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# CCD Photometry of Nova V1974 Cygni

by

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ABSTRACT

We report a CCD optical photometry of Nova V1974 Cygni. The period of the short-term modulation is equal to 0.0850 days (122.4 min), different from 0.08123 days (117 min) reported by DeYoung and Schmidt (1993). The period seems to be changing but the present observations do not allow to reach any definite conclusion about the sign of its derivative. A longer-term modulation is also visible in the July 1994 observations of V1974 Cygni. If it is periodic then the most probable approximate value of its period favored by our data is 3.75 days but 5.31 day period is also possible.

**Key words:** *binaries: close – novae, cataclysmic variables – Stars: individual: V1974 Cyg*

## 1. Introduction

V1974 Cygni (Nova Cygni 1992), discovered by Collins (1992) on February 19, 1992, was the brightest nova since the outburst of Nova V1500 Cygni in 1975. Its $V$ magnitude at maximum light was 4.4 and its outburst amplitude was as large as 15 mag (Annuk, Kolka and Leedjärv 1993). With its $t_{2,V} = 16$ days it was classified as a fast nova. After entering the nebular phase the star revealed very strong forbidden emission lines of neon (Barger *et al.* 1993) and was included to the subclass of ONeMg novae, whose white dwarf components are believed to have masses very near to the Chandrasekhar limit. Photometric measurements of a general behavior of the nova, its rapid rise to maximum and subsequent decline, were continued very intensively in many observatories and in almost all wavelengths. First reports on periodical photometric changes on the light curve of V1974 Cygni appeared three months after the outburst (Hurst 1992 and Kidger 1992). Kidger reported on a 4.6 days periodicity in the early post-maximum visual light curve of the nova, which however disappeared when the star declined below $t_3$ (44 days in $V$ according to Chochol *et al.* 1993). Chochol *et al.* (1993) performed also a period analysis of $U$, $B$ and $V$ data obtained before $t_3$ and found in their power spectra a few significant periods with values between 0.814 and 7.634 days.

Short-term periodicity in the light curve of V1974 Cygni was discovered only in October 1993 by DeYoung and Schmidt (1993). Basing on $I$-band observations from 4 nights in October 1993 DeYoung and Schmidt (1993) determined the period of the modulation as equal to 0.08123 days (117 min). Its peak-to-peak amplitude was then equal to 0.16 mag.

The present observations were undertaken in July 1993 to search for a short period modulation in the light curve of nova V1974 Cygni. After its discovery by DeYoung and Schmidt (1993) we decided to continue the observations, mainly with the aim of following its period behavior.

## 2. Observations

The present observations of V1974 Cygni were collected on 14 nights from July 16, 1993 through July 28, 1994. In 1993 we obtained only 105 observations on two nights, July 16 and 17. A very rough estimate of a mean $V$ magnitude of the nova based on the *Guide Star Catalog* gives $V \approx 12.8$ for the July 1993 observations and $V \approx 14.0$ for the end of July 1994. All 1994 observations were obtained in July, except for a single night of April 28. A journal of observations is given in Table 1.

Table 1

Journal of the Ostrowik CCD Observations of Nova V1974 Cygni

| Date | Time of start JD 2449000. + | Length of run (hours) |
|---|---|---|
| 1993 Jul 16 | 185.462 | 1.5 |
| 1993 Jul 17 | 186.516 | 0.9 |
| 1994 Apr 28 | 471.531 | 2.2 |
| Jul 1 | 535.393 | 3.1 |
| Jul 2 | 536.353 | 4.5 |
| Jul 3 | 537.347 | 4.9 |
| Jul 12 | 546.355 | 4.3 |
| Jul 13 | 547.368 | 2.2 |
| Jul 14 | 548.363 | 4.5 |
| Jul 15 | 549.379 | 4.1 |
| Jul 25 | 559.357 | 4.8 |
| Jul 26 | 560.340 | 3.5 |
| Jul 27 | 561.349 | 5.2 |
| 1994 Jul 28 | 562.345 | 5.1 |

All the observations were carried out with a Tektronics TK512CB CCD at the Cassegrain focus of the 0.6 m telescope at the Ostrowik station of the Warsaw University Observatory. The CCD system used was described by Udalski and Pych (1992). The lengths of observational runs are given in Table 1. The exposure times were 60 seconds for the first three runs, and 120 seconds for the nights of July 1994. The dead time between the frames was around 20 seconds. We have monitored the nova generally in the yellow $V$ filter. Only during the night of July 12, 1994 we measured the star additionally also in the red $R$ and the infrared $I$ filters. The total number of $V$ observations is 1282, and the number of frames obtained with $R$ and $I$ filters is 31 for each of them.

