Radiative Signatures of Relativistic Reconnection in Blazar Jets

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CIERA (Northwestern University)

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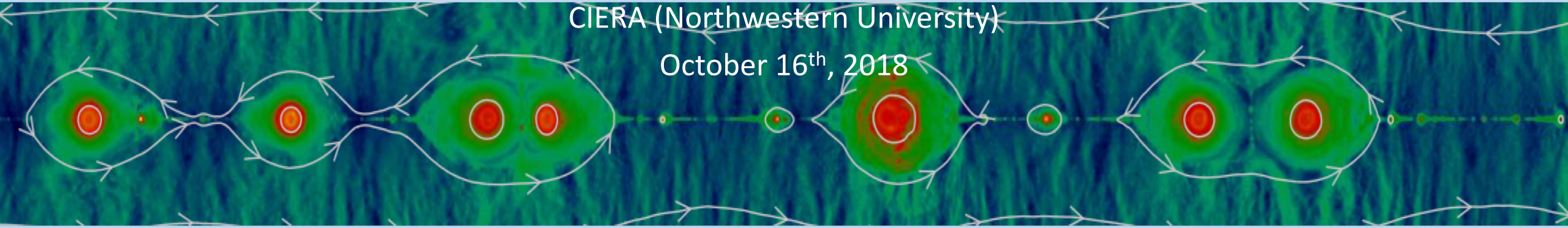


In Collaboration with:

Maria Petropoulou (Princeton)

Lorenzo Sironi (Columbia)

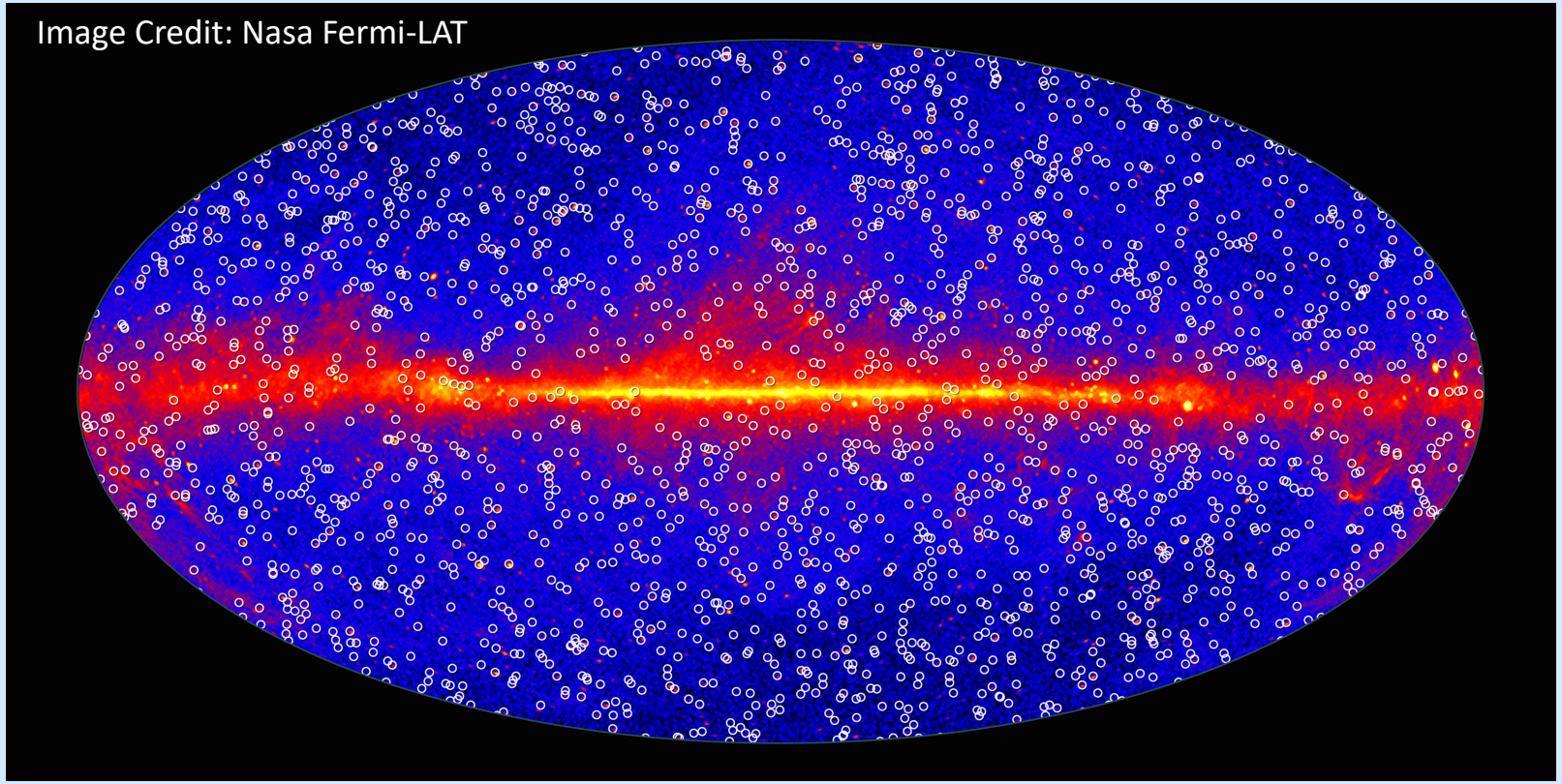
Dimitrios Giannios (Purdue)

