Describing the ultra fast very-high-energy gamma-ray flare of IC 310 with relativistic reconnection models

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Nordic-Baltic Astronomy Days
Turku, May 26-29 2026

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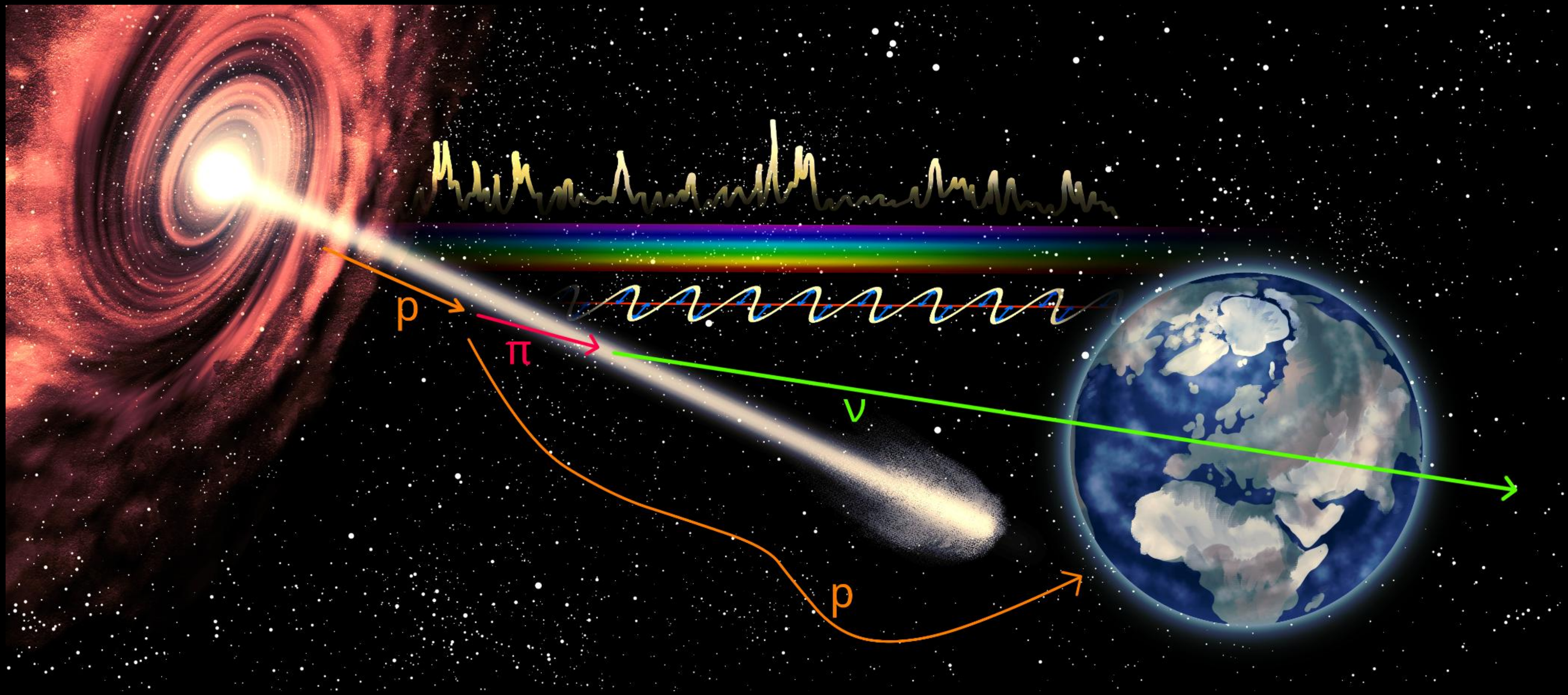
Relativistic jets