### *2.1. Data Reduction*

All the data reductions have been performed with a standard procedure available in the Warsaw University Observatory, based on the IRAF[1] package. The profile photometry have been derived with the DAOphotII package.

Relative magnitudes $\Delta V$, $\Delta R$, and $\Delta I$ of V1974 Cygni were obtained as the difference of magnitude of the variable and the magnitude corresponding to the sum of intensities of four comparison stars. The comparison stars are marked in the chart displayed in Fig. 1. The accuracy of measurements varied in the range from 0.007 mag at clear sky to 0.017 mag for worse atmospheric conditions.

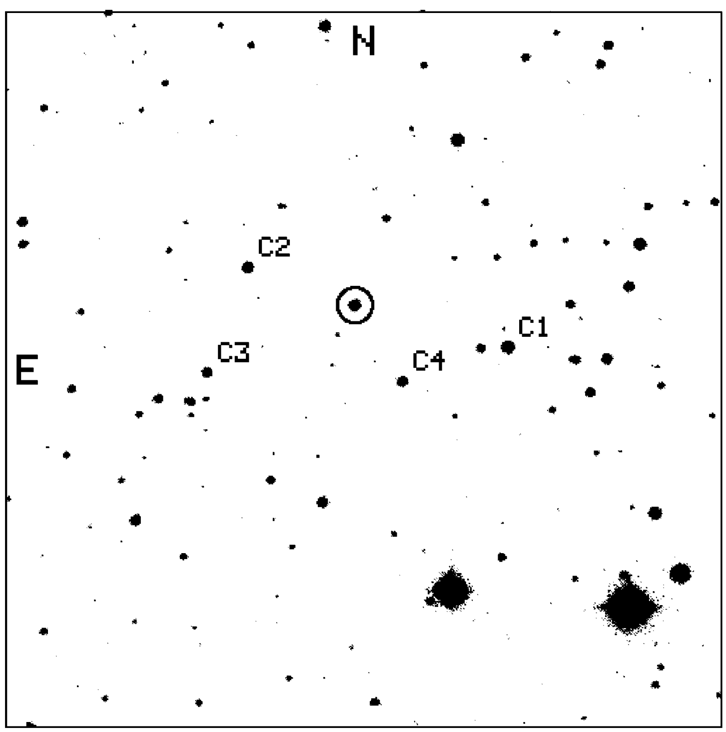


Fig. 1. Finding chart for V1974 Cygni and comparison stars covering a region $6.5 \times 6.5$ arcminutes. North is up and East to the left.

[1] IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation

*2.2. Light Curves*

Fig. 2 presents a general photometric behavior of V1974 Cygni as observed in July 1994. Beside the general decrease of brightness one can also see a cyclic variation with the scale of several days. Its amplitude is about 0.04 mag.

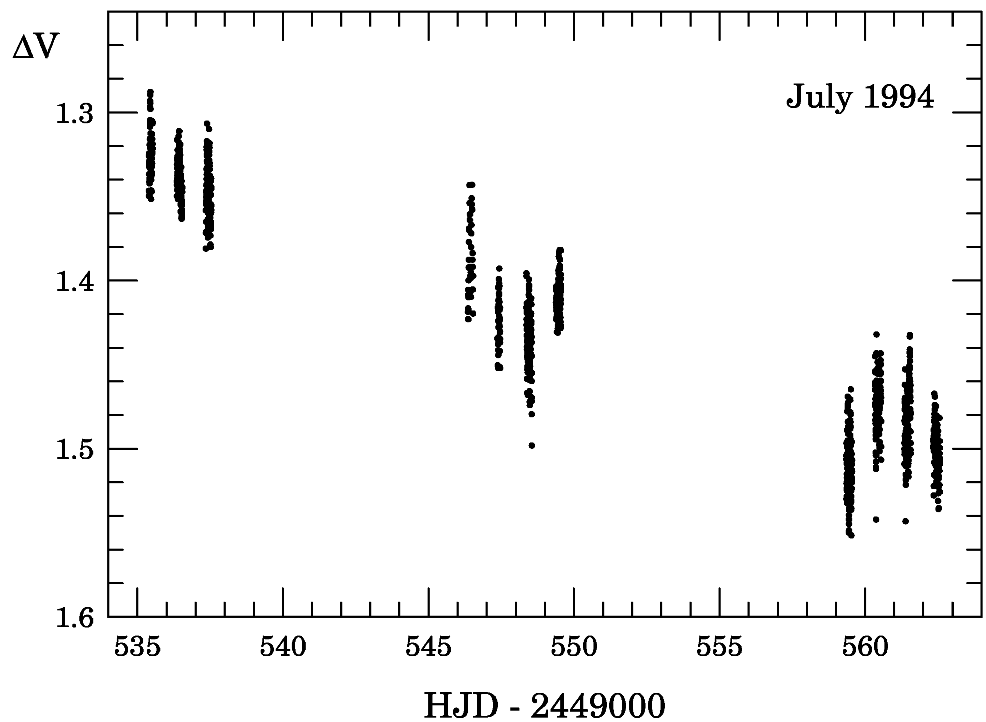


Fig. 2. The light curve of V1974 Cygni observed in July 1994. It shows a several day modulation superimposed on the general decrease of brightness.

