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Two Short-Term Periodicities of Nova V1974 Cygni

by

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ABSTRACT

We report on analysis of V and I CCD photometry of Nova V1974 Cygni from the observational seasons 1993 and 1994. The analysis gives evidence that only one short-term modulation with period 0.0813 days was obviously present in the 1993 I light curve of the nova. On the other hand the analysis shows that two short-term modulations with periods 0.0813 and 0.085 days (whose values are close to 2-day aliases of one another) are present in the 1994 V and I light curves of Nova V1974 Cygni. The 0.0813-day period is stable and we interpret it as the orbital period of the system, while the 0.085-day period is decreasing and may be the spin period of the white dwarf component of the system.

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

1. Introduction

The fast galactic Nova V1974 Cygni (Nova Cygni 1992), was discovered in the second half of February 1992 (Collins 1992). As the brightest nova which appeared during almost 20 years since the outburst of Nova V1500 Cygni in 1975, the star was intensively observed both photometrically and spectroscopically. Its early photometric and spectroscopic history was extensively described in many papers (Chochol *et al.* 1993, Shore *et al.* 1994, DeYoung and Schmidt 1994, Semeniuk *et al.* 1994). Although the star has actually faded below 14 mag, it still remains a very intriguing object deserving continuous observation. The main reason for that is its short-term variability.

The short-term periodicity of Nova V1974 Cygni was first discovered in October 1993 by DeYoung and Schmidt (1993). From I-band observations on 4 nights in October 1993, DeYoung and Schmidt determined the period of the short-term modulation to be equal to 0.08123 days (117 min). Its peak-to-peak amplitude was then equal to 0.16 mag. DeYoung and Schmidt continued to observe the star during that observing season to December 10, 1993, obtaining observations on a total of 25 nights. They confirmed the value of the period, determined it more precisely, and concluded that the period was stable. They interpreted it as the orbital period of the system (DeYoung and Schmidt 1994).

In 1994 Semeniuk *et al.* based mainly on their V observations collected on 12 nights from April 16 through July 28, 1994, discovered a different period of short-term modulations equal to 0.0850 days (122.4 min). The period was changing and therefore they interpreted it as a white dwarf spin period. Semeniuk *et al.* (1994) suggested also that a peak in their power spectra, which corresponded to 0.0813-day period, might be a 2-day alias of their 0.0850-day period. When the paper of DeYoung and Schmidt (1994) appeared, it became clear that the 0.0813 day periodicity was really present in their 1993 data, and that two short-term modulations with periods close to 2-day aliases of one another were also really present in the Semeniuk *et al.* (1994) observations.

In the present paper both the USNO team and the Warsaw (Ostrowik) team have decided to join their observational results to reach a better understanding of the two photometric periods.

2. Observational Material

In the present analysis for elucidation of the problem of the two periods, we have used all our observations obtained on 62 nights during the period from July 16, 1993 to January 2, 1995, at the US Naval Observatory in Washington, DC and at the Ostrowik station of the Warsaw University Observatory. Cassegrain telescopes of the same diameter, 0.6-m, were used at both observatories. A mean visual magnitude of V1974 Cygni was approximately 12.8 at the beginning of this period and fell to about 14.6 at its end. A journal of observations is given in Table 1.

A portion of the observations presented in Table 1, collected before August 1994, have already been described in our previous papers (DeYoung and Schmidt 1994, Semeniuk *et al.* 1994). In those papers we have also described the CCD camera systems employed in the observations, procedures of data reduction and the way of obtaining relative ΔV and ΔI magnitudes.

The total number of V images compiled in Table 1 is 1933, and the total number of I images is 3354. A run of 142 observations performed without any filter during the night of October 7, 1993, is also recorded in Table 1. On the nights of July 12 and 13, 1994, beside the V and I observations marked in Table 1, additional 34 observations in the filter R were obtained.

