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

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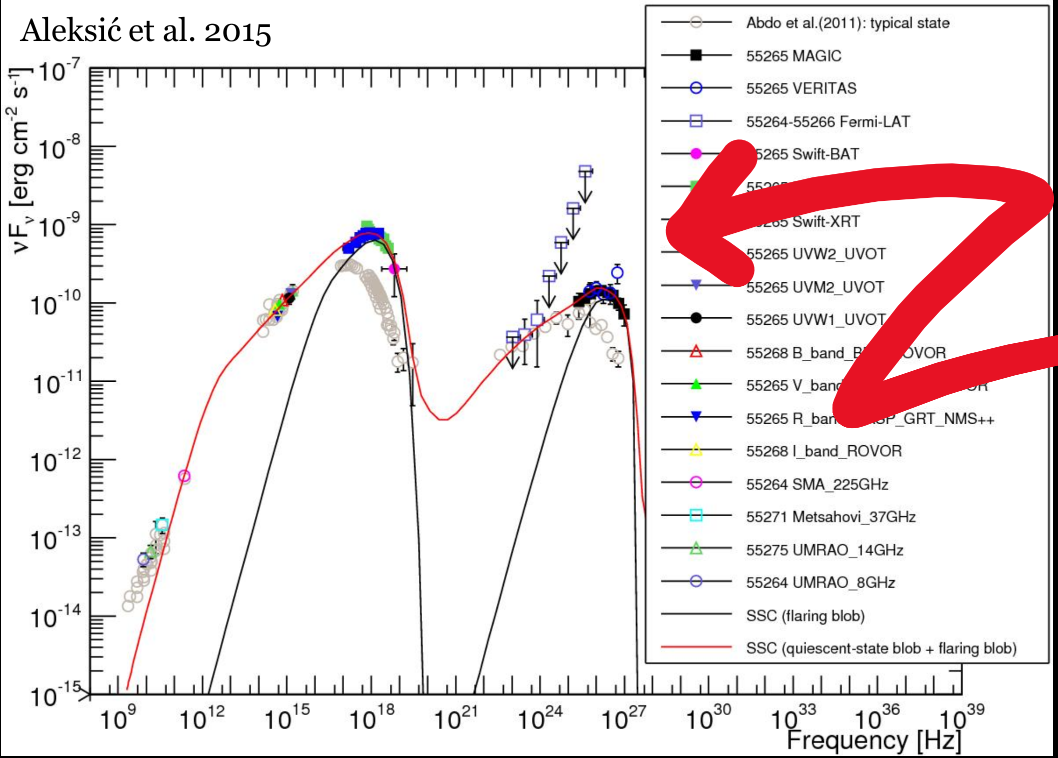
Relativistic jets

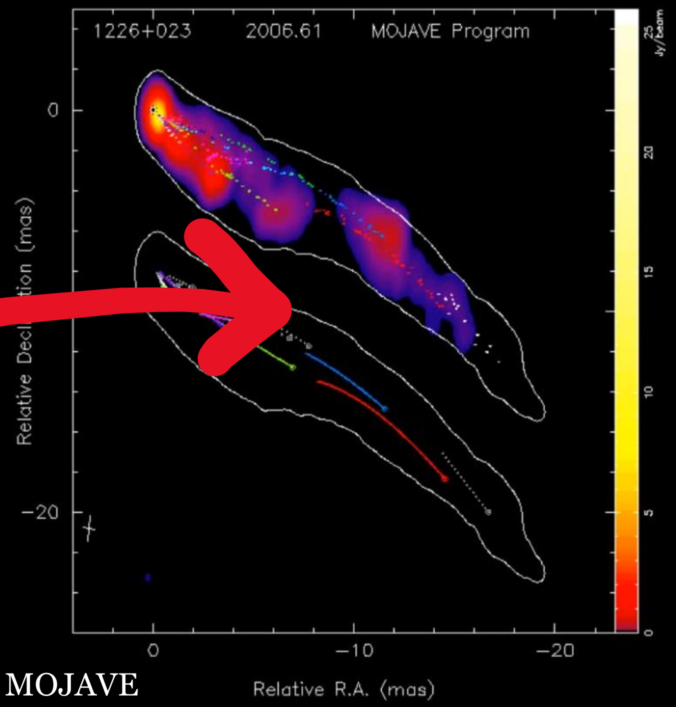
- In a small fraction of AGN we see relativistic jets shooting out from the poles of the BH
  - Among the most extreme particle accelerators in the universe
  - In blazars, the jet is seen pointing towards us: extreme luminosities and variabilities across the whole electromagnetic range
    - In radio galaxies, the jet inclination is slightly more misaligned, 10-20°

Marscher et al., Wolfgang Steffen, Cosmovision, NRAO/AUI/NSF

Characteristics of the jet – how to uncover them?