Fig. 3 presents the individual light curves of V1974 Cygni for three selected nights of July 1994. In all three runs the short-term modulation is clearly visible. Its average peak-to-peak amplitude for the 1994 observations reaches about 0.05 mag in $V$. The amplitude varies slightly in the range from 0.03 to 0.07 mag from night to night and even from cycle to cycle. The three color observations of July 12, 1994 show that the amplitude of the modulation in the other filters used is of comparable value being 0.06 mag in $R$ and 0.07 mag in $I$ for that particular run. Our observations from July 16, 1993 indicate that the $V$ amplitude was then at least 0.10 mag *i.e.*, about twice as large as in July 1994.

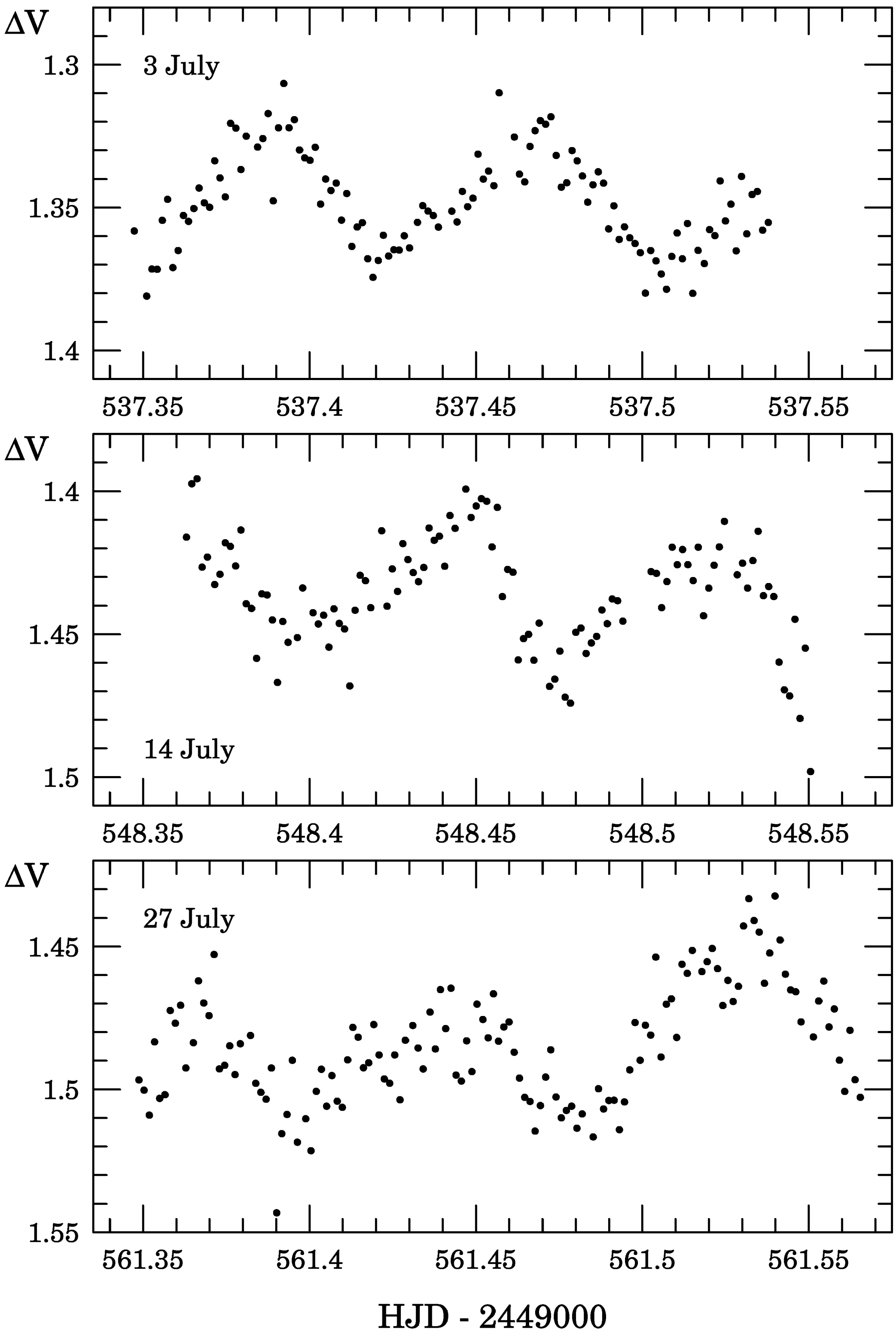


Fig. 3. Light curves of V1974 Cygni for three selected nights of July 1994.

