Search for a periodic component in the optical light variations of the nuclei of the Seyfert galaxies NGC 1275 and NGC 3516

M. M. Basko and V. M. Lyutyi

Institute for Space Research, USSR Academy of Sciences, Moscow
and Crimean Station, Shternberg Astronomical Institute

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The optical brightness variations of NGC 1275 and NGC 3516 have been analyzed for periodicity. Against the background of strong ($\approx 1^m$) random fluctuations, any regular components with periods in the range $7^d.5 < P < 300^d$ have an amplitude no greater than $0^m.15$.

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The question of whether a periodic component exists in the variable optical radiation of Seyfert-galaxy nuclei and quasars is a very important one for an understanding of the nature of these objects.

In some objects there is evidence that the variable optical radiation contains a periodic component. For example, from observations in 1965-1967 Kinman et al.[1] found a period of 80 days for the quasar 3C 345. By analyzing the variability of the object 3C 120 on Harvard plates covering 60 years, Jurkevich et al.[2] identified a periodic component with P = 350 days and an amplitude of about $0^m.5$. From photographic observations of the N galaxy 3C 371, Babadzhanyants and Belokon'[3] report that the variable optical radiation has a period of 163 days; the mean amplitude of the periodic component is about $0^m.5$. According to photoelectric observations by one of us (Lyutyi), the light variations of the nucleus of the Seyfert galaxy NGC 4151 have a period[4] of 130 days, and the amplitude of the periodic component is comparable to the amplitude of the variability ($0^m.5$–$0^m.8$).

It is worth noting, however, that in nearly all cases the periodic component has been established from observations extending over only 2 or 3 years. The 80-day period of 3C 345 has not recurred in observations made since 1969, and the 130-day period of NGC 4151 seemed to go amiss in 1974-1976. Perhaps the periodic components in the brightness variability of such objects manifest themselves only for relatively short time intervals. Furthermore, the results of photographic observations should be approached with caution, especially when the amplitude of the brightness variation is small.

Photoelectric observations of the variability in the nuclei of the Seyfert galaxies NGC 1275 and NGC 3516 have been carried out[5] in 1966-1976, and the data permit a search for periodic components in the radiation of these objects. For both objects the variability is of fairly large amplitude, about 1^m (the observational error is no more than $0^m.03$).

The observational data have been analyzed on a BÉSM-6 computer, following a program described in detail elsewhere[6] by one of us (Basko). This program is based on two independent routines proposed earlier by Jurkevich[7] and Kurochkin.[8] Both algorithms involve a successive testing of values for the period P with a step

$$\Delta\left(\frac{1}{P}\right)=\frac{1}{L\Delta t},$$

where Δt is the time interval covered by the observations, and the integer L specifies the number of equal parts into which the interval of orbital phases $0 \le \varphi < 1$ is subdivided in the computation process. For each of the periods P tested, one computes: a) the dispersion – the rms deviation D from the averaged light curve (Jurkevich's algorithm); b) the correlation coefficient A with respect to the sine curve $\sin(2\pi t/P + \psi)$ (Kurochkin's algorithm). In the latter case the normalization of A and the phase of ψ are taken such that the function $A \sin(2\pi t/P + \psi)$ will give the best fit to the curve $m(t) - \overline{m}$ (the magnitude as a function of time). The quantity A is called the semiamplitude of the periodic component. The confidence in the period P improves as the dispersion D(P) decreases and the semiamplitude A(P) increases. The computed values of $D(P^{-1})$ and $A(P^{-1})$ are printed out on a plotter.

TABLE I. Quasiperiods for Two Seyfert Nuclei

NGC 1275			NGC 3516		
P	1/*P*	*A* (*P*)	*P*	1/*P*	*A* (*P*)
340^d	0.0029	$0^m.10$	315^d	0.0032	$0^m.08$
47.1	0.0212	0.08	16.0	0.0625	0.07
63.6	0.0157	0.08	25.3	0.0395	0.06
14.9	0.0671	0.07			
112.5	0.0089	0.07	11.79	0.0848	0.06
28.9	0.0346	0.07			

At least two components can be distinguished in the light curves of Seyfert-galaxy nuclei[9]: a fast component with a characteristic variability time scale of tens of days (component 1), and a slow component with a time scale of several years (component 2). For the nucleus of the galaxy NGC 1275, it is evident directly from the light curve that component 2 is cyclic with a duration of 1-2 yr (see Fig. 1 of a previous letter[10]). Over the time covered by the photoelectric observations (1967-1976), the slow component has passed through six cycles.