- Multiwavelength observations can be used to estimate some characteristics of the jet
  - Fitting the spectral energy distribution (SED) with expected emission components
- Very Long Baseline Interferometry (VLBI) can be used to map the inner jet structure in detail
- Results from the SED modelling and VLBI don't always agree, and there are also parameters we cannot constrain with these methods, thus additional constraints are needed





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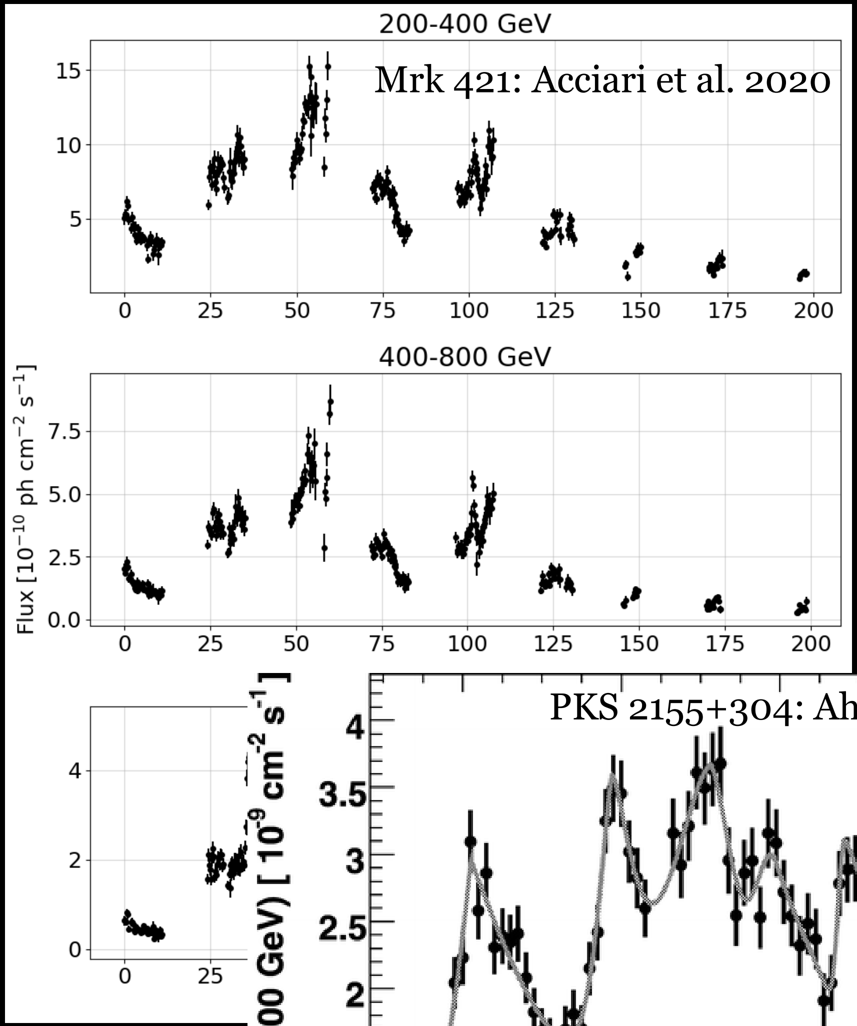
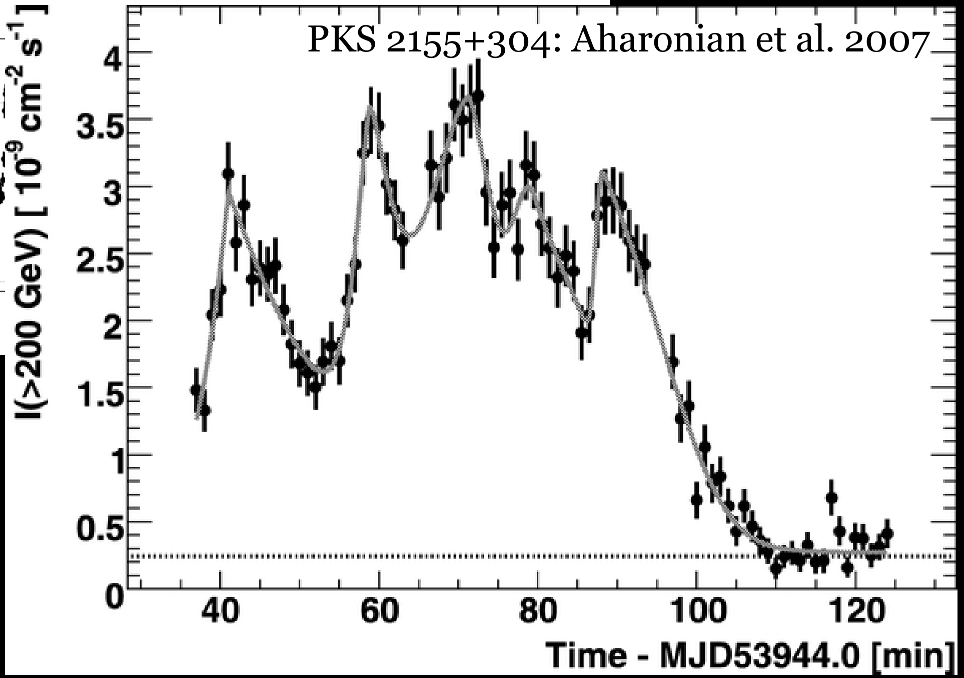


