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Optical monitoring of the Seyfert galaxy NGC 4151 and possible periodicities in its historical light curve *

Di-Fu Guo[1], Shao-Ming Hu[1], Jun Tao[2], Hong-Xing Yin[1], Xu Chen[1] and Hong-Jian Pan[2]

[1] Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, Institute of Space Sciences, School of Space Science and Physics, Shandong University, Weihai, 264209, China; *husm@sdu.edu.cn*
[2] Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai 200030, China

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Abstract We report B, V and R band CCD photometry of the Seyfert galaxy NGC 4151 obtained with the 1.0 m telescope at Weihai Observatory of Shandong University and the 1.56 m telescope at Shanghai Astronomical Observatory from 2005 December to 2013 February. Combining all available data from literature, we have constructed a historical light curve from 1910 to 2013 to study the periodicity of the source using three different methods (the Jurkevich method, the Lomb-Scargle periodogram method and the Discrete Correlation Function method). We find possible periods of $P_1 = 4 \pm 0.1$, $P_2 = 7.5 \pm 0.3$ and $P_3 = 15.9 \pm 0.3$ yr.

Key words: methods: data analysis — galaxies: active — galaxies: individual (NGC 4151)

1 INTRODUCTION

The nature of active galactic nuclei (AGNs) is an important and open question in astrophysics. Photometric observation of AGNs is an important tool for constructing their light curves and for studying their variability behavior over different time scales. Photometric observations have been made for a long time, so it is possible to search for periodicity in the light curves of a number of objects (e.g. Kidger et al. 1992; Liu et al. 1995; Fan et al. 1997, 1998, 2002a, 2010; Qian & Tao 2004; Tao et al. 2008; Li et al. 2009; Chen 2014).

Based on the variability analysis, we can derive much information about the physical mechanisms associated with AGNs. In addition, a confirmed periodicity would help us investigate the relevant physical parameters and limit the physical models in AGNs (Lainela et al. 1999).

NGC 4151 (Seyfert type 1.5) is one of the nearest and brightest Seyfert galaxies ($z = 0.00332$ and $D = 13.2$ Mpc when a Hubble constant of $75\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$ is used). It is also one of the best studied objects across the entire electromagnetic spectrum owing to its brightness and variability properties. The nucleus of this galaxy shows flux variability over a wide range of wavelengths, with time scales from a few hours in hard X-ray (Yaqoob et al. 1993) to several months in infrared (Oknyanskij et al. 1999).

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The photometric observations of NGC 4151 began as early as 1906. The nucleus of NGC 4151 was first discovered in 1967 as variable in the optical region (Fitch et al. 1967), and the variability was confirmed by Zaitseva & Lyutyi (1969). Since then it has been intensively monitored by several monitoring campaigns (e.g. Clavel et al. 1990; Yaqoob et al. 1993; Kaspi et al. 1996). Optical variability time scales ranging from tens of minutes to decades were reported by many investigators (Lyutyi et al. 1989; Lyutyi 1977; Lyutyj & Oknyanskij 1987; Longo et al. 1996; Guo et al. 2006; Oknyanskij & Lyuty 2007). Oknyanskij et al. (2012) pointed out that NGC 4151 has different variable components: fast variations with a time scale of about tens of days; slow variations with a time scale of about several years; a very slow component with a time scale of about tens of years. NGC 4151 is one of the very few AGNs whose optical light curve data span more than a century, so it provides us a very good opportunity to analyze its periodicity.

In this work, we present optical (*BVR*) observations over 7.2 yr using the 1.0 m telescope at Weihai Observatory of Shandong University and the 1.56 m telescope at Shanghai Astronomical Observatory (SHAO). In Section 2, we describe our observations and data processing. Then in Sections 3 and 4, we present the light curves and the periodicity analysis. Discussions and conclusions are given in Section 5.