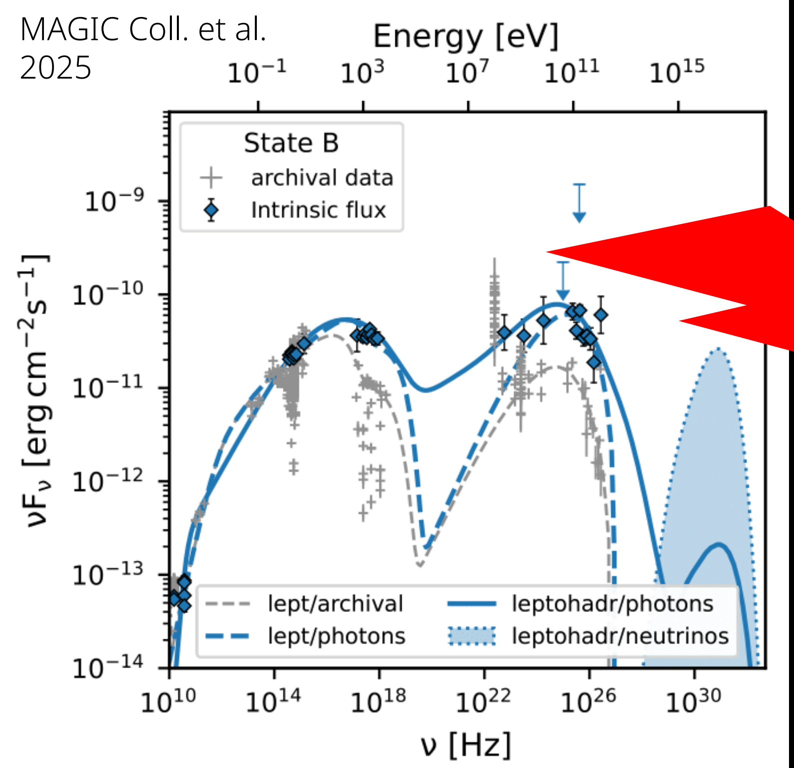
- In a small fraction of AGNs, relativistic jets are shooting out from the vicinity of the SMBH
  - Among the most extreme particle accelerators in the universe
  - In blazars, the jet is pointing towards us: extreme luminosities and variability across the whole electromagnetic range
    - In radio galaxies, the jet inclination is slightly more misaligned, 10–20°

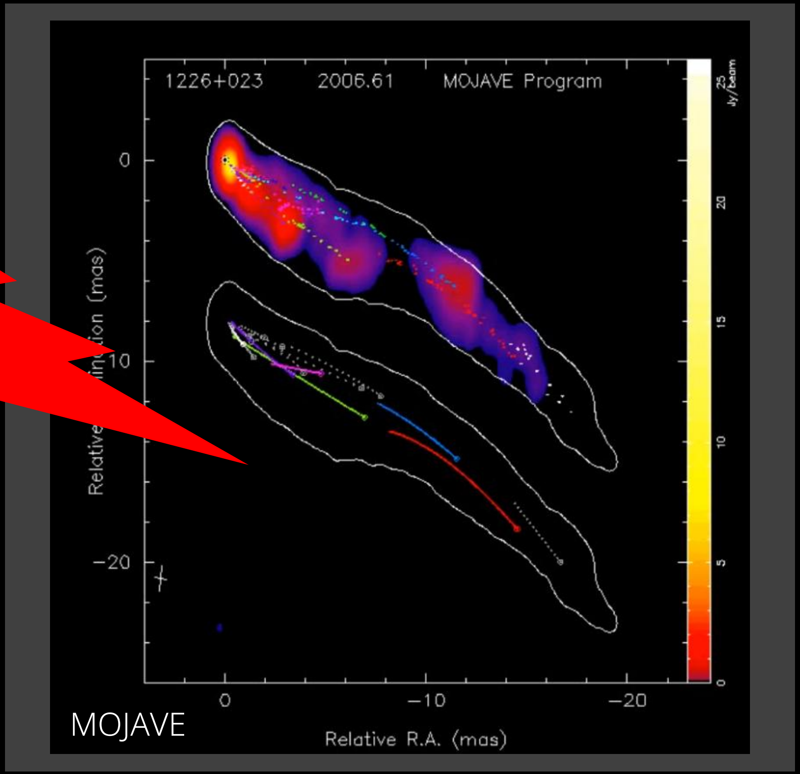


Characteristics of the jet – how to uncover them?

- Multiwavelength observations give us some characteristics of the jet
  - Fitting the spectral energy distribution (SED) with expected emission components
- Very long baseline interferometry (VLBI): mapping the inner jet structure in detail
- Results from the SED modelling and VLBI don't always agree → We need additional constraints!