## 3. Determination of the Period of the Short-Term Modulation

### *3.1. Power Spectra*

In order to determine the period of the short-term modulation visible in Fig. 3, as well as to search for some possible weaker modulations, we have computed power spectra using two methods of spectral analysis: the Lomb-Scargle (Lomb 1976, Scargle 1982) method for unevenly spaced data, and the CLEAN algorithm (Roberts, Lehár and Dreher 1987).

The analysis was performed for the 1994 data only, containing a single night of April 28 and 11 nights of July. As one can see in Fig. 2, the July data consist of three subsets of consecutive nights (3, 4, and 4 nights, respectively) spaced by several days. At first, we have computed power spectra separately for each of the three subsets using the Lomb-Scargle method. Before the calculation the general decrease and the parabolic change, seen in the data, were subtracted from the merged observations of each subset. Next, we have calculated the power spectrum for the merged, also corrected in this way, observations of all July nights, and finally the power spectrum for all 1994 data.

Fig. 4 presents results of the analysis. Three upper panels of the figure show the power spectra for the three July subsets of consecutive nights. The lower panel shows the power spectrum for all 1994 data including the run of April 28. The power spectrum for the merged observations of July 1994 alone, not presented in Fig. 4 shows no significant difference in comparison to the all 1994 data spectrum. Three most prominent peaks of each spectrum are indicated in the figure with vertical tick marks. The solid marks indicate the frequency 11.762 cycles/day, which has the highest power in the uppermost and lowermost spectra, and the second highest power in both middle spectra. This frequency corresponds to the period 0.08502 days *i.e.*, 122.4 min, which – as it will be confirmed in what follows – is the correct period of the short-term modulation. The dashed marks indicate two conspicuous peaks neighboring directly to the 122.4 min peak. They are the 1-day aliases of the 122 min period corresponding to the periods 134 min and 113 min, respectively. We have marked them to show that the 117 min period reported by DeYoung and Schmidt (1993) appears, with a power comparable to the most prominent peaks, in the data of the first three July nights only, and it reveals no significant power in the other spectra. In all spectra of Fig. 4 the first overtone of the 122.4 min period is also visible. It is marked with the solid tick at the frequency 23.52 cycles/day. The solid thick at the frequency 35.29 cycles/day marks the position of the second overtone of the 122.4 min period.

Fig. 5 displays the power spectrum for all 1994 data computed using the CLEAN algorithm. This algorithm removes artefacts in the spectrum related to the window frequencies. The most prominent peak (marked with a solid thick) appears at the frequency 11.765 cycles/day corresponding to the 122.4 min period in the cleaned spectrum. The position of the first and the second overtones of the 122.4 min period is also marked in the figure.