2 OBSERVATIONS AND DATA REDUCTION

From 2005 December to 2013 February, 1587 observations were obtained on 22 nights using the 1.0 m telescope at Weihai Observatory of Shandong University (observed from 2009 May to 2013 February) and the 1.56 m telescope at Sheshan Station administered by SHAO (observed from 2005 December to 2008 February). The seeing at Weihai Observatory usually varies from $1.2''$ to $2.5''$. The one-meter Cassegrain telescope at Weihai Observatory was equipped with a back illuminated PIXIS 2048B CCD camera from Princeton Instruments and a standard Johnson/Cousins set of *UBVRI* filters controlled by a dual layer filter wheel from American Astronomical Consultants and Equipment Inc. (ACE). The PIXIS camera has 2048×2048 square pixels and the pixel size is 13.5 μm. The scale of the image is about $0.35''$ per pixel and the field of view is about $11.8' \times 11.8'$. Readout noise and gain of this CCD detector is 3.64 electrons and 1.65 electrons/ADU, respectively, for slow readout and a low-noise output setup. The standard Johnson/Cousins filters (B, V and R) were used during our observations. For each observing night, twilight sky flats were taken and several bias frames were taken at the beginning of the observation. All data were processed by bias and flat-field correction. The instrumentation and data reduction information for SHAO is the same as in Guo et al. (2006). The task APPHOT in the IRAF software package was used to do the photometry. Comparison stars 2 and 3 taken from Penston et al. (1971) were used for calibration. An aperture radius of about $13''$ was adopted, which was larger than the minimum aperture recommended by Cellone et al. (2000). Then we were able to derive the magnitude of the source by differential photometry. The error is given as

$$\sigma = \sqrt{(m_2 - \overline{m})^2 + (m_3 - \overline{m})^2}\,, \tag{1}$$

where m_2 and m_3 are the magnitudes of NGC 4151 calibrated by the 2nd and 3rd comparison stars respectively, and $\overline{m}$ is the mean magnitude of the object obtained from the comparison stars.

3 LIGHT CURVES

Panels (a), (b) and (c) in Figure 1 show the light curves of NGC 4151 and the difference in magnitude between comparison stars 2 and 3 in the B, V and R bands, respectively. Different constants were added to the corresponding differential magnitudes of the comparison stars for clarity. During our observations, variations of 0.669 mag (12.199 to 12.868) in the B band, 0.964 mag (11.542 to 12.506) in the V band and 0.451 mag (10.875 to 11.326) in the R band were detected. Our observations in the V band illustrate that NGC 4151 was decreasing in its brightness from the beginning

