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

J. Jormanainen, T. Hovatta, E. Lindfors, I. Christie, M. Petropoulou, I. Liodakis

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Jenni Jormanainen
Finnish Centre for Astronomy with ESO (FINCA),
University of Turku, Finland

Introduction

- Blazars: extremely variable jetted AGN where the jet is seen closely aligned with our line of sight

  - Source of the variability in Very High Energy (VHE) gamma-rays still largely unknown

  - **Magnetic reconnection** is one possibility and is considered in this study

- The focus of this study is on the **very fast VHE flares** that have been observed from a handful of blazars

  - Time scales of these flares are ranging from hours to some minutes

- 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

  - Can we constrain the unknown simulation parameters using observations?
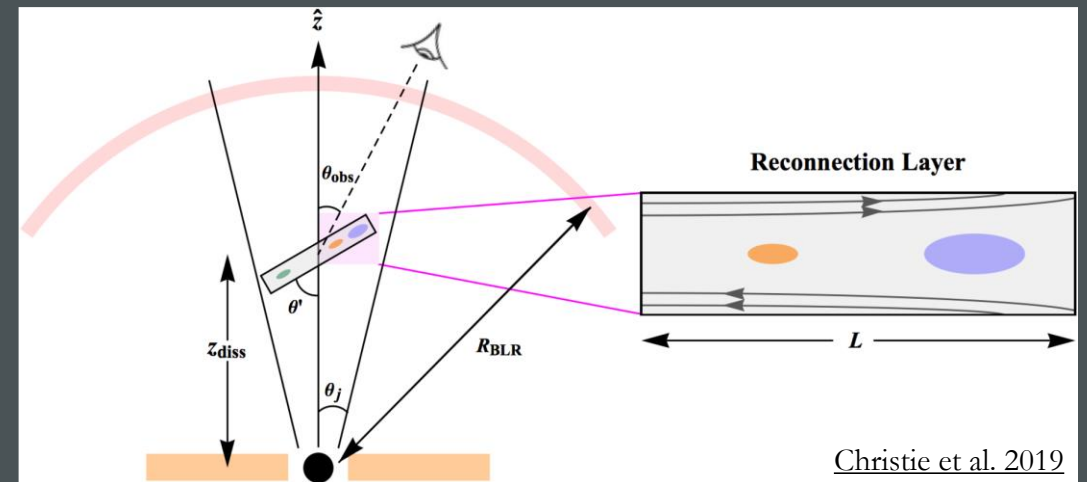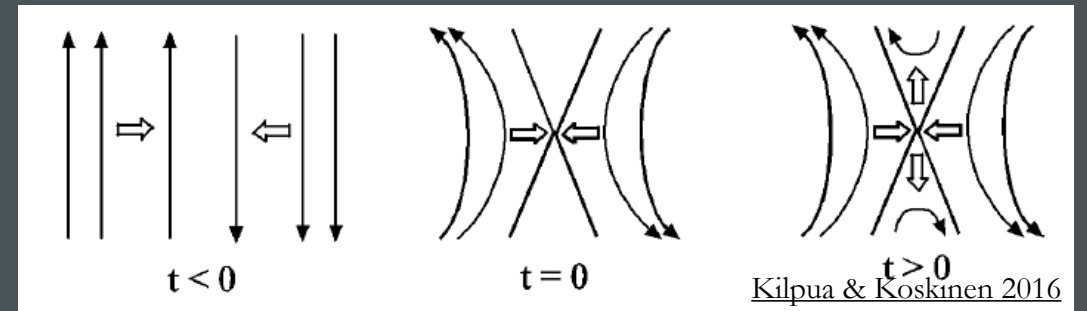
Kilpua & Koskinen 2016