Fermi Gamma-ray Space Telescope

CIERA

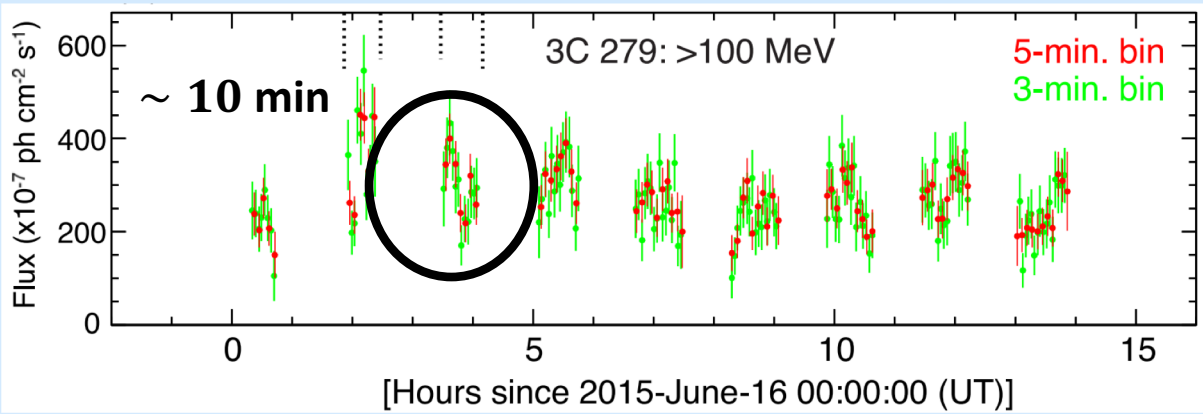
Blazars

Catalog of Fermi-LAT Detected AGN



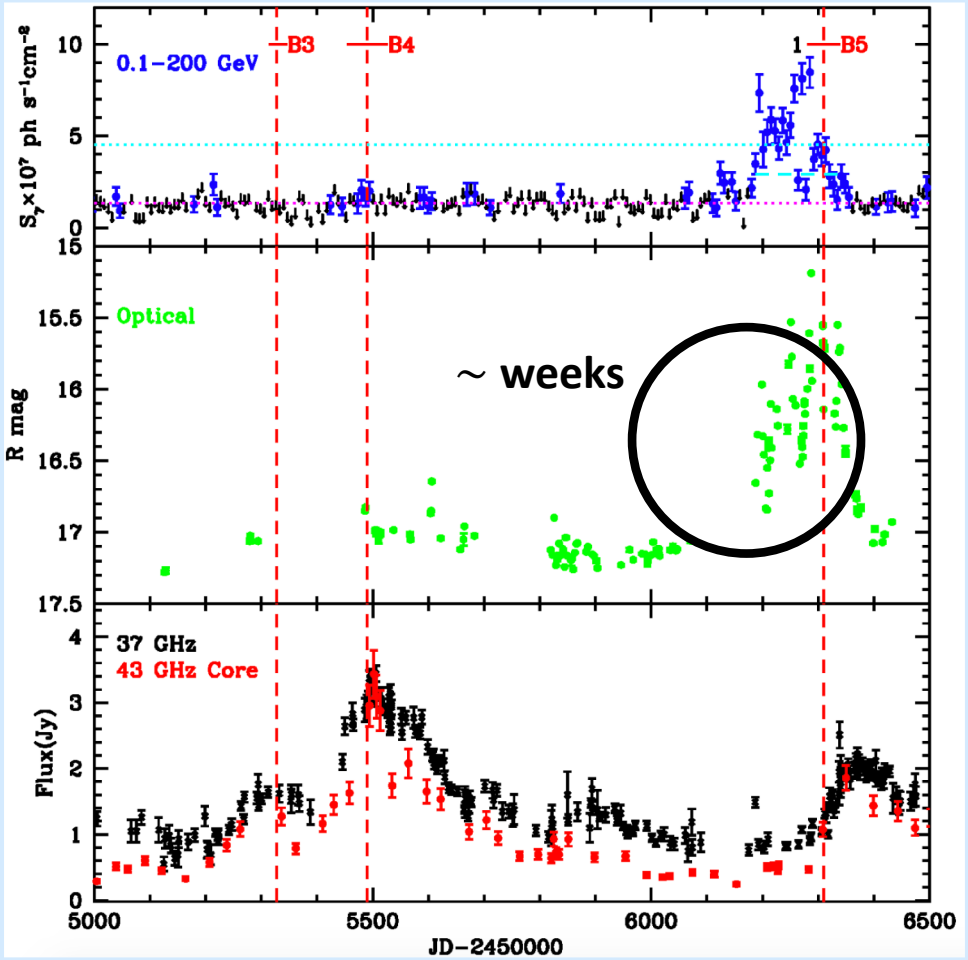
- AGNs with jets pointing towards the observer
- Most abundant sources of extragalactic γ-rays
  (Ajello et al. 2015)
- Non-thermal, multi-wavelength emission