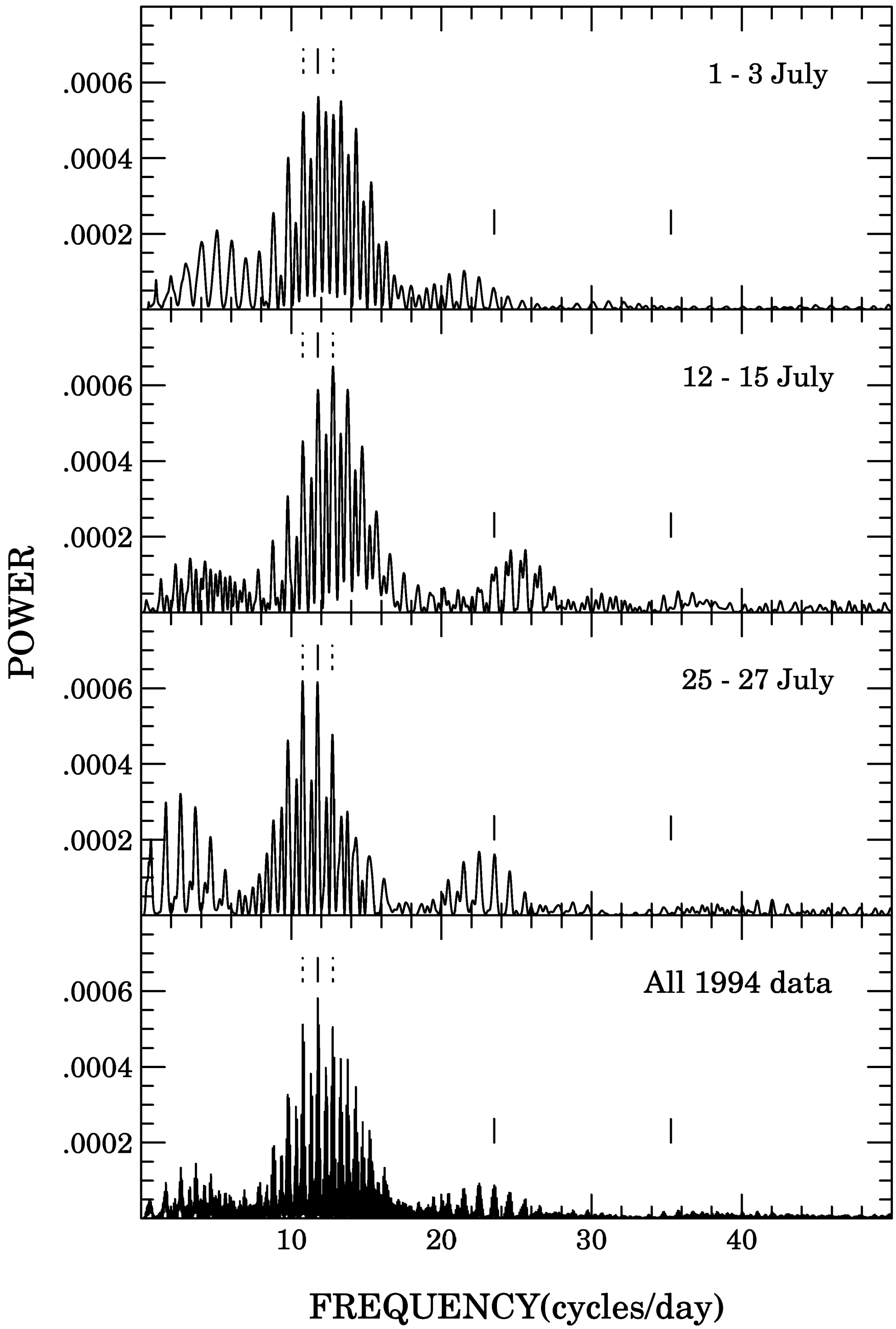


Fig. 4. Lomb-Scargle power spectra for the three July 1994 subsets of consecutive nights (three upper panels) and for all 1994 data (lower panel).The solid vertical tick marks at the frequency 11.8 indicate the 122 min period. Dashed ticks mark the 1-day aliases of this period, corresponding to 113 and 134 min. The solid ticks at the frequencies 23.5 and 35.3 indicate the position of the first and second overtones of the 122 min period.

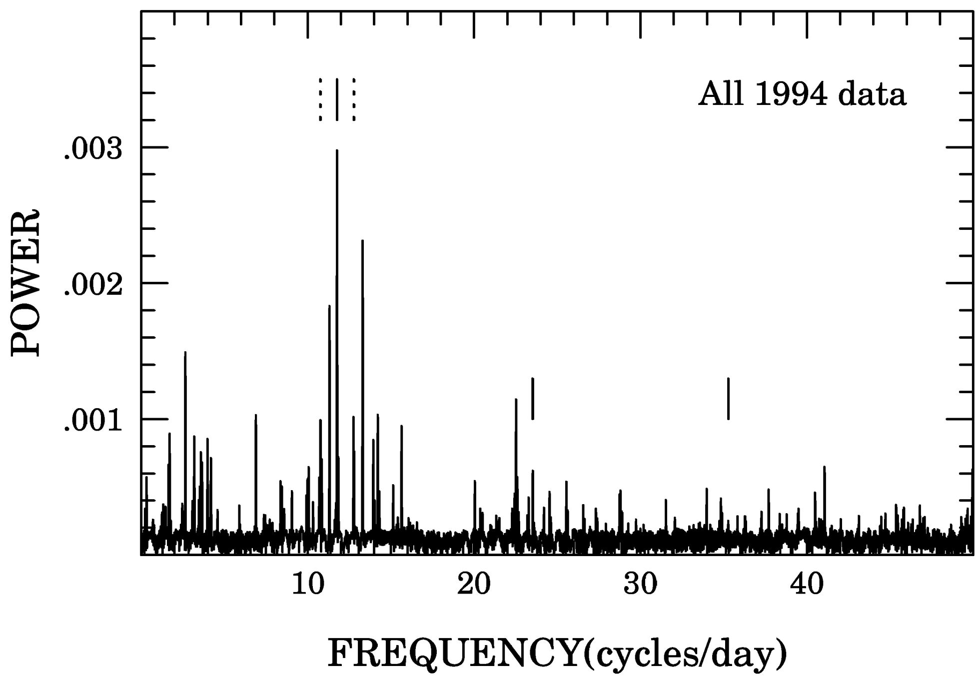


Fig. 5. The CLEANed power spectrum for all 1994 data. The solid ticks indicate the 122 min period and the position of its first and second overtones. The dashed ticks show the position of the 1-day aliases of the 122 min period.

