Preliminary results from 2015/16 observing campaign of the blazar OJ287

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OJ287 is the only blazar known to exhibit certain quasi-periodic variability in its light curve with a rough period of 12 years. A model that successfully explains this observational feature requires the blazar central engine to contain a binary, consisting of two SMBHs (Valtonen et al., 2008, Nature, 452,851 and references therein). The less massive BH (150 million solar mass) orbits the more massive one (18 billion solar mass) and pierces the accretion disk surrounding the latter BH twice per orbit (Fig 1). The general relativistic orbital precession naturally explains the quasi-periodic light curve variability of OJ287.

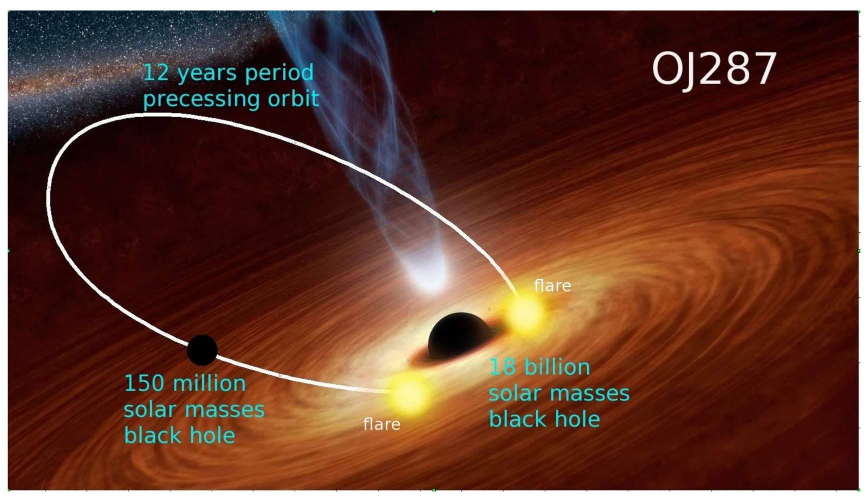

FIGURE 1: A binary model of OJ287.

Since 2006, OJ287 has been regularly monitored in optical at the Mt. Suhora observatory. with supporting observations at Krakow and Athens. In the 2015/16 season, we started observations in September, soon after the blazar became visible after the summer conjunction with the Sun. In anticipation of the outburst predicted for this season by the binary model, a multi-site campaign was organized. Polarimetric observations were also scheduled to reveal the nature of the expected brightening. The predicted outburst started at the end of November 2015 with an initial slow rise in brightness followed by a very rapid brightening. On our alert, almost two dozen telescopes in 4 continents joined photometric observations providing a very good coverage of the event shown in Figs. 2 and 3. Polarimetric observations were taken at Canary Islands, Hawaii, Mt. Suhora and in India. The season LC of OJ287 taken until mid May 2016 is presented in Fig. 2, symbols in green denote dates when low polarisation was measured. UV and X-ray data were also obtained with the SWIFT satellite.

