Confronting observations of VHE gamma-ray blazar flares with reconnection models

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ICRC 2021 Conference, 12 – 23 Jul

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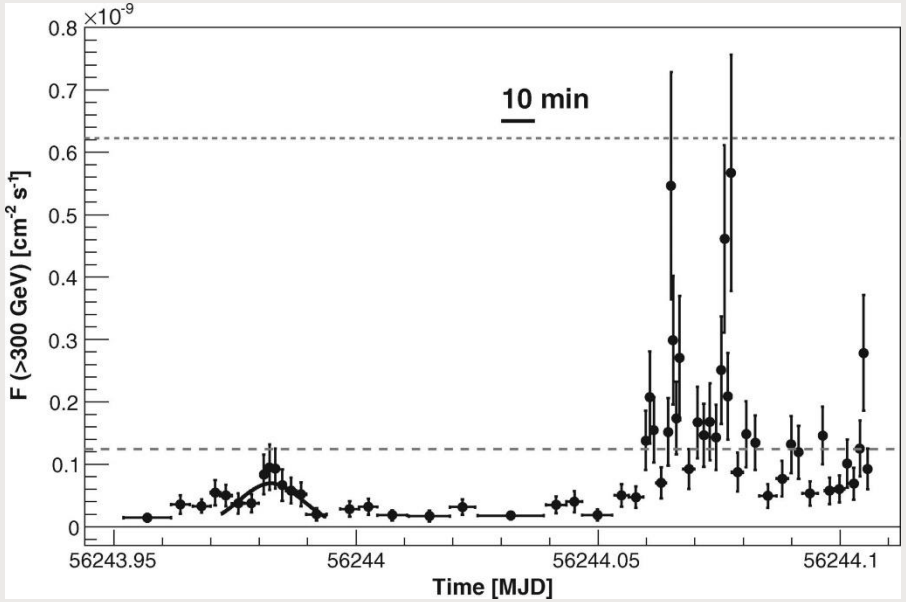
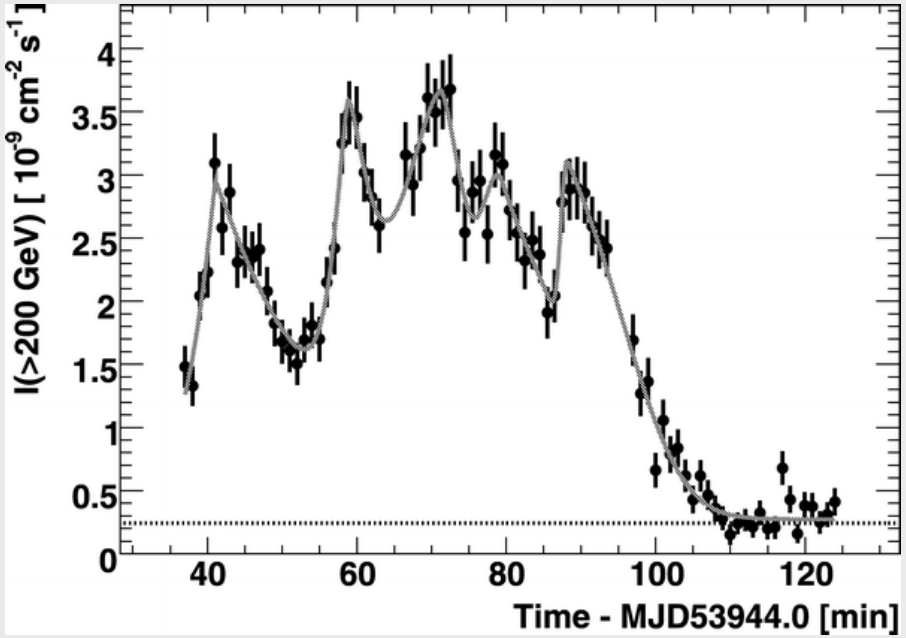