The main conclusion of this subsection is that the most reliable value of the short-term modulation period is 122.4 min.

### *3.2. Analysis of Times of Maxima of the Short-Term Modulation*

In order to confirm that the 122.4 min (0.0850 days) period indicated by our power spectra is the correct one we have carried out analysis of times of maxima of the short-term periodicity. We have determined 17 times of maxima of the modulation from our observations. They are listed in Table 2. Basing on these data we have tried to analyze first the 16 times of maxima of July 1994. The best fit to these maxima obtained with the least squares method gives the following linear ephemeris

$$\begin{aligned} HJD_{Max} &= 2449535.4345 + 0.08502\,E \\ &\quad \pm 0.0025 \pm 0.00001 \end{aligned} \qquad (1)$$

Our attempt to derive an equally good linear ephemeris for all the maxima of Table 2 has however failed. A much better fit was found with a quadratic term included into calculations what might indicate that the 122 min period is changing. The lack of observations between April 28 and July 1 does not allow however to determine the sign of its derivative conclusively. We are prone to believe that the period is increasing because the three subsets of the July data analyzed independently have given consecutively increasing values of the 122 min period.

Table 2

Times of Maxima of the 122 min Periodicity of V1974 Cygni

| UT Date 1994 | HJD 2449000.+ | E | O – C (cycles) |
|---|---|---|---|
| Apr 28 | 471.540 | –752 | 0.348 |
| Jul 1 | 535.438 | 0 | 0.031 |
| 3 | 537.390 | 23 | –0.006 |
| 3 | 537.470 | 24 | –0.065 |
| 12 | 546.406 | 129 | 0.056 |
| 12 | 546.487 | 130 | 0.009 |
| 13 | 547.424 | 141 | 0.032 |
| 14 | 548.448 | 153 | 0.078 |
| 14 | 548.524 | 154 | –0.028 |
| 25 | 559.407 | 282 | –0.003 |
| 25 | 559.490 | 283 | –0.026 |
| 26 | 560.437 | 294 | 0.114 |
| 27 | 561.367 | 305 | 0.054 |
| 27 | 561.445 | 306 | –0.028 |
| 27 | 561.533 | 307 | 0.007 |
| 28 | 562.395 | 317 | 0.148 |
| Jul 28 | 562.479 | 318 | 0.136 |

Assuming that the period is increasing we have obtained the following quadratic ephemeris

$$\begin{array}{rcl} \mathrm{HJD}_{Max} & = & 2449535.4354 \; + \; 0.085007\,\mathrm{E} \; + \; 5.2 \times 10^{-8}\,\mathrm{E}^2 \\ & & \pm\, 0.0023 \;\; \pm \;\; 0.000007 \;\;\;\; \pm \;\; 1.4 \end{array} \qquad (2)$$

Fig. 6 shows the change of the period. The O – C deviations plotted in the figure are taken from Table 2. They were calculated using the linear ephemeris $\mathrm{HJD}_{Max} = 2449535.4354 + 0.085007\,E$. The open circle corresponds to the O – C value for the first time of maximum obtained with its cycle number reduced by one in comparison to the cycle count of Table 2.

## 4. The Long-Term Periodicity

Our observations are insufficient to obtain a conclusive value of the period of the long-term modulation visible in Fig. 2. Nevertheless we have undertaken an attempt to search for this period. Inspection of Fig. 2 leads to the conclusion that this period cannot be shorter than about 3 days. To get at least some approximate value of the period we have removed the general decrease trend from the combined July 1994 observations and then performed power spectrum analysis of the corrected data in the appropriate frequency domain. The results obtained using both the