In order to exclude the effect of the slow component from the analysis of periodicity (it clearly gives a quasiperiod equal to the mean duration of a cycle), we have subtracted from the observed brightness measurements the level of the slow component (the lower envelope of the light curve). Periods have been sought within the range 7.5 < P < 800 days, and "periodograms" for both galaxies are displayed in Figs. 1-3.

The computer analysis demonstrates that no periodic components occur with an amplitude comparable to the

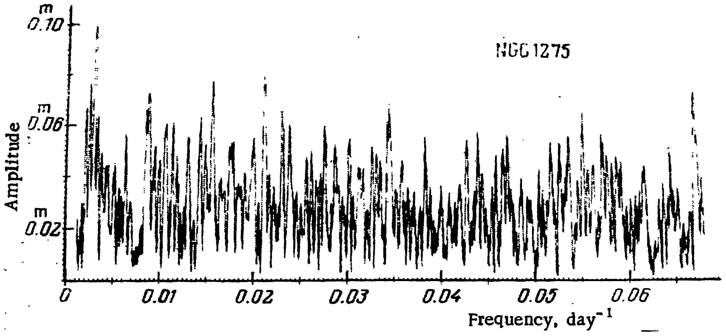

FIG. 1. Results of a periodicity analysis of photoelectric observations of the NGC 1275 nucleus, according to Kurochkin's algorithm. The greater the amplitude, the more reliable the period will be.

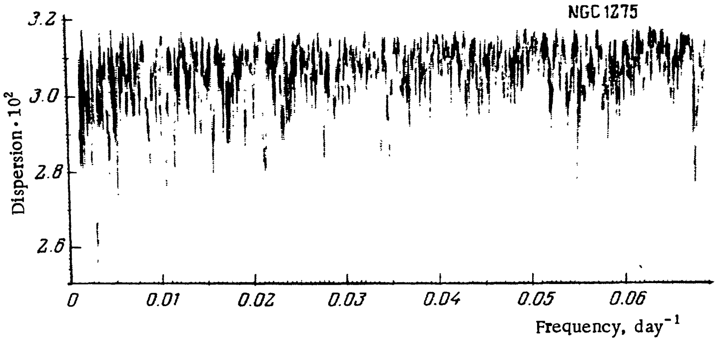

FIG. 2. Results of a periodicity analysis of the brightness of the NGC 1275 nucleus, according to Jurkevich's algorithm. The smaller the dispersion, the more reliable the period will be.

mean amplitude of the fast component (≈ $0^m.5$). We recall that the interval of observation is about 8 yr for NGC 1275 and 10 yr for NGC 3516. However, the periodograms contain peaks that coincide for the two algorithms and do not disappear when L is changed (L = 6, 7, 11). The corresponding periods are given in Table I, arranged in order of diminishing confidence.

All the quasiperiods indicated in Table I have a very low level of reliability; the full amplitude of the quasiperiodic components is no more than $0^m.15$-$0^m.2$. The observations cannot all be referred to any one of these periods, although over limited time intervals a particular period may provide a fairly good representation. For example, the 1973-1974 observing season corresponds quite well to a $28^d.9$ period, which was maintained for about 300 days to within $\Delta P/P \approx 5 \cdot 10^{-2}$.

To obtain a more trustworthy assessment of how many of the periods in Table I rise above the noise level, we have performed the following experiment: Setting aside the dates of observation of NGC 1275, we have replaced the corresponding brightness values (magnitudes) by random numbers distributed normally with a dispersion equal to the rms scatter of the magnitudes. Clearly this procedure should leave unchanged a spectrum due to the presence of gaps in the observations. Figure 4 shows the results of an analysis of these data, using Kurochkin's algorithm (the Jurkevich method gives similar results). We may conclude from the analysis that only one peak, at a period P ≈ 340^d, has any real reliability (which is low even in this case); all the other peaks in Figs. 1 and 2 can be attributed to random scatter of the points. The absence of a peak in Fig. 4 near P = 340^d means that such a period is not associated with the annual cycle of the observing season.