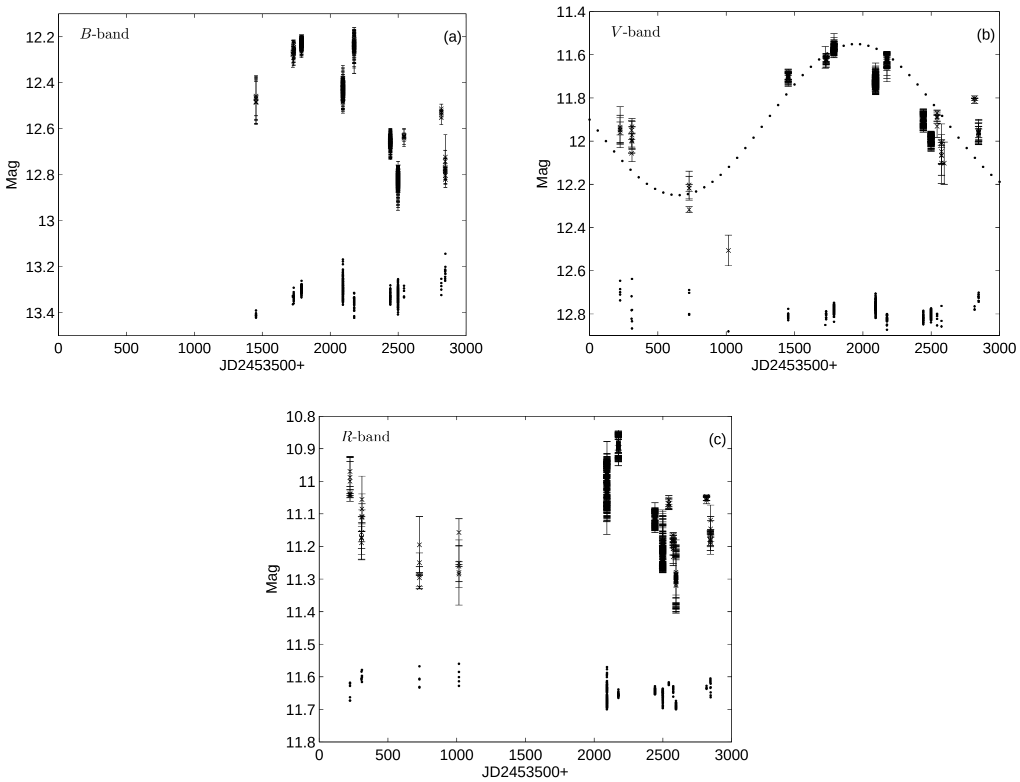

Fig. 1 Light curves of NGC 4151. '×' symbols denote the B, V and R band light curves of NGC 4151. Dots denote the difference in magnitude between the comparison stars 2 and 3 (constants were added). The dotted line in panel (b) is the fitted sine function for the V band data.

of our campaign and reached its minimum in 2008 February, then it began to brighten and reached its maximum in 2011 April; finally it slowly declined in brightness again on the whole with some fluctuations. The light curve can be roughly fitted by a sine function during our 7.2 yr observation period, but more data are needed to confirm whether this periodicity is real. The patterns of optical variability in these three bands are similar.

In order to detect microvariability, both C tests (Jang & Miller 1997; de Diego 2010) and F tests (de Diego 2010; Gaur et al. 2012) were performed on 10 out of 22 nights when we have more than five observations in the three bands simultaneously. However, no significant microvariability was detected during our observations.

4 PERIODICITY ANALYSIS

Many authors have investigated the variability periodicity of NGC 4151. Oknyanskij (1983) suggested a possible period of 16 yr using photographic estimates based on Odessa's plates. Lyutyi & Oknyanskii (1987) found periods of 4 and 14 yr applying the method of Deeming (1975) to a set of about 400 photoelectric photometry data. No evident periodicity was found by Longo et al. (1996). Fan & Su (1999) obtained a period of 14.08±0.8 yr using the Jurkevich method (JV). Oknyanskij & Lyuty (2007) found a periodic component of about 15.6 yr using the Fourier (CLEAN) algorithm.

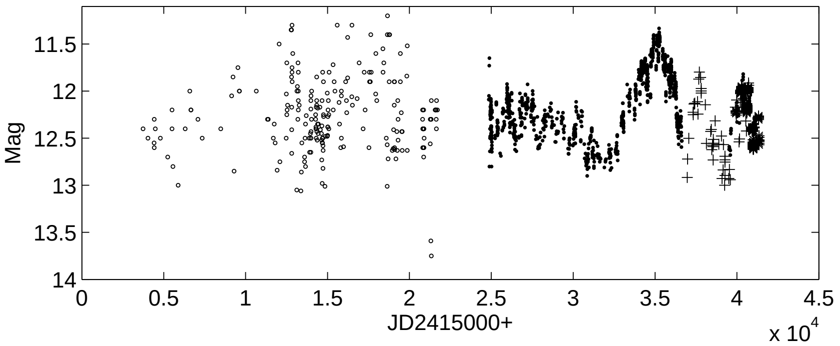

Fig. 2 Historical light curve of NGC 4151 from 1910 to 2013 in the B band. Dots denote the Crimean series data, circles denote the raw photographic data, pluses denote the data from Roberts & Rumstay (2012) and stars denote our observations.

Oknyanskij et al. (2012) suggested that NGC 4151 has different long-term variable time scales ranging from several years to tens of years, so we have reconstructed the historical light curve by combining our own observations with data in the literature (Zaitseva & Lyutyi 1969; Lyutyi 1973, 1977; Belokon et al. 1978; Lyuty & Doroshenko 1999; Doroshenko et al. 2001; Oknyanskij et al. 2012; Roberts & Rumstay 2012) and the raw photographic data from as early as 1910 to research periodicity. The long-term light curve in the B band was shown in Figure 2. The data used in this paper are mainly from Lyuty & Doroshenko (1999), Doroshenko et al. (2001) and Oknyanskij et al. (2012). These data are consistent with each other and they are from many published data. Their data set was subsequently called the Crimean series. We found that the data derived from Roberts & Rumstay (2012) were about 0.35 mag fainter compared with the Crimean data which were acquired on the same day. Unfortunately, our data did not overlap with the Crimean data set. However, we noticed that for the Crimean data set, the brightness of NGC 4151 remained nearly constant between JD 2456042 and JD 2456044, and we just had observations on JD 2456043. Furthermore, no microvariability was detected during our observations, so a linear interpolation can be used to combine our data with the Crimean data. A constant of about 0.25 mag was subtracted in order to combine our data with theirs.