- Emission region size
- Doppler factor
- Magnetic field strength
- Jet power
- …

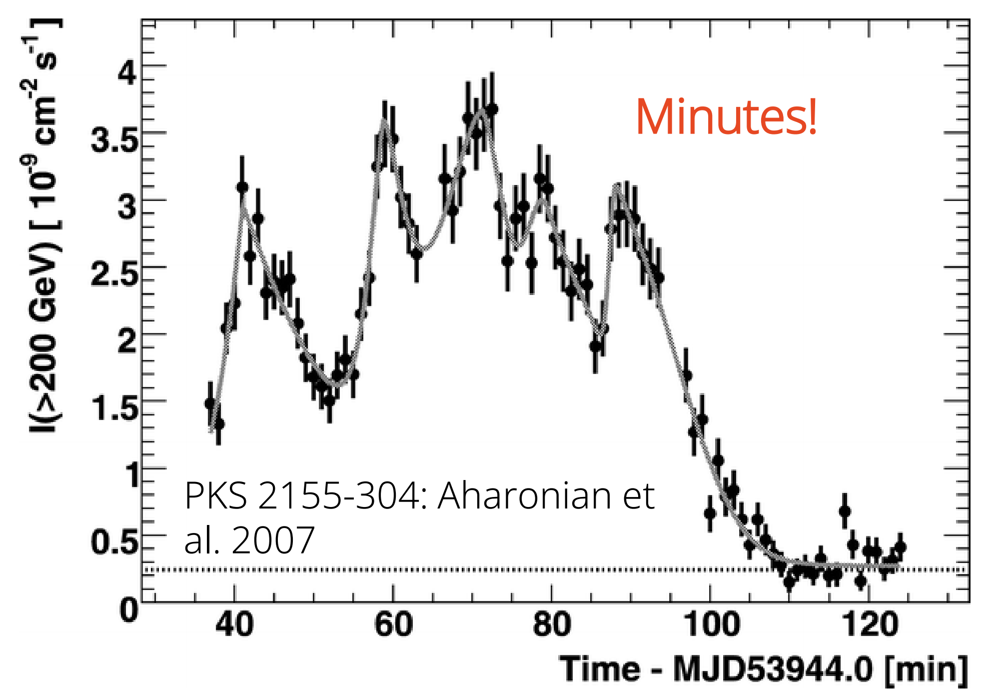


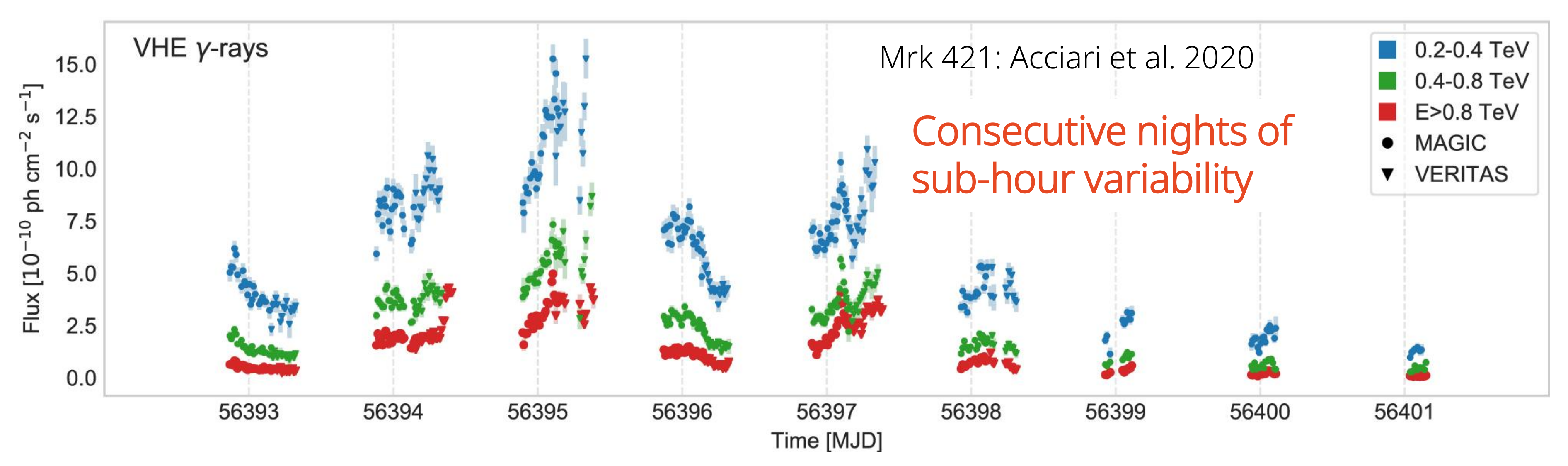


- Jet speed
- Viewing angle
- Bulk Lorentz factor
- Magnetic field strength

Fast gamma-ray flares

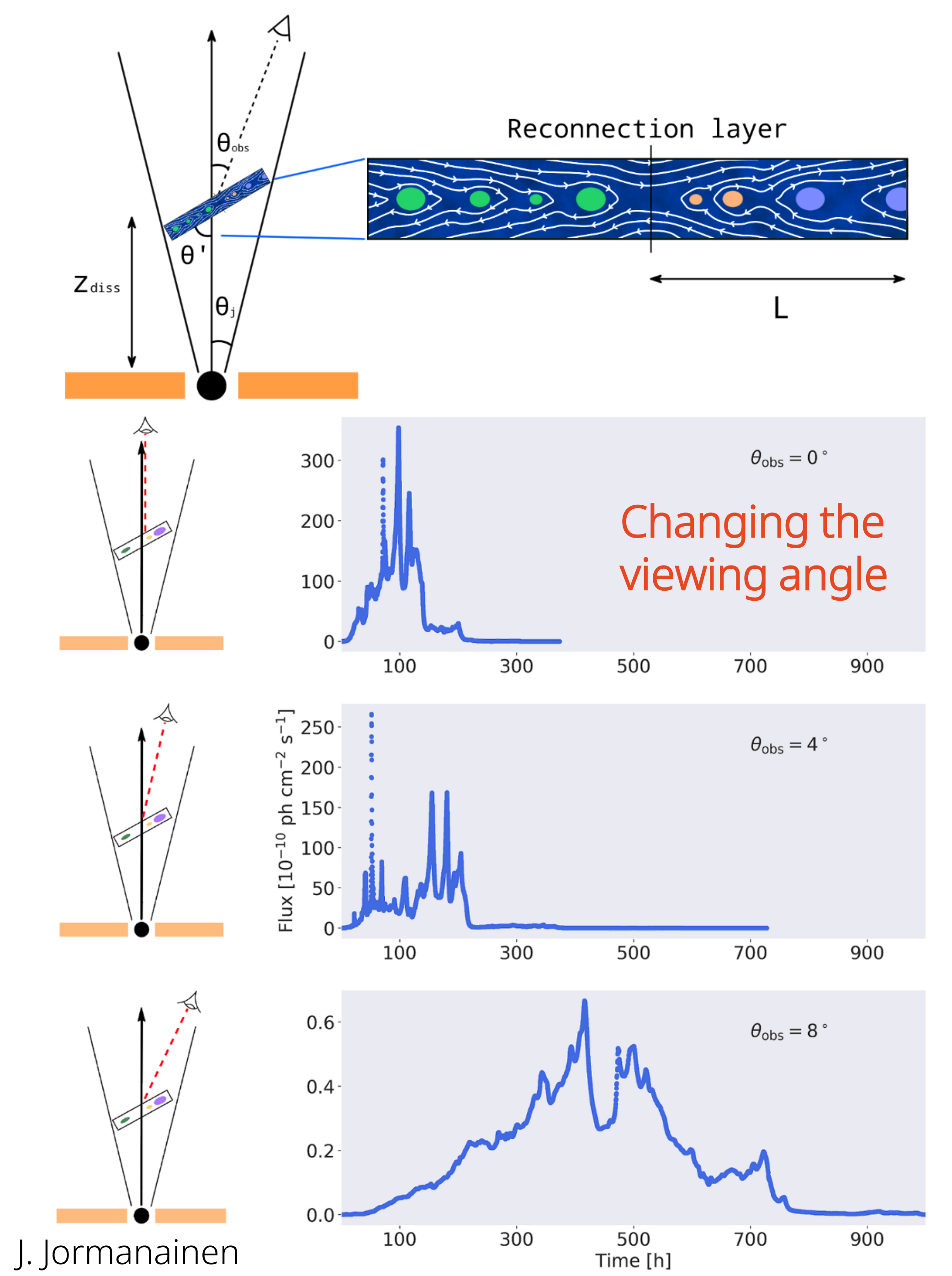
- Extremely fast flares seen from a handful of blazars in the very high energy (VHE) gamma rays (100 GeV – 100 TeV)
- Many models to explain this variability
    - Shock models describe the slower variability well
    - Need a mechanism that can produce fast flares → Magnetic reconnection is one possibility





