Probing Particle Acceleration with Multi-Wavelength Flare and Polarization

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Scientific Goals and Methods

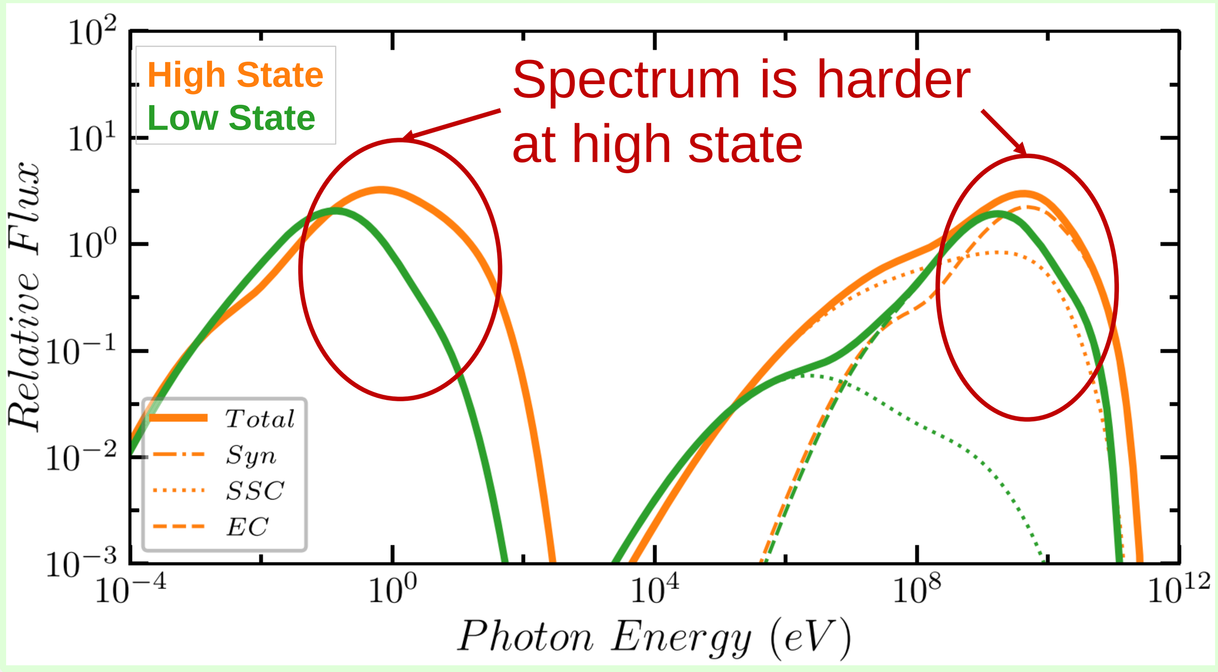
- Blazars exhibit highly variable multi-wavelength emission, implying strong particle acceleration in very localized regions.
- Shock, magnetic reconnection, and turbulence are potential particle acceleration mechanism that drives blazar flares.
- Previous works have not thoroughly explored how to distinguish those mechanisms with multi-wavelength radiation and polarization signatures.
- We use coupled **particle-in-cell and polarized radiation transfer** simulations to study observable patterns under first principles.
- We focus on the **multi-wavelength variability patterns** and try to **quantify the observable differences** of the three mechanisms.

Take Away Messages

- **All three mechanisms** exhibit **harder-when-brighter** trends.
- **All three mechanisms** show **energy stratification.**
- **Reconnection** uniquely produces **fast gamma-ray flares** via synchrotron self Compton during **major plasmoid mergers**.
- **Reconnection** show **correlated polarization angle swings and dips in the polarization degree** in the synchrotron component with **multi-wavelength flares** during **plasmoid mergers**.
- **Different mechanisms show different optical and X-ray polarization variability amplitudes and rates in high synchrotron peaked blazars**. We plan to quantify these differences to distinguish the three mechanisms.