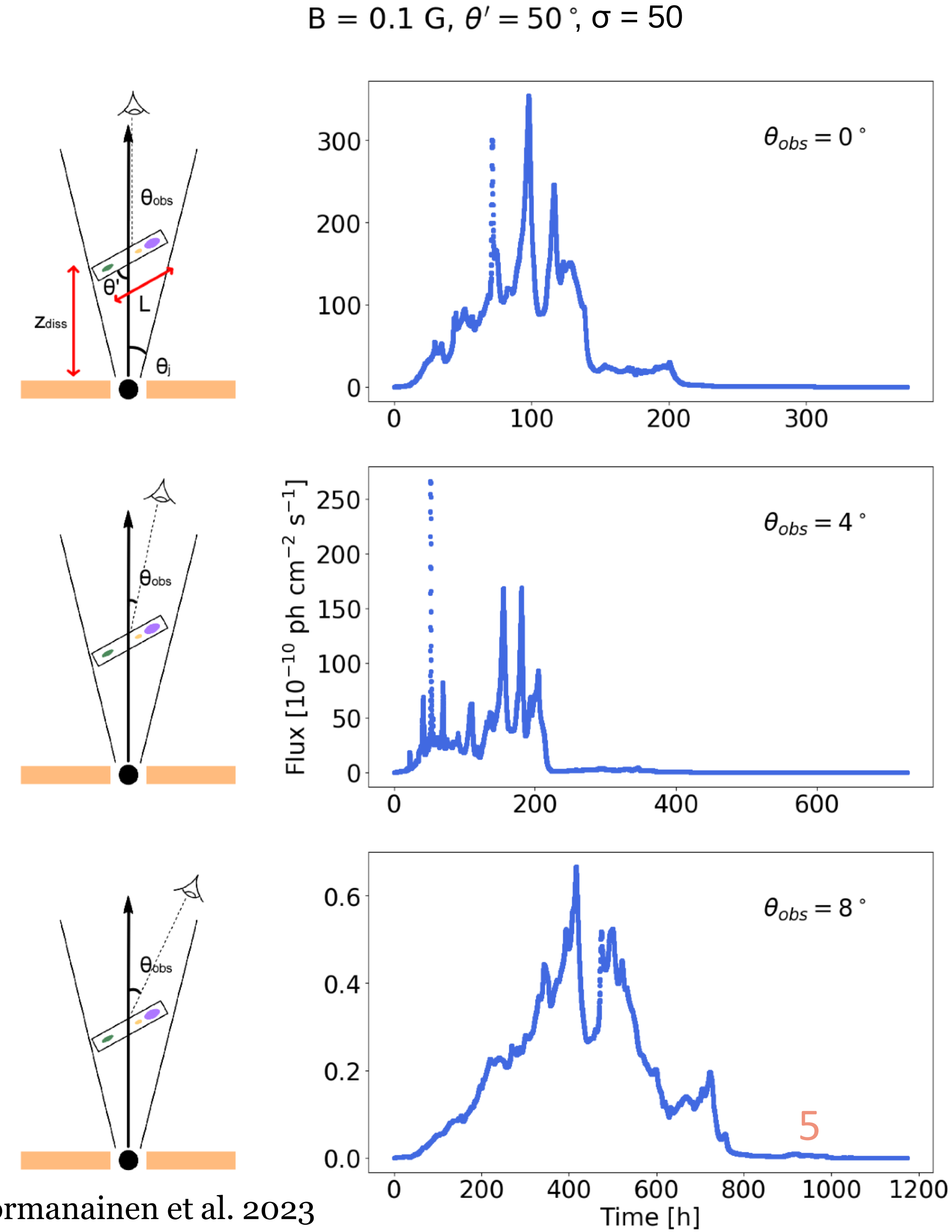


Fast gamma-ray flares

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

Simulating magnetic reconnection in blazar jets

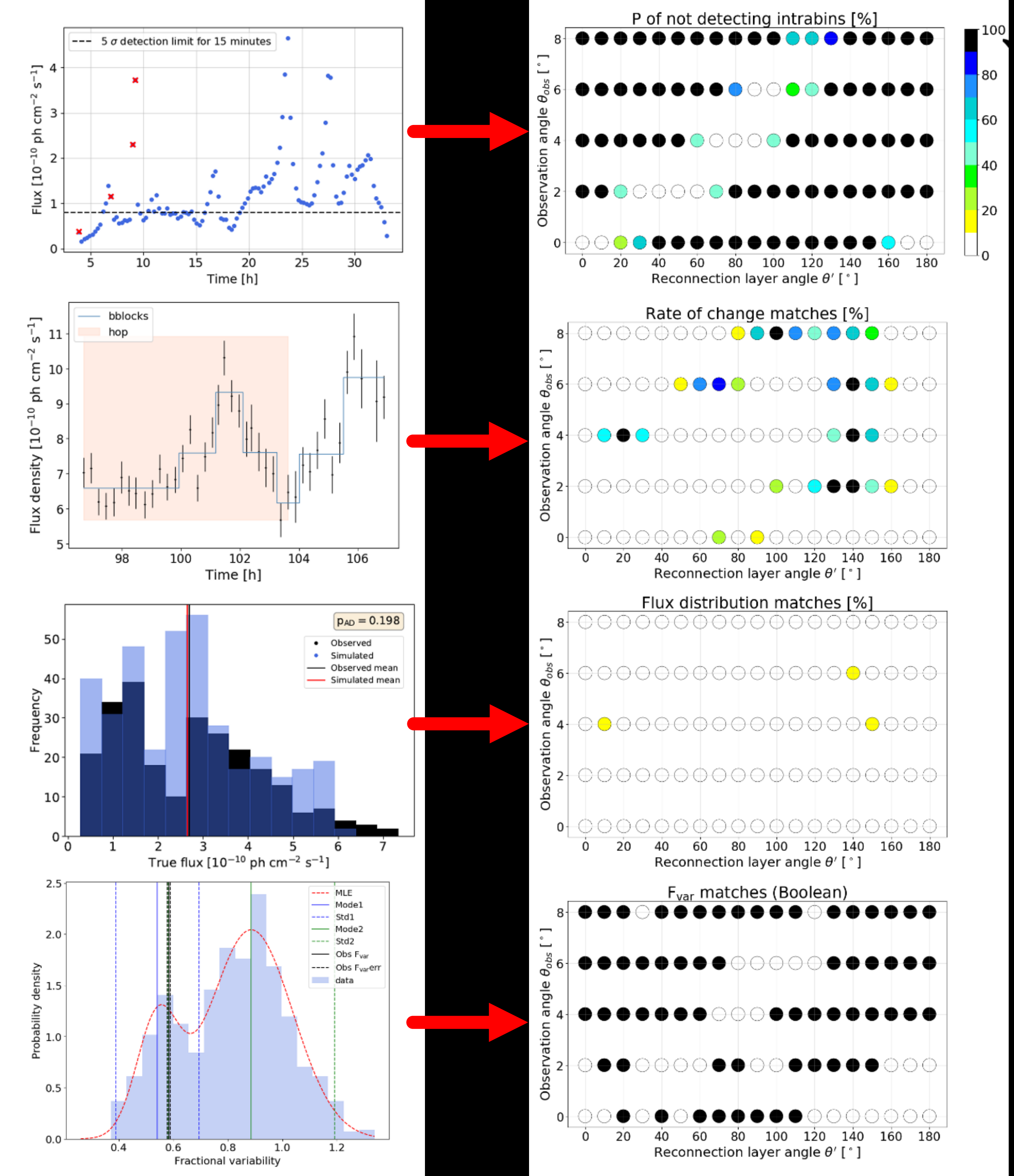
- One possible model of magnetic reconnection in blazar jets presented in Christie et al. 2019:
  - Instabilities of the jet create current sheets where reconnection takes place