Table 1

Journal of CCD Photometric Observations of Nova V1974 Cygni

	Date	Time of start JD 2449000. +	Length of run(hr) *V*	*I*	Observatory
1993	Jul 16/17	185.462	1.5		Ostrowik
	Jul 17/18	186.516	0.9		Ostrowik
	Oct 6/7	267.490		2.2	USNO
	Oct 7/8 *)	268.483		3.9	USNO
	Oct 10/11	271.483		4.0	USNO
	Oct 12/13	273.483		4.8	USNO
	Oct 14/15	275.610		1.5	USNO
	Oct 15/16	276.468		5.1	USNO
	Oct 22/23	283.562		2.4	USNO
	Oct 23/24	284.492		3.4	USNO
	Oct 24/25	285.464		3.8	USNO
	Oct 25/26	286.461		3.1	USNO
	Oct 28/29	289.448		4.3	USNO
	Nov 1/2	293.455	3.9	4.2	USNO
	Nov 7/8	299.457		1.8	USNO
	Nov 8/9	300.459	3.7	3.8	USNO
	Nov 9/10	301.475		2.5	USNO
	Nov 10/11	302.465		4.6	USNO
	Nov 12/13	304.464		3.3	USNO
	Nov 14/16	306.447		1.1	USNO
	Nov 21/22	313.444	1.3	1.3	USNO
	Nov 22/23	314.442		2.8	USNO
	Nov 29/30	321.513		1.8	USNO
	Dec 2/3	324.468		1.7	USNO
	Dec 7/8	329.447		0.4	USNO
	Dec 8/9	330.446		1.3	USNO
1993	Dec 9/10	331.469		2.0	USNO
1994	Apr 28/29	471.531	2.2		Ostrowik
	Jul 1/2	535.393	3.1		Ostrowik
	Jul 2/3	536.353	4.5		Ostrowik
	Jul 3/4	537.347	4.9		Ostrowik
	Jul 12/13	546.355	4.3	3.7	Ostrowik
	Jul 13/14	547.368	2.2	0.3	Ostrowik
	Jul 14/15	548.363	4.5		Ostrowik
	Jul 15/16	549.379	4.1		Ostrowik
	Jul 25/26	559.357	4.8		Ostrowik
	Jul 26/27	560.340	3.5		Ostrowik
	Jul 27/28	561.349	5.2		Ostrowik
	Jul 28/29	562.345	5.1		Ostrowik
	Aug 23/24	588.621		2.5	USNO
	Sep 7/8	603.540		3.7	USNO
	Sep 29/30	625.489		2.6	USNO
	Oct 1/2	627.477	2.3	2.5	Ostrowik
	Oct 6/7	632.483		3.0	USNO
	Oct 11/12	637.231	6.6	6.6	Ostrowik
	Oct 12/13	638.221	4.6	5.9	Ostrowik
	Oct 15/16	641.471		3.2	USNO
	Oct 16/17	642.467		2.8	USNO
	Oct 20/21	646.230	4.5	4.5	Ostrowik
	Nov 2/3	659.305	3.2	4.0	Ostrowik
	Nov 2/3	659.470		2.6	USNO
	Nov 3/4	660.269	2.6	5.1	Ostrowik
	Nov 4/5	661.174	6.7	7.3	Ostrowik
	Nov 5/6	662.214	4.6	7.3	Ostrowik
	Nov 6/7	663.178	4.5	7.3	Ostrowik
	Nov 12/13	669.161	4.6	4.9	Ostrowik
	Dec 7/8	694.153	0.5	0.6	Ostrowik
	Dec 7/8	694.302		2.2	Ostrowik
	Dec 20/21	707.443		2.3	USNO
	Dec 21/22	708.444		2.1	USNO
	Dec 26/27	713.452		2.2	USNO
	Dec 27/28	714.446		2.3	USNO
1994	Dec 30/31	717.442		2.2	USNO
1995	Jan 2/3	720.448		1.8	USNO

*) observations without filter

3. Power Spectrum Analysis

The most effective way to search for periodicities, when the observational data do not allow them to be discerned clearly in the light curve of a variable star, is to perform Fourier analysis of the data.

In order to search for periods in the short-term modulations of V1974 Cygni, we have computed power spectra using the Lomb-Scargle (Lomb 1976, Scargle 1982) method of Fourier analysis for unevenly spaced data. We have done this for the different filters and for different data sets.