Aleksić et al. 2014



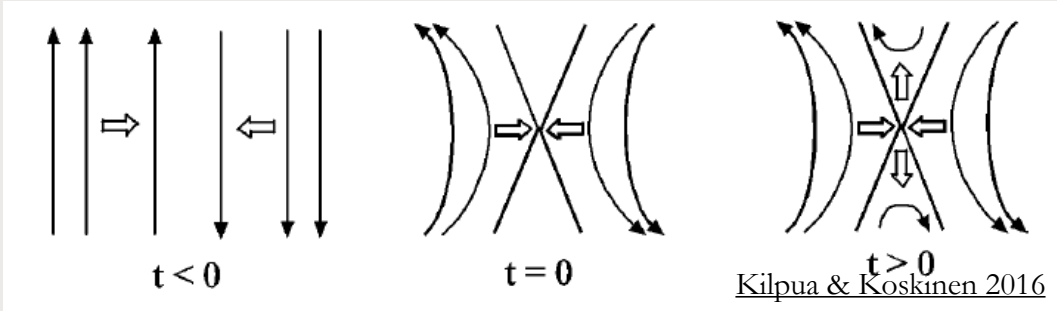
Aharonian et al. 2007

Introduction

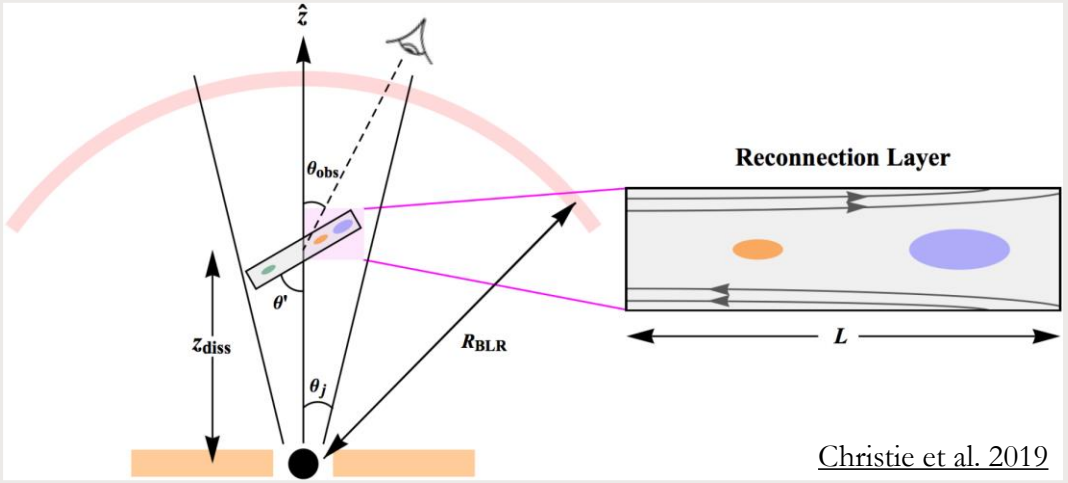
- Blazars: extremely variable jetted AGN where the jet is seen closely aligned with our line of sight
- **Very fast VHE flares** have been observed from a handful of blazars
  - Time scales of these flares are ranging from hours to some minutes
- Several models have been invoked to explain blazar variability, typically shocks
  - Shocks manage to explain the slower variability in the lower energies well
  - Need a mechanism that can produce fast flares → **Magnetic reconnection**

Motivation

- In magnetic reconnection magnetic energy is converted into heating of the plasma and acceleration of the particles
- Model in Christie et al. 2019: Produce light curves of different jet scenarios using **particle-in-cell (PIC) simulations** and varying the viewing angle θ_{obs}, the reconnection layer angle θ', magnetic field B, and magnetization σ
- Many simulations have been performed in the past but not extensively compared with the observations
- Can we constrain the unknown simulation parameters using observations?
  - Several free parameters that we set on a more realistic range by **using observed values (VLBI observations, SED modelling)**
    - Jet power, bulk Lorentz factor, viewing angle, SED peak, and γ_{max}