In order to give more uniform weighting to different epochs, we carried out a 10-day averaging for all the available data. This bin size is short enough compared with the long-term periods which we are looking for (years) and is thus unlikely to distort long-term variations.

4.1 Jurkevich Method

The JV (Jurkevich 1971) is based on the expected mean square deviation. It does not require equally spaced observations, so it is less inclined to generate a spurious periodicity compared to Fourier analysis. It tests a series of trial periods and the data are folded according to the trial periods. Then all data are divided into m groups according to their phases around each trial period. The variance V_i^2 for each group and the sum of each group variance V_m^2 are computed. If a trial period equals the real one, then V_m^2 would reach its minimum. The detailed computation of the variances is described in Jurkevich (1971). In order to estimate the reliability of the period, Kidger et al. (1992) introduced a parameter,

$$f = \frac{1 - V_m^2}{V_m^2}\,, \tag{2}$$

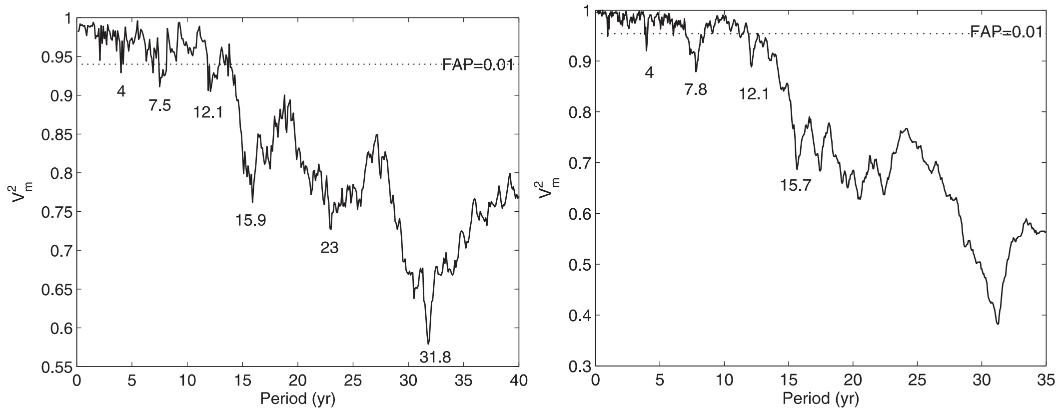

Fig. 3 Relationship between the trial period and V_m^2. The plots in the left and right panels were derived using all the available data and the post-1968 data, respectively.

where V_m^2 is a normalized value. In the normalized plot, a value of $V_m^2 = 1.0$ means that $f = 0$, hence there is no periodicity. The possible periods can be easily obtained from the plot. In general, if $f \geq 0.5$, it suggests that there is a strong periodicity in the data; if $f \leq 0.25$, this usually indicates that the periodicity, if genuine, is a weak one. A further test is the relationship between the depth of the minimum and the noise in the "flat"section of the V_m^2 curve close to the detected period (Kidger et al. 1992; Fan et al. 2006). Fan et al. (2010) pointed out that this method is not good enough to give a quantitative criterion and the False Alarm Probability (FAP, Horne & Baliunas 1986) can deal with all kinds of periodicity analysis methods if the variations (mainly) consist of randomly distributed noise. So, we adopted FAP to give a quantitative criterion (see Fan et al. 2010; Chen et al. 2014) for the detected periods. One should also keep in mind that the confidence level derived by this method tends to be overestimated because independent random values were used to evaluate the statistical significance of periods and it may have neglected the fact that there are dependent random values in the light curves of AGNs.