  - Current sheets (reconnection layers) are unstable due to tearing instability → break into **a chain of plasmoids**: "blobs"
- 2D particle-in-cell-inspired simulations coupled with radiative transfer to produce simulated light curves
  - Obtain **different jet scenarios** by varying the jet parameters such as the viewing angle



Jormanainen et al. 2023

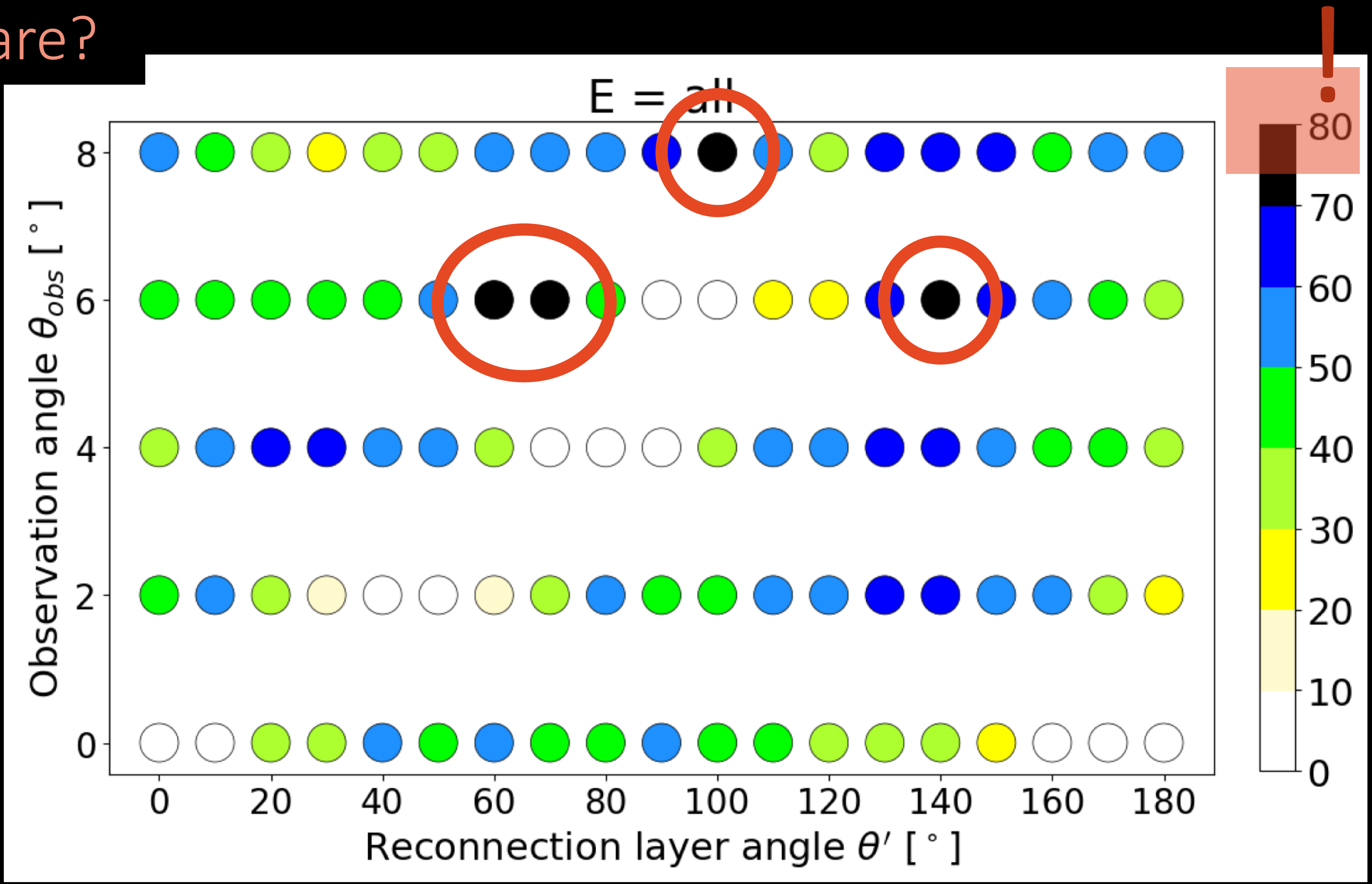
How do we compare?