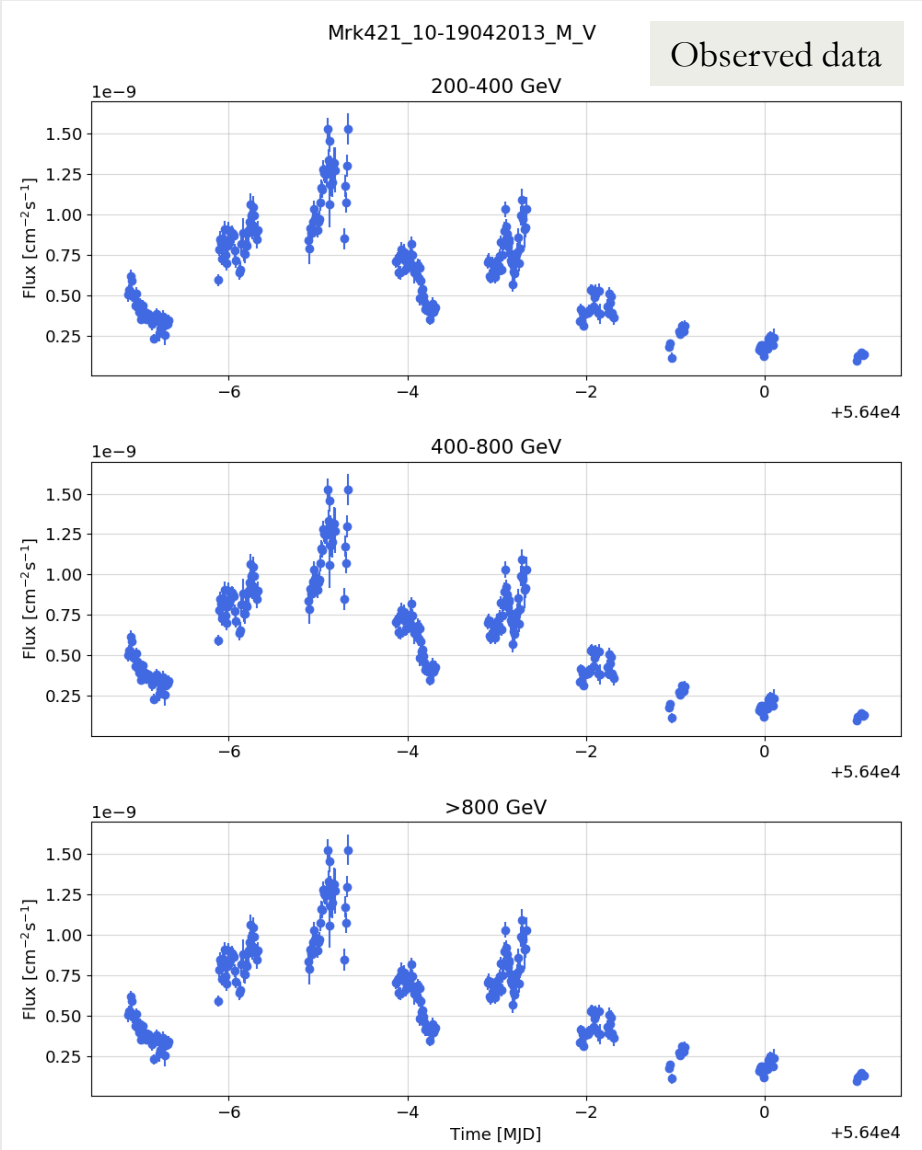
Kilpua & Koskinen 2016



Christie et al. 2019

Observations vs simulations: how to compare?

- For the introduction of the method only one source, **Mrk 421**, was used in this analysis
  - Observing campaign with MAGIC and VERITAS in 2013 when the source was flaring
  - Particularly well-sampled light curves in three energy bands
- Magnetic reconnection was already suggested for this source in Acciari et al. 2020
  - They estimated the peak flux and flux-doubling time scale of plasmoids of different sizes and find **a range of layer angles compatible with the observed values** of one of the flares (Feb 15th)