The results by the JV method with $m = 5$ are shown in the left panel of Figure 3 and there are no significant differences when $m = 10$ was used. FAP level of 0.01 is also marked in the figure derived from the Monte Carlo method as proposed by Fan et al. (2010). From the figure, there are several obvious minimum values for V_m^2 whose FAP is smaller than 0.01, indicating possible periods in the trial. The first minimum of $V_m^2 = 0.92$ is at the period $P_1 = 4 \pm 0.1$ yr, which is consistent with the result of 4 yr found by Lyutyi & Oknyanskii (1987). The second minimum of $V_m^2 = 0.91$ corresponds to $P_2 = 7.5 \pm 0.3$ yr. The third minimum of $V_m^2 = 0.9$ corresponds to $P_3 = 12.1 \pm 0.2$ yr. The fourth minimum of $V_m^2 = 0.76$ corresponds to $P_4 = 15.9 \pm 0.3$ yr. The fifth minimum of $V_m^2 = 0.72$ corresponds to $P_5 = 23 \pm 0.3$ yr and the sixth minimum of $V_m^2 = 0.58$ corresponds to $P_6 = 31.8 \pm 0.2$ yr. We note that those periods have the following simple relationships: $P_3 \approx 3P_1$, $P_5 \approx 3P_2$ and $P_6 \approx 2P_4$.

From Figure 2, one can see a large gap between JD 2436717 and JD 2439849 which may strongly affect the sensitivity of the method and result in the appearance of a false period. So, we apply both the JV method and the Monte Carlo method to the more homogeneous data set after 1968 (beginning from JD 2439849, called post-1968 data hereafter) to calculate the periodicity and FAP (0.01). The results are shown in the right panel of Figure 3. One can see from the right panel of Figure 3 that there are several obvious minimum values for V_m^2 whose FAP is smaller than 0.01. Taking the shorter time span (only about 45 yr of observation) which was less than six times the period (Kidger et al. 1992) into consideration, periods larger than ten years were ruled out. The periods of 4 ± 0.1 and 7.8 ± 0.4 yr found in the right panel are in good agreement with the periods of $P_1 = 4 \pm 0.1$ and $P_2 = 7.5 \pm 0.3$ yr found in the left panel of Figure 3, respectively.

4.2 Lomb-Scargle Periodogram Method

In order to investigate the reliability of these results, we also generated the Lomb-Scargle (LS) normalized periodogram to analyze the periodicity. The LS normalized periodogram (Lomb 1976; Scargle 1982; Press et al. 1992) is a powerful method which can be applied to the periodicity analysis of random and unevenly sampled observations.

For a time series $X(t_k)(k = 0, 1...., N_0)$, the periodogram as a function of frequency ω is defined as

$$P_x(\omega) = \frac{1}{2}\left\{\frac{[\Sigma_i X(t_i)\cos\omega(t_i - \tau)]^2}{\Sigma_i \cos^2\omega(t_i - \tau)} + \frac{[\Sigma_i X(t_i)\sin\omega(t_i - \tau)]^2}{\Sigma_i \sin^2\omega(t_i - \tau)}\right\}, \tag{3}$$

where τ is defined by the formula

$$\tau = \frac{1}{2\omega}\tan^{-1}\left[\frac{\Sigma_i \sin 2\omega t_i}{\Sigma_i \cos 2\omega t_i}\right]. \tag{4}$$

Here and throughout, ω is the angular frequency and $\omega = 2\pi\nu$, so the periodogram is also a function of frequency ν. According to the definition of $P_x(\omega)$, the power in $P_x(\omega)$ follows an exponential probability distribution if the signal $X(t_k)$ is purely noise. This exponential distribution provides a convenient estimate for the probability that a given peak is a real signal, or it is only the result of randomly distributed noise. For a power level z, FAP is calculated as (see Scargle 1982; Press et al. 1992)

$$p(> z) \approx N \cdot \exp(-z), \tag{5}$$

where N is the number of frequencies considered when searching for the maximum. N is very nearly equal to the number of data points N_0 when the data points are approximately equally spaced and the estimate of N does not need to be very accurate (Press et al. 1992), and the half width at half maximum of the peak can be used to estimate the corresponding periodic error.

