Periodicity Analysis of Mrk 501 and Mrk 421 in Gamma-Rays

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Introduction:

Blazars are a highly variable subclass of active galactic nuclei (AGN). Quasi periodic oscillations, which might originate from a binary black hole located at the AGN core, have been found in several blazar light curves. For the blazars Mrk 421 and Mrk 501, different and sometimes conflicting results have been reported [1–5], depending on energy ranges and used methods. We analyse FACT light curves using a variety of methods (generalized Lomb-Scargle Periodogram, CARMA, Wavepal, A-T plane and NIFTy), studying in detail systematic effects, in order to determine if the Markarians exhibit quasi periodic oscillations.

Data:

- 8 years of FACT data, binning: 20-min to monthly
- Yearly and monthly observational dependencies, due to zenith distance and the moon

Lomb-Scargle Periodogram:

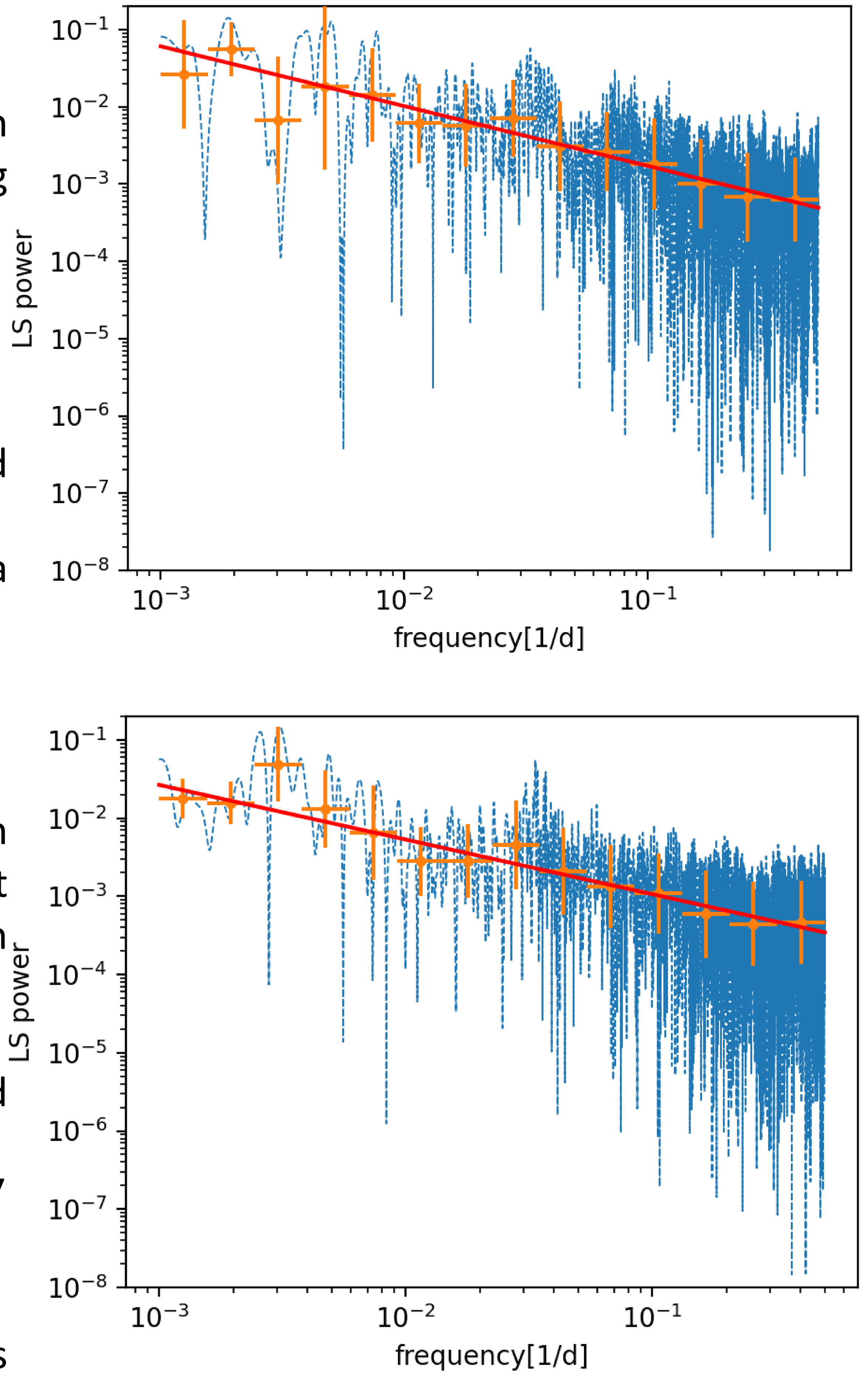
- We compute the general Lomb-Scargle periodogram [6], using the Scipy implementation [7]
- Identical to Least squares spectral analysis
- Possible periodic signals from observational dependencies
- Higher peaks at lower frequencies due to red noise [8]
- Modeling of red noise necessary for periodogram significance estimations

Significance Estimation:

- Fit of both flux distributions with combination of a log-normal and normal distribution, using Maximum Log-Likelihood estimation