Blazar Variability



Ackermann et al. 2016

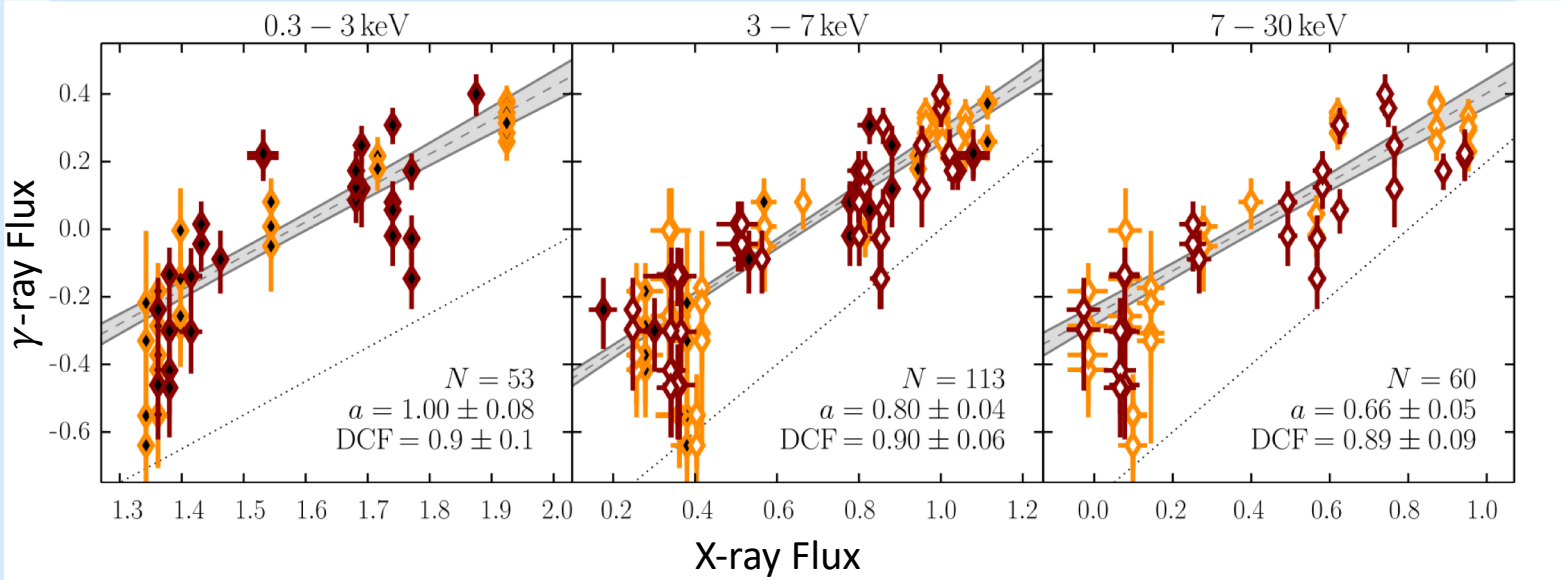
Quasar: 0827+243



Jorstad & Marscher 2016

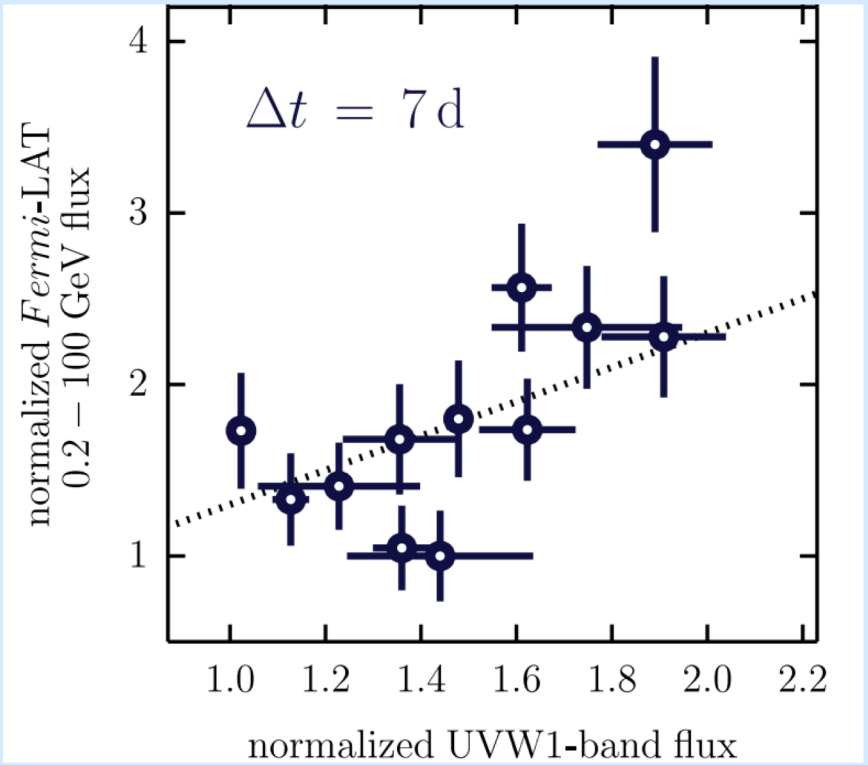
- Multi-wavelength variability lasting from minutes to weeks!