The results of the LS periodogram and FAP are shown in Figure 4. Power curves in the left panel and in the right panel were calculated using all the available data and the post-1968 data, respectively. From the left panel of Figure 4, we find several peaks ($P_1 = 4 \pm 0.2$, $P_2 = 7.64 \pm 0.3$, $P_3 = 12.41 \pm 0.6$, $P_4 = 15.91 \pm 0.9$, $P_5 = 22.68 \pm 1.6$, $P_6 = 34.09 \pm 3.2$) whose FAP are smaller than 0.001. For the results of P_2, P_3, P_4, P_5 and P_6, we note that $P_5 \approx 3P_2$, $P_4 \approx 4P_1$ and $P_3 \approx 3P_1$. The periods found by the LS periodogram are in good agreement with the results found by the JV method using all the available data. We also apply the LS periodogram with the post-1968 data to calculate the periodicity and the results are shown in the right panel of Figure 4. The periods of 3.96 ± 0.1 and 7.6 ± 0.4 yr correspond to $P_1 = 4 \pm 0.1$ and $P_2 = 7.5 \pm 0.3$ yr found by the JV method using the same data set, respectively.

4.3 Discrete Correlation Function Method

For comparing and further investigating the reliability of these periods, we have performed the Discrete Correlation Function (DCF) method to analyze the periodicity. The DCF method, introduced by Edelson & Krolik (1988), can be used to analyze unevenly sampled variability data, with the advantage of not requiring interpolation of the data. It can be done as follows. Firstly, we calculate

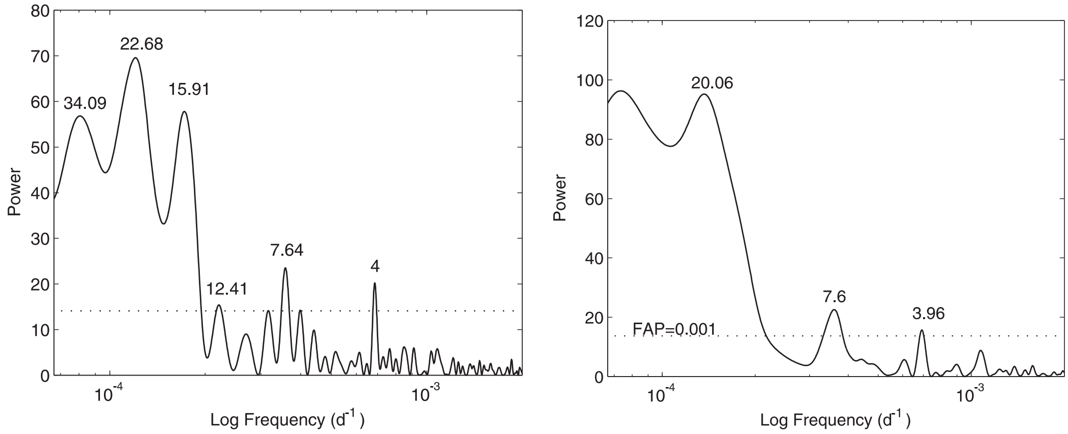

Fig. 4 Results of the LS method for NGC 4151. The power curves in the left and right panels were calculated using all the available data and the post-1968 data, respectively. The dotted lines denote the FAP of 0.001.

the values of the unbinned discrete correlation function (UDCF) for all measured pairs (a_i, b_j), i.e.

$$\mathrm{UDCF}_{ij} = \frac{(a_i - \overline{a})(b_j - \overline{b})}{\sigma_a \sigma_b}\,, \tag{6}$$

where $\overline{a}$ and $\overline{b}$ are the average values of the data sets, and σ_a and σ_b are the corresponding standard deviations. Secondly, we averaged the points sharing the same time lag τ by binning the UDCF_{ij} in suitably sized time-bins, then $\mathrm{DCF}(\tau)$ can be calculated as follows:

$$\mathrm{DCF}(\tau) = \frac{1}{M} \sum \mathrm{UDCF}_{ij}(\tau)\,, \tag{7}$$

where M is the number of pairs satisfying $\tau - \Delta\tau/2 \leq \Delta t_{ij} < \tau + \Delta\tau/2$. Then, the standard error for each time lag τ is

$$\Delta\tau = \frac{1}{M-1} \left\{ \sum \Big[\mathrm{UDCF}_{ij} - \mathrm{DCF}(\tau) \Big]^2 \right\}^{0.5}\,. \tag{8}$$

