J. Astrophys. Astr. (2014) **35,** 279–281

Computing Optical Variable Periods of BL Lac Object S5 0716 + 714 with Period04 Analysis Method

Junping Fu, Xiong Zhang* & Dingrong Xiong
Department of Physics, Yunnan Normal University, 650500 Kunming, China.
**e-mail: ynzx@yeah.net*

Abstract. From a large volume of literature, we have collected effective observation of BL Lac object S5 0716 + 714 in the optical band, and constructed its long-term light curve from 1994 to 2006 AD. The light curve shows that S5 0716 + 714 is very active and exhibits very complicated non-sinusoidal variations. We used Period04 to analyse the period of light curve variation. Our results show that for S5 0716 + 714, the long-term period of variation is 3.3 yr which is consistent with the result of Raiter *et al.* (2003).

Key words. BL Lac object: general—S5 0716 + 714: individual.

1. Introduction

The study of long-term periodical variation is an important way to get the characteristics of BL Lac objects (Villata *et al.* 1997). If the long-term period of variation exists, which often means that the BL Lac objects have rotation, vibration and orbital movements. These movements are also scaling out of body mass of the central black hole, the radiation area and internal structure (Lehto *et al.* 1996). In recent years, many theoretical models have been proposed to explain the long-term periodical variation of BL Lac objects, such as black hole double-jet model and moving accretion disk model (Sillanpää *et al.* 1988). So, the study of long periodic optical variability of BL Lac objects is very much necessary (Jurkevich 1971; Zhang *et al.* 1998). From a large number of references, we obtained the most complete observational data of S5 0716 + 714 at the optical B, V, R, I bands from 1994 to 2006 (Zhang *et al*. 2007). Then we use the Period04 analysis methods to analyse the long-term periodical variation of S5 0716 + 714 (Fig. 1).

2. Principle of the Period04

The Period04 used in this paper is the spectrum analysis software, which is used in astronomy and specialized for processing the time series data. The Period04 provides a tool to extract period from complex multi-cycle timing data and a flexible interactive interface to do a multi-cycle fitting. For discrete Fourier transform, we assume

