Optical variability modeling of newly identified blazars and blazar candidates behind the Magellanic Cloudss

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Introduction

In Żywucka et al. 2018, we identified a sample of 44 blazar candidates, including 27 FSRQs and 17 BL Lacs, whereof only nine objects (six FSRQs and three BL Lacs) were considered as secure blazar candidates. All objects in the sample were selected based on their radio, mid-infrared, and optical properties. Here, we extend the analysis of our blazar candidates with modeling of optical LCs provided by the Optical Gravitational Lensing Experiment (OGLE; Fig. 1). All objects were selected from the long-term, deep optical monitoring survey, therefore they constitute a sample of faint sources with irregularly sampled optical LCs. We investigate them to determine variability-based classification of the blazar candidates and to analyze their long-term behavior.

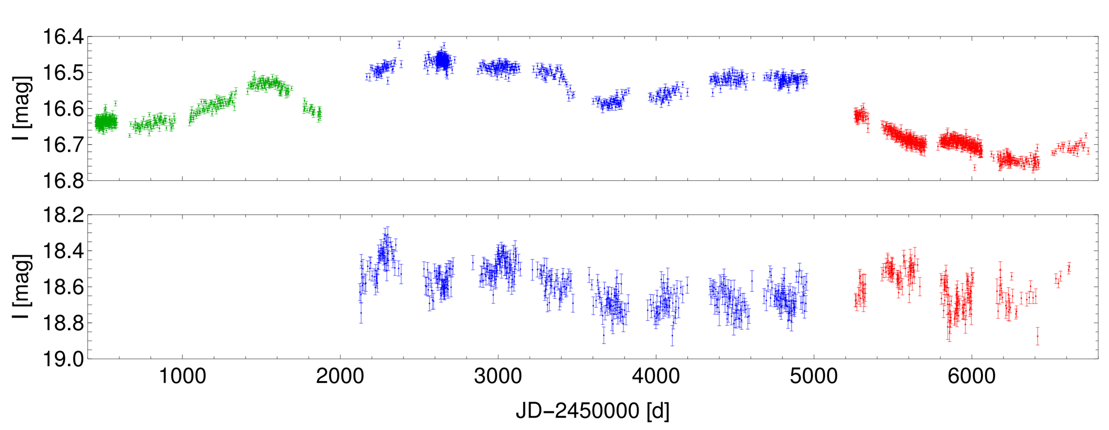

Figure 1: Example of the analyzed LCs. J0532-6931 FSRQ candidate (*top*) and J0518-6755 BL Lac candidate (*bottom*). The OGLE-II data are shown with green color, OGLE-III with blue color, and OGLE-IV with red color.

Methodology

The LCs were analyzed with the Lomb-Scargle periodogram (LSP), to generate a power spectral density (PSD) for unevenly sampled time series. Alternatively, we used the Hurst exponent H, which measures the statistical self similarity of a time series x(t), and the $\mathcal{A}-\mathcal{T}$ plane, to quantify the smoothness of a time series by comparing the sum of the squared differences between two subsequent measurements with the standard deviation of the time series. All the above methods are applied to look for the blazar-like characteristic features and to study the long-term behaviour of the optical fluxes.

Results

The LSP fitting (Fig. 2, left panel): power law (PL) plus Poisson noise is a better description of 10 FSRQs, while for 13 of them a smoothly broken PL (SBPL) plus Poisson noise is preferred. For 13 out of 17 BL Lacs, PL plus Poisson noise is in favour, however, for only two instances an SBPL plus Poisson noise was preferred. The remaining 4 FSRQs and 2 BL Lacs are fitted well enough by both models. The indices derived with PL plus Poisson noise for the FSRQ blazar candidates mostly lie in the range $(1,2)$. BL Lacs are slightly flatter, spanning the range $(1,1.8)$; one object has a flat PSD, hence a pure PL was fitted. On the other hand, three BL Lacs have steeper PSDs, with $\beta \sim 3-4$.