Acciari et al. 2020

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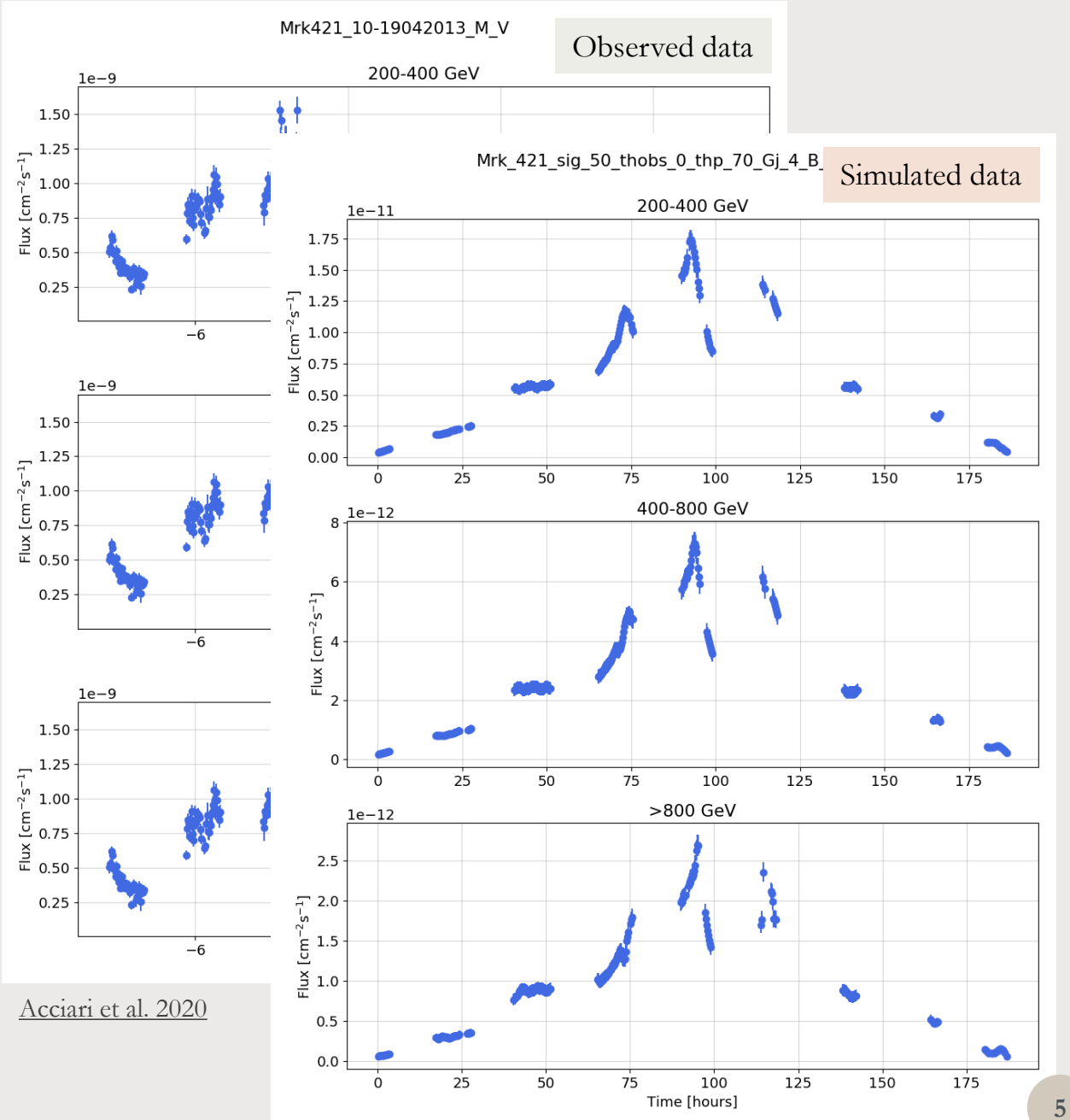
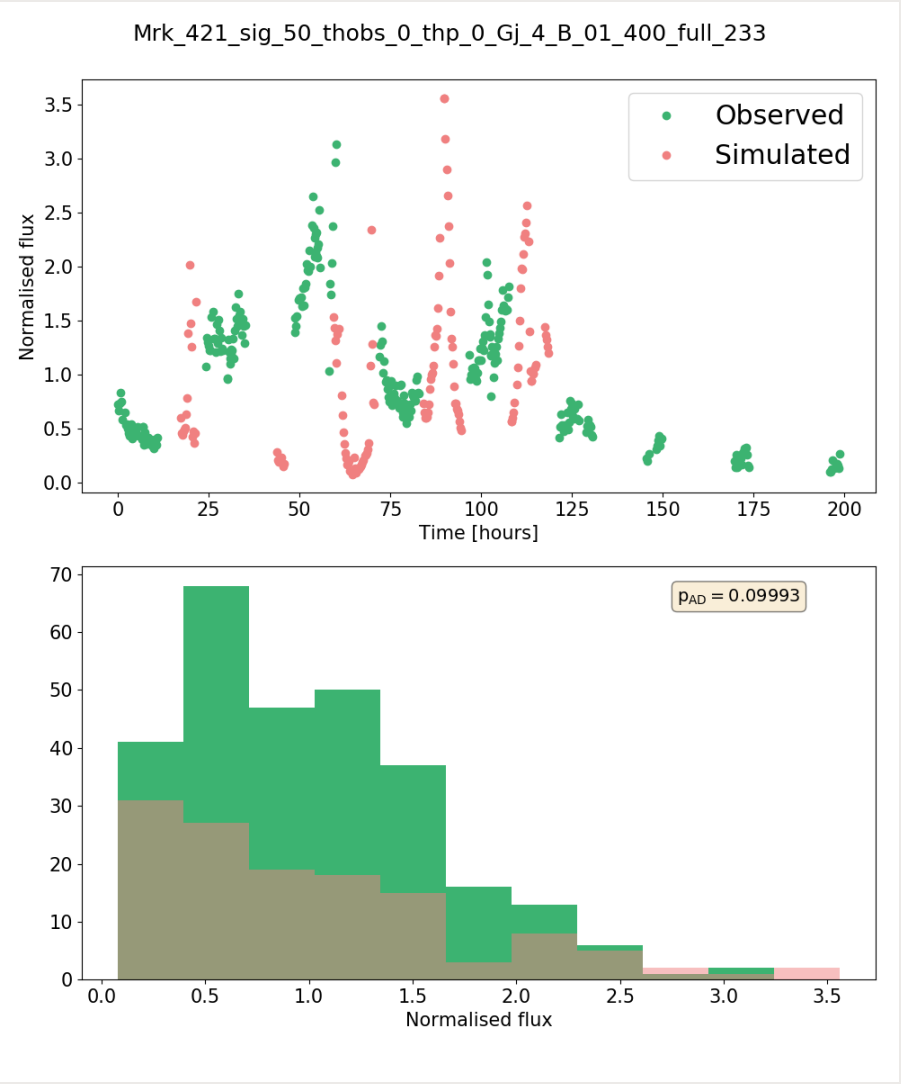
- Several things had to be taken into account before comparison: energy range of the observations, observed flux units, binning and observed cadence, error assignment, etc.