Reconnection Layer

Christie et al. 2019
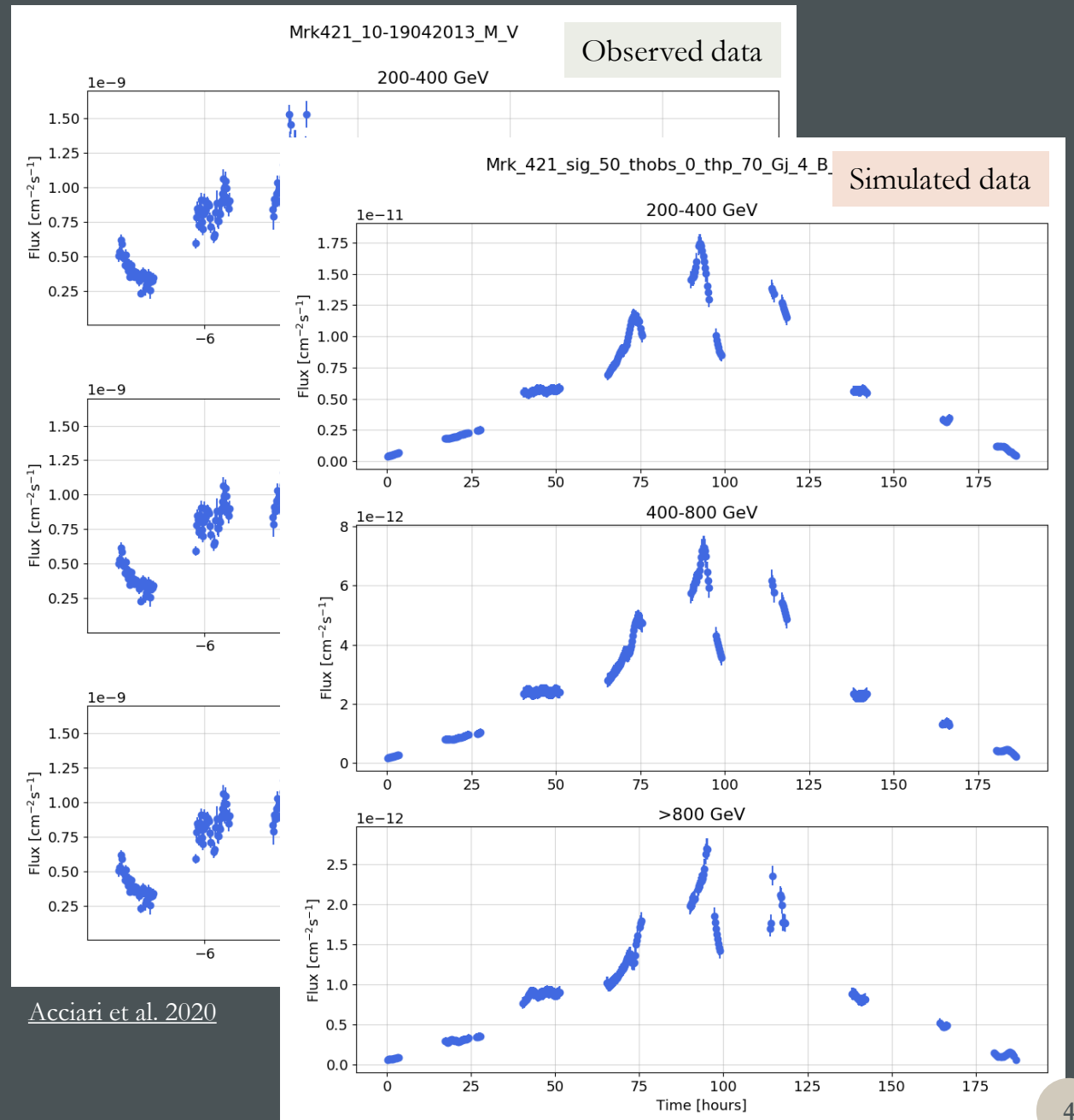
Observations vs simulations: how to compare?