Other Characteristics



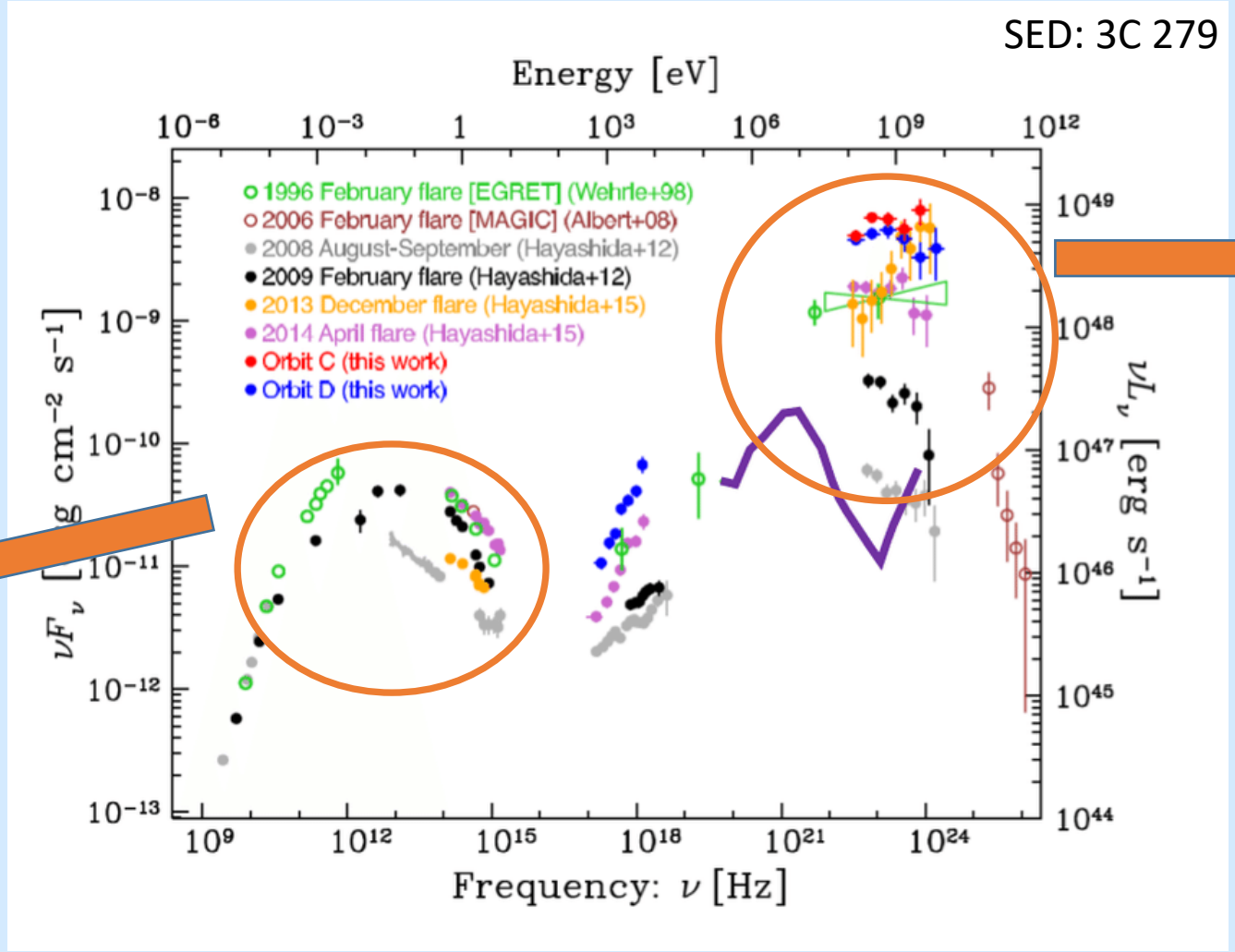
Balokovic et al. 2016

Mrk 421



Jorstad & Marscher 2016

Blazar SED: FSRQ

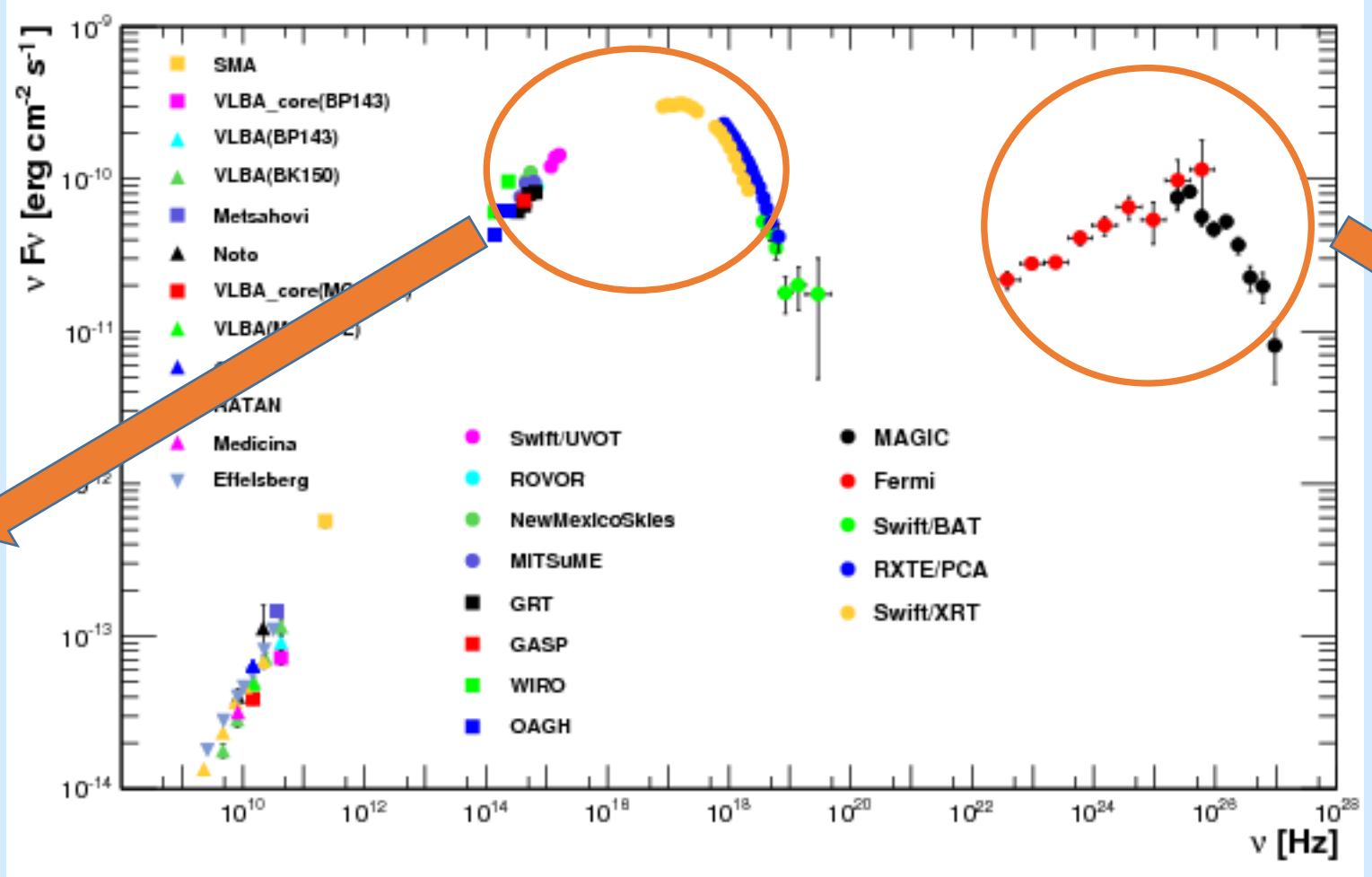


High-energy Bump:
Inverse Compton (SSC or EC)

Low-energy Bump:
Synchrotron

Blazar SED: BL Lac

SED: Mrk 421



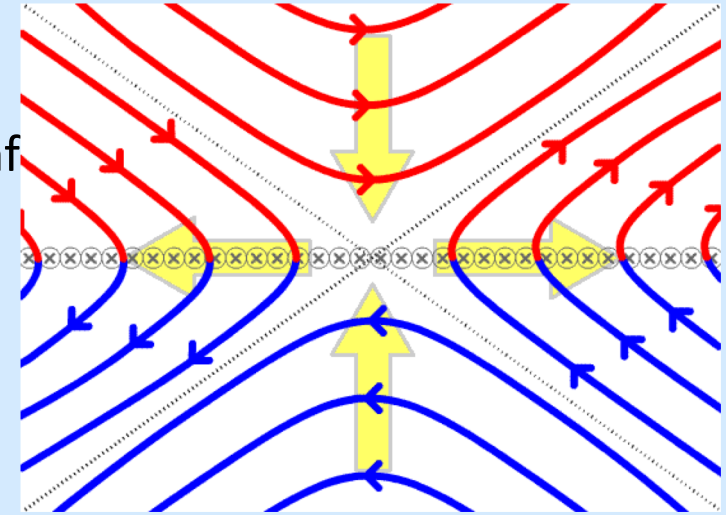
Low-energy Bump:
Synchrotron

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

Can we model blazar emission?

- Short-term variability **<** light-crossing time
- Large Doppler factor of emitting regions **>** inf bulk Lorentz factor of jet
- How do we obtain relativistic, non-thermal particles?

Animation of Magnetic Reconnection



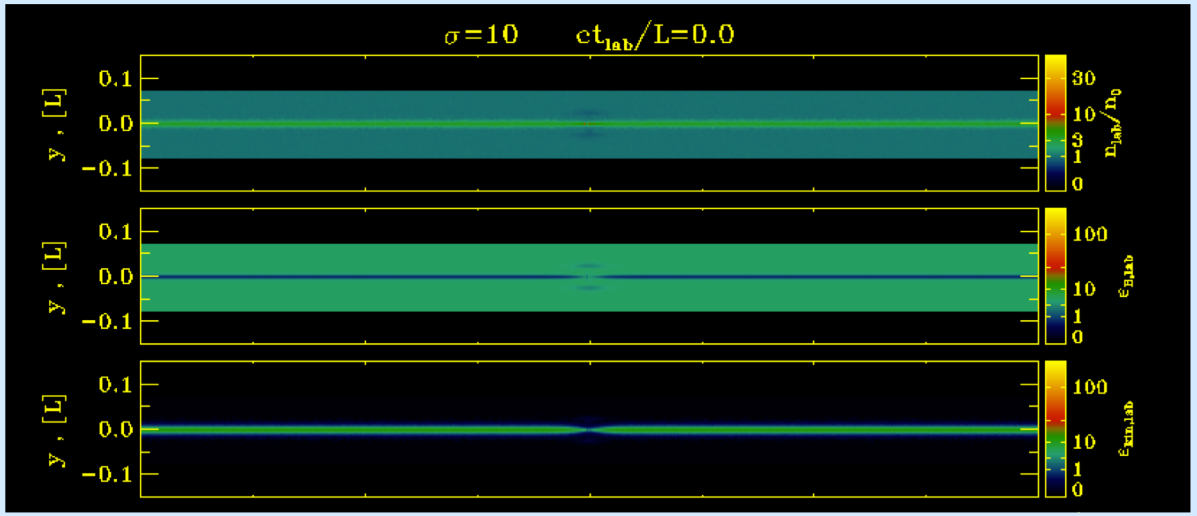
Magnetic Reconnection & PIC

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

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

(Guo et al. 2014, Sironi et al. 2015 & 2016, Werner et al. 2016, Sironi & Spitkovsky 2014)