In general, a positive peak constitutes a possible period and the height of the peak indicates the periodicity strength (Hufnagel & Bregman 1992). The results of DCF are displayed in Figure 5. The DCF curves in the left and right panels were obtained using all the available data and the post-1968 data, respectively. Several possible periods, estimated from positive peaks in the DCF, are $7.4 \pm 0.1, 15.3 \pm 0.2, 16.1 \pm 0.2, 19.7 \pm 0.3, 22.8 \pm 0.3, 23.7 \pm 0.3, 27.6 \pm 0.3$ and 31.8 ± 0.2 yr for the left panel of Figure 5; $15.5 \pm 0.2, 16.2 \pm 0.3, 19.7 \pm 0.3, 22.8 \pm 0.3, 23.8 \pm 0.4, 27.8 \pm 0.4$ and 31.8 ± 0.2 yr for the right panel. One can note that the periods found by the DCF method have relationships such that one frequency is a multiple of another frequency with the periods of $P_1 = 4 \pm 0.1$, $P_2 = 7.5 \pm 0.3$ or $P_3 = 15.9 \pm 0.3$ yr found by the JV method.

4.4 Results

From the analyses of the results given above, we summarize the main periods in Table 1. For the periods of P_1, P_2, P_3, P_4, P_5 and P_6 derived by the JV method and the LS periodogram (see Table 1),

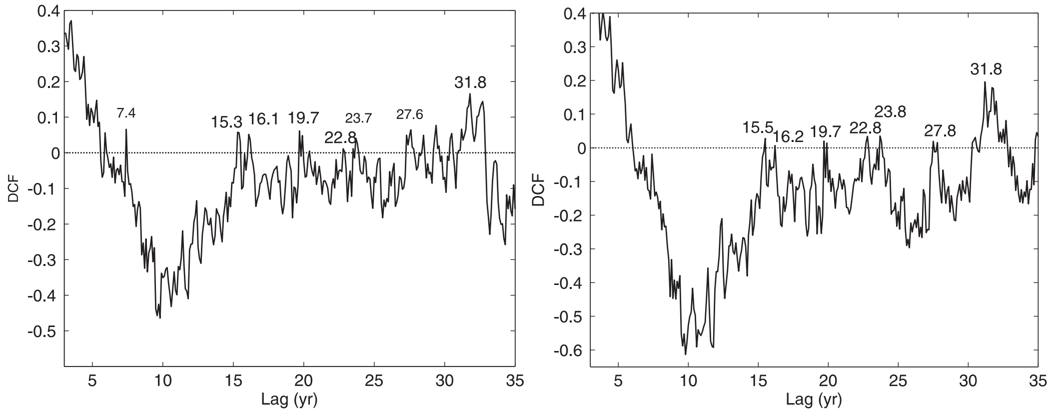

Fig. 5 Results of the DCF method for NGC 4151. The DCF curves in the left and right panels were obtained using all the available data and the post-1968 data, respectively.

Table 1 Periodicity Analysis Results

	P_1 (yr)	P_2 (yr)	P_3 (yr)	P_4 (yr)	P_5 (yr)	P_6 (yr)
JV$^\diamond$	4 ± 0.1	7.5 ± 0.3	15.9 ± 0.3	$12.1 \pm 0.2\,(3P_1)$	$23 \pm 0.3\,(3P_2)$	$31.8 \pm 0.2\,(2P_3)$
JV(post-1968)*	4 ± 0.1	7.8 ± 0.4				
LS$^\diamond$	4 ± 0.2	7.64 ± 0.3	15.91 ± 0.9	$12.1 \pm 0.6\,(3P_1)$	$22.68 \pm 1.6\,(3P_2)$	$34.09 \pm 3.2\,(2P_3)$
LS (post-1968)*	3.96 ± 0.1	7.6 ± 0.4				
DCF$^\diamond$		7.4 ± 0.1	16.1 ± 0.2		$22.8 \pm 0.3\,(3P_2)$	$31.8 \pm 0.2\,(2P_3)$
DCF (post-1968)*			16.2 ± 0.3		$22.8 \pm 0.2\,(3P_2)$	$31.8 \pm 0.2\,(2P_3)$

$\diamond$: Using all the available data. *: Using photoelectric photometry and CCD observational data after 1968.

one can note that there exists a simple relationship: $P_3 \approx 4P_1$, $P_4 \approx 3P_1$, $P_5 \approx 3P_2$ and $P_6 \approx 3P_3$. According to the result by Kidger et al. (1992), the period of $P_1 = 4 \pm 0.1$ yr found by the JV method is a weak one, whereas $P_3 = 15.9 \pm 0.3$ yr is a strong periodicity. At the same time, Oknyanskij & Lyuty (2007) and Bon et al. (2012) also found a possible period of around 16 yr using different methods and data, so we think that the periods $P_1 = 4 \pm 0.1$ and $P_3 = 15.9 \pm 0.3$ yr have different origins, although they represent a case where one frequency is a multiple of the other frequency, $P_3 \approx 4P_1$.