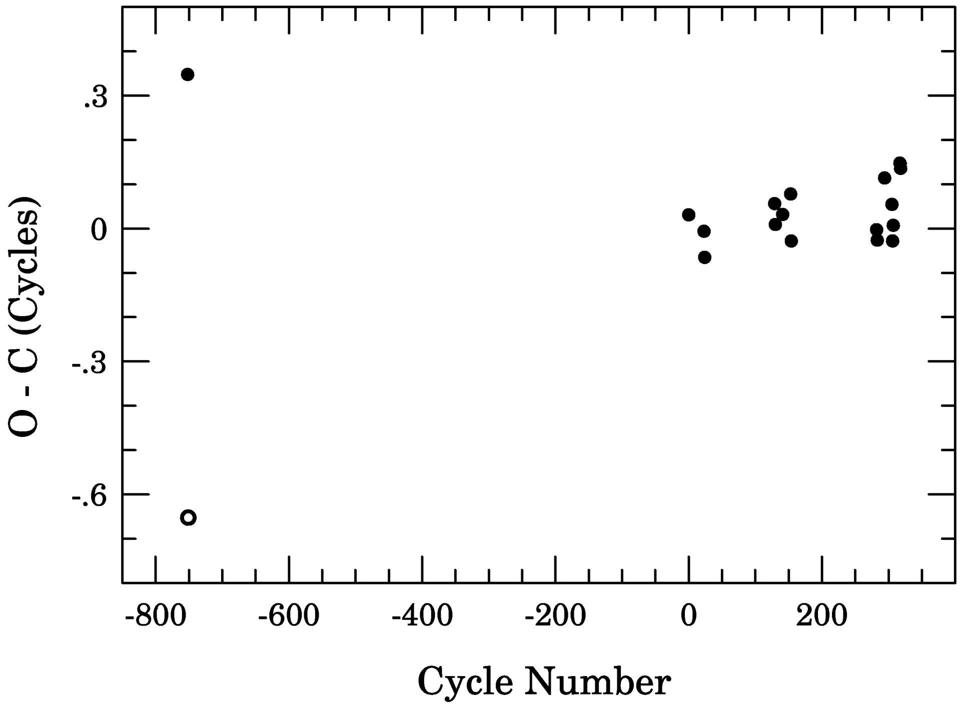


Fig. 6. The O – C values for times of maxima of the 122 min modulation calculated with the constant period equal to 0.085007 days. The open circle corresponds to the O – C value obtained with the cycle number reduced by one in comparison to the cycle count of Table 2.

Lomb-Scargle method and the CLEAN algorithm are plotted in the upper and lower panels of Fig. 7 respectively. Among four significant peaks in the upper panel the two highest frequencies are out of the question as they are not allowed by Fig. 2. Only two first peaks come into consideration and they correspond to the periods 5.31 and 3.75 days, respectively. In the lower CLEANed spectrum only the 3.75 day peak is visible with a significant power what suggests, that the 3.75 day period may be the correct one. The least squares fitting of a sinusoid to the data gives also a slightly better results for the 3.75 day period. Although our present data favor the 3.75 day period, we consider at the moment that they are insufficient to exclude the 5.3 day period definitely. We hope that a future observational run of at least 5 consecutive nights will clarify the problem.

## 5. Conclusions and Discussion

Basing on the Ostrowik CCD observations we have determined the period of the short-term modulation of Nova V1974 Cygni. Its correct value is 0.0850 days (122.4 min), different from 0.08123 days (117 min) reported previously by DeYoung and Schmidt (1993). The period is changing but our data are insufficient to determine the sign of its derivative in a conclusive way. We believe that the period increases as three subsets of the July 1994 data, analyzed separately, show its slight