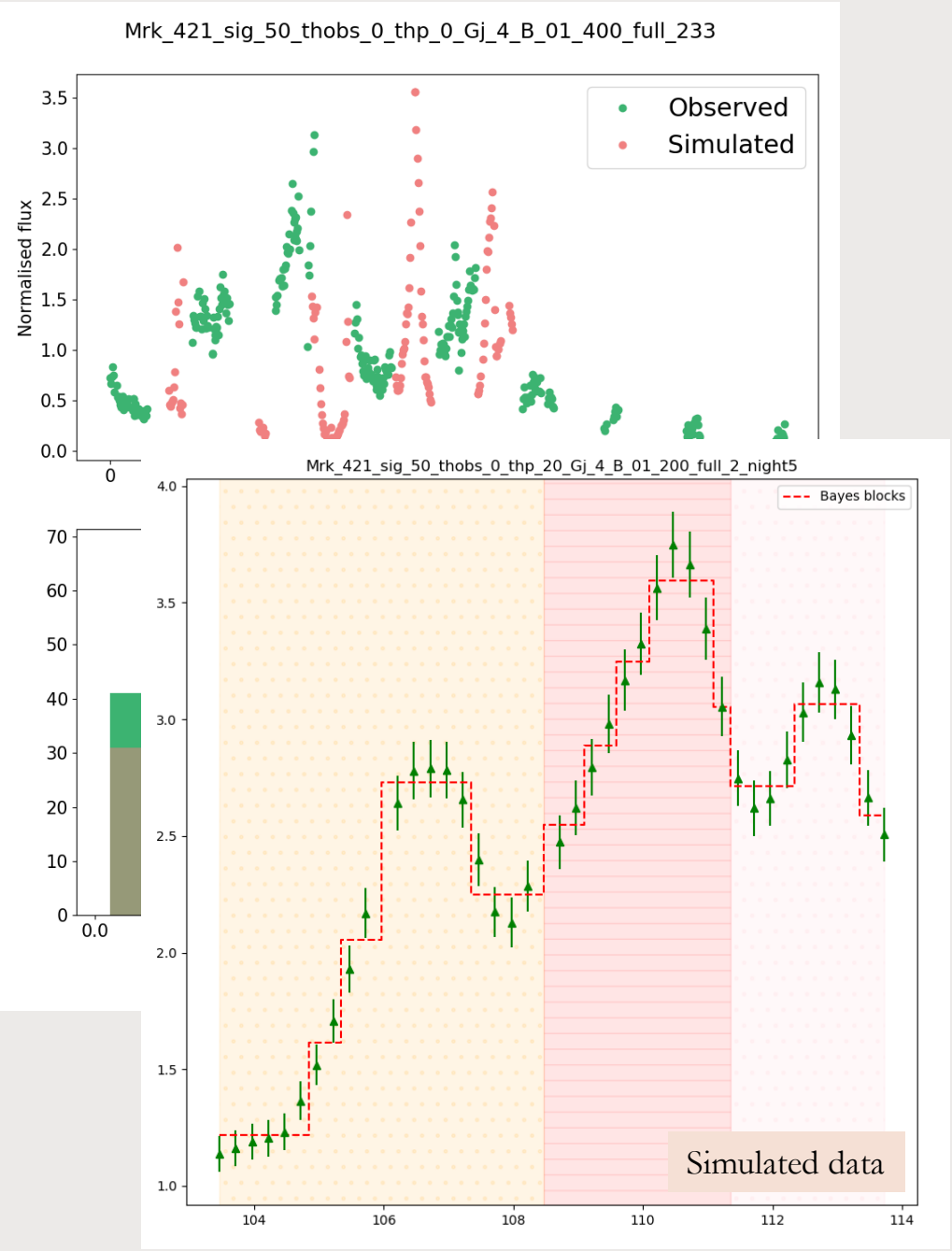


Acciari et al. 2020



Analysis methods

- Combined several methods in the analysis process to get a versatile view of the simulated data
- Quantitative comparisons of simulated flux amplitudes:
  - **Flux distributions**: can we find matching distributions of (normalized) flux?
  - **Fractional variability**: how do the fractional variability factors compare?