3.1. I Observations

First we Fourier analyzed the 1993 I observations. We have divided them into four subsets corresponding to four consecutive time intervals between October 6 and December 10, 1993. The subsets contained data taken on five to seven nights, and were spaced by several days. The last subset, starting with the night of November, 23, was eventually excluded from the Fourier analysis, as most of its runs had only partial coverage of a full period, and it was impossible to remove properly a changing mean level of magnitudes. Therefore, we have computed power spectra for each of the three first subsets only. Before the calculation, the general decreasing trend in the nova light was subtracted from each individual run, so that the nightly average magnitude value was equal to zero.

Fig. 1 presents results of the analysis for the three subsets of the 1993 I data. We can see that in all three frames of Fig. 1 the frequency 12.31 cycles/day, corresponding to the period of 0.0813 days (117 min), appears with the highest power. This frequency is indicated in Fig. 1 with the solid vertical tick marks.

The dashed marks in Fig. 1 indicate the position of the frequency 11.73 corresponding to an expected value of the 0.085-day period. This value is predicted for autumn 1993 by the exponential ephemeris (Eq. 4) describing temporal behavior of the period. Fig. 1 shows that there is no obvious evidence of the 0.085-day period in the power spectra.

Consequently, inspection of Fig. 1 leads to the conclusion that the only short-term modulation which is conspicuously present in the 1993 I observations, is that with a period equal to 0.0813 days. The amplitude of the modulation remains almost constant and equal to about 0.16 mag to the end of this observational period.

The 1994 I observations are not so favorably distributed as the 1993 I observations. Among our 1994 I observations we have however one subset which is properly distributed to be analyzed for the presence of the short-term modulations: the subset of five consecutive nights from November 2 to 6. The power spectrum calculated for this subset, after removing the nightly mean and a longer-scale change trend from each individual run, is displayed in the lower frame of Fig. 2. The vertical tick marks indicate peaks at the frequencies 11.77 and 12.28 cycles/day corresponding to the periods 0.085 days and 0.0813 days. These peaks are the highest and the third highest peaks in the spectrum. The upper frame of