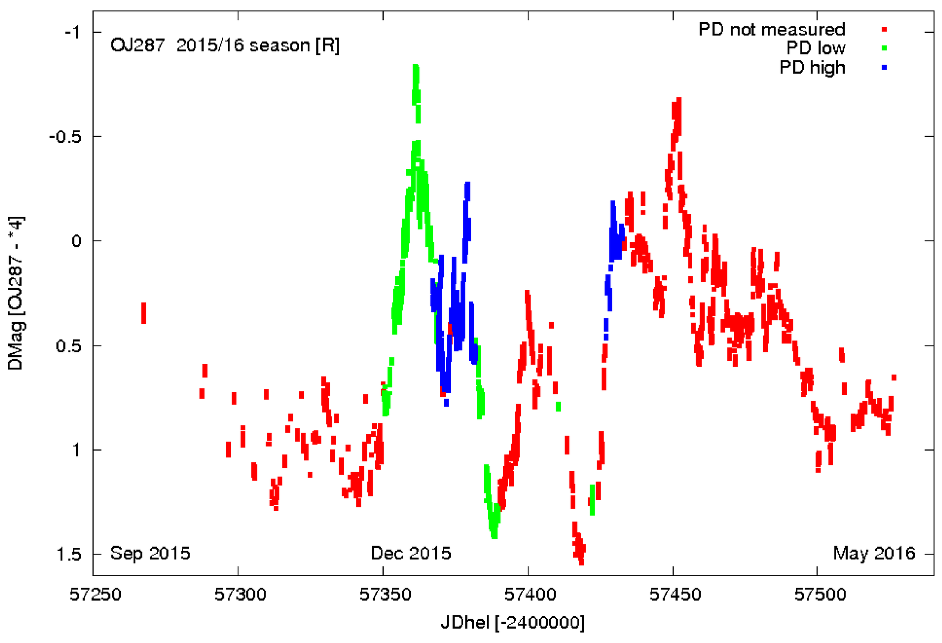

FIGURE 2: 2015/16 season LC of OJ287. The December 2015 outburst turned out to be unpolarized. Points when PD was lower than 11% are shown in green.

Timing of this and previous outbursts allowed to revise masses of the SMBHs and to measure the spin of the more massive BH to be 0.31±0.01 (Valtonen et al., 2016, ApJL, 819, L37). The updated spin value is 0.38 while employing more accurate general relativistic description for the binary black hole central engine.

Search for Periodic/Quasi-Periodic Oscillations

Our first goal was to search for any periodic signal present in the data around the December flare. We analyzed the residuals left after the trend plotted as the model line (Fig. 3) have been subtracted. Three methods were applied: regular Fourier Transform (FT), wavelet and running FT (rFT). We found no significant (above 4 σ level) peaks with FT. A period of about 3 hours can be recognized, however, at the 2 σ level only. Both wavelet and rFT techniques revealed a presence of a statistically significant period of about 3 days at the outburst maximum. The period of its visibility was centered at the maximum of brightness (Fig. 4) - it showed up near JD2457360 and disappeared after about 4 days.

We also performed a thorough search using the entire season dataset covering the period from mid September 2015 to mid May 2016. Several tools have been used and we show the Lomb-Scargle periodogram in Fig. 5. No significant peaks corresponding to short periods were found. In the longer periods domain there seems to be statistically significant peaks in the range between 0.01 and 0.1 c/d. However, the WWZ analysis (Foster, 1996, AJ, 112, 1709) indicate they are not stable. As seen in Fig. 6, the length of the longest, about 95 days period, has been increasing since it started to be visible at about JD 2457330.

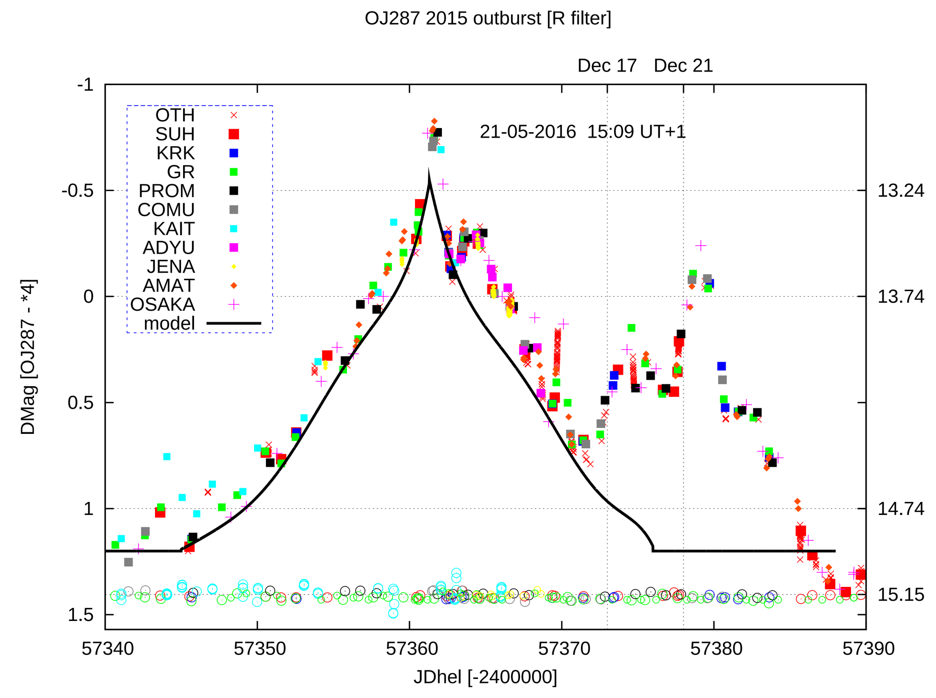

FIGURE 3: The December 2015 mostly thermal flare of OJ287 followed by a jet outburst.