- Modelling of red noise:
- binning the periodigram in log-log space
- => no bias on the fit by more densely sampled high frequencies
- Linear fit in log-log space, translating to a power-law $P(f) \sim f^{-\alpha}$
- Result for steepness:
  - Mrk 501: $\alpha = 0.699$
  - Mrk 421: $\alpha = 0.774$
- Power spectrum density and flux distribution of FACT data as input for artificial [9] light curves generated with the python implementation [10]

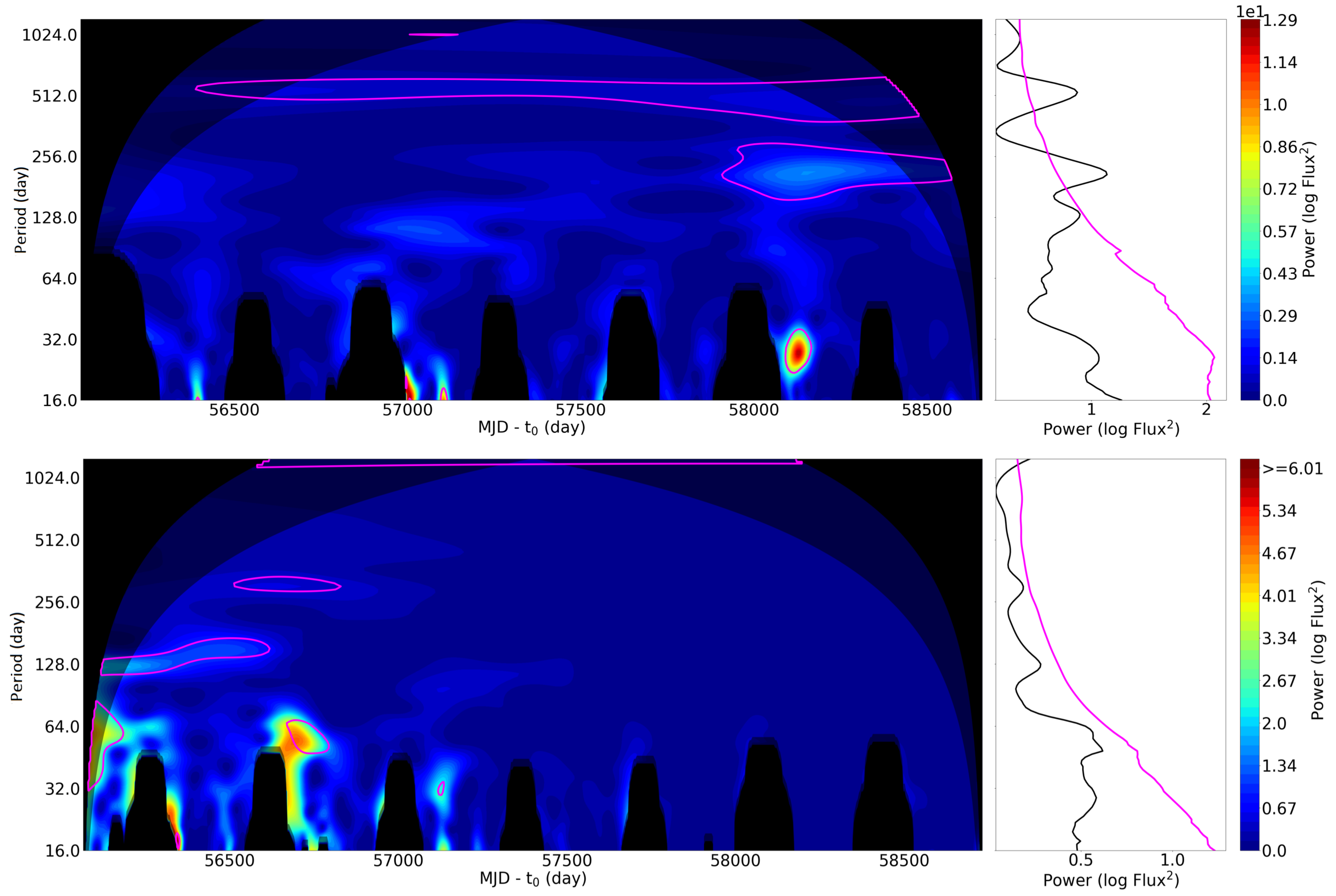
- Observational windows reduce the measured α through red noise leakage
- => generation of light curves with higher α' and applying window function
- => Determine needed input red noise α'
- Final step: simulate ~10k artificial light curves and determine the significance of the periodograms numerically



Linear fit to the binned log-log periodograms for Mrk 421 (top) and Mrk 501 (bottom)

Wavelet Scalogram:

- Gives global scalogram power, but also shows at which times periodic signals are present, for instance flares
- Data are described by short, localized wavelets



Wavelet scalograms for Mrk 421 (top) and Mrk 501 (bottom) computed using WAVEPAL [11]

Further methods:

CARMA: [5] Continuous-time Auto Regressive Moving Average, used to model light curves and detect periodicities

Nifty: [12] New method to detect periodic signals based on information field theory

A-T plane: [5] New tool for classifying time series

Results from all methods - paper in preparation!

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