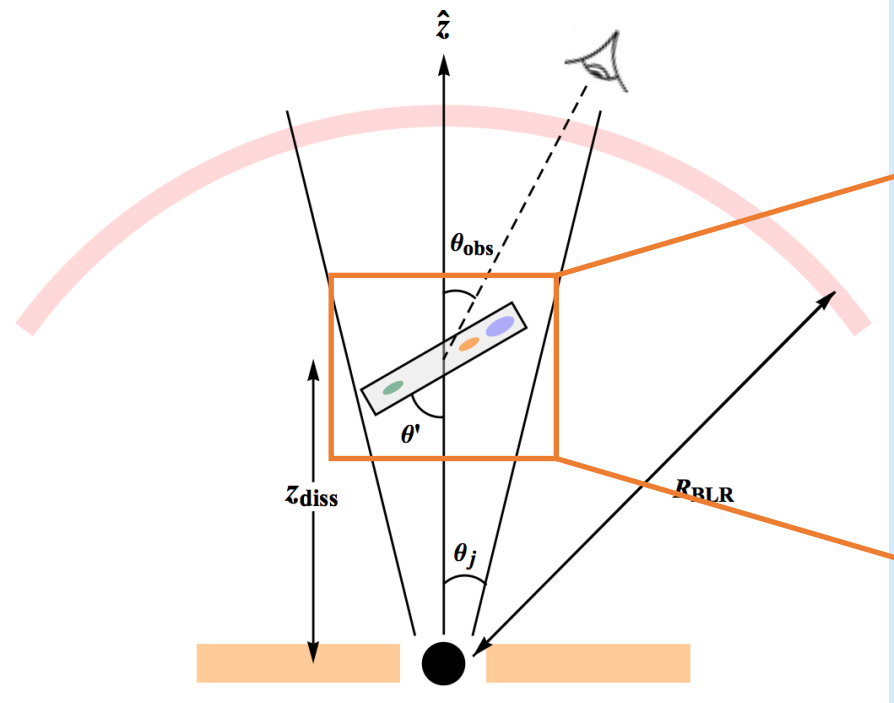
PIC Simulation of Relativistic Reconnection:
density, kinetic energy, magnetic energy



Sironi et al. 2016

Blazar Flares Via Plasmoids

Schematic Diagram of Blazar Jet



Christie et al. 2018

PIC Simulation of Relativistic Reconnection:
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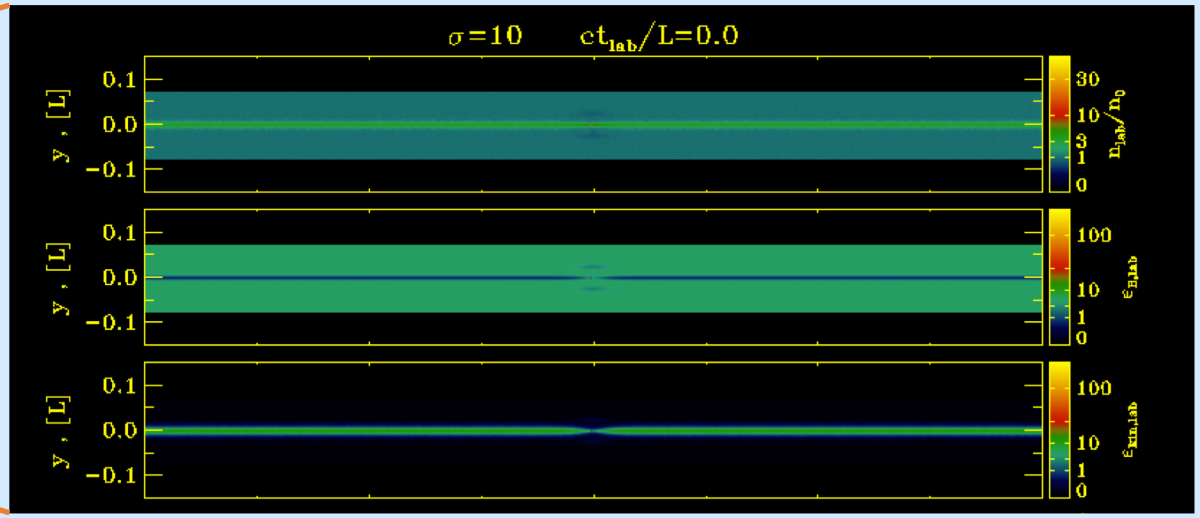


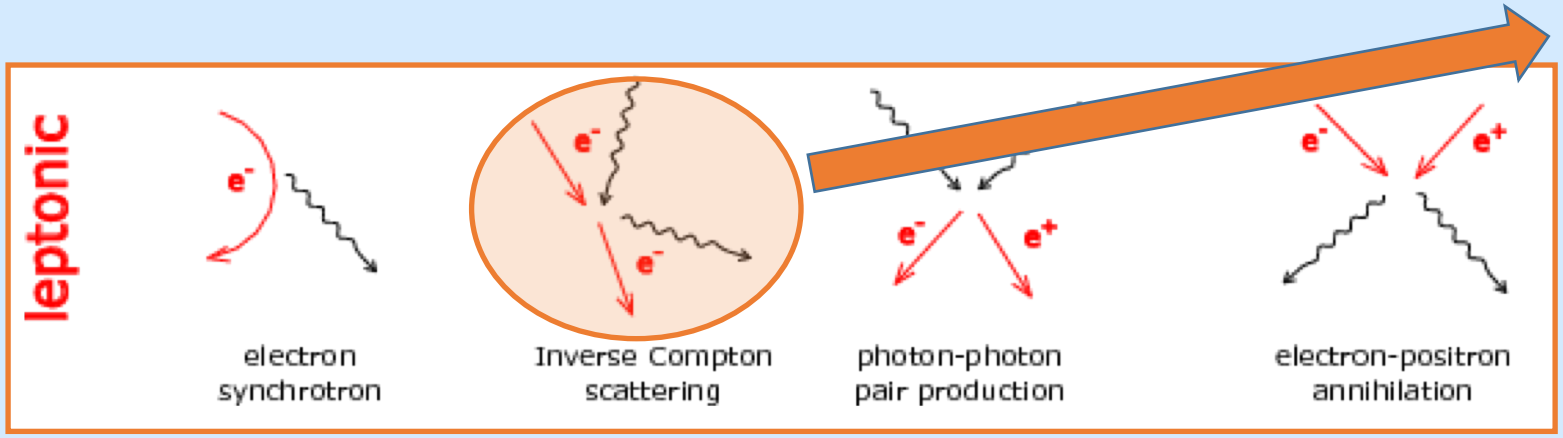
Sironi et al. 2016

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, external radiation fields, size of reconnection layer, strength of external radiation fields, orientation of reconnection layer)***

