

Long Term Periodicity Analysis of OJ 287 at Optical V Waveband

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Abstract. BL Lacertae object OJ 287 is one of the blazar that shows convincing evidence to support periodic variations. We have collected V band data for OJ 287 from 1891 to 2010, from the University of Michigan Radio Observatory (UMRAO) database and the available literature. Based on the spectral estimate theory, this paper used the periodogram spectral estimate, the maximum entropy spectral estimate and bispectrum spectral estimate methods. Applying these methods to the periodic analysis of OJ 287, we find the most eminent period as 12.1 yr. The results confirm that the variability period of OJ 287 in the optical V band is in agreement with the radio variability period of about 12 years.

Key words. Galaxies: BL Lacertae objects—individual: OJ 287—periodic variation—methods: numerical: periodic analysis.

1. Introduction

Blazars are a special subclass of Active Galactic Nuclei (AGNs). One of the most prominent characteristics of blazars is large-amplitude and rapid variability over the whole electromagnetic spectrum (Kapanadze 2009). In recent years, the study of blazars variability plays an important role in providing important information for understanding the structure and physical process in the central region of AGNs. (Valtonen *et al.* 2008). The long-term variability in some of the blazars show significant periodicity or quasi-periodicity ranging from several months to years, respectively.

There are many methods of time series data analysis to study the periodicity or quasi-periodicity in the light curves of blazars. The power spectrum estimation methods have been widely used, because, the method for period searching is effective and satisfactory. It can obtain variability timescales of blazars when the whole light curve

can fit in a single sinusoid (Hovatta *et al.* 2008). In order to verify the feasibility of these spectrum estimation methods in the periodicity analysis on real observational data. We select the blazar OJ 287 for our experiments. In addition to make certain comparative studies, we studied the properties and differences of the methods. We organize the paper as follows: the light curves and data of OJ 287 are presented in section 2. In section 3, we present the results, and the discussion and conclusion are given in section 4.

2. Data

The blazar OJ 287 at redshift $z = 0.306$ has been observed for more than 100 years since the late 19th century. Recently, OJ 287 has received more attention from international astronomical community, because its recurrent optical outbursts exhibit a period of 12 years with a double-peaked maximum in its flux variations. The binary black-hole model can possibly explain the periodic outburst. The observational data of OJ 287 at the optical V band used in the present paper has been collected from 1891 to 2010, including the observed data given by UMRAO database and the following literature (Fan *et al.* 2009; Valtonen *et al.* 2006). The data are shown in Fig. 1.

3. Methods

3.1 Periodogram method

The periodogram method is a kind of classical spectrum estimation method, and the periodogram power spectrum estimation is based on the fast Fourier transform of observed data. Lomb (1976) introduced this method. The power spectrum of OJ 287 at the optical V band by the periodogram method are given in Fig. 2. From the figure

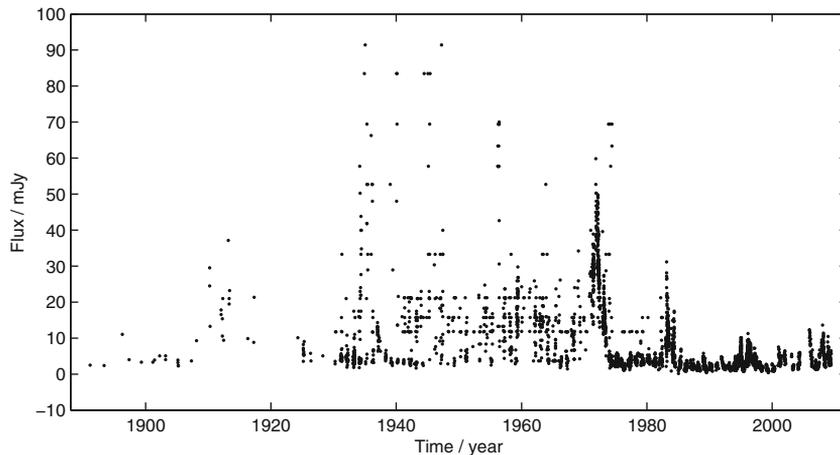


Figure 1. The light curve of OJ 287 at the optical V waveband from 1891 to 2010 and the fluxes are in the ordinate.