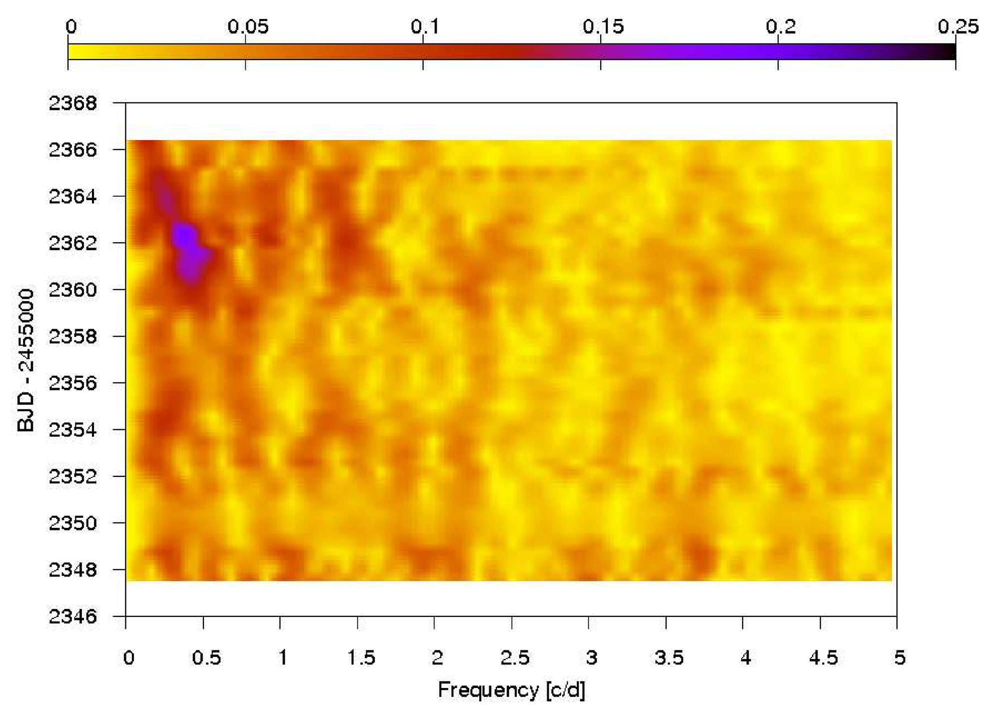

FIGURE 4: rFT for the Deecember 2015 flare residuals.