- 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

- Collected **observable parameters (VLBI observations, SED modelling)** needed to set up the simulations

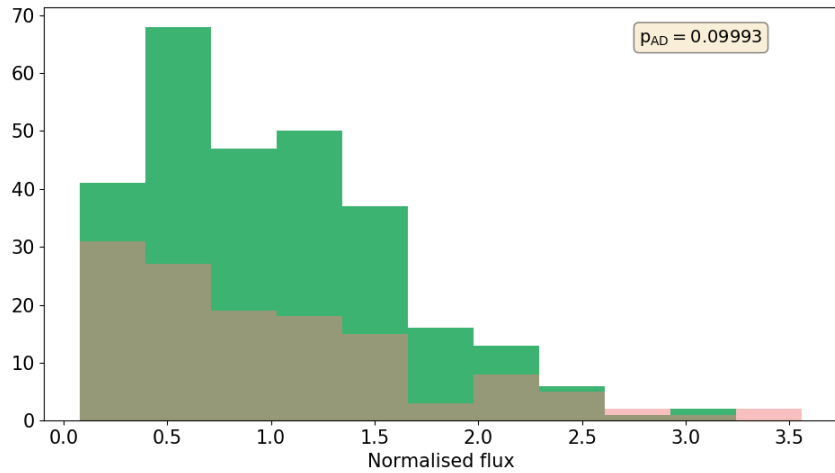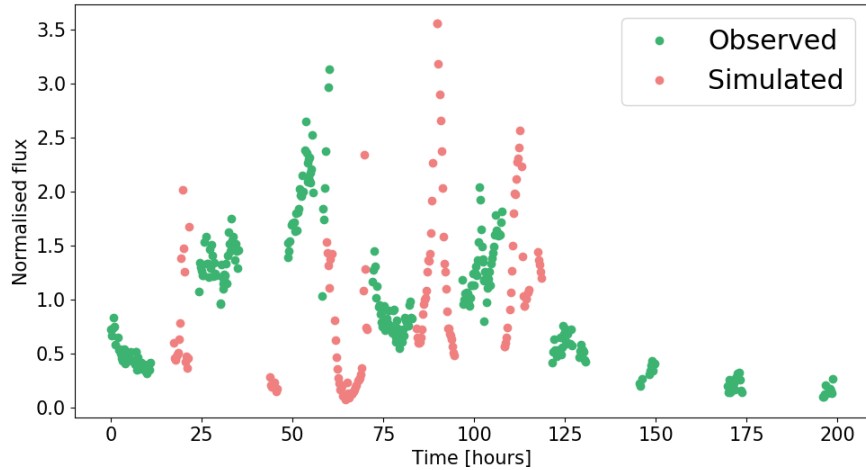 - Jet power, bulk Lorentz factor, viewing angle, SED peak, and γ_{max}
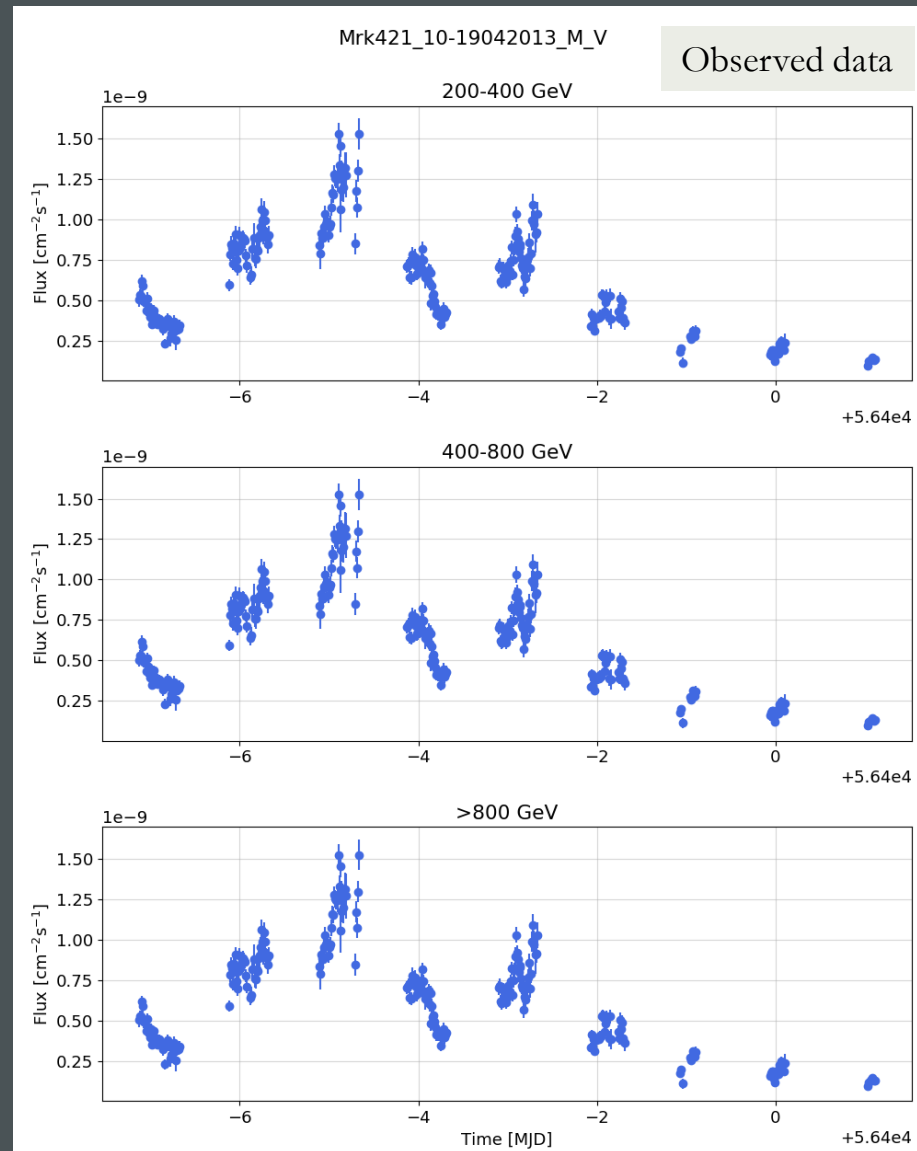
Acciari et al. 2020