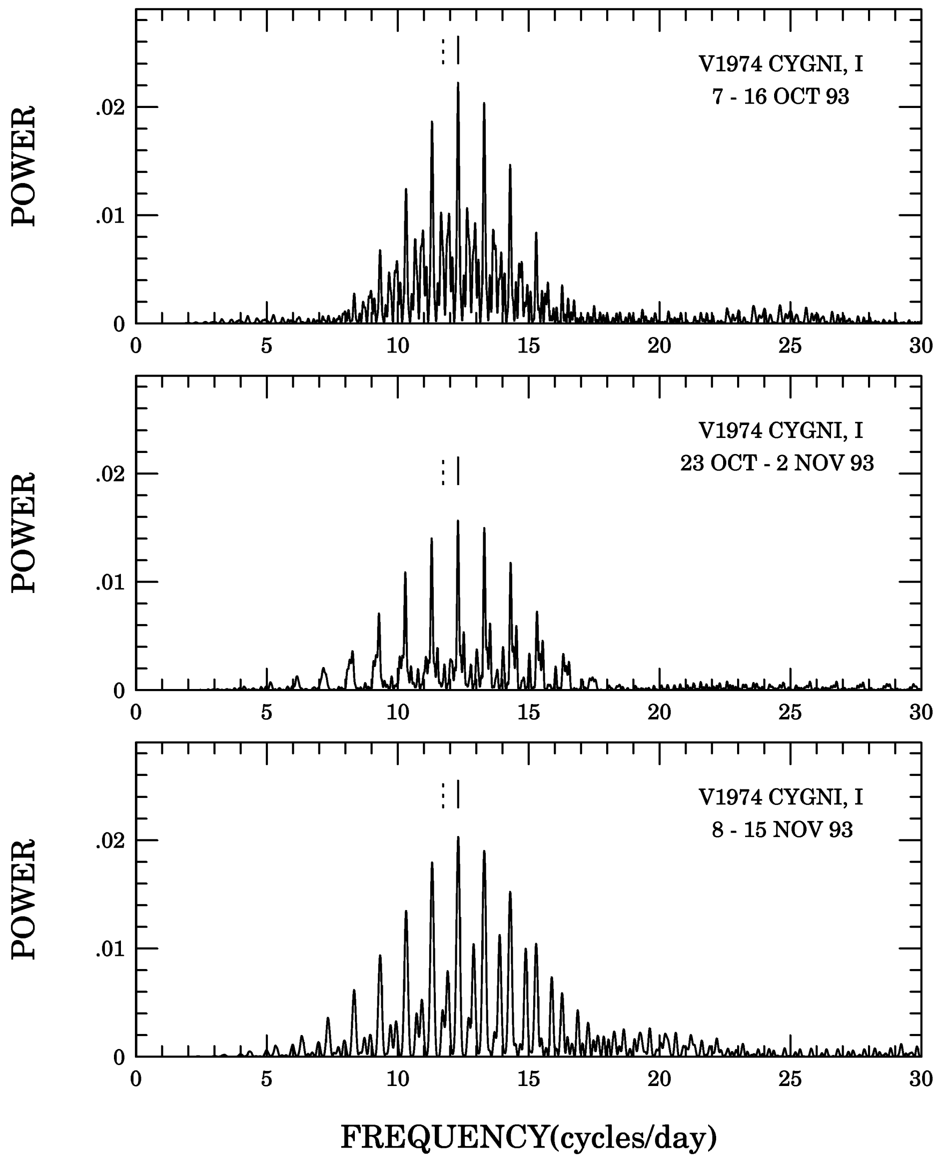

Fig. 1. Power spectra for three consecutive subsets of the 1993 I observations. The solid vertical tick marks indicate the frequency 12.3 corresponding to the 0.0813-day period. Dashed ticks mark an expected position of the 0.085-day period.

Fig. 2 illustrates the power spectrum window for the subset, which shows that the aliasing in the lower diagram is due only to a 1-day gap in the data. Comparison of the upper and lower frames leaves no room for doubt that the 0.085-day peak and the 0.0813-day peak, in spite of what is suggested by their position in the power spectrum, are not 2-day aliases of one another, but correspond to two real short-term modulation periodicities present in the observations.

