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The Optical Variability of 3C 273

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Abstract B-band measurements of 3C 273 over some 110 years are compiled and used in a search for periodicities using the Jurkevich method. Periods of 2.0, 13.65±0.20 and 22.5±0.2 yr are found. If the long-term periodicity is from the instability of a slim disk, then the periodicity ($\sim$ 13-yr or $\sim$ 22-yr) suggests masses of $10^7 M_\odot$ for the central black holes.

Key words: Galaxies: active — Galaxies: individual: 3C 273

1 INTRODUCTION

The nature of AGNs is still an open problem. The study of their variability can yield valuable information about their nature, and carries important implications for quasar modeling (see Fan et al. 1998). Some objects have been claimed to show periodicities in their light curves (see Jurkevich 1971; Sillanpaa et al. 1988; Kidger et al. 1992; Babadzhanyants & Blelokon 1991; Fan et al. 1997, 1998, 1999; Fan & Lin 2000; Fan & Su 1999; Su 2000; Zhang et al. 1998). 3C 273 is variable at all wavelengths (Curvoisier et al. 1988, 1990; Curvoisier 1991; von Montigny et al. 1997; and references therein). Recently, Curvoisier(1998) reviewed the properties of this object. There has been intense interest in searching for possible periodicity in the light curve of 3C 273: 9 yr period (Ozernoi, Gudzenko and Chertoprud 1977); 13.4 yr and 18.3 yr period (Babadzhanyants & Belokon 1991); week evidence of a period of 16 years (Kunkel 1967) in the radio band (Abraham & Romero 1999). Here, we use the Jurkevich method to investigate periodicity in the light curve of 3C 273. The paper has been arranged as follows: in Section 2, the Jurkevich method is used to search for periodicities; in Section 3, some discussions and a brief conclusion are given.

2 METHODS OF PERIODICITY ANALYSIS AND RESULT

2.1 Light Curves

Measurements in the optical B-band over some 110 years are available for 3C 273. They are from the literature: Angione et al. (1981); Antione & Smith (1985); Barbieri & Erculiani (1968); Burkhead (1968), (1969), (1980); Burkhead & Hill (1975); Burhead & Lee (1970); Burkhead &

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Rettic (1972); Burkhead & Stein (1971); Corso et al. (1985), (1986), (1988); Curvoisier et al. (1988); Cutri et al. (1985); Doroshenko (1987); O'Dell et al. (1978); Okyudo (1993); Raitern et al. (1998); Sadun (1985); Sandage (1964), (1966); Schaefer (1980); Sembay et al. (1993); Sillanpaa et al. (1988), (1991); Smith et al. (1987, 1991, 1992); Sitko et al. (1982); Takalo et al. (1992); Tritton & Selmes (1971). The data are shown in Figure 1.

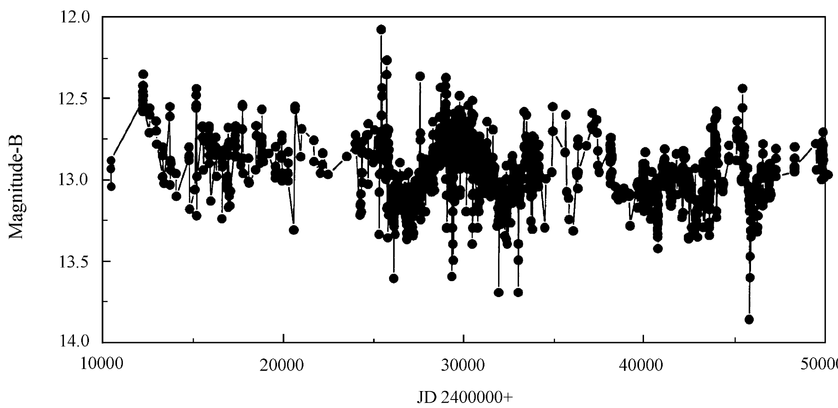

Fig. 1

2.2 Periodicity

The photometric observations of 3C 273 indicate that it is variable, but different periods are claimed in the light curve even when the same data set are used (see Angion & Smith 1985). With some recent observations becoming available, it is good for a renewed search. We will apply the Jurkevich method to the periodicity analysis.

The Jurkevich method (Jurkevich 1971, also see Fan et al. 1998; Fan 1999) is based on the expected mean square deviation and is less liable to generate spurious periodicity than the Fourier analysis. It tests a run of periods around which the data are folded. All the data are assigned to m groups according to their phase in each trial period. The variance V_i^2 for each group and the sum V_m^2 of all groups are computed. If a trial period is equal to the true one, then V_m^2 reaches minimum. So a 'good' period will give a much more reduced variance than an almost constant value given by other false trial periods. A further test is to check the depth of the minimum and the noise in the 'flat' section. If the former is large enough as compared with the standard error of the 'flat' section, five times for instance, the periodicity in the data can be considered as significant and the minimum as highly reliable (see Kidger et al. 1992; Fan et al. 1998; Fan 1999).

The Jurkevich method is used to analysis the 3C 273 B-band measurements, the results are shown in Fig. 2 ($m = 10$). Fig. 2 shows several minima corresponding to trial periods of 2.0, (13.65 ± 0.2), (22.5 ± 0.2) and (26.65 ± 0.15) yr, they are all five times higher than the flat noise. There is also a minimum corresponding to a period of 9 yr. A possible period of 18.22 yr, which is consistent with the period of 18.3 yr found by Babadzhanyants & Beloken (1991) also shows up with a feature, but it is much narrower and weaker compared with the periods of about 13 yr and about 22 yr, and there is no sign for the 16 yr period. The optical observations are not sampled evenly, which may cause false periods. To reduce this effect, we use Monte Carlo method to produce artificial data, then apply the Jurkevich method to the artificial data. If the periodicity appearing in the observed light curve also appears in the artificial light curve, then it is likely to be a spurious one and therefore should be ruled out. For 3C 273, the corresponding Monte Carlo result is shown in Fig. 3. Comparing Fig. 2 and Fig. 3, we can say that the derived periods of 2.0, 13, and 22.5 yr are reasonable.