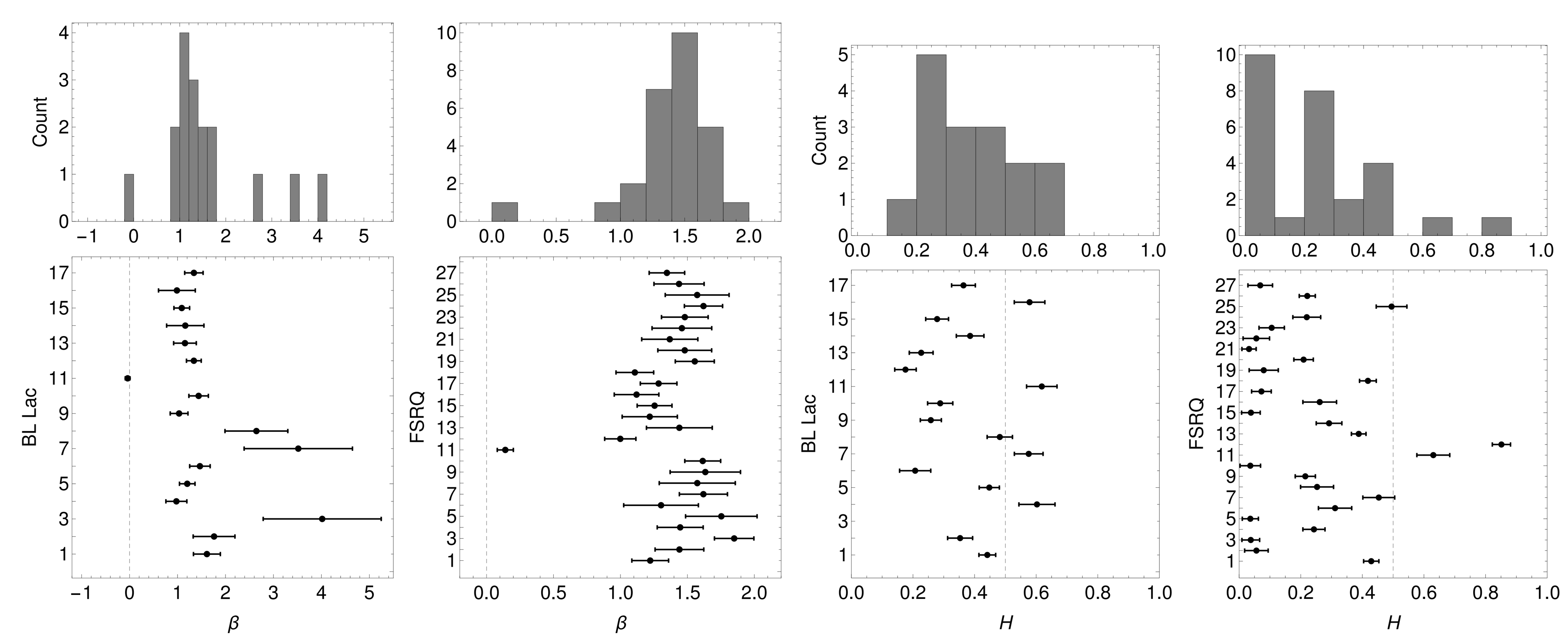

Figure 2: *left panel*: Distributions of PL indices β from a PL plus Poisson noise fitted to the binned LSPs. *Right panel*: Distributions of the Hurst exponents of examined BL Lac and FSRQ candidates.