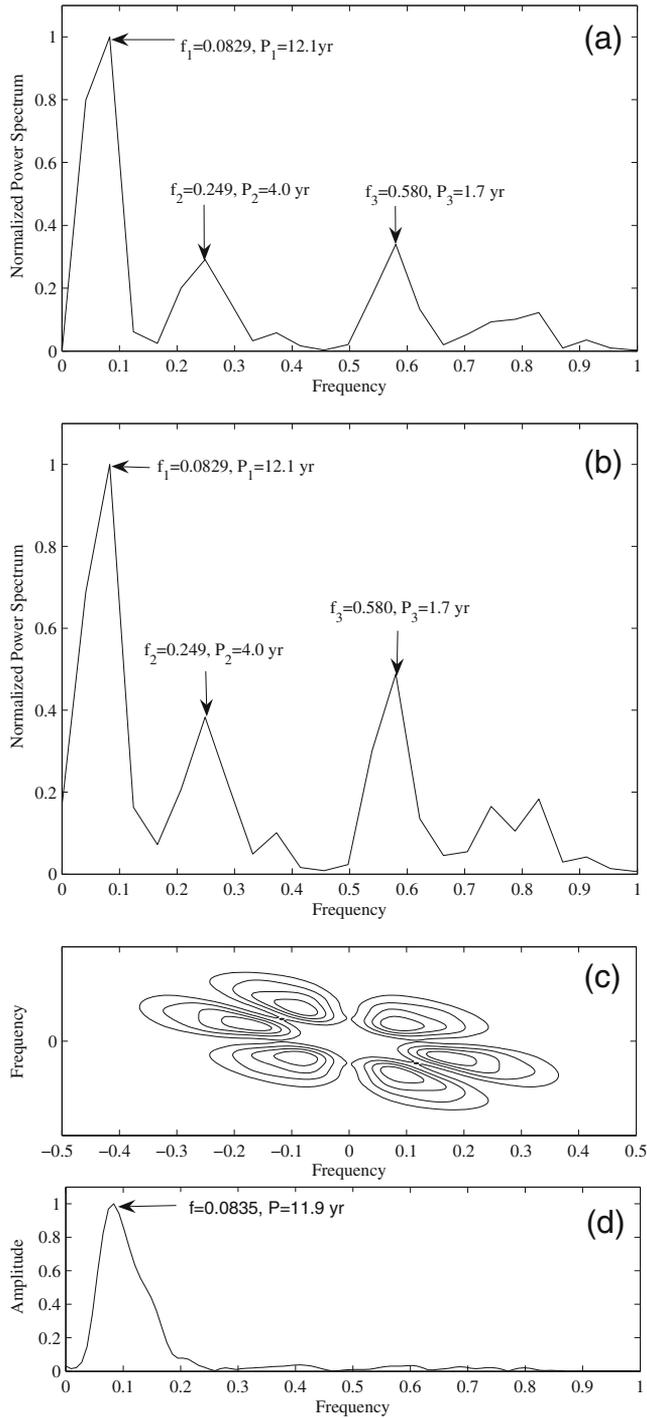


Figure 2. The results obtained for OJ 287 at the optical V waveband. (a) The periodogram method; (b) the maximum entropy method. The bispectrum estimation – (c) bispectrum, (d) slice bispectrum.

we can see three peaks, so there are obviously three periodicities for OJ 287, viz., 12.1, 4.0 and 1.7 years.

3.2 Maximum entropy method

The maximum entropy method was originally proposed by Burg (1975) for use in seismic wave analysis. The maximum entropy method has been applied to the time series for the blazar object OJ 287 in an optical V band, and the result is shown in Fig. 2. By the maximum entropy analysis method, we have obtained the same periods, viz., 12.1, 4.0 and 1.7 years, which are in good agreement with the results obtained by the periodogram power spectrum estimation method.

3.3 Bispectrum spectral method

In recent years, the higher-order spectra is widely used in radar, sonar, geophysics, biomedicine, etc. As one high-order spectrum estimation, bispectrum estimation is the Fourier transform of the third-order cumulant sequence. Bispectrum and slice bispectrum analysis techniques are especially suited to non-Gaussian and nonlinear signal processing (Nikias & Raghuvver 1987). Using V-band observational data of OJ 287, we obtain the results shown in Fig. 2. Figure 2 indicate bispectrum and slice bispectrum, respectively. From the figure of slice bispectrum, we can easily find that the highest peak corresponds to the 11.9 yr period.

4. Discussion and conclusion

This paper mainly introduces the basic principles of the periodogram spectral estimate, the maximum entropy spectral estimate and bispectrum spectral estimate. It also compares the advantages and disadvantages of these power spectral estimate methods through periodicity analysis on V-band data of the blazar OJ 287, and provides the reference for the selection of periodicity analysis methods. The periodogram spectrum estimation method easily produces false peaks, but the periodogram method gives similar results as the maximum entropy spectrum estimation method when the observational data are very large. Compared to the periodogram and maximum entropy methods, the bispectrum spectral method can improve the resolution of spectrum estimation and give a high-stability spectrum estimation with a rather high accuracy. We have found that the blazar OJ 287 has 12.1-, 4.0- and 1.7-yr periods. The analysis given in the preceding discussion confirms the existence of 12 yr periods. It is shown that these results are completely consistent with those of astronomical literature obtained by other methods, and all the further analysis proves that these power spectral estimation methods are concise and effective. We are not certain whether 4.0- and 1.7-yr periods are true periods or not, and it needs to be confirmed by future observations.

Acknowledgements

This work is supported by the National Nature Science Foundation of China (U1231202, 11063004), the innovation team of gravitation theory research in

Yunnan Normal University (2011CI127), the innovation team of High Energy Astrophysics Science and Technology in Yunnan Province Universities, the Science Foundation of Yunnan Province of China (2010CD016, 2012FB140).

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