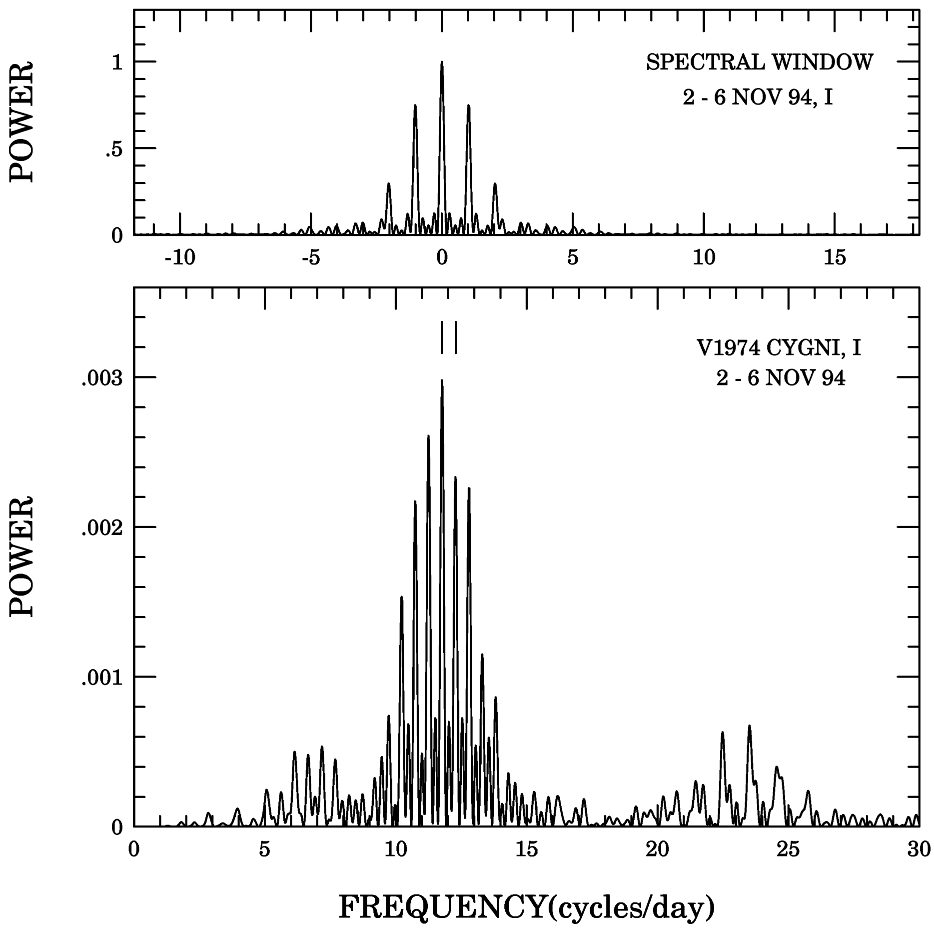

Fig. 2. Power spectrum for the subset of the 1994 *I* observations containing five consecutive November nights. The vertical tick marks indicate peaks at frequencies 11.77 and 12.28 corresponding to the periods 0.085 and 0.0813 days. In the upper frame the power spectrum window is displayed.

Both peaks, the 0.0813-day and 0.085-day ones, are also visible with powers comparable to those of Fig. 2, in power spectra calculated for earlier subsets of the 1994 *I* observations. The situation changes for the latest subset of the data, beginning from December 7, where no privileged periodicity is visible in the power spectrum.

3.2. V Observations

As can be seen from Table 1, we have no 1993 *V* observations suitable for Fourier analysis. The 1994 *V* observations earlier than August 1994 were already spectrally analyzed elsewhere (Semeniuk *et al.* 1994) and led to discovery of the 0.085-day period, while the 0.0813-day peak, occurring in the spectra with a lower power, was interpreted as a 2-day alias of the former period. Fig. 3 provides evidence that, in spite of their misleading position in power spectra, both the 0.085-day and 0.0813-day periodicities are really present also in the 1994 *V* observations of Nova V1974 Cygni, as they are in the 1994 *I* data.