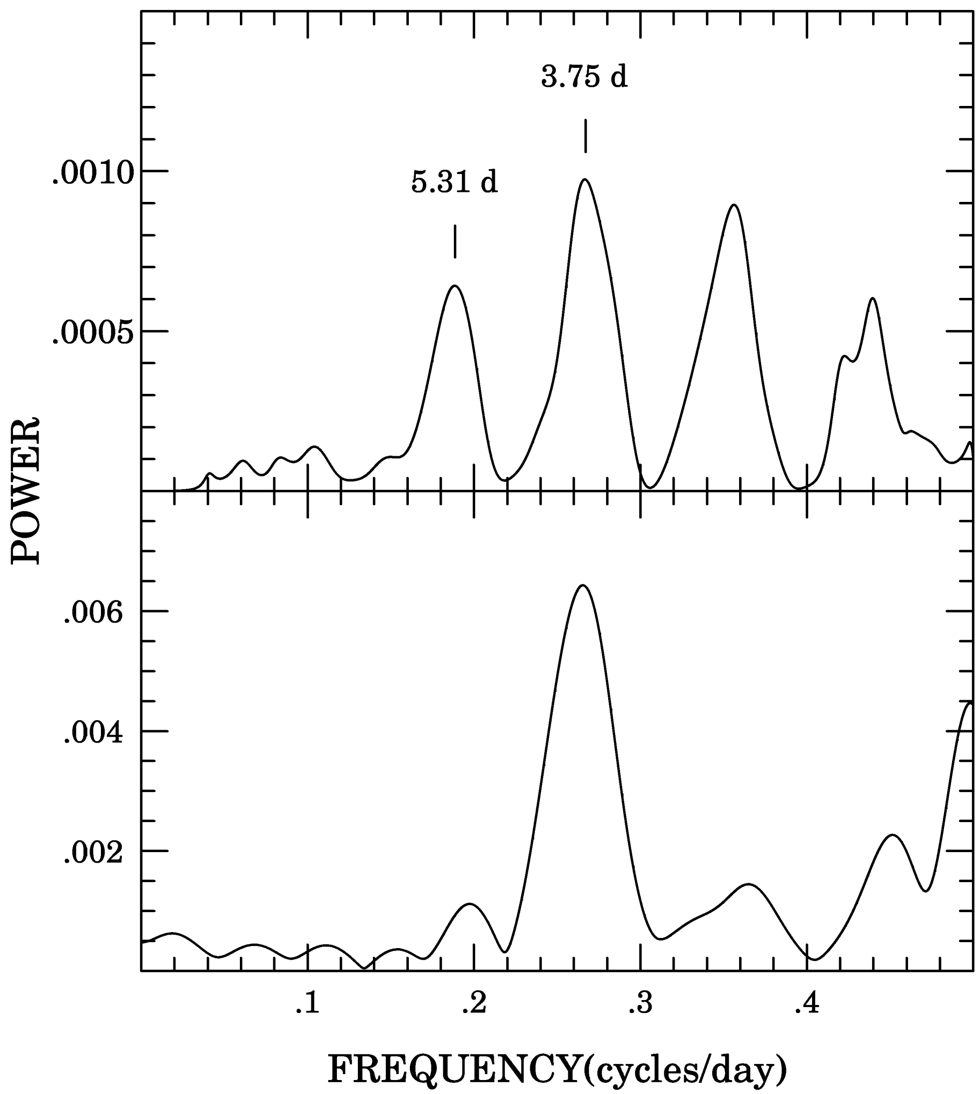


Fig. 7. Power spectra computed for investigation of the long-term modulation period. The upper panel shows the Lomb-Scargle spectrum and the lower panel the CLEANed spectrum. Two possible values of the period permitted by Fig. 2 are marked.

monotonic increasing. The change of the period cannot be responsible for the 117 min value in October 1993 – the epoch of the DeYoung and Schmidt observations. An extrapolated value of the period for this epoch, derived with the rate of increase predicted by the ephemeris (2), is only 0.2 min shorter than our July 1994 value. A possible explanation is that the 117 min value is a 2-day alias of the 112 min period and results from an incorrect cycle count between observations spaced by 2 days. The amplitude of the modulation also changes. Its value in the $V$-band was at least 0.1 mag in July 1993 and about 0.05 mag in July 1994. The $R$ and $I$ amplitudes measured on the July 12 night were comparable to the $V$ amplitude.

Our observations of July 1994 show also the presence of a long-term modulation in the light curve of V1974 Cygni with an amplitude of about 0.04 mag in $V$. The most probable value of its period suggested by our data is 3.75 days, but 5.31 value is also possible. None of these values is present in the Chochol *et al.* (1993) power spectra.

Finally, we would like to discuss the nature of the observed 122 min period of V1974 Cygni. In their short note the discoverers, DeYoung and Schmidt (1993), restrained from interpretation of the period, while Taylor *et al.* (1994) interpret it as the orbital period of the nova. The relatively fast change of the period is an evidence against such an interpretation. The observed long-term modulation with the period of a few days suggests that there may be also a third period in the system not yet revealed in the direct photometry – a true orbital period of the system. We believe that the 122 min period is rather a white dwarf spin period. In this respect V1974 Cygni would resemble intermediate polars and particularly the nova V1500 Cygni. It was suggested (Semeniuk *et al.* 1977), that prior to outburst in 1975, V1500 Cygni was a system similar to a magnetized, synchronously rotating AM Her binary. The explosion has broken down the spin/orbit synchronism, and the quickly decreasing period of the short-term modulation, observed during the first two seasons after outburst, was the spin period of the white dwarf. This period was absent in the third observational season after the outburst. Instead, a more stable and a little longer orbital period appeared in the light curve of V1500 Cygni (Patterson 1979). The spin period was rediscovered in polarimetry 12 years after outburst with the value 0.1371 days which was about 2% shorter than the orbital 0.1396 day period (Stockman, Schmidt, and Lamb 1988). Subsequently, the spin period appeared to be increasing (Schmidt and Stockman 1991), what was an evidence that the white dwarf component of the system was evolving into synchronization. We suggest that V1974 Cygni may be a similar system, with the 122 min increasing period being a spin period, its long-term period being a beat period between the spin and orbital period, and its orbital period waiting yet to be discovered. To confirm or disprove this suggestion further photometric, spectroscopic, and particularly polarimetric observations, performed in an appropriate time, after nebular emission stops interfering, are clearly needed.

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