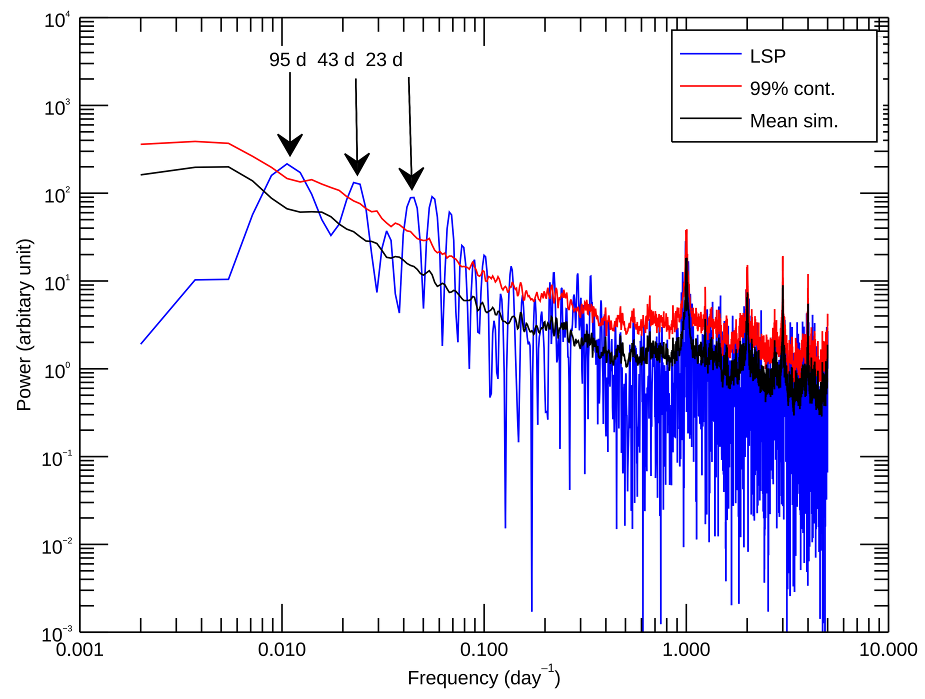

FIGURE 5: Lomb-Scargle periodogram. The red-noise (β=1.5) light curves were simulated by the randomization of both phase and amplitude as described in Timmer & Koenig, 1995, A&A, 300, 707.

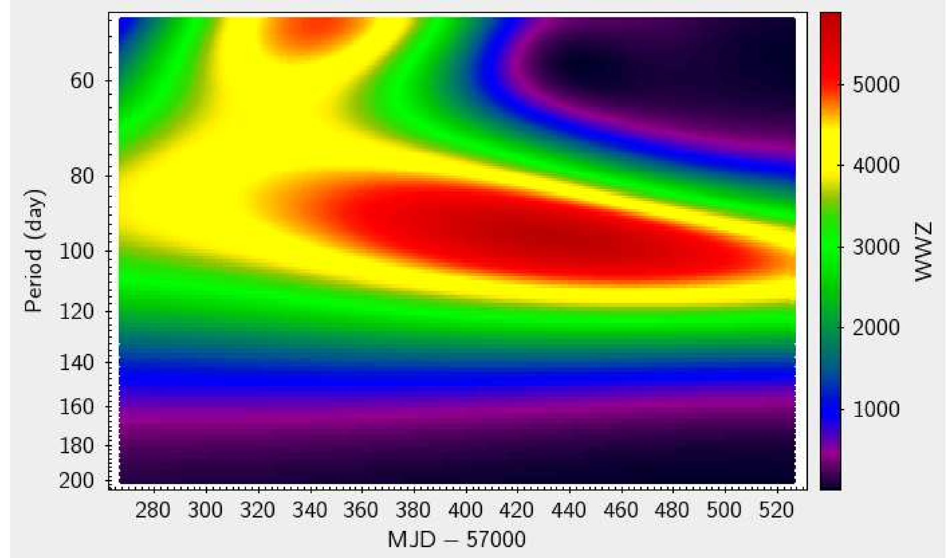

FIGURE 6: WWZ plot for the OJ287 LC during the 2015/16 season.

Comparison with the K2 data

OJ287 had been observed by the Kepler spacecraft during K2 Campaign 5. We used both short cadence and long cadence target pixel files. We employed our custom IRAF tasks to pull out fluxes, applying three-pixel circular apertures. The resulting light curve is shown in Fig. 7. We computed PSD functions for these and 2015/16 ground based data and that for K2 data is presented in Fig. 8. Neither show any statistically significant periodicites.