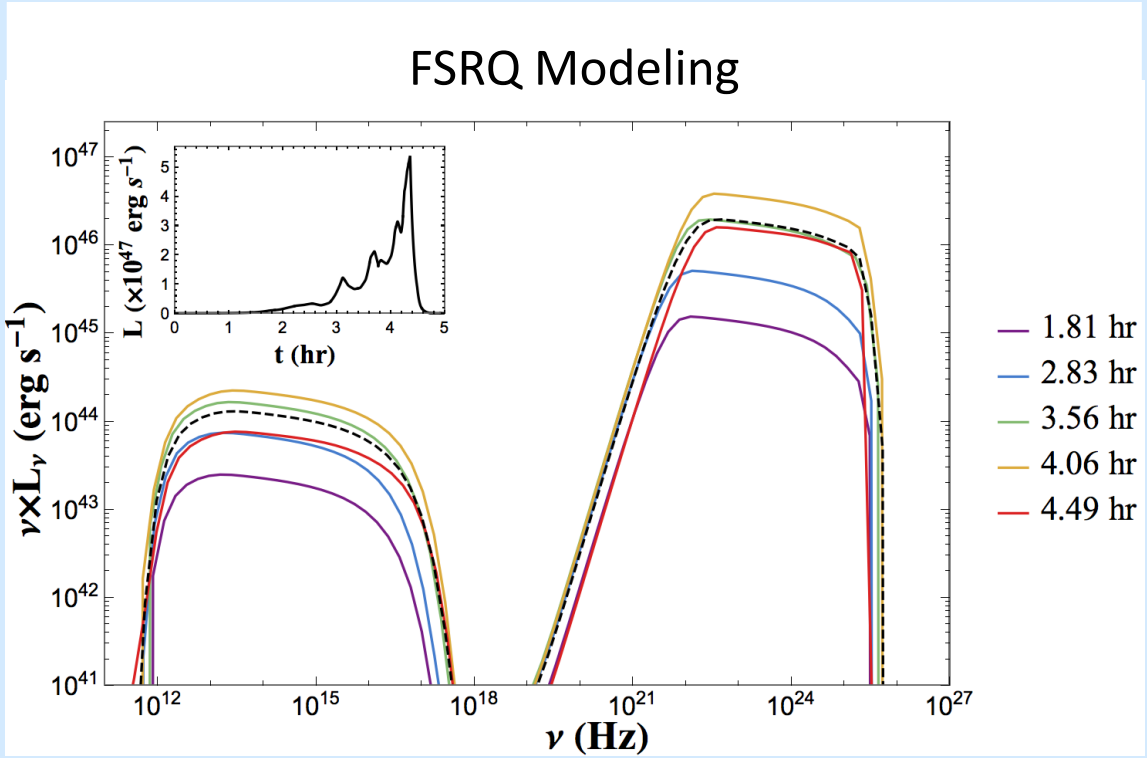
- Compute the emission from the entire reconnection layer ⟶ ***model BL Lacs & FSRQs***



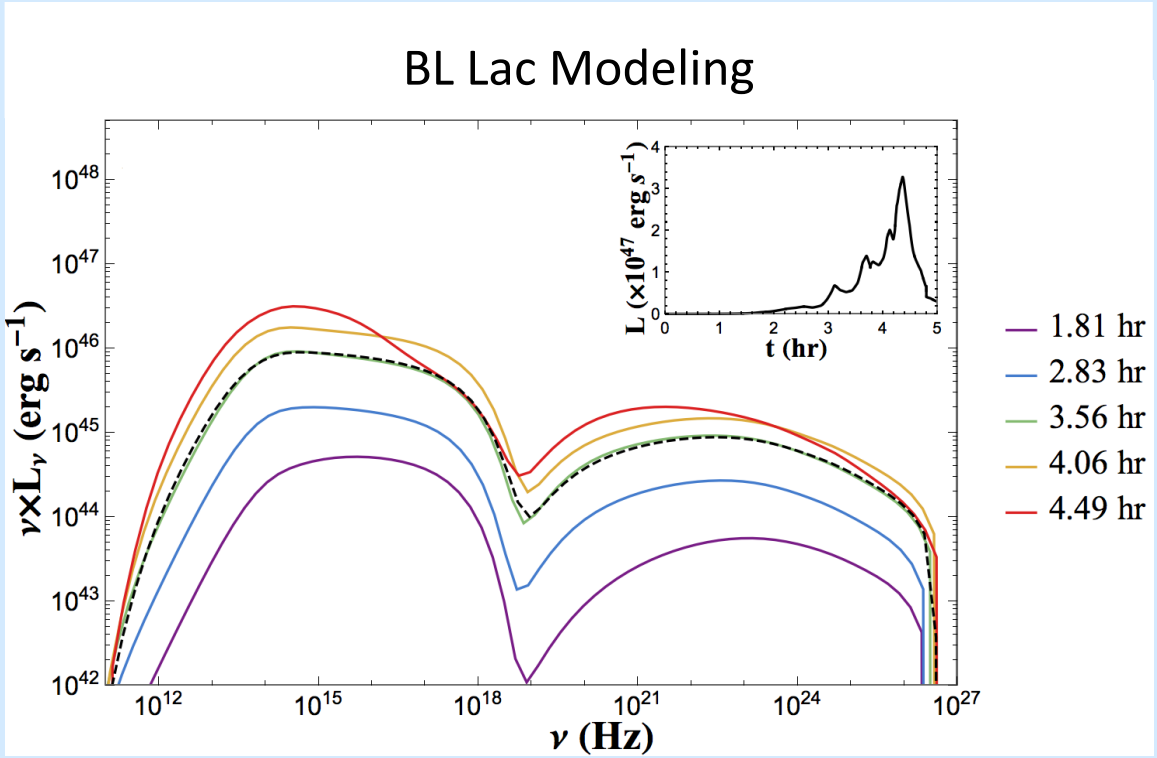
Includes emission from Broad Line Region