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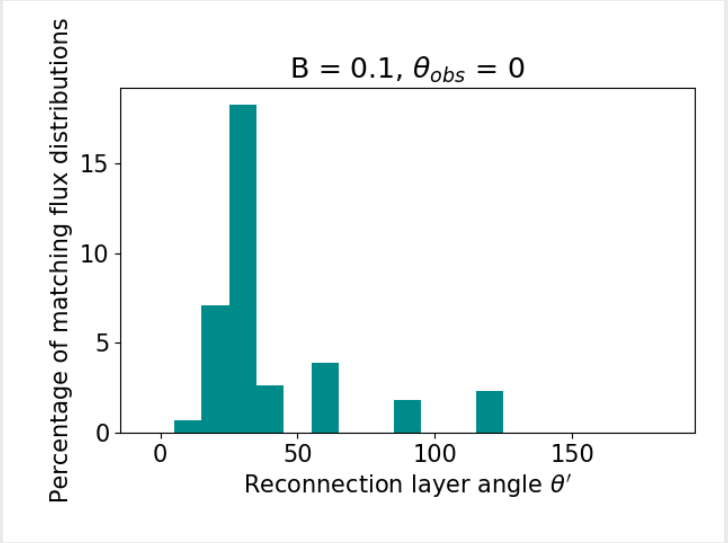
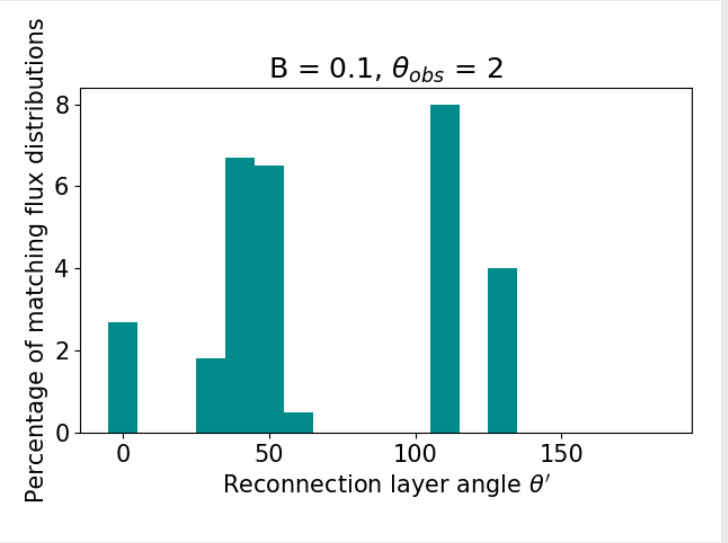
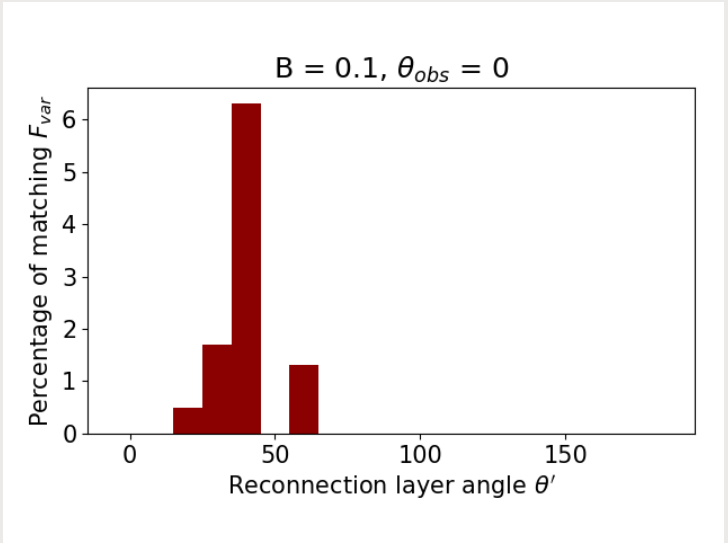
- …and time scales:
  - **Risetimes**: what kind of ”flares” do we see in the simulated data compared to the observed?
    - Bayesian blocks used in fitting the light curves
    - Comparison is done based on detected rate of change (amplitude/rise time) of a fitted structure → Flares may not have been observed completely