For a further comparison, we use the DCF method for periodicity analysis. However, there is no sign of a 4 yr period in the DCF analysis. This may be due to the period of P_1 being weak. Furthermore the DCF analysis diluted the sign of other periods if more than one period is present (Fan et al. 2006). Although there is no sign of a 4 yr period in the results from the DCF method, it is interesting to note that the periods of $19.7 \pm 0.3, 23.7 \pm 0.3$ and 27.6 ± 0.3 yr are about 5, 6 and 7 times the 4 yr period (see Fig. 5), respectively. It implies that they have a relationship of frequencies that is based on an astronomical phenomenon. Based on the analysis above, we think that the period of 4 ± 0.1 yr does indeed exist. Taking into account the fact that our light curve in the V band can be roughly fitted by a 7.1-year sine function, which is consistent with the period of $P_2 = 7.5 \pm 0.3$ yr, the possible periods found by the three methods are $P_1 = 4 \pm 0.1$, $P_2 = 7.5 \pm 0.3$ and $P_3 = 15.9 \pm 0.3$ yr.

5 DISCUSSION AND CONCLUSIONS

The variability mechanism of AGNs is not yet well understood and some models have been proposed to explain the possible optical long-term periodic variations: the binary black hole model, the disk-instability model and the perturbation model. As for NGC 4151, Aretxaga & Terlevich (1994) found that the long term variability of NGC 4151 can be described well by the starburst model. However, it is difficult to explain the short time scale of the optical variability and the extreme energetics (Gopal-Krishna et al. 2000). Fan et al. (2002b) adopted the structure function to B band data to discuss the emission origin in the Seyfert galaxy NGC 4151 and the result favored the disk instability model. Czerny et al. (2003) concluded that the long term variability may be caused by radiation pressure instability in the accretion disk by analyzing 90 yr of the optical data and 27 yr of the X-ray data using the normalized power spectral density and the structure function. Lyuty (2005) found that the pattern of ultraviolet and optical variability in NGC 4151 agreed excellently with the theory of disk accretion instability for a supermassive black hole suggested by Shakura & Sunyaev (1973). Oknyanskij & Lyuty (2007) thought the 14–16 yr cycles seen in the light curve probably correspond to some dynamic time for accretion. Analysis by Bon et al. (2012) showed that periodic variations in the light curve and radial velocity curve can be accounted for by an eccentric, sub-parsec Keplerian orbit with a 15.9 yr period.

The historical light curve of NGC 4151 showed strong variability and three possible periods were found by different methods that analyze periodicity. The periods of $P_1 = 4\pm0.1$, $P_2 = 7.5\pm0.3$ and $P_3 = 15.9 \pm 0.3$ yr are consistent with the findings by Oknyanskij et al. (2012) that NGC 4151 has different long-term variable time scales ranging from several to tens of years. The period of $P_1 = 4 \pm 0.1$ yr is in good agreement with the result found by Lyutyi & Oknyanskii (1987), and the period of $P_3 = 15.9 \pm 0.3$ yr is also consistent with the results found by many investigators (Oknyanskij 1983; Guo et al. 2006; Oknyanskij & Lyuty 2007; Bon et al. 2012). The multiple periods we derived may imply there are instabilities in the disk.

In our monitoring program, we observed NGC 4151 from 2005 December to 2013 February. The observations clearly show that the source is variable in the optical band with amplitudes varying by 0.669, 0.964 and 0.451 mag in the B, V and R bands, respectively. The B band historical light curve is constructed, which has a time span of 103 yr. Possible periods of $P_1 = 4\pm0.1$, $P_2 = 7.5\pm0.3$ and $P_3 = 15.9 \pm 0.3$ yr were found in the light curve by adopting the JV method, the LS periodogram method and the DCF method.

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