Thus our analysis of periodicity in prolonged (≈ 10 yr) photoelectric observations of the variability of the nuclei of the Seyfert galaxies NGC 1275 and NGC 3516 implies that: 1) the optical radiation of these nuclei contains no periodic component with an amplitude compar-

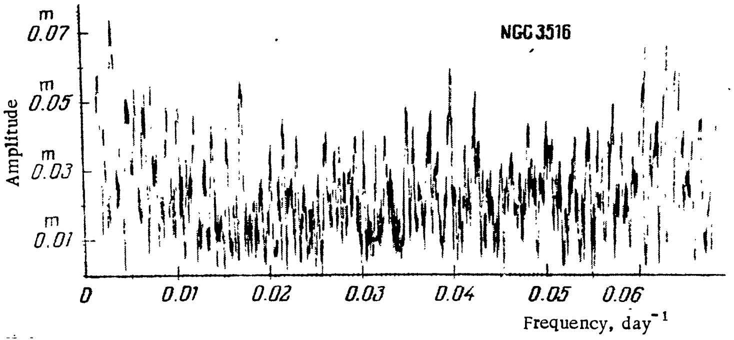

FIG. 3. Results of the search for a periodic component in the brightness of the NGC 3516 nucleus, according to Kurochkin's algorithm.

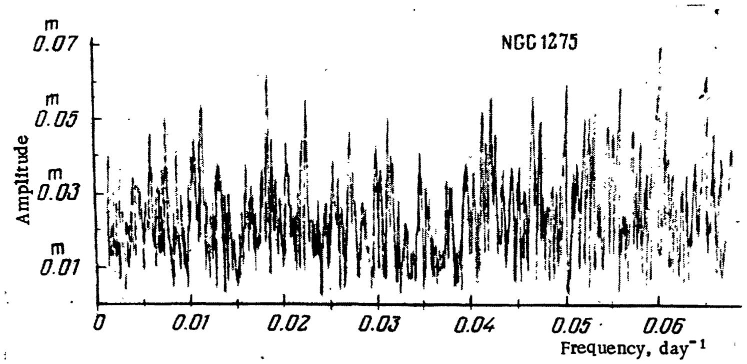

FIG. 4. Periodogram of NGC 1275 obtained with Kurochkin's algorithm for the case in which the values of the brightness have been replaced by normally distributed random numbers.

able to the mean amplitude of the variability, for periods ranging from 7.5 to 800 days; 2) several quasiperiodic components of small amplitude might be present simultaneously, with a characteristic lifetime of the order of 10-15 cycles.

There is some evidence for the reality of the quasiperiods from their repeatability for different algorithms and resolutions, but the small amplitude (for all the observations) makes them unreliable. Estimates for the probability that the peaks mentioned are random (the white-noise hypothesis; see the Appendix to the detailed paper[6]) yield values of several tens of percent.

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Variable stellar polarization in the Orion Nebula cluster

O. S. Shulov and E. N. Kopatskaya

Leningrad University

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A statistical estimate shows that nearly one-half the stars observed at least twice in the Orion Nebula cluster have variable polarization. The bulk of the polarization of the cluster members accordingly arises in circumstellar envelopes, rather than in the nebula itself, as suggested by M. Breger.

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Breger[1,2] has attributed the observed diversity in the polarization parameters of the stars comprising the extremely young cluster in the Great Orion Nebula to a differing depth of the stars inside the nebula. This interpretation presupposes that the polarization remains constant with time; hence the detection of polarization variability among the cluster stars would serve as a decisive test of the hypothesis.

In 1974–1975, polarimetric observations were carried out at the Leningrad University Observatory for about 120 cluster members. The observations were made in a wide yellow–red color band with $\lambda_{\mathrm{eff}} = 0.63\ \mu$. This observing program has turned out to have good overlap with Breger's program. A comparison of the results reveals many disparities attributable neither to observational error nor to the influence of the probable wavelength dependence of the polarization because of differences in the color bands; they should therefore be ascribed to time variability. We obtain below a statistical estimate for the relative number of stars with variable polarization.

Our data, together with those of Appenzeller[3,4] and Breger,[2] provide us with a sample of 98 stars for which at least two observations with error estimates are available. Two stars, θ^2 Ori A and BM Ori, whose polarization is already known to be variable, have been excluded from the sample. Of the 98 stars, 58 have two observations