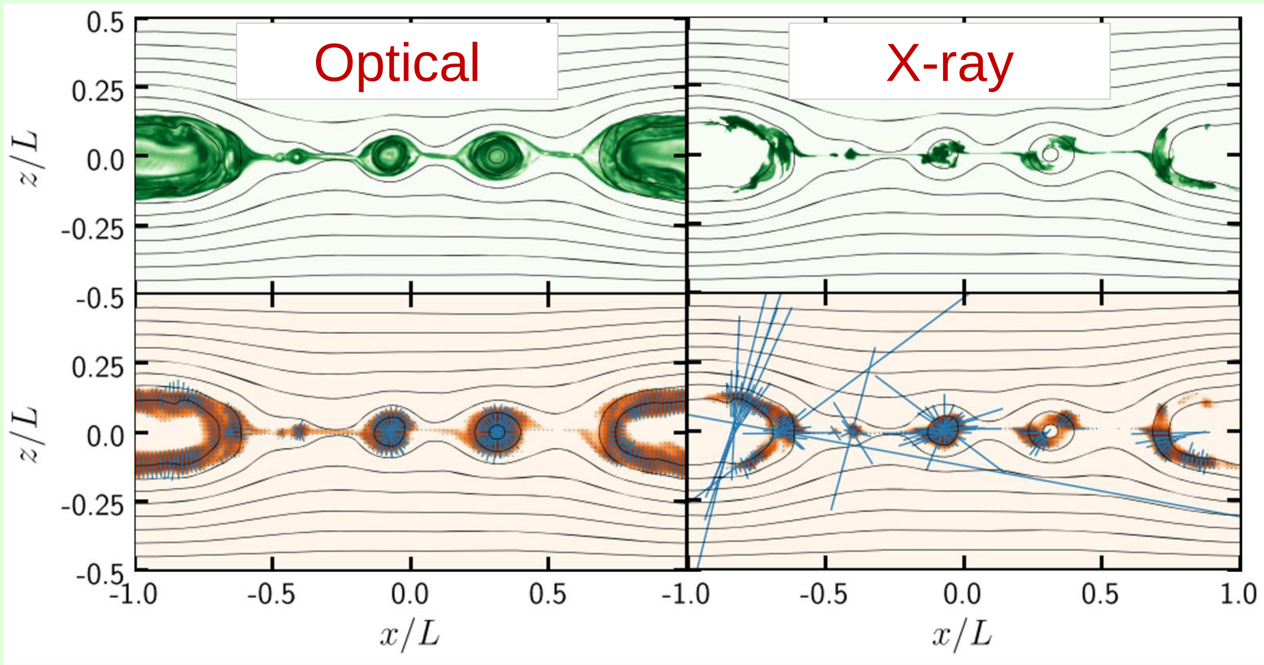
Harder-When-Brighter Trend

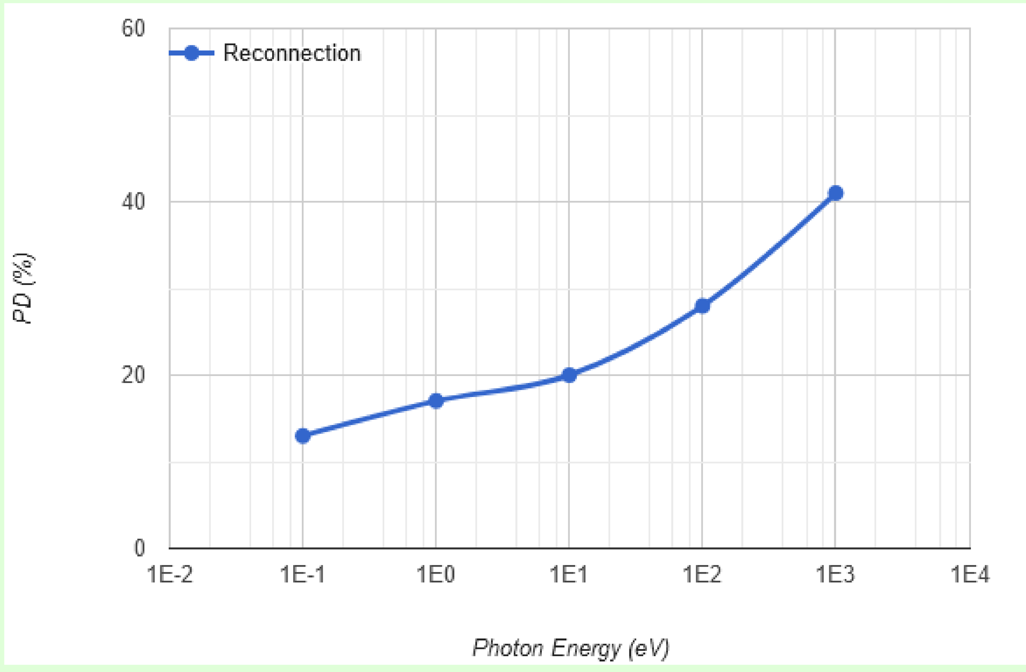
- Electron spectrum becomes harder, and, in some cases, the maximal energy increases during particle acceleration, resulting in the **harder-when-brighter** trend, sometimes even **shift in the synchrotron peak energy**.