Simulating reconnection in relativistic jets

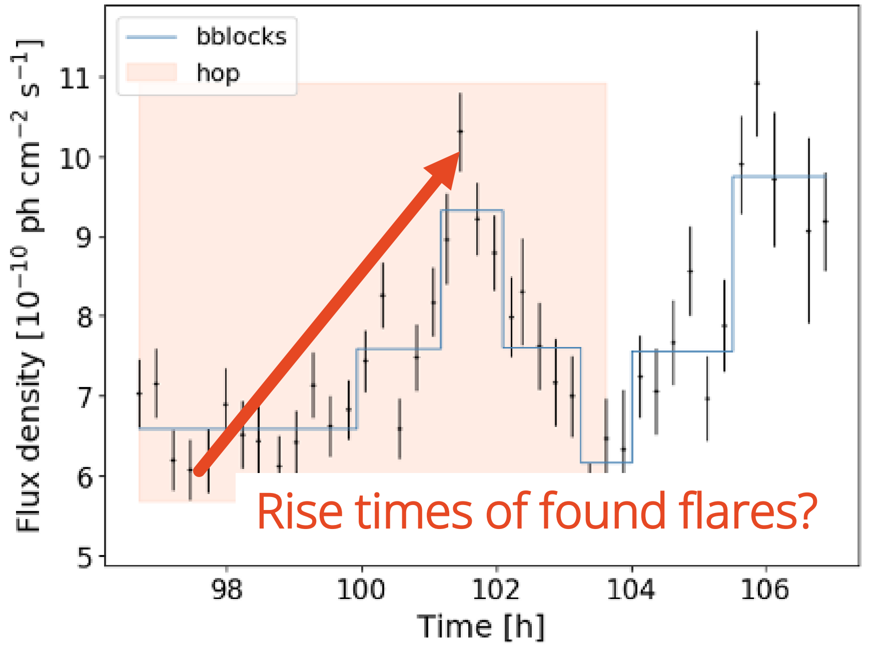
- Instabilities of the jet create current sheets where magnetic reconnection takes place
  - Current sheets (reconnection layers) are unstable to tearing → break into a chain of plasmoids
- A model presented in Christie et al. 2019: the results of 2D particle-in-cell simulations coupled with radiative transfer → simulated light curves
  - Assume that the reconnection event outshines the rest of the jet
  - Obtain different jet scenarios by varying the jet parameters

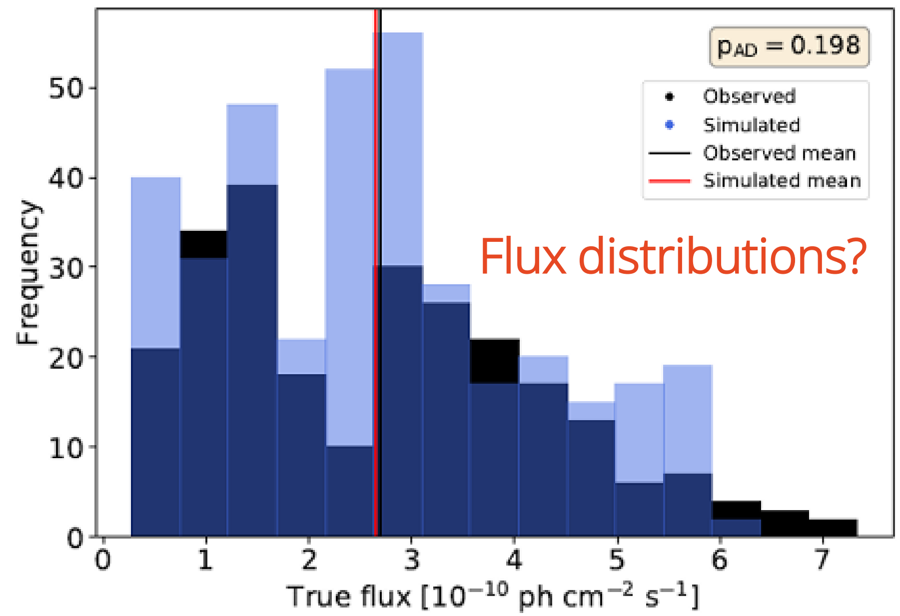


J. Jormanainen

How to compare the observations?