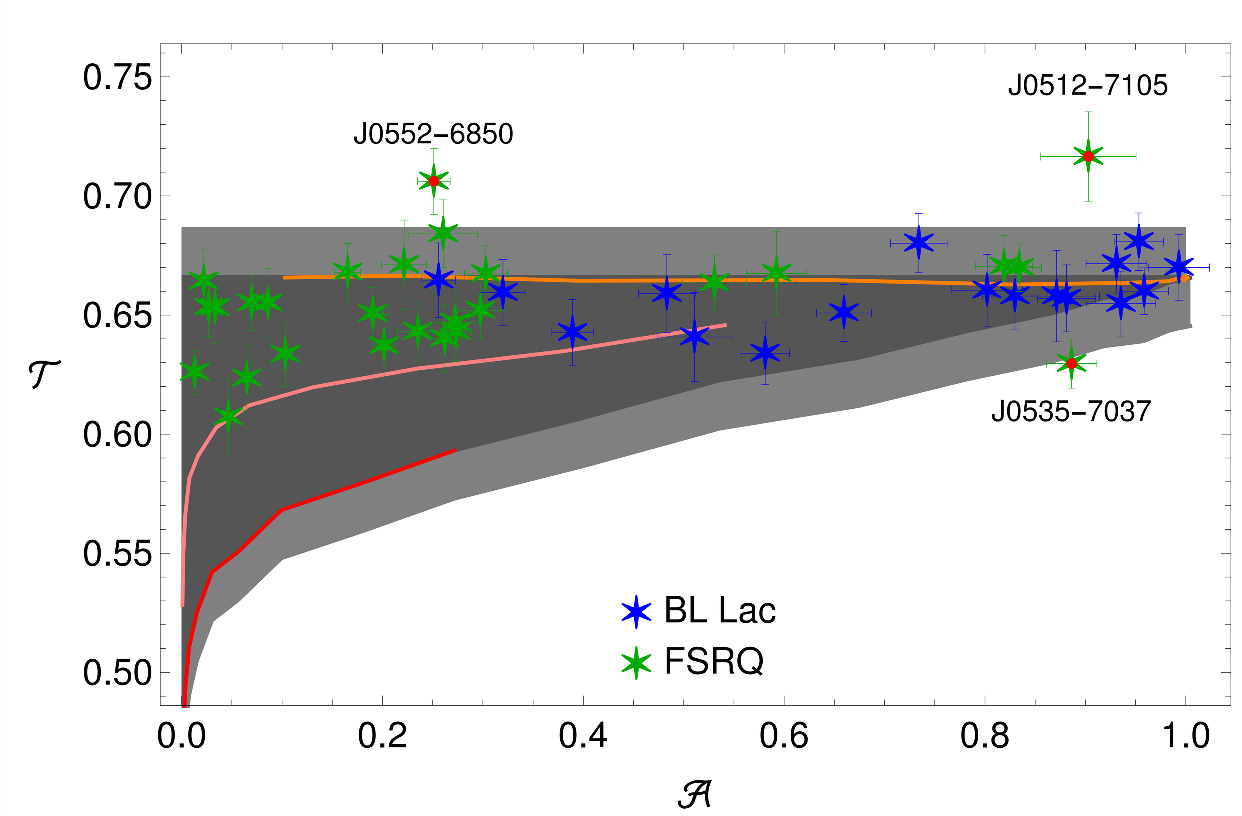

Figure 3: Locations of the blazar candidates in the $\mathcal{A}-\mathcal{T}$ plane. The dark gray area is the region between the pure PL line and $\mathcal{T}=2/3$, while the light gray regions correspond to the error bars of the simulations. Two FSRQs lie above the region admitted by a PL plus Poisson noise and one is located marginally below.

The H estimation (Fig. 2, right panel): for the majority of objects $H \leq 0.5$, indicating short-term memory. 4 BL Lacs and 2 FSRQs yield $H > 0.5$, implying long-term memory. A few objects are characterized by $H \approx 0.5$, so the modeled stochastic process is not necessarily uncorrelated. There is also a number of objects with $H \lesssim 0.2$, i.e. their H estimates are uncertain. In general, the autocorrelation functions drop to zero after time scales comparable to $T_{\rm break}$, above which the system becomes decorrelated.

The $\mathcal{A}-\mathcal{T}$ plane (Fig. 3): most objects fall in the region occupied by PL plus Poisson noise type processes. 3 FSRQs are interestingly placed: J0535−7037 marginally below the pure PL line, while J0512−7105 and J0552−6850 above the limiting $\mathcal{T}=2/3$ line. The LSP implies that J0535−7037 has a PL PSD with $\beta \approx 1$, i.e. pink noise. J0512−7105 has a flat PSD, but yields $H > 0.5$. The PSD of J0552−6850 shows a clear flattening on time scales greater than 1200 days, and has $H < 0.5$.

Conclusions & Next Steps

We have analyzed the optical data of 44 blazars and blazar candidates, using three different approaches and finding that:

→ The jet domination should be visible in the PSD as a PL, without a flattening at low frequencies at all, or with a break at time scales >1000 days.

→ The disk domination in QSOs manifests through a break at time scales 100–1000 days.

→ The secure blazar candidates (5 FSRQs and 2 BL Lacs) have an LSP best described by an SBPL, with break time scales at 200–300 days; an FSRQ and a BL Lac are consistent with a PL PSD.

→ For FSRQs such a break is not really surprising—they can be interpreted as disk dominated. But the two BL Lacs with a broken PSD are interesting, as BL Lacs are believed to be jet dominated.

→ The steepness of the high frequency component of an SBPL is intriguing: it can indicate a new class of AGNs, or it can be a sign of a double BH system, where the shorter time scale variability from the disk is wiped out—the accretion disk surrounds both BHs, outside their orbit.

→ Three objects (an FSRQ and 2 BL Lacs) show QPOs in their PSDs on timescales of a few days – this can be caused by the infrequent sampling.

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