- **Jormanainen et al. 2023, A&A, 678, A140:**
  - Developed a methodology for comparison of the simulated and observed light curves
  - Used Mrk 421 (Acciari et al. 2020) as a test subject
  - Comparison of…
    - Timescales
    - Flux amplitudes



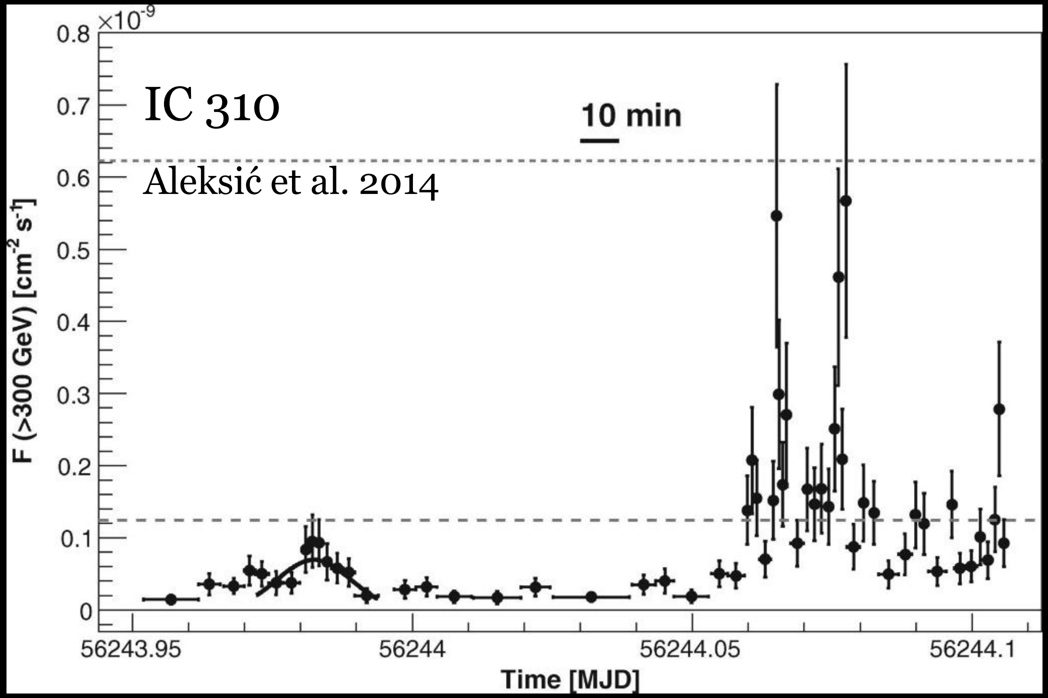
How do we compare?