Energy Stratification and Higher X-ray Polarization in High Synchrotron Peaked Blazars

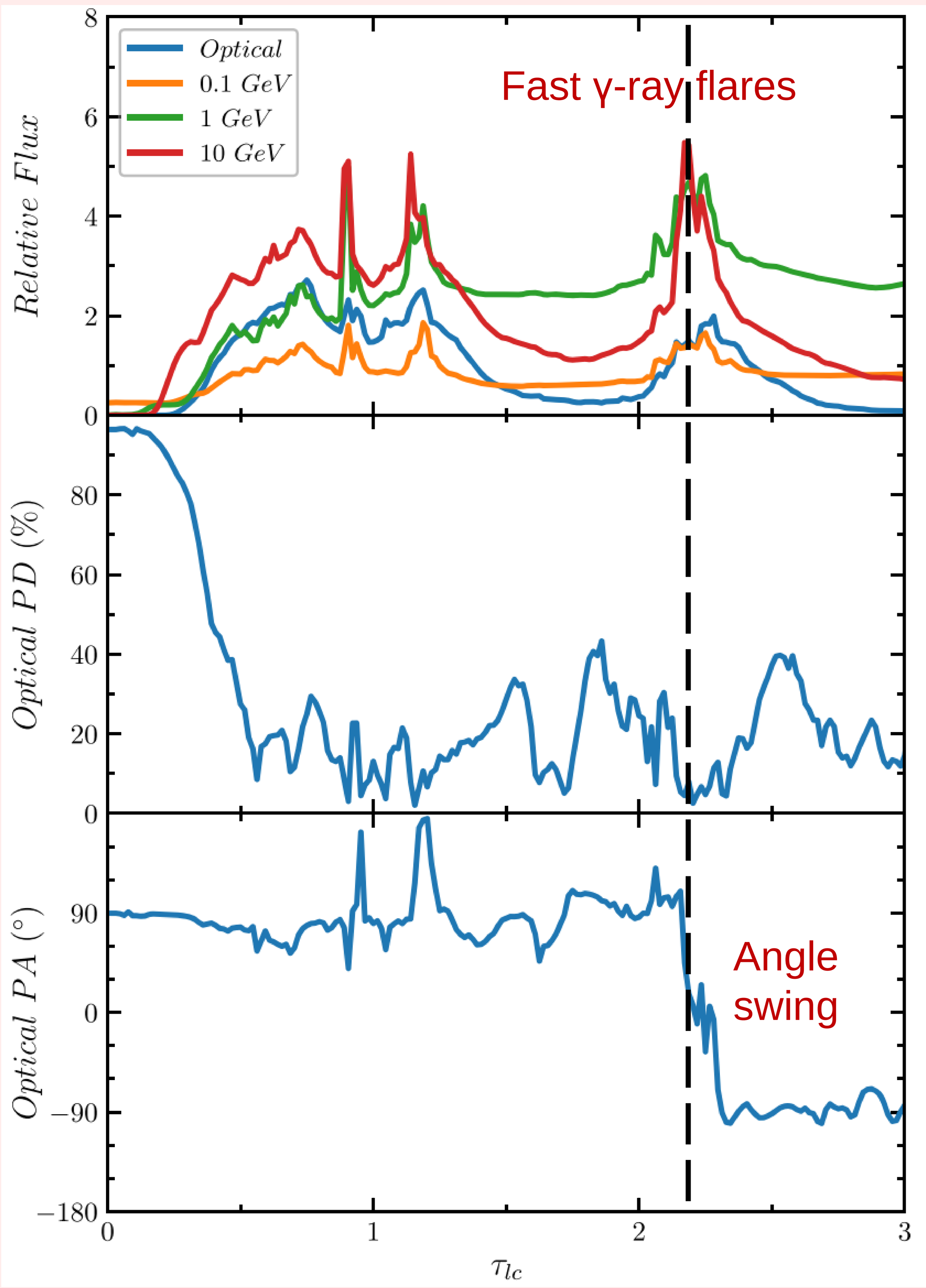
- **High-energy electrons** that emit X-rays **cool faster than low-energy electrons** that emit in optical band. Thus they can only **spatially transport (via e.g., advection and diffusion) to smaller areas** than the low-energy electrons, resulting in an **energy stratified distribution**.
- X-ray synchrotron emits in smaller regions with **less variations in magnetic field morphology** than the optical synchrotron, leading to **higher X-ray polarization**. **This applies to for all three mechanisms.**