Individual Plasmoid Spectra & Light Curves

FSRQ Modeling



BL Lac Modeling

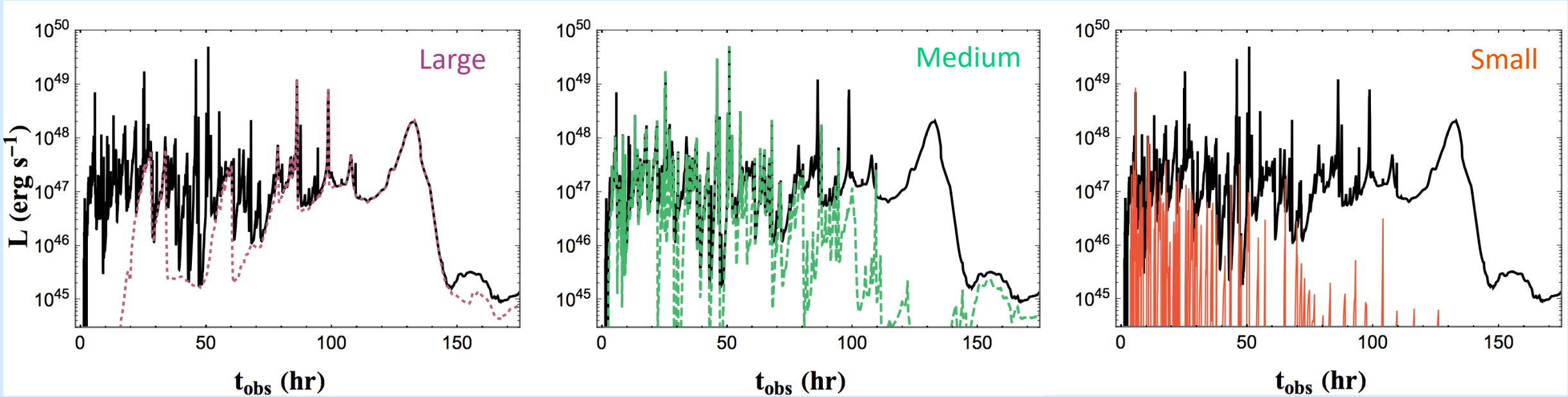


Same Medium Sized Plasmoid

Christie et al. 2018

Plasmoid Size Dependence

0.1 – 300 GeV Light Curve



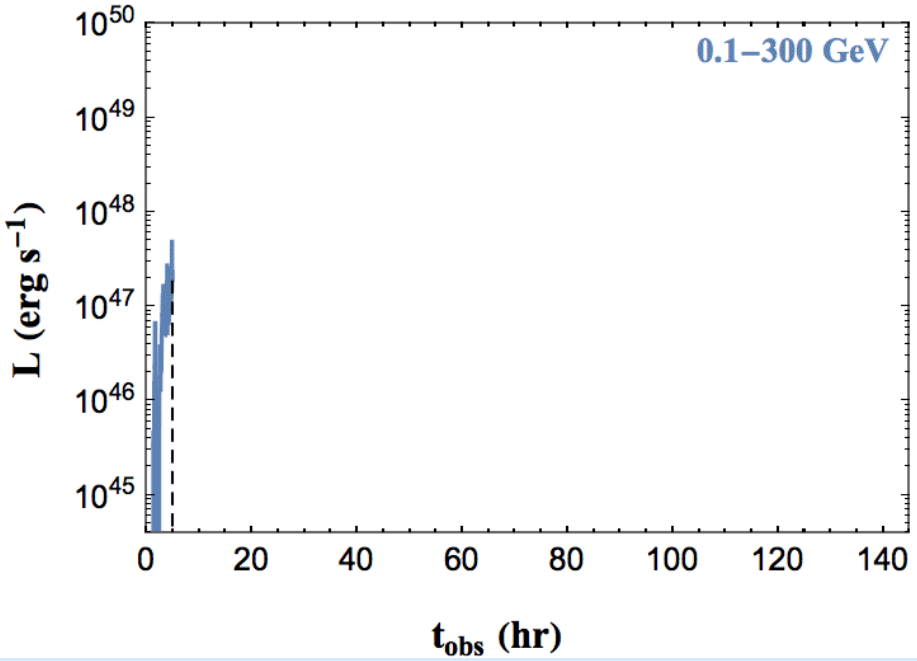
Christie et al. 2018

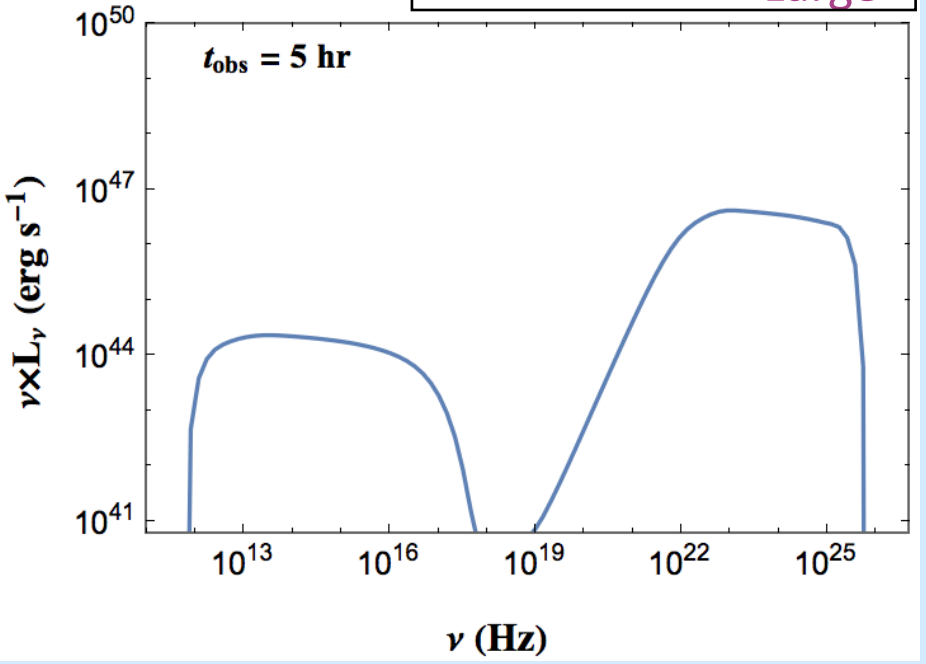
- Fast flares, produced by medium-sized plasmoids, appear on top of a slow-evolving envelope developed by the largest plasmoids