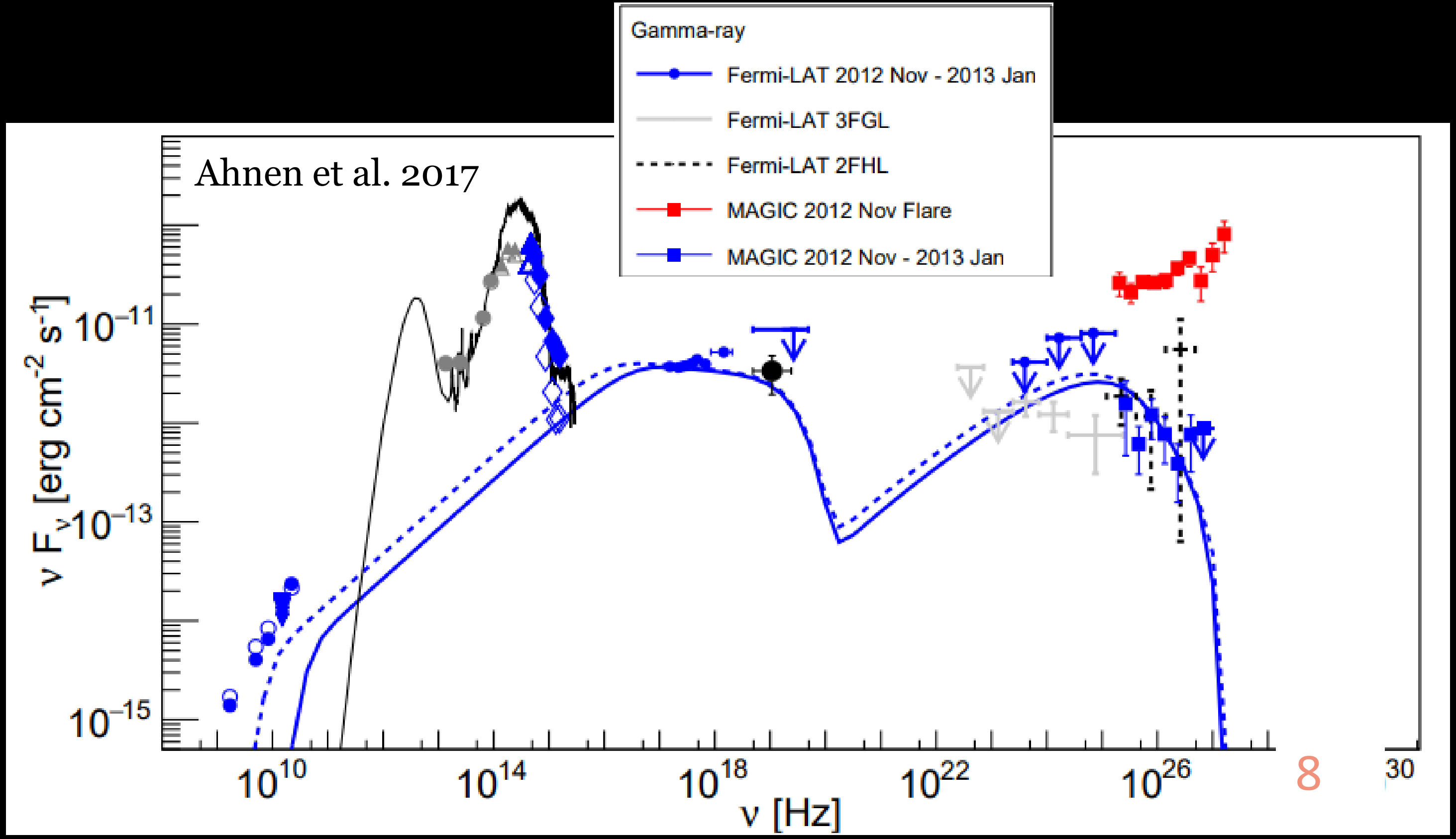
- By combining the results from these tests we obtained the final result
- Best matching simulations are at viewing angles of 6 and 8 degrees with B = 0.1 G
  - In this case the misaligned layer could be the solution to the Doppler crisis



The case of IC 310

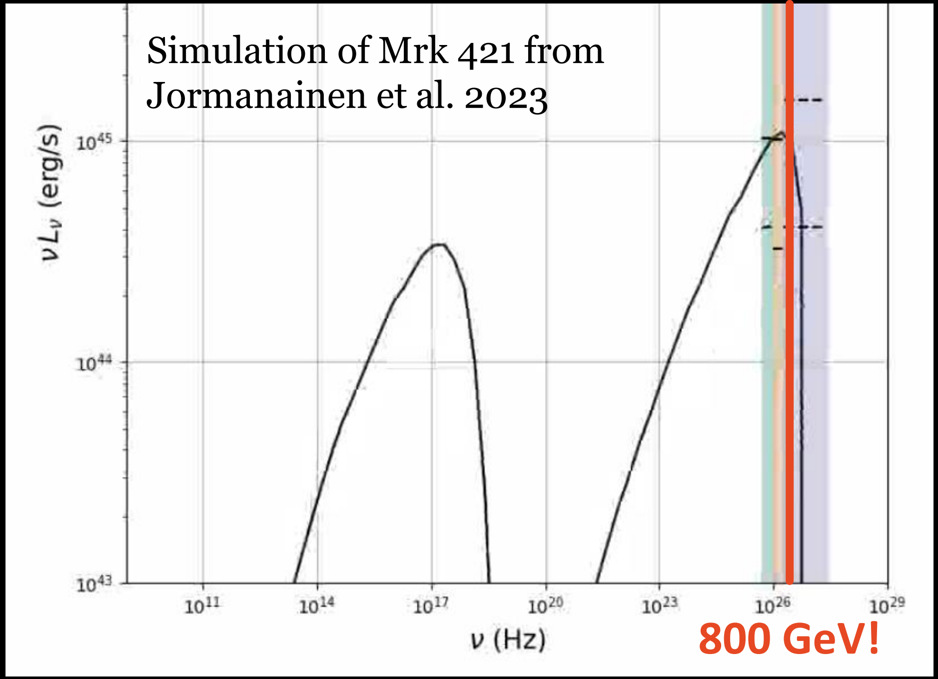
- IC 310, a radio galaxy, underwent an extreme flaring episode in 2012, ”a black hole lightning”
- The light curve shows variability with doubling time scales faster than 4.8 minutes
- Also the spectrum reflects the extreme nature of this event in comparison to the longer term average behaviour of the source