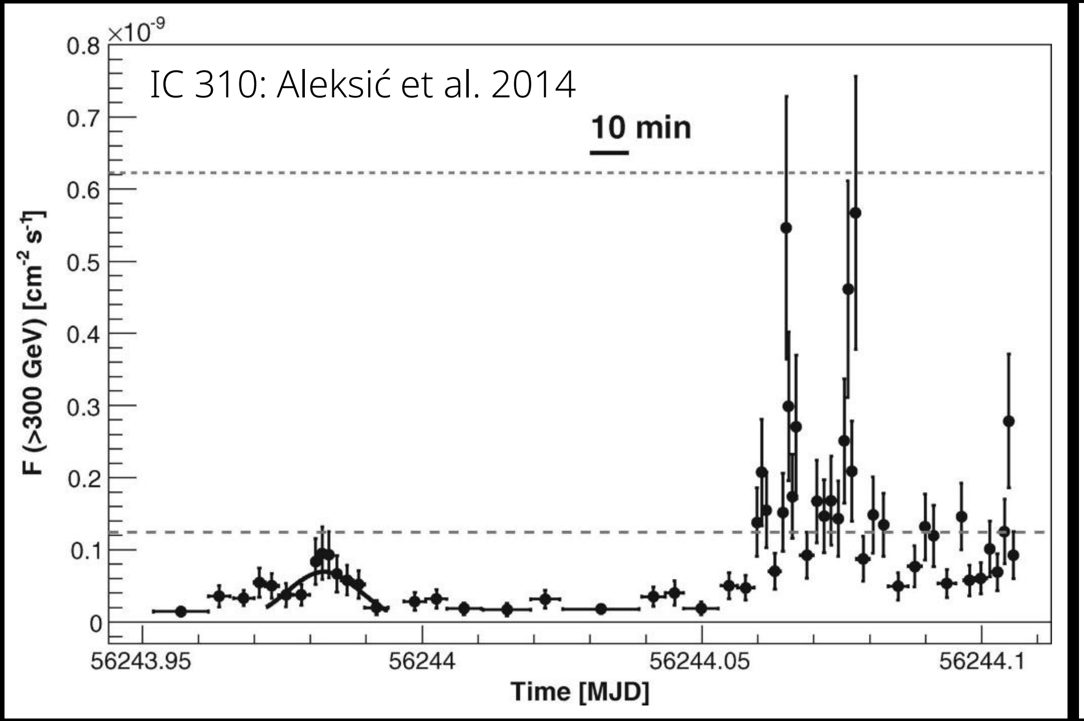
- [Jormanainen et al. 2023, A&A, 678, A140](#):
  - Developed a methodology for the comparison of simulated and observed light curves
    - Comparing the time scales and flux amplitudes
  - We were able to constrain the viewing angle and magnetic field strength for one test blazar, Mrk 421