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  - Observing campaign with MAGIC and VERITAS in 2013 when the source was flaring
  - Particularly well-sampled light curves in three energy bands
- Collected **observable parameters (VLBI observations, SED modelling)** needed to set up the simulations
  - Jet power, bulk Lorentz factor, viewing angle, SED peak, and γ_{max}
- 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.
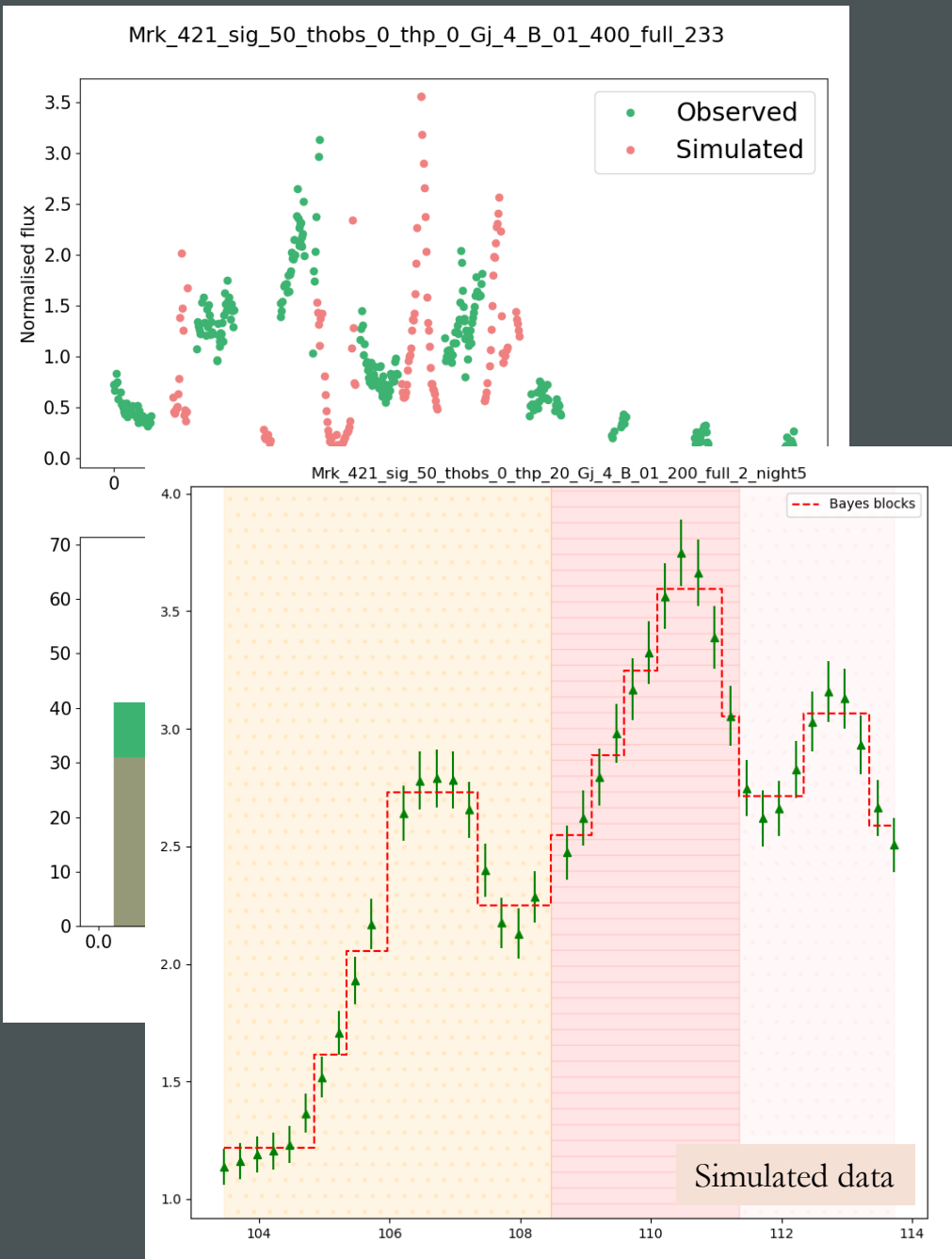