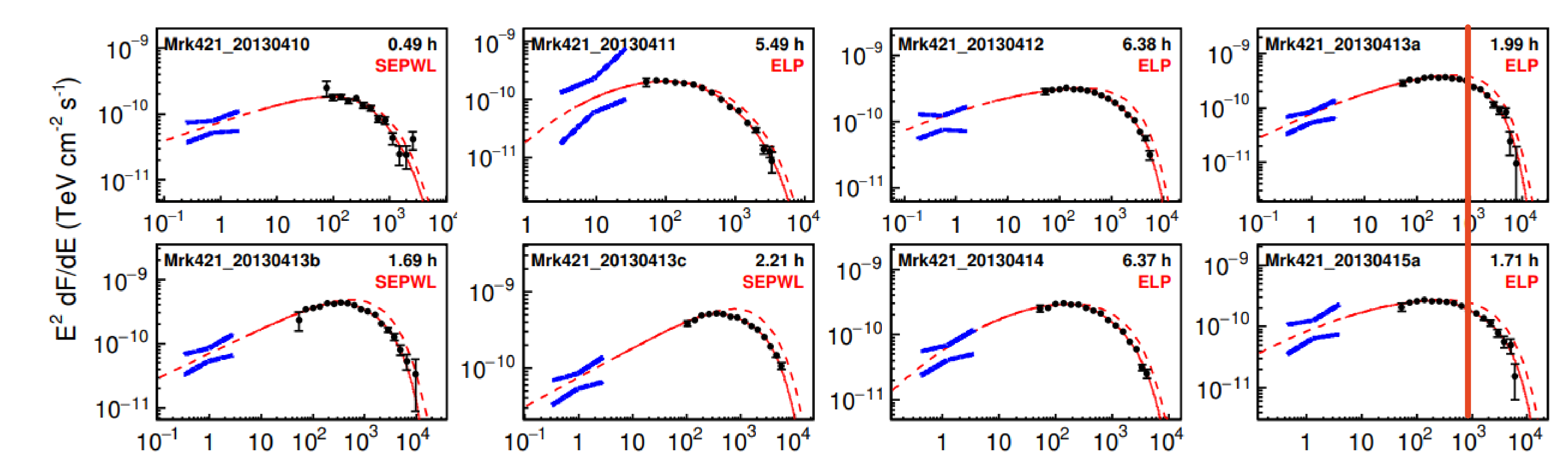




The case of IC 310

- What did we learn from Mrk 421?
  - Comparing the light curves was very restrictive in the energies that match the SED, but higher energies found least matches
    - IC 310: Also want to **match the spectral shape**
  - The IC bump was tuned to higher fluxes by scaling U_B
    - IC 310: Testing **an external photon field** that could result from misaligned layers