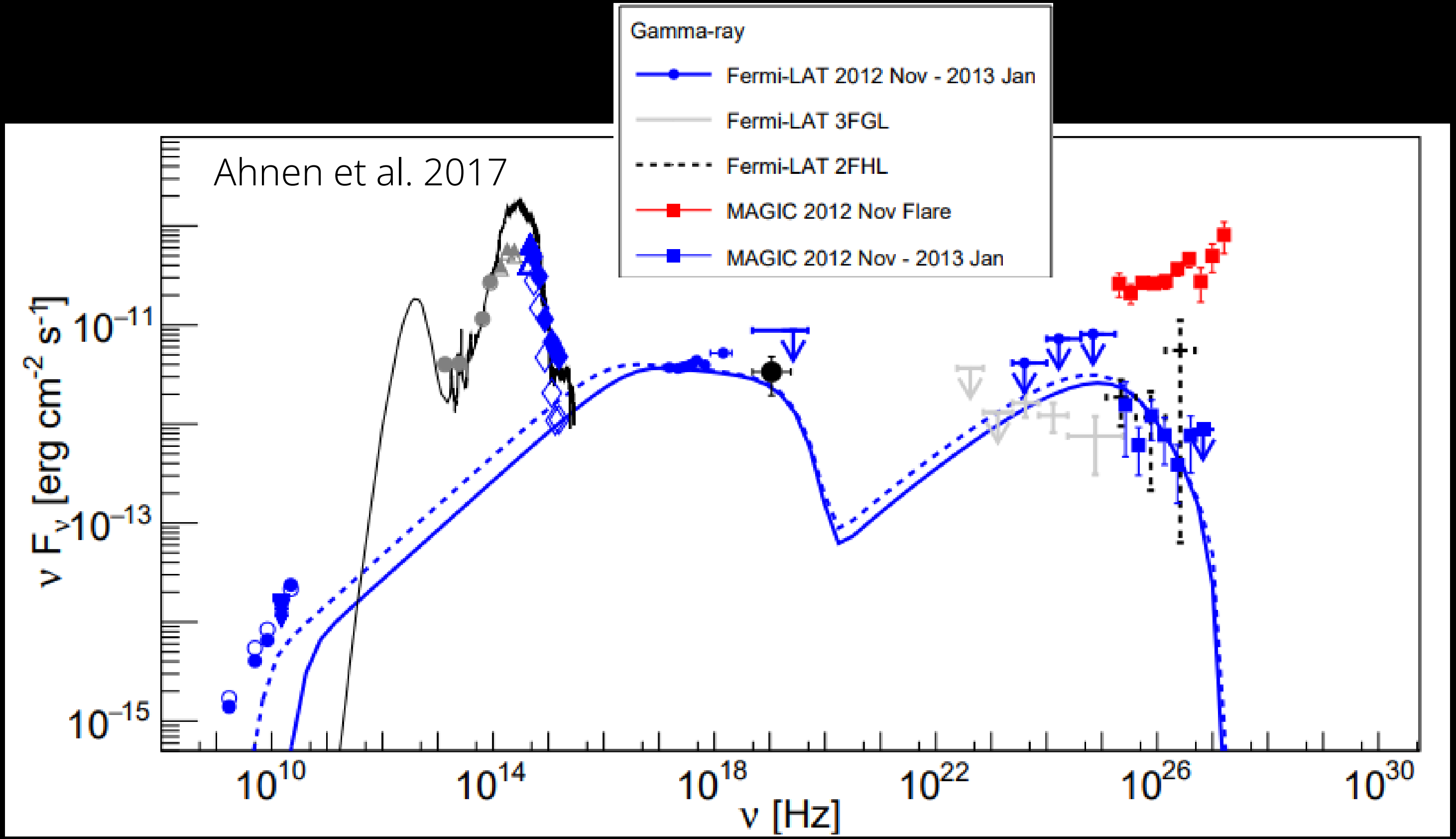




The case of IC 310

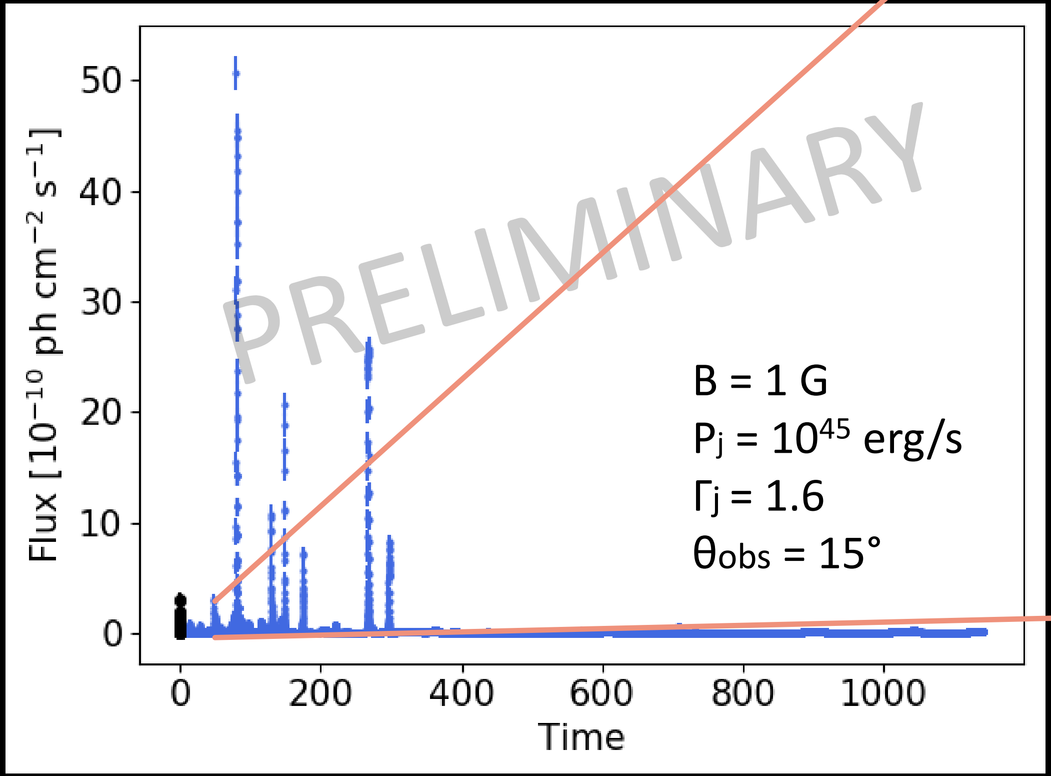
- IC 310, a radio galaxy, underwent an extreme flaring episode in 2012, "a black hole lightning"
- The light curve shows variability with doubling time scales faster than 4.8 minutes
- Also the spectrum reflects the extreme nature of this vs the average behaviour of the source
- Remarkable: a more misaligned jet means less Doppler boosting!