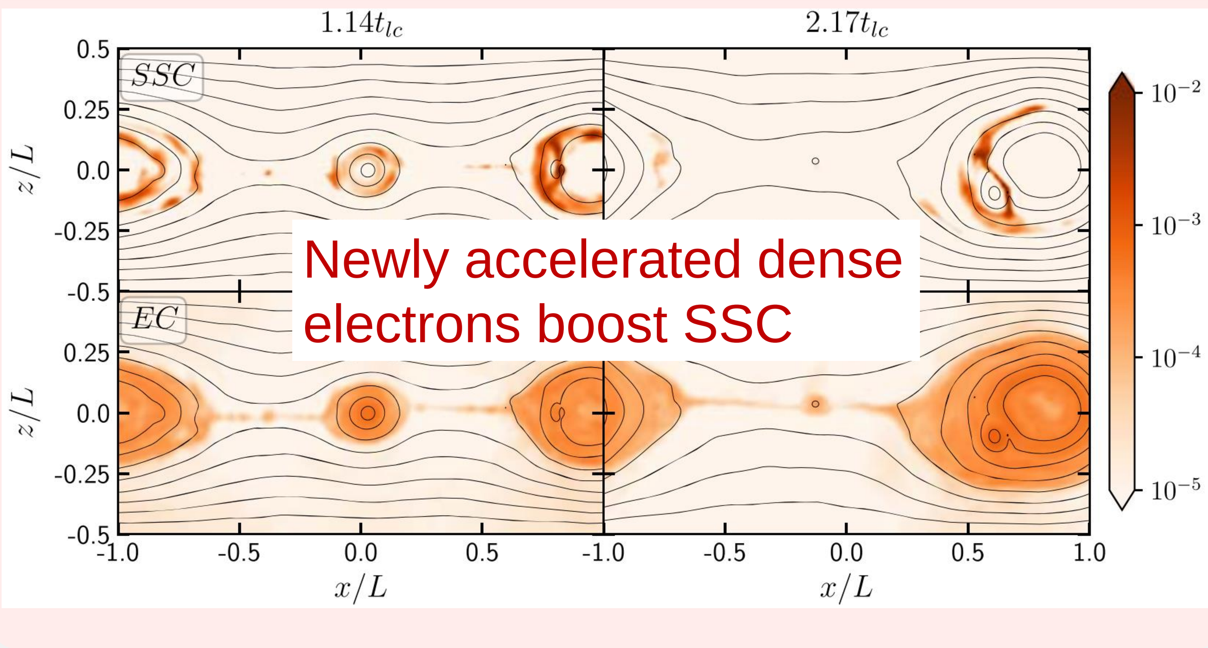




Fast γ-ray Flare and Angle Swing

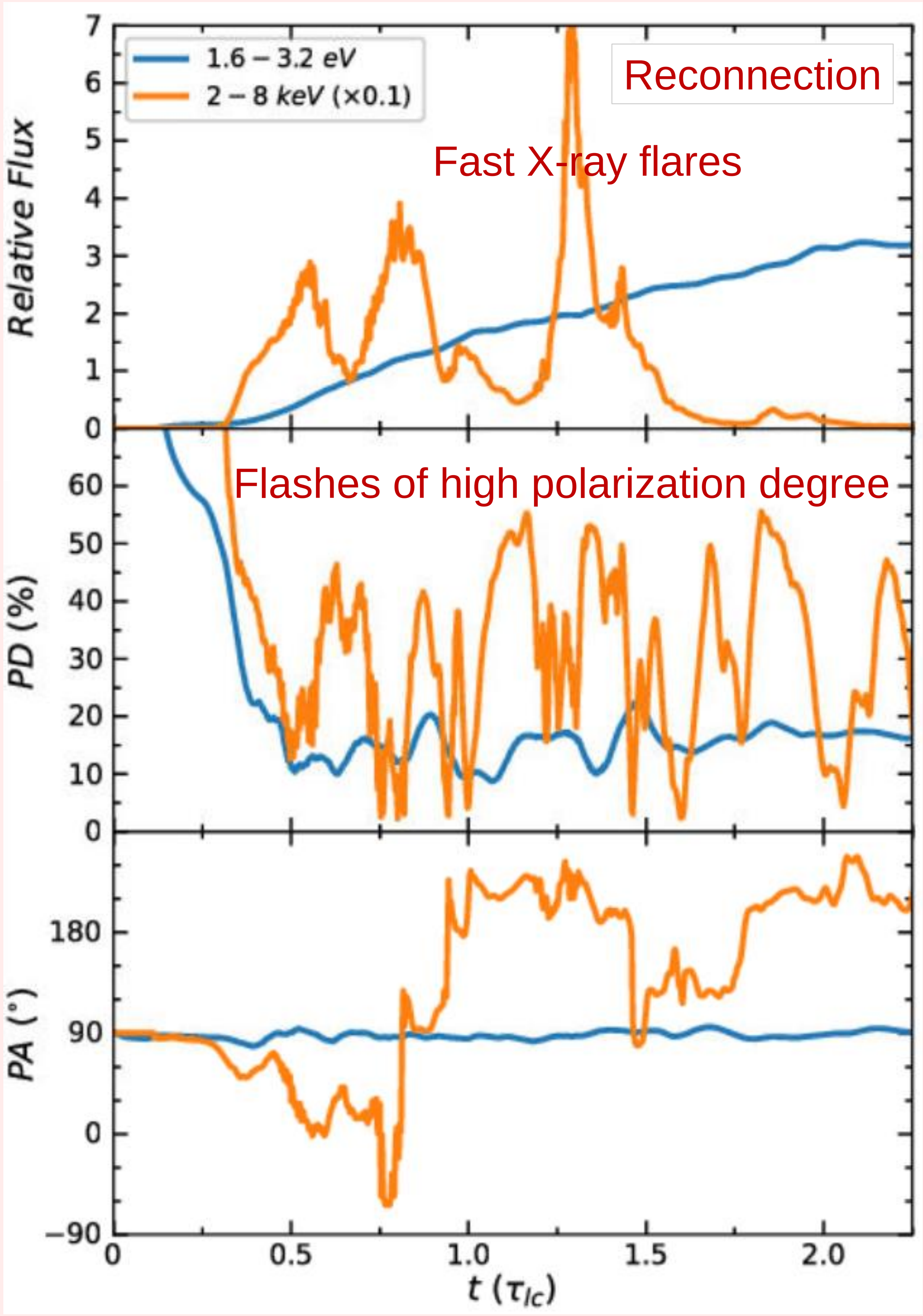
- **Plasmoid mergers in reconnection** trigger secondary reconnection, leading to **dense newly accelerated electrons**.
- The dense electrons boost synchrotron and external Compton by n but synchrotron self Compton by n^2, making **γ-ray flashes**.
- Electrons can **stream along the magnetic field lines** around the post-merger plasmoid, making **angle swings and dips in polarization degree correlated with flares**.