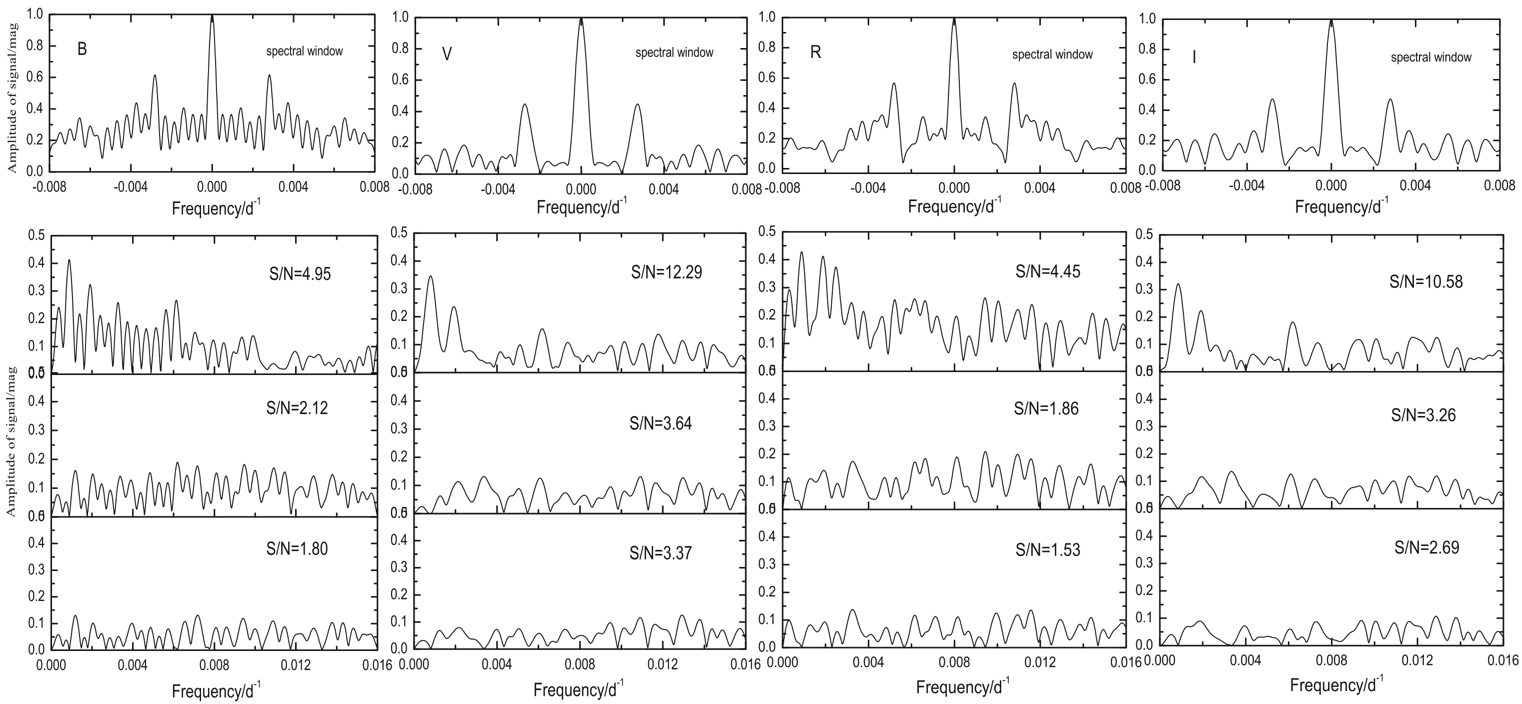

Figure 1. Period04 analysis results, from columns left to right are the optical B, V, R, I bands. The rows are analysis results in different signal-to-noise levels.

that the timing data $x(t)$ is a continuous function, wherein only some of the discontinuous point t_i is known. The discrete Fourier transform when contacted with the continuous Fourier transform together, define a window function, and finally obtain the following formula:

$$\frac{F_N(v)}{N} = \frac{1}{N}\sum_{k=1}^{M}\sum_{i=1}^{N}\exp(2\pi\ (v - v_k)t_i)\,. \tag{1}$$

Using this method on the light curve for discrete Fourier transform, we first find F_1, and then remove F_1 spectrum. Then we persistently conduct the next Fourier transform and recycle many times, until only a noise remains.

3. Discussion and conclusion

In this paper, we study the long-term periodical variation of S5 0716 + 714 at optical B, V, R and I bands. According to Breger *et al.* (1993), we can only consider the S/N ratio of a frequency greater than 4.0 for further analysis. Therefore, to analyse the result of each band, the ratio of each band frequency F_1 frequency must meet the requirement. We use $F_{\rm B}$, $F_{\rm V}$, $F_{\rm R}$ and $F_{\rm I}$ which stands for optical B, V, R and I band frequencies respectively. Analysis shows that their S/N's are 5.55, 10.54, 4.70, 9.33, respectively. Each bands' periods are $T_{\rm B} = 3.30$ yr, $T_{\rm V} = 3.42$ yr, $T_{\rm R} = 3.27$ yr and $T_{\rm I} = 3.35$ yr, respectively. So the long-term period of variation of S5 0716 + 714 is about 3.3 yr at optical B, V, R, I bands, which is consistent with the result of Raiter *et al.* (2003). If S5 0716 + 714 has the long-term period of variation, our finding will be a very significant result. This result supports that BL Lac objects may have a long-term period and medium timescale of variability.

Acknowledgements

This work is supported by the National Natural 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).

References

Breger, M. *et al.* 1993, *Astron. Astrophys.*, **271**, 482.
Jurkevich, I. N. 1971, *Astrophys. Space Sci.*, **13**, 154.
Lehto, H. J. *et al.* 1996, *Astrophys. J.*, **460**, 207.
Raiter, C. M. *et al.* 2003, *Astron. Astrophys.*, **402**, 151.
Sillanpää, A. *et al.* 1988, *Astrophys. J.*, **325**, 628.
Villata, M. *et al.* 1997, *Astron. Astrophys. Suppl.*, **121**, 119.
Zhang, X. *et al.* 1998, *Astron. Astrophys.*, **320**, 469.
Zhang, X. *et al.* 2007, *Astrophys. J.*, **133**, 1995.