Temporal Evolution of Layer's Spectra

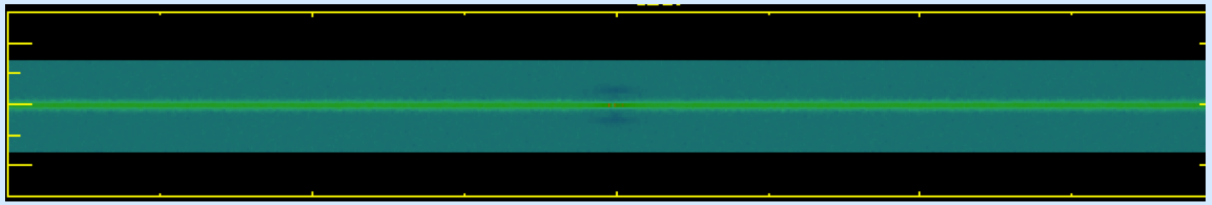
FSRQ Modeling

Plasmoid Size: Small Medium Large





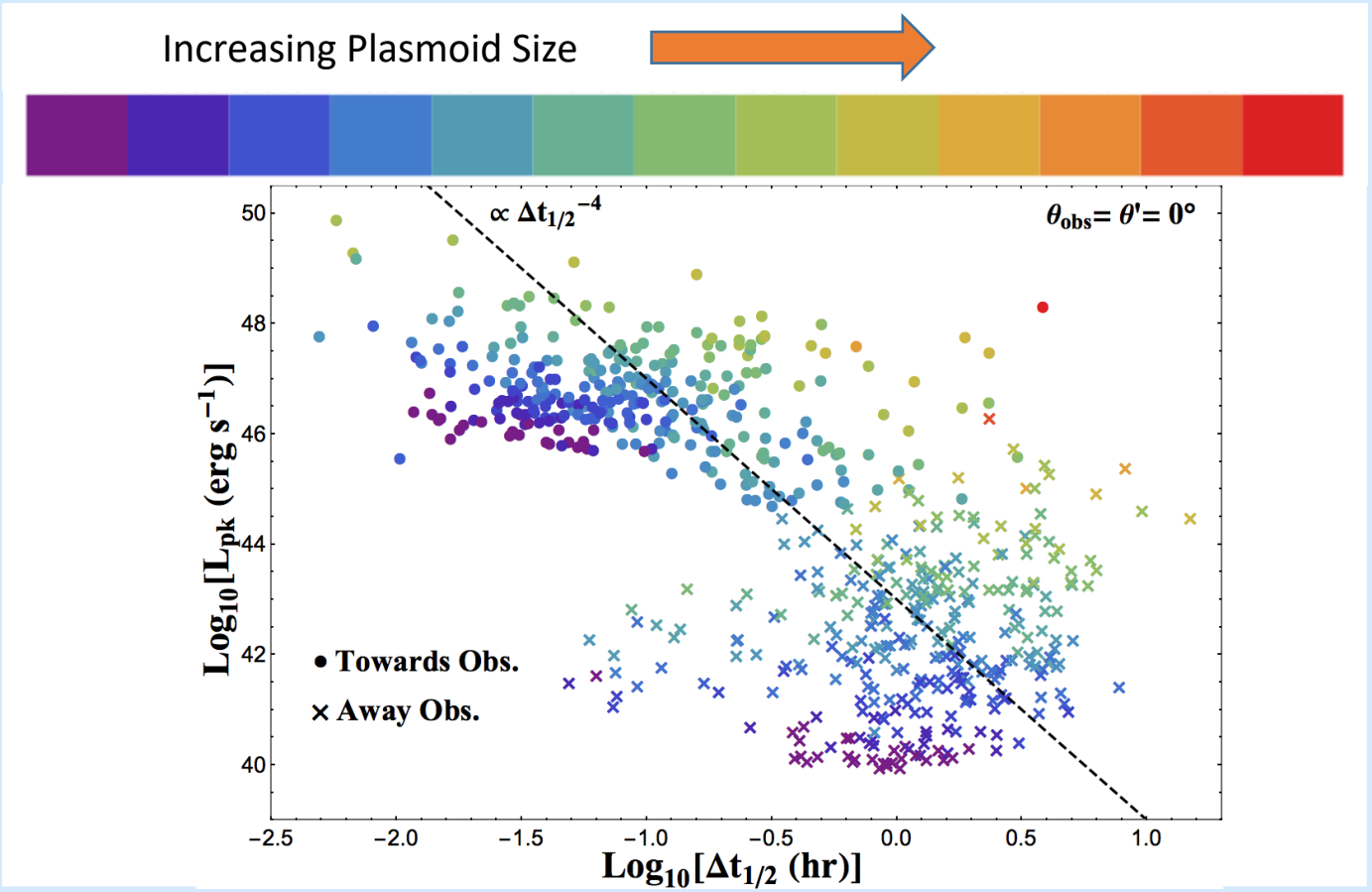
Jet Lorentz factor: 10
Size of Reconnection layer: 10^{16} cm
B-field: $4\ G$



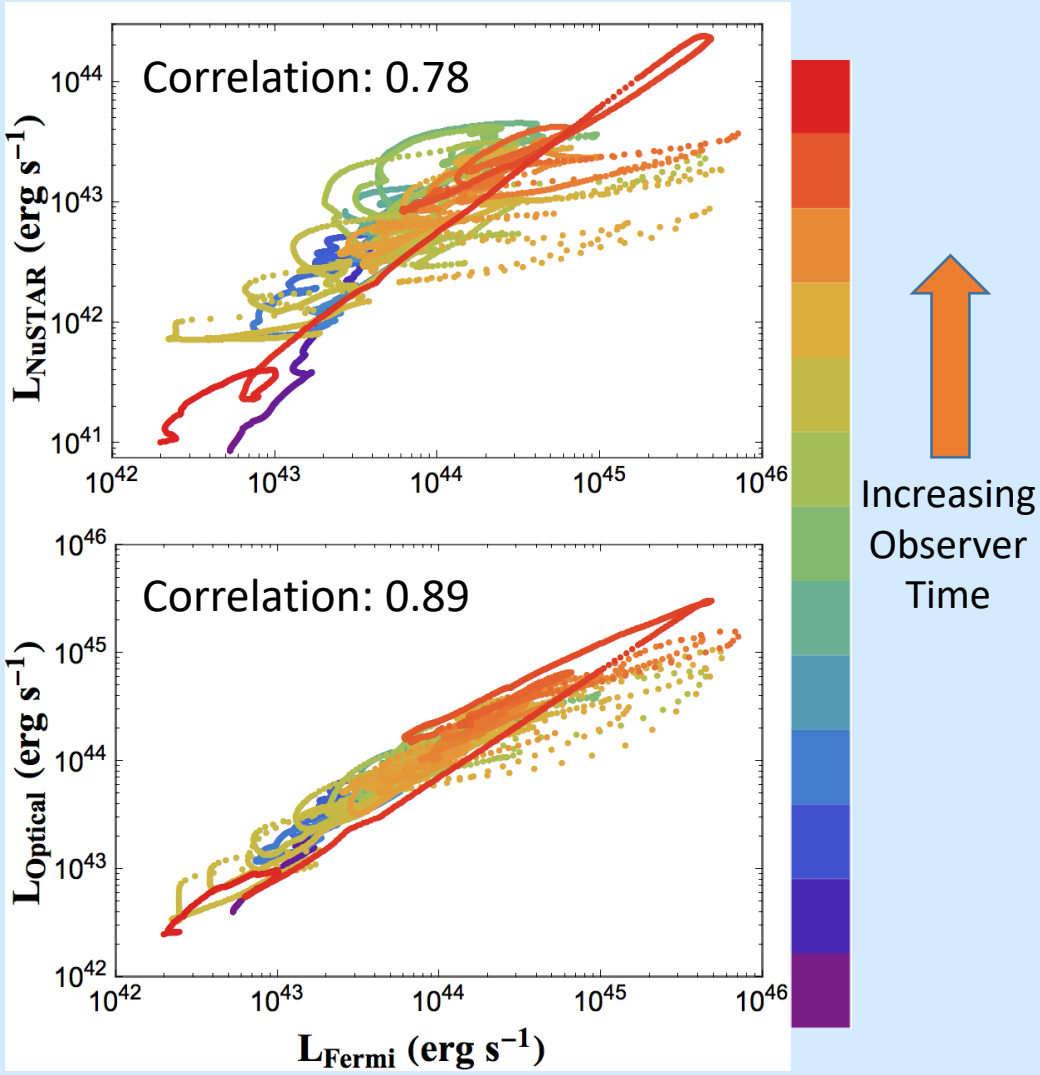
Additional Signatures

Flaring Statistics

Increasing Plasmoid Size



Christie et al. 2018



Christie et al. in prep.

Summary

- Our fundamentally-built model displays similar spectral features in FSRQs and BL Lacs!
- Requires few free parameters
- Can produce the fast (minutes) timescale and long (days) flares observed in many blazars!

Outlook

- Numerous comparisons with observations (e.g. PSDs, correlation, flaring statistics) to come!
  (Christie et al., in prep.)
- Inclusion of Hadronic components within model to determine potential neutrino flux
  (Christie et al., in prep.)

arXiv: 1807.08041