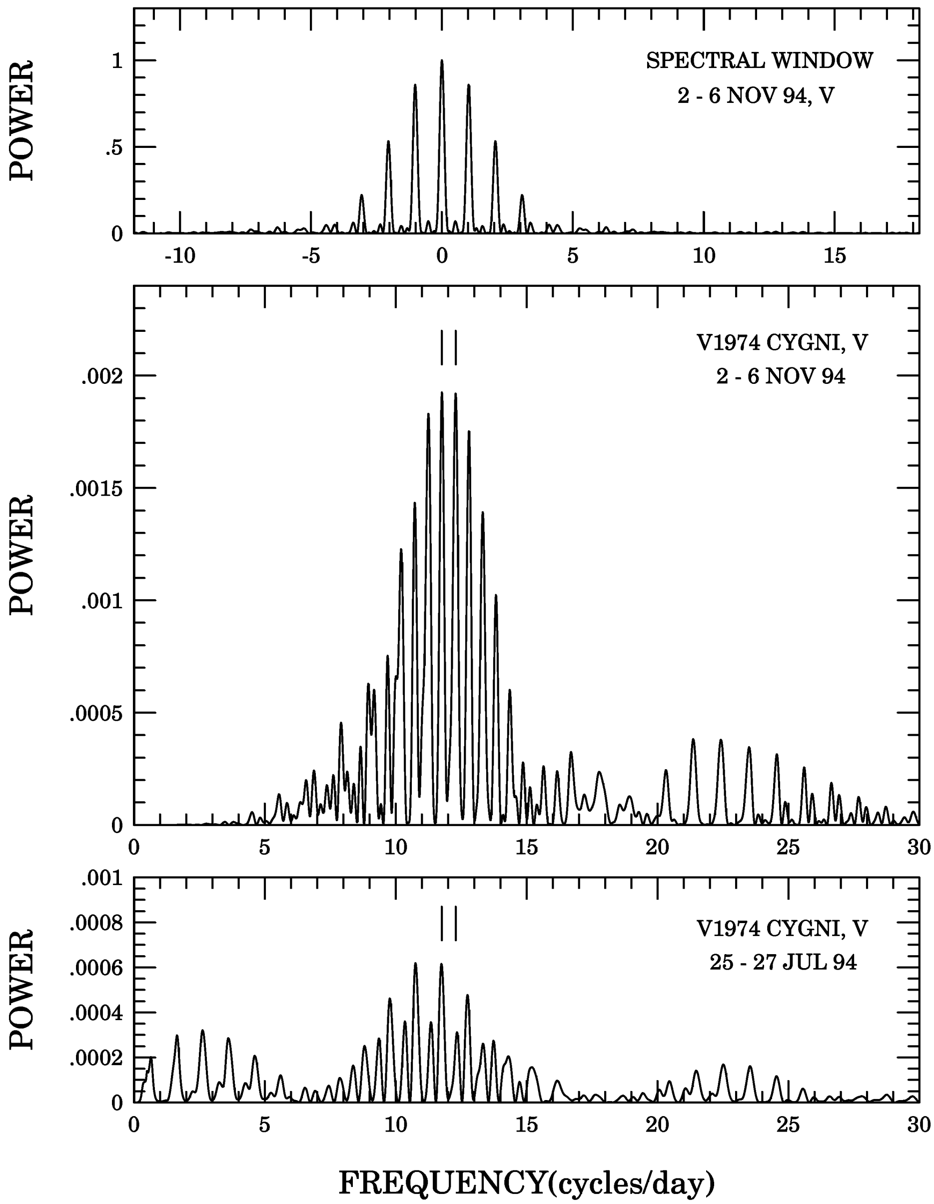

Fig. 3. Power spectra for two subsets of the 1994 V observations. The middle frame shows the spectrum for the subset of five consecutive November nights while the lower frame is for a subset of four consecutive nights in July. The vertical ticks mark the peaks corresponding to the periods 0.085 and 0.0813 days. The uppermost frame displays the power spectrum window for the November subset.

Fig. 3 displays the power spectrum calculated for V observations obtained during the same five consecutive November nights as in Fig. 2. The two most prominent peaks in the spectrum, marked with the ticks, correspond to the periods of 0.085 and 0.0813 days. The spectral window, presented in the upper frame, excludes the possibility of interpreting the peaks as 2-day aliases of one another. For comparison we included into Fig. 3 the power spectrum for the last subset of four consecutive nights of July 1994. The spectral window for these data looks identical like that displayed in the upper frame of the Fig. 3. One can see that in the November spectrum the power of both significant peaks was about three times higher than the power of the 0.085-day peak in the July spectrum, and about five times as high as the power of the 0.0813-day peak.

The main conclusions derived from the Fourier analysis are that only one, the 0.0813-day periodicity, is present in the 1993 I observations of Nova V1974 Cygni and that two short-term modulations with periods 0.0813 days and 0.085 days occur in 1994, both in V as in I observations.

4. Comparison of the 1993 and 1994 Light Curves of V1974 Cygni

The facts that only one short-term periodicity is present in the 1993 observations of V1974 Cygni and two are undeniably present in the 1994 data should obviously manifest themselves as differences between light curves from the two observing seasons. These differences are demonstrated in the following three figures.

Fig. 4 presents the I light curves of V1974 Cygni for four consecutive nights of October 1993. In all four runs the short-term modulation is clearly visible. Its average peak-to-peak amplitude reaches about 0.16 mag and one cannot see any particular difference from night to night in the character of variability.

Fig. 5 shows the I light curves of the nova for five consecutive nights of November 1994 after removing a longer-scale change from each individual run. One can see that the short-term modulation is distinctly visible only during the first, third and the fifth nights of the set, while during the second and the fourth nights the character of variability changes. That is what we should expect if there are two short-term periodicities with periods of 0.0813 and 0.085 days. A beat period between the two periods is 1.85 days. We should then expect to observe well pronounced extrema in the light curve approximately every second night, when the two periodicities meet in approximately the same phase. During the nights such as the second and the fourth one of the set, the extrema coming from the two modulations meet obviously in the opposite phases. The distinct 0.08-day periodicity disappears, but one can trace – although not so distinctly marked – extrema coming alternately from both periodicities spaced about half that period away. We have fitted these observations with a combination of four sinusoids with frequencies corresponding to the 0.0813-day and 0.085-day periods and to the first overtones of these frequencies. We find that this combination of sinusoids, presented in Fig. 5 as a solid line, gives quite a satisfactory reproduction of the light curves.