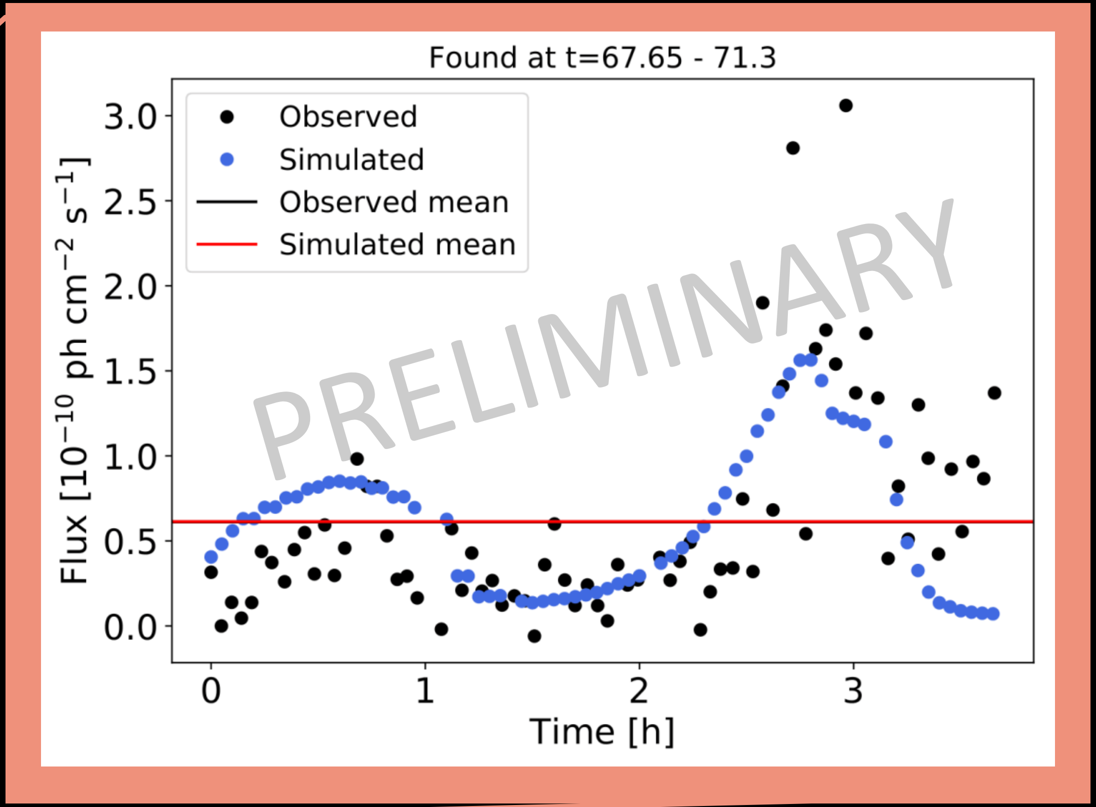




The case of IC 310

- Jormanainen et al. (in prep.):
  - We find similar behaviour as in the observed data: conveniently aligned layer offers more Doppler boosting vs the greater jet inclination
  - Magnetic reconnection is stochastic: we are not looking for exact patterns and similarity
  - Still want to compare the spectra





Summary

- Simulations that can produce light curves an important bridge between observations and theory
  - Comparing simulations with observations help narrow down the parameter space
  - Possibility of using these methods in different time scales and energies
- Strong constraints can be placed to still find matching simulations!
- IC 310: Extreme variability and SED shape
  - Want to match both the SED and the light curve

Paper coming soon!

Backup

Backup: The case of IC 310

- Jormanainen et al. (in prep.):
  - Similar approach as in Jormanainen et al. 2023 but consider the statistical tests that can be used with the short observed data (fewer data points, fewer found flares)
  - We simulated 360 jet scenarios: rule out cases e.g. based on flux level and fastest timescales!