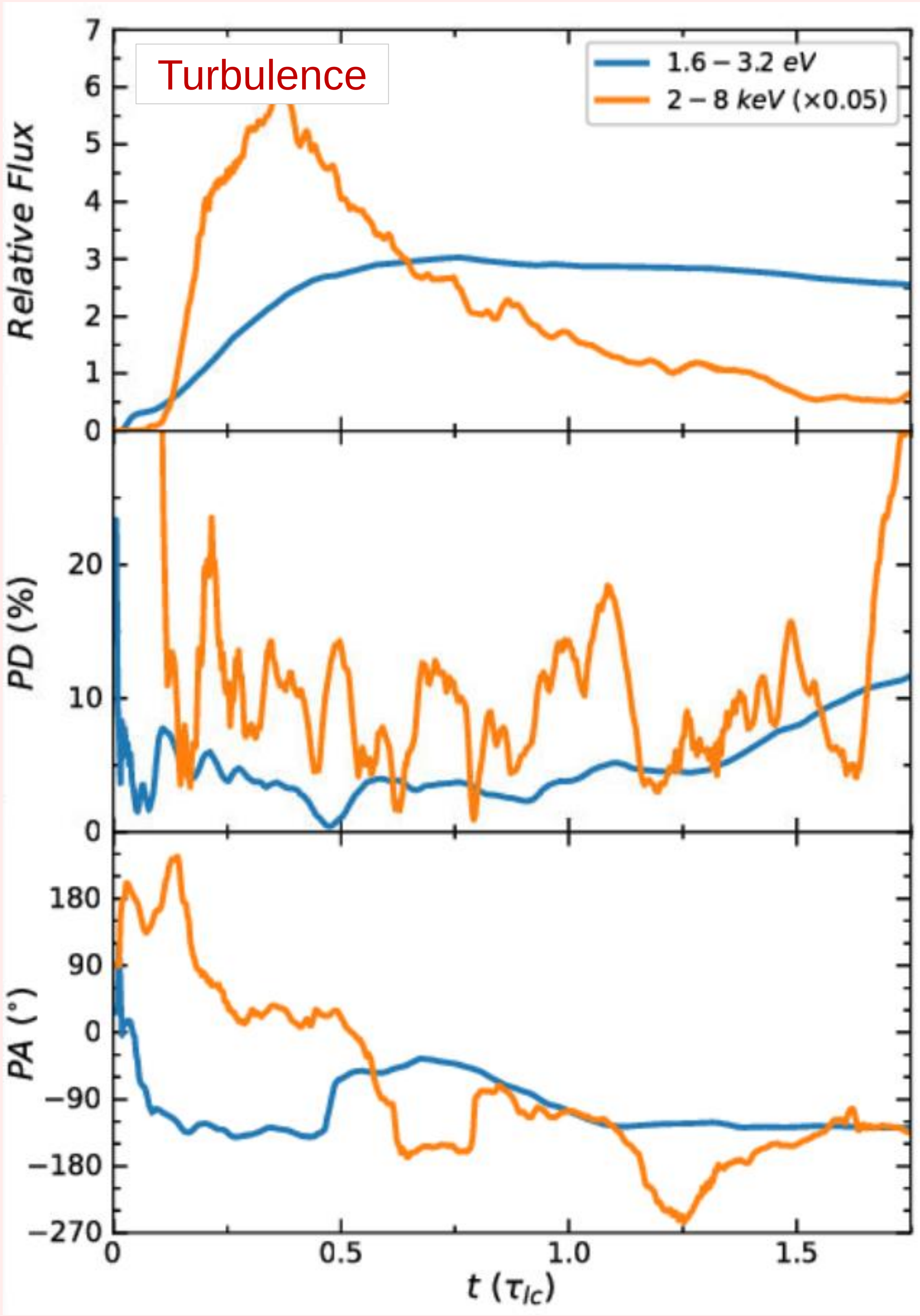




Optical and X-ray Polarization Variability of High Synchrotron Peaked Blazars

- **Reconnection shows much stronger variability in both flux and polarization in X-rays than optical band.**
- **Reconnection** can explain rare phenomena such as **fast X-ray** (and **TeV** if it is leptonic) **flares**, **flashes of X-ray polarized flare**, and **very high (>40%) X-ray polarization degree**.
- **Turbulence shows comparable variability in both flux and polarization in X-rays with optical band.**
- **Turbulence** can explain rare phenomena such as **uncorrelated optical and X-ray polarization angle swings** and **orphan angle swings in either optical or X-ray bands**.
- We will quantify variability patterns, such as the polarized flare amplitude and duration, by adding a quiescent component to the flaring simulations. These patterns can distinguish the three mechanisms.





References

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