The same is also true for the 1994 observations made in the filter V. Fig. 6 presents the V observations from the last set of four consecutive nights of July

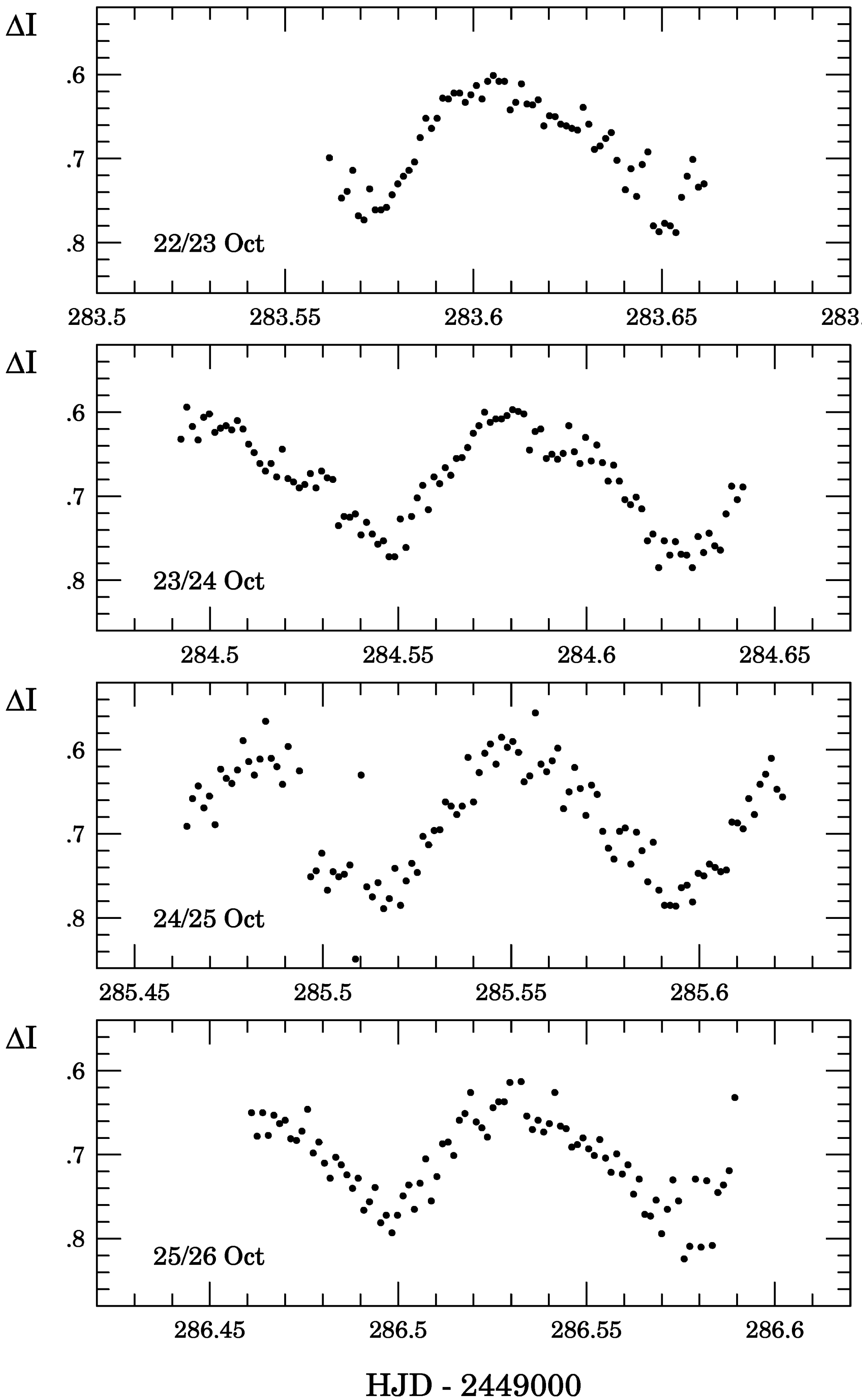

Fig. 4. The I light curves of V1974 Cygni observed during four consecutive nights in October 1993.