Acciari et al. 2020

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?

Mrk_421_sig_50_thobs_0_thp_0_Gj_4_B_01_400_full_233

Mrk_421_sig_50_thobs_0_thp_20_Gj_4_B_01_200_full_2_night5

Simulated data

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?

- …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 risetime+amplitude combination 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**

  - Rather narrow ranges of layer angle + observation angle combinations are found to produce most matches

- Fractional variability test gives a smaller subset of simulations than the flux distributions test

- **Timescale analysis still ongoing!**
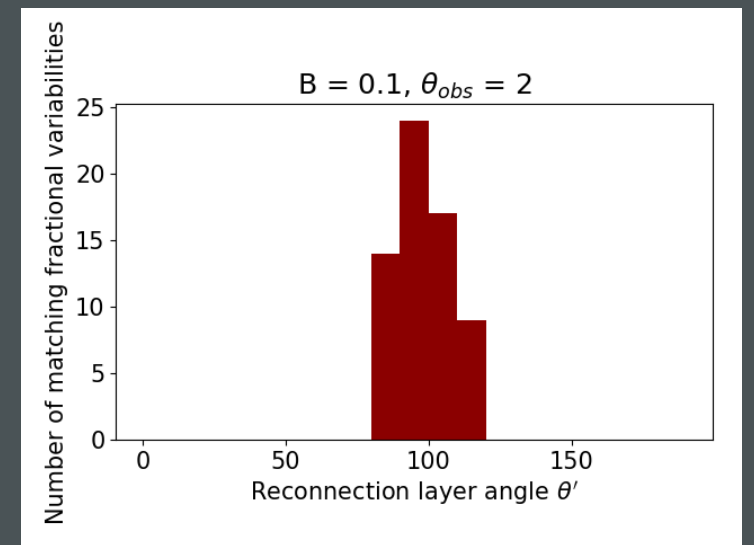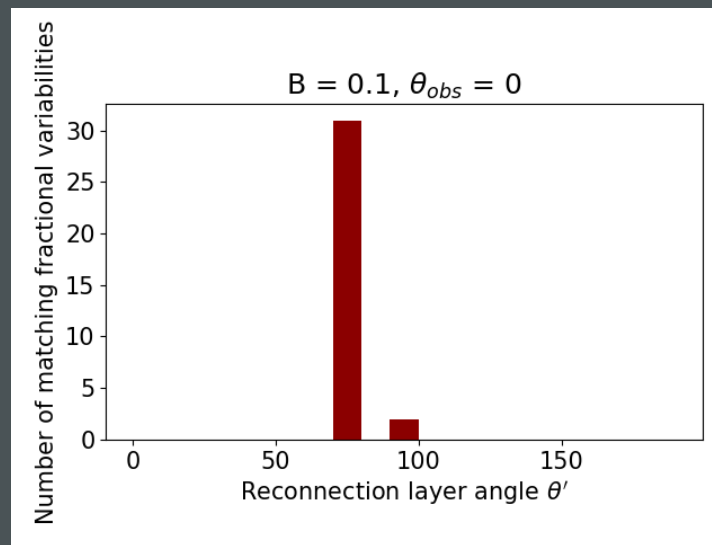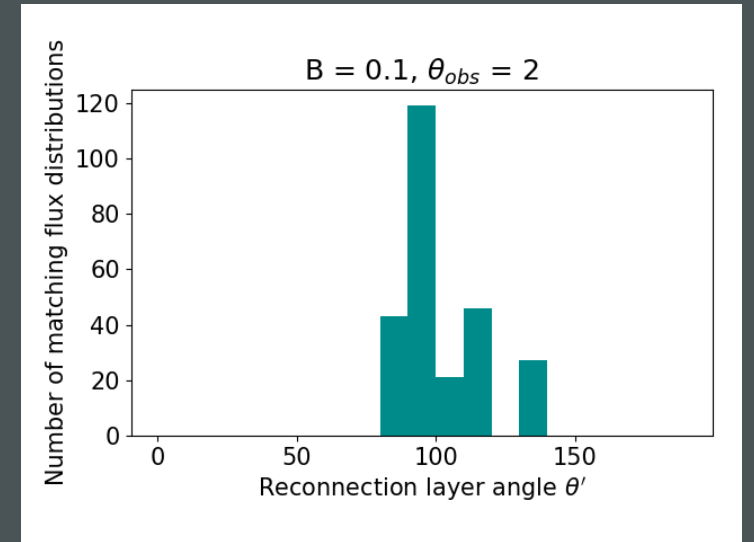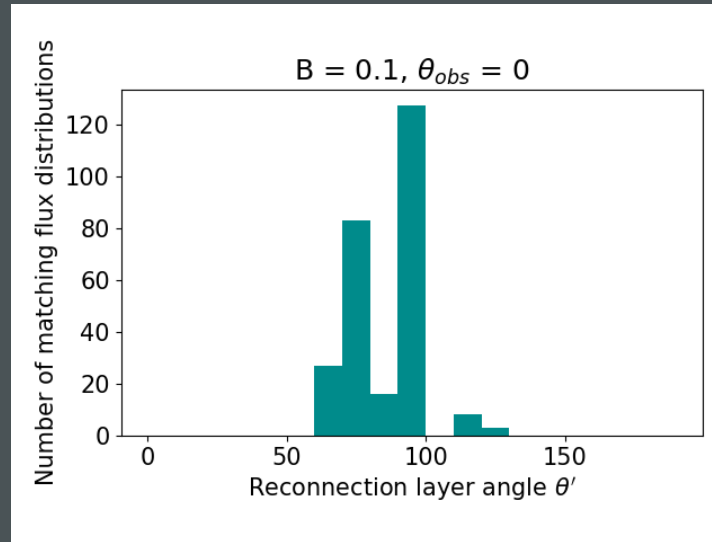
Summary and future

- 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!

  - Still need to compare the time scales and amplitudes of the flares

- Working on producing and analysing **a new set of simulations with slightly tweaked input parameters** that match the observed flux range more closely

Mrk_421_sig_50_thobs_0_thp_0_Gj_4_B_01_400_full_233