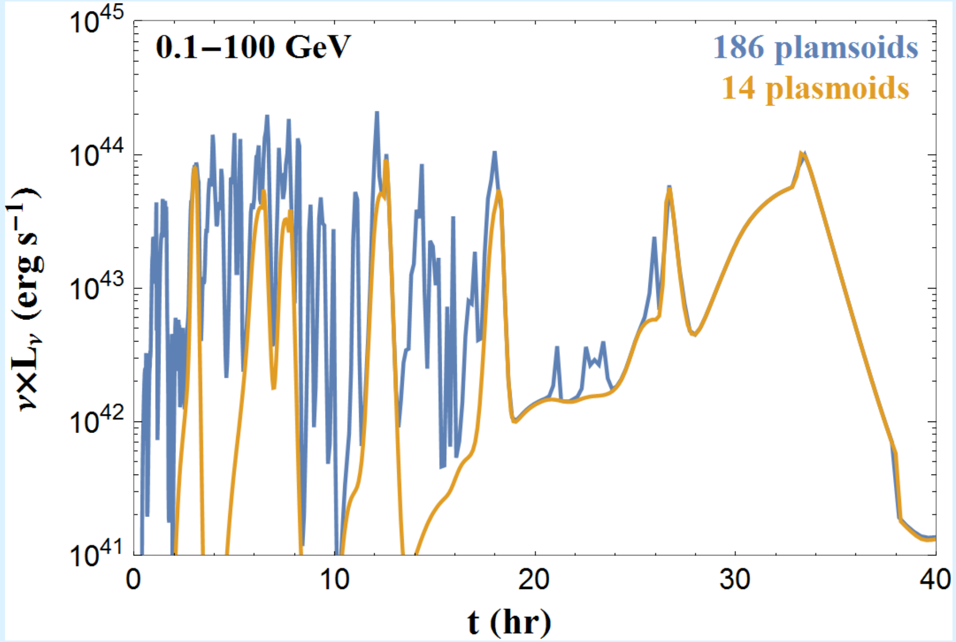
MHD instabilities in Poynting-flux dominated blazar jets lead to the formation of current sheets. Magnetic reconnection is then triggered, allowing the current sheet to fragment into a chain of plasmoids which result in powerful flares consistent with observations.

The larger, slow-moving plasmoids forming within the reconnection layer produce luminous and long-duration flares with typical timescales of hours to days (see orange light curve in Fig.1 for the largest developed plasmoids). Smaller plasmoids move with relativistic speeds in the layer and can power fast flares occurring on timescales on minutes to hours with luminosities similar to or greater than the largest plasmoids (see blue light curve in Fig. 1).

Fig. 1: Cumulative γ-ray light curve a plasmoid chain



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Motivation

- Powerful blazar flares with short (i.e. several minutes to hours) variability timescales, as shown in Fig. 2, pose tight constraints on blazar emission models [1,2,3].

- The variable emission is often associated with blobs, containing relativistic particles and magnetic fields, located within the blazar jet and characterized by large Doppler boosting [4,6]. **However, these models do not explain the origin of the blobs.**

- The production of quasi-spherical blobs, denoted as *plasmoids*, through relativistic magnetic reconnection has been studied extensively with 2D particle-in-cell (PIC) simulations [8,9]. **The plasmoid chain can accurately account for several requirements in emission models** [5,7].