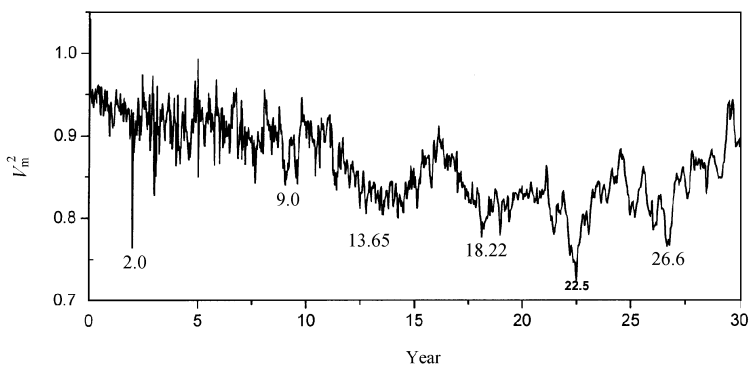

Fig. 2

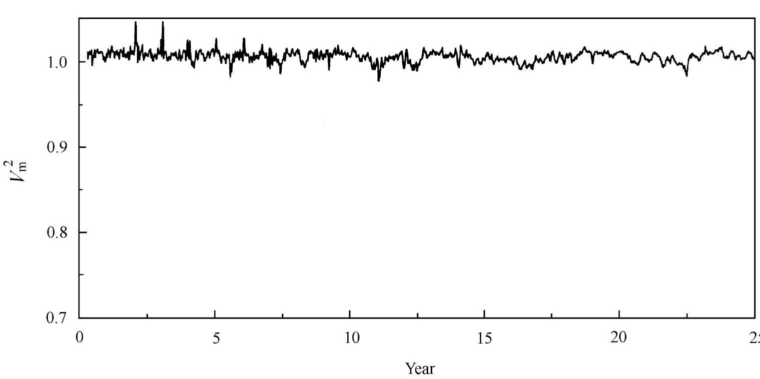

Fig. 3

3 DISCUSSION

Periodicities are searched for in the B-band light curve, the analysis gives the results of periods of 2.0, 13, and 22.5 yr.

Some models have been proposed to explain the long-term period variation (Sillanpaa et al. 1998; Meyer & Meyer-Hofmeister 1984; Horiuchi & Kato 1990; Abraham & Romero 1999). If we take the width of the half-maximum value as the time duration of the outburst, then Fig. 1 indicates that the duration of the outburst occurred in 1940 is about half the length of the derived period of about 13 yr. This feature can be explained as due to an instability of a slim disk in the AGNs. It is accepted that the central engine in AGNs contains a massive black hole surrounded by a slim accretion disk. Romero et al. (1999) found a 16 yr variability period in the radio band, which is longer than that found in the optical band. This feature suggests that the radio period is from precession of an inner jet while the shorter optical period could be the result of interaction between an orbiting object and the accretion disk that dominates the optical emission. In addition, there are other mechanisms which can be used to explain this kind of periodicity as we discussed in our paper (Fan, Romero, & Lin 2000).

Honma et al. (1991) has shown that the slim accretion disk can perform limit-cycle type oscillations as in the case of dwarf novae. The basic characteristic of the thermal limit cycle depends strongly on the viscosity parameter α, the mass of the central black hole M, the accretion rate $\dot{M}$, and the generalized stress parameter μ. But the time duration of the burst does not depend on μ and $\dot{M}$, and

$$T_b \sim 4.5(\mathrm{yr})(\alpha/0.1)^{-0.62} M_6^{1.37}$$

may be expressed on $\mu \sim 0.5$ and $\dot{M} \sim 0.2\dot{M}_{\mathrm{E}}/\eta$, where $\dot{M}_{\mathrm{E}}$ is the Eddington rate and η is the accretion efficiency, $M_6 = M/10^6\,M_\odot$. So the variation period can be written as $2T_b$. It should be noted that the Doppler factor δ affects the observed period P^{ob}, that a P^{ob} corresponds to a period of $\delta P^{\mathrm{ob}}/(1+z)$ in the source frame, where z being the redshift of the source. So the mass of central black hole is a function of the observed period P, α and δ, i.e.,

$$M_6^{1.37} \sim (1/9)(\delta P^{\mathrm{ob}}/(1+z))(\alpha/0.1)^{0.62},$$

which means that the upper limit of the mass of the central black hole can be written in the form

$$M_6^{1.37} \sim (1/9)(\delta P^{\mathrm{ob}}/(1+z))(\alpha/0.1)^{0.62} = 0.463\delta P^{\mathrm{ob}}/(1+z),$$

for the periods of about 13 yr and 22.5 yr. But it should be kept in mind that the upper limit of the mass, estimated from the above method, for the black hole at the center is smaller than the estimates in other works (see Fan 1999). The 2.0 yr periodicity is the result of penetration of the disk by secondary black holes (see Romero et al. 2000).

In this work, the optical B-band measurements are compiled from the available literature and used to search for periodicity using the Jurkevich method. Periods of 2.0 yr, $\sim$ 13 yr, and 22.5 yr are found.

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