Radiative Signatures of Relativistic Reconnection in Blazar Jets

Ian Christie
CIERA (Northwestern University)
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In Collaboration with:

M. Petropoulou (Princeton)  L. Sironi (Columbia)
D. Giannios (Purdue)        M. Meyer (Stanford)
Blazars

- AGNs with jets pointing towards the observer
- Most abundant sources of extragalactic $\gamma$-rays (Ajello et al. 2015)
- Non-thermal, multi-wavelength emission

Image Credit: Beckmann & Shrader (2012)
Blazars

- AGNs with jets pointing towards the observer
- Most abundant sources of extragalactic $\gamma$-rays (Ajello et al. 2015)
- Non-thermal, multi-wavelength emission
Blazar Variability

- Multi-wavelength variability lasting from minutes to weeks!

Ackermann et al. 2016

Quasar: 0827+243

Jorstad & Marscher 2016
Blazar SED: FSRQ

Low-energy Bump: Synchrotron

High-energy Bump: Inverse Compton (SSC or EC)
Blazar SED: BL Lac

Low-energy Bump: Synchrotron

High-energy Bump: Inverse Compton (SSC or EC)

SED: Mrk 421

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Previous Emission Modeling

- Modeled individual flaring events
- Assumed relativistically moving blob contained magnetic fields and a relativistic, non-thermal particle distribution

Can we model blazar emission?

- Short-term variability $< \text{light-crossing time}$
- Large Doppler factor of emitting regions $> \text{inferred bulk Lorentz factor of jet}$
- How do we obtain relativistic, non-thermal particles?
Magnetic Reconnection & PIC

- Reconnection can:
  i. accelerate particles to relativistic energy
  ii. produce relativistically moving plasmoids

- Is simulated through first-principles particle-in-cell (PIC) simulations

Particles are accelerated at:

1. X-points
2. during mergers of plasmoids (i.e. secondary reconnection)
3. plasmoid compression

Particle Acceleration in Reconnection

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Blazar Flares Via Plasmoids

Schematic Diagram of Blazar Jet

PIC Simulation of Relativistic Reconnection: density, kinetic energy, magnetic energy

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Our Emission Model

- Use 2D PIC simulation results of relativistic magnetic reconnection

- PIC governs majority of model parameter → **few free parameters (e.g. B-field, size of reconnection layer, strength of external radiation fields, orientation of reconnection layer)**

- Compute the emission from the entire reconnection layer → **model BL Lacs & FSRQs**

Includes emission from Broad Line Region

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Individual Plasmoid Spectra & Light Curves

FSRQ Modeling

BL Lac Modeling

Same Medium Sized Plasmoid
Different External Radiation Fields
Plasmoid Size Dependence

Fast flares, produced by medium-sized plasmoids, appear on top of a slow-evolving envelope developed by the largest plasmoids.
Temporal Evolution of Layer’s Spectra

Jet Lorentz factor: 12
Size of Reconnection layer: $10^{16}$ cm
B-field: $2G$
Additional Signatures

Flaring Statistics

Increasing Plasmoid Size

- \( \propto \Delta t_{1/2}^{-4} \)
- \( \theta_{\text{obs}} = \theta' = 0^\circ \)

- Towards Obs.
- Away Obs.

Christie et al. 2018

Christie et al. in prep.
Detectability of Model Light Curves

- Conduct a standard Fermi analysis on our simulated light curves to reconstruct source light curves.

- Test which features of the model light curves are retained within Fermi observations.

Meyer, Petropoulou, Christie, in prep.

Preliminary
Summary

- Our fundamentally-built model displays similar temporal and spectral features in FSRQs and BL Lacs!

- Because of the fundamental nature of PIC, we require few free parameters

Outlook

- Numerous comparisons with observations (e.g. PSDs, correlation, flaring statistics) to come!

- PIC simulations of proton-electron plasmas + lepto-hadronic radiative model

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ichristi231@gmail.com