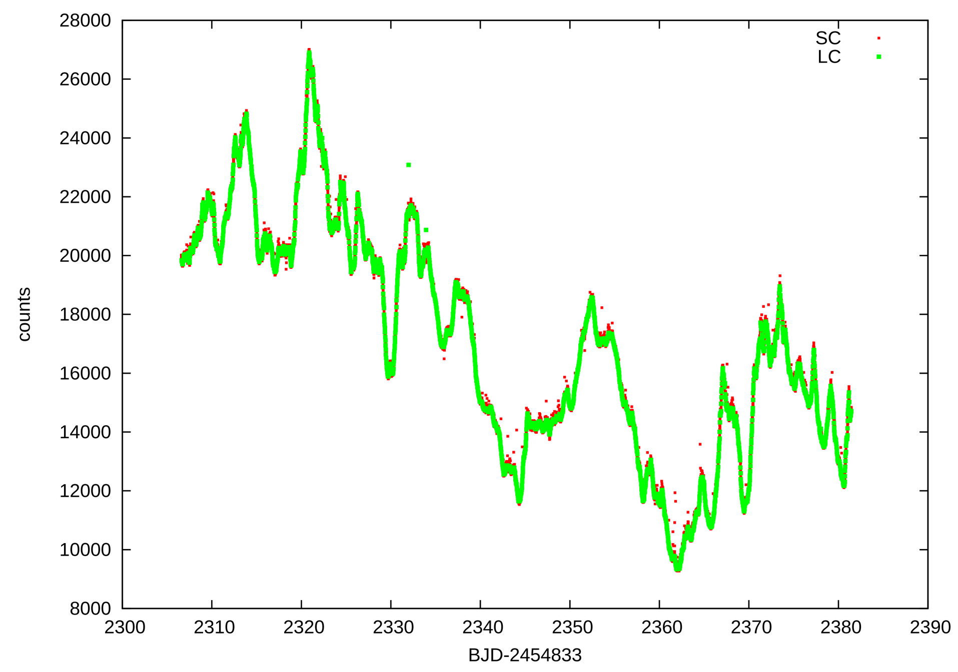

FIGURE 7: Kepler Campaign 5 light curve of OJ287.

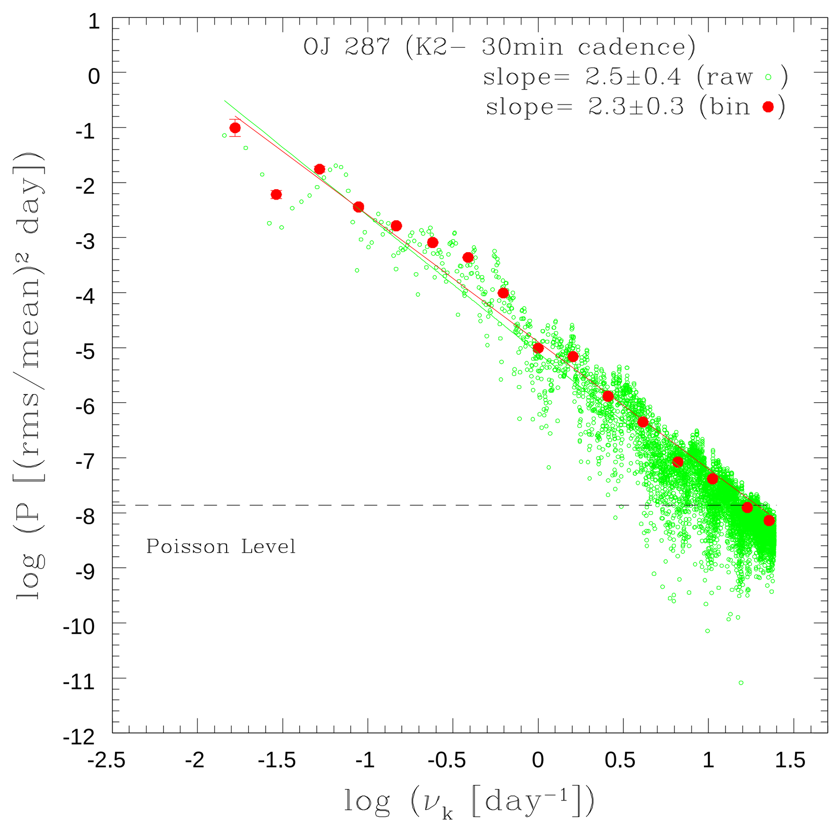

FIGURE 8: The PSD function for K2 data.

Conclusions

We found no stable periods in the OJ287 photometric data over the entire 2015/16 season. However, the 43-day peak in the power spectrum corresponds to the half period for the more massive BH ISCO and its updated spin value. There is also no firm evidence of any short period variability that could be attributed to the secondary black hole (at ISCO or the event horizon). The peaks that different techniques revealed are either transient, like the 3-day period found in the maximum of the December 2015 flare, or, the periods and the variability amplitudes of these in the higher frequency domain change with time. Such flux changes are most likely to be originated in the jet. The PSD analysis for both ground and K2 data shows no statistically significant peaks. However, if they do exist they could be hidden due to high amplitude variability of the flaring component present after the unprecedented December 2015 outburst.

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