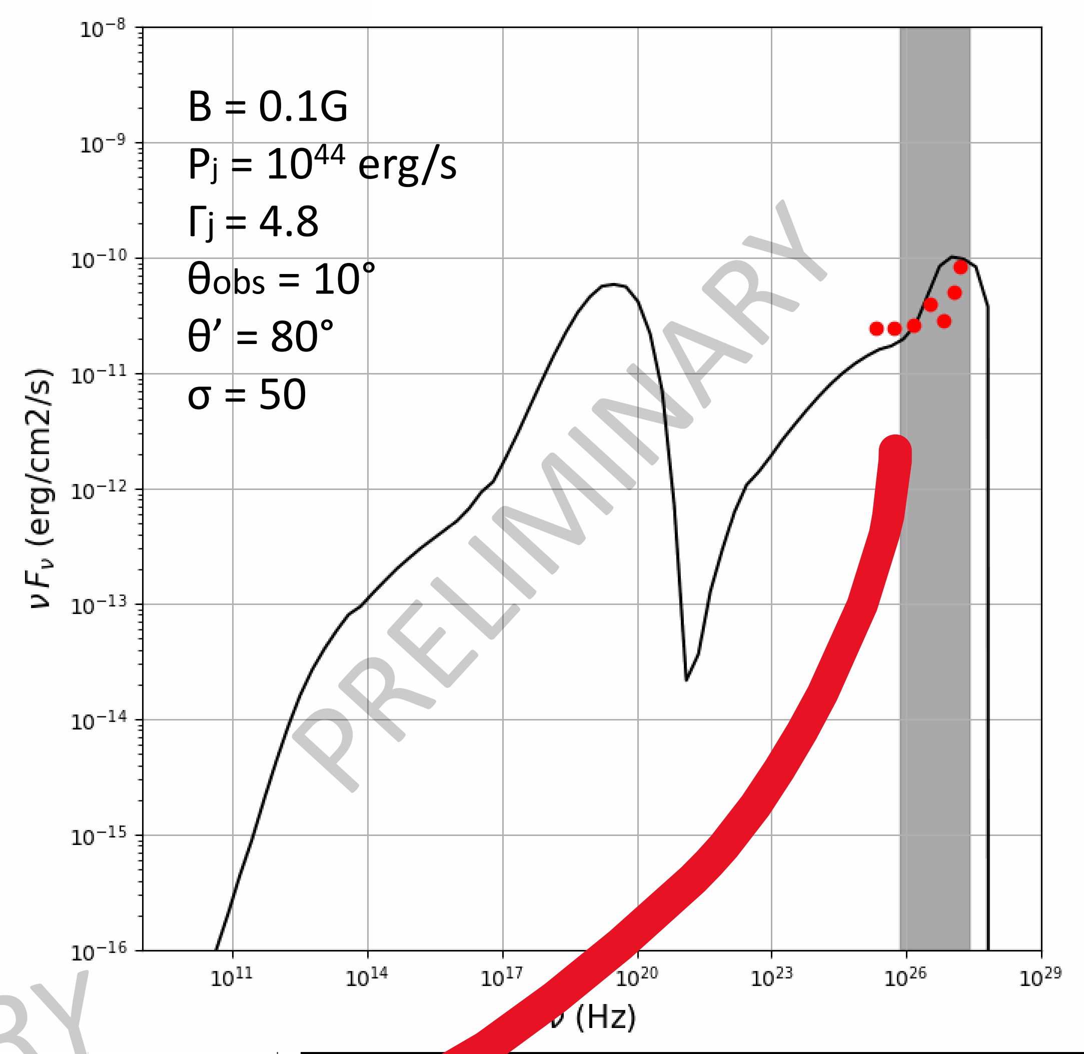


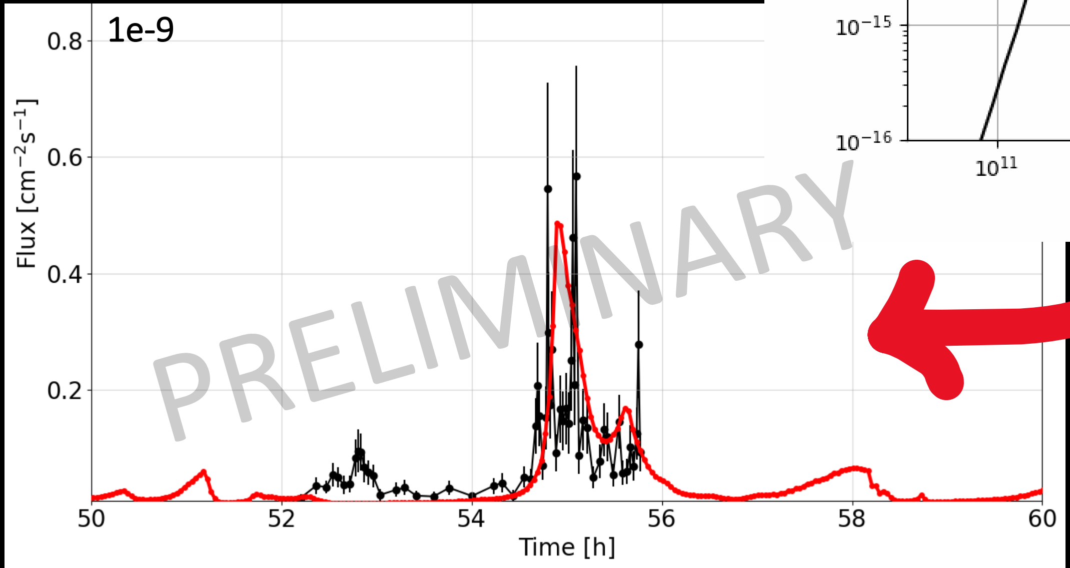


MAGIC Coll. et al. 2018

The case of IC 310

- New approach:
  - Testing the ranges for the input parameters
    - Estimates from observations
    - What is physically feasible?
  - More attention was paid to the shape of the SED
  - Similar comparison analysis as for the light curves of Mrk 421 will be done with these simulations





Summary and future steps

- Simulations that can produce light curves an important bridge between different observation channels and theory
- Comparing the simulation results with observed data help us **narrow down the parameter space**
  - Strong constraints can be put in place to still find matching simulations!
- IC 310: Extreme variability and SED shape
  - Want to **match both the SED and the light curve**
- Making similar comparison with **other sources where intranight VHE variability** has been observed
- Possibility of using these methods in **different time scales and energies**