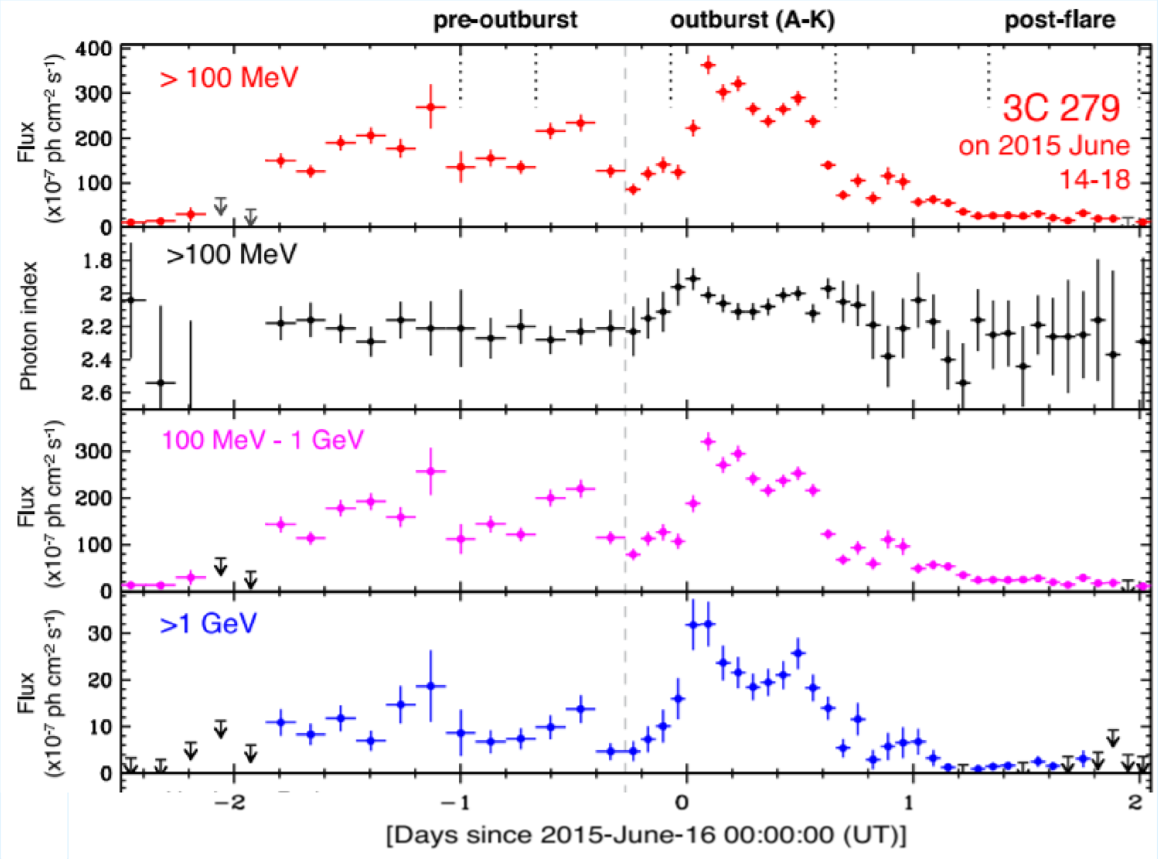

Fig. 2: γ-ray light curves of 3C 279 observed by *Fermi*-LAT [1].

Development

- By coupling our model with 2D PIC simulations, we can accurately track the evolution of individual plasmoids and the plasmoid chain within the reconnection layer (see Fig. 3) [8,9].

- In addition to PIC results, we have developed a radiative transfer model to capture the proper cooling of electron-positron pairs within each plasmoid while taking into account:
  i. Synchrotron
  ii. Inverse (External) Compton
  iii. Pair production
  iv. Absorption & photon escape

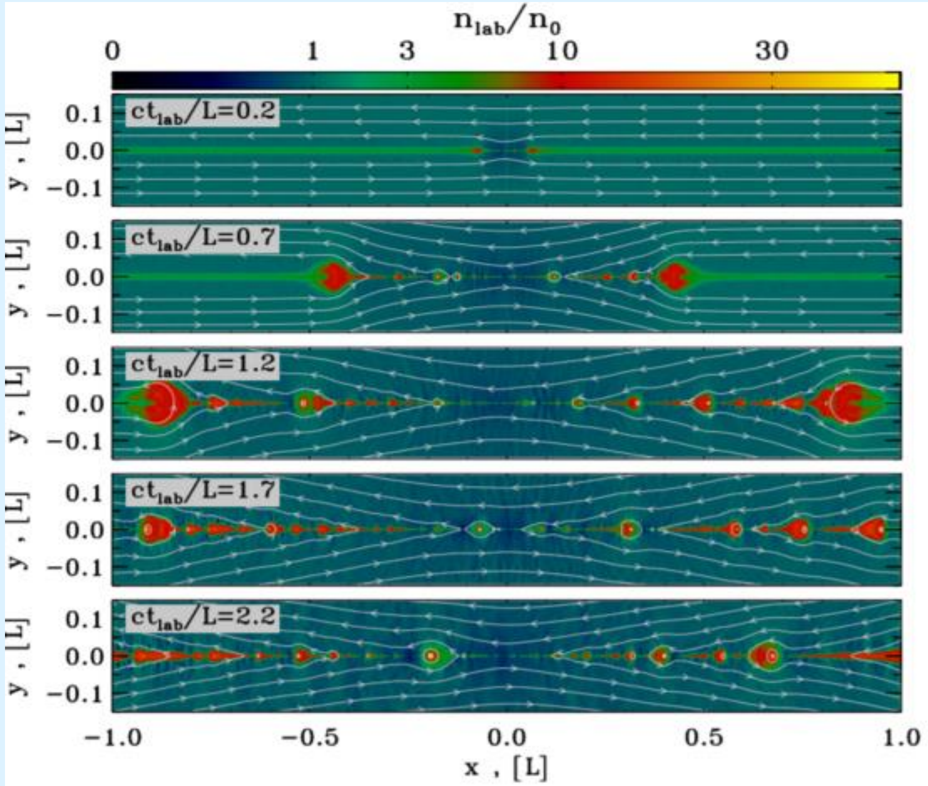

Fig. 3: 2D PIC simulation snapshots of number density within reconnection layer [9].

References

[1] Ackermann, M., et al. (2016). Minute-timescale >100 MeV γ-Ray Variability during the Giant Outburst of Quasar 3C 279 Observed by Fermi-LAT in 2015 June. *APJL*, 824: pp. 8

[2] Aharonian, F. , et al. (2007). An Exceptional Very High Energy Gamma-Ray Flare of PKS 2155-304. *APJ*, 664: L71 – L74

[3] Aleksić, J. , et al. (2011). MAGIC Discovery of Very High Energy Emission from the FSRQ PKS 1222+21. *APJ*, 730: L8

[4] Chiaberge, M. , Ghisellini, G. (1999). Rapid variability in the synchrotron self-Compton model for blazars. *MNRAS*, 306: 551 - 560

[5] Giannios, D. (2013). Reconnection-driven plasmoids in blazars: fast flares on a slow envelope. *MNRAS*, 431: 355 – 363

[6] Mastichiadis, A. , Kirk, J. G. (1997). Variability in the synchrotron self-Compton model of blazar emission. *Astronomy & Astrophysics*, 320: 19 – 25

[7] Petropoulou, M. , Giannios, D. , Sironi, L. (2016). Blazar flares powered by plasmoids in relativistic reconnection. *MNRAS*, 462: 3325 – 3343
Petropoulou, M. ,
[8] Christie, I. M. , Sironi, L. , Giannios, D. (2017). Plasmoid statistics in relativistic magnetic reconnection. *arXiv*: 1710.00724

[9] Sironi, L. , Giannios, D. , Petropoulou, M. (2016). Plasmoids in relativistic reconnection, from birth to adulthood: first they grow, then they go. *MNRAS*, 462: 48 – 74