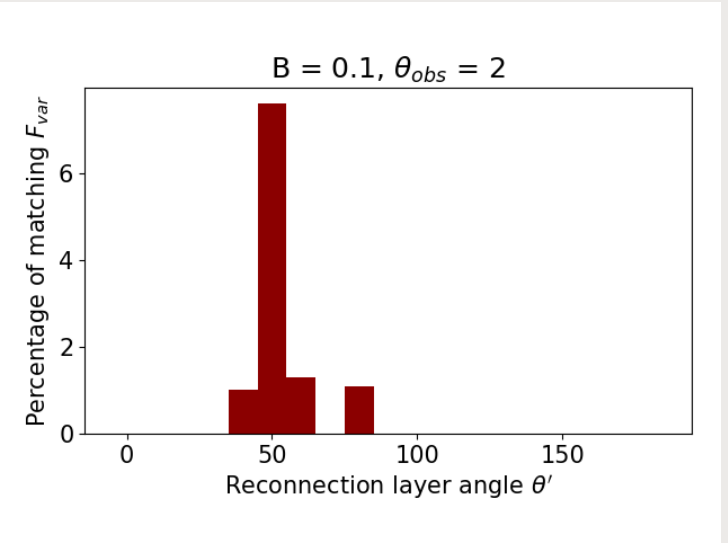
Preliminary results

- Examples shown here are for simulations with B = 0.1G and θ_{obs} = 0°, 2°
- Flux distribution and fractional variability comparisons find simulations in different angle combinations that **resemble the observations the most**
  - Both tests find ranges of reconnection layer angles that produce matches
  - Fractional variability test gives a smaller subset of simulations than the flux distributions test
- **Timescale analysis still ongoing!**









Summary and future

- Comparison of very fast VHE gamma-ray flares with simulated light curves of different jet scenarios
  - Simulation set up based on observations
  - Introduction of the method: comparison of only one source, Mrk 421
- Combining several analysis methods to statistically compare observations and simulations is the key to constraining the parameter space of the simulations
- Preliminary results show that it is possible to find favourable jet parameters that produce light curves that most resemble observations!
- Working on producing and analysing **a new set of simulations with slightly tweaked input parameters** that match the observed flux range more closely
- In the future, our method will also be applicable to **different sources** in different energies and time scales!