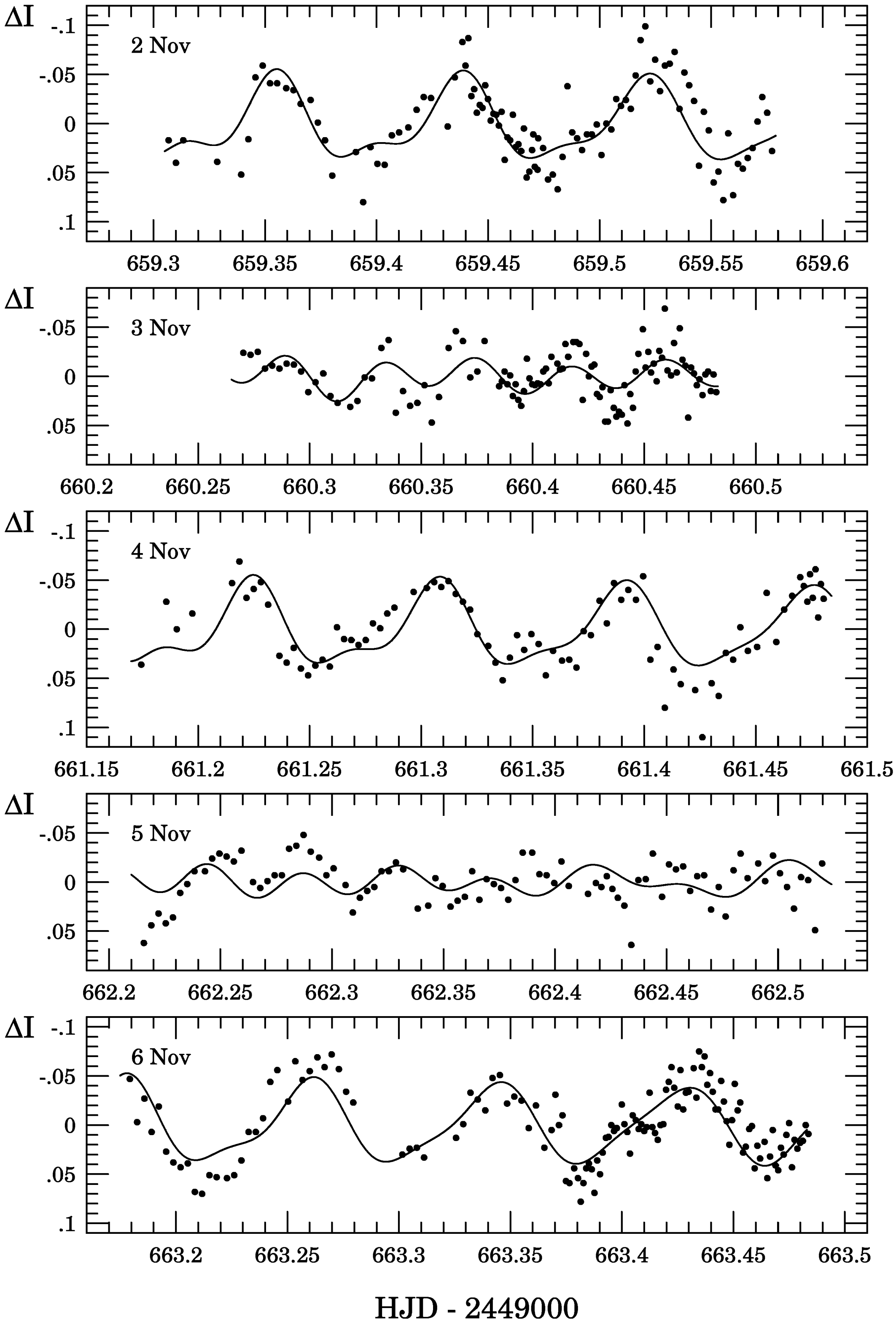

Fig. 5. The *I* light curves of V1974 Cygni for five consecutive nights of November 1994 after removing a longer-scale change from each individual run. The solid line presents a fit of four sinusoids with frequencies corresponding to the the periods 0.0813 and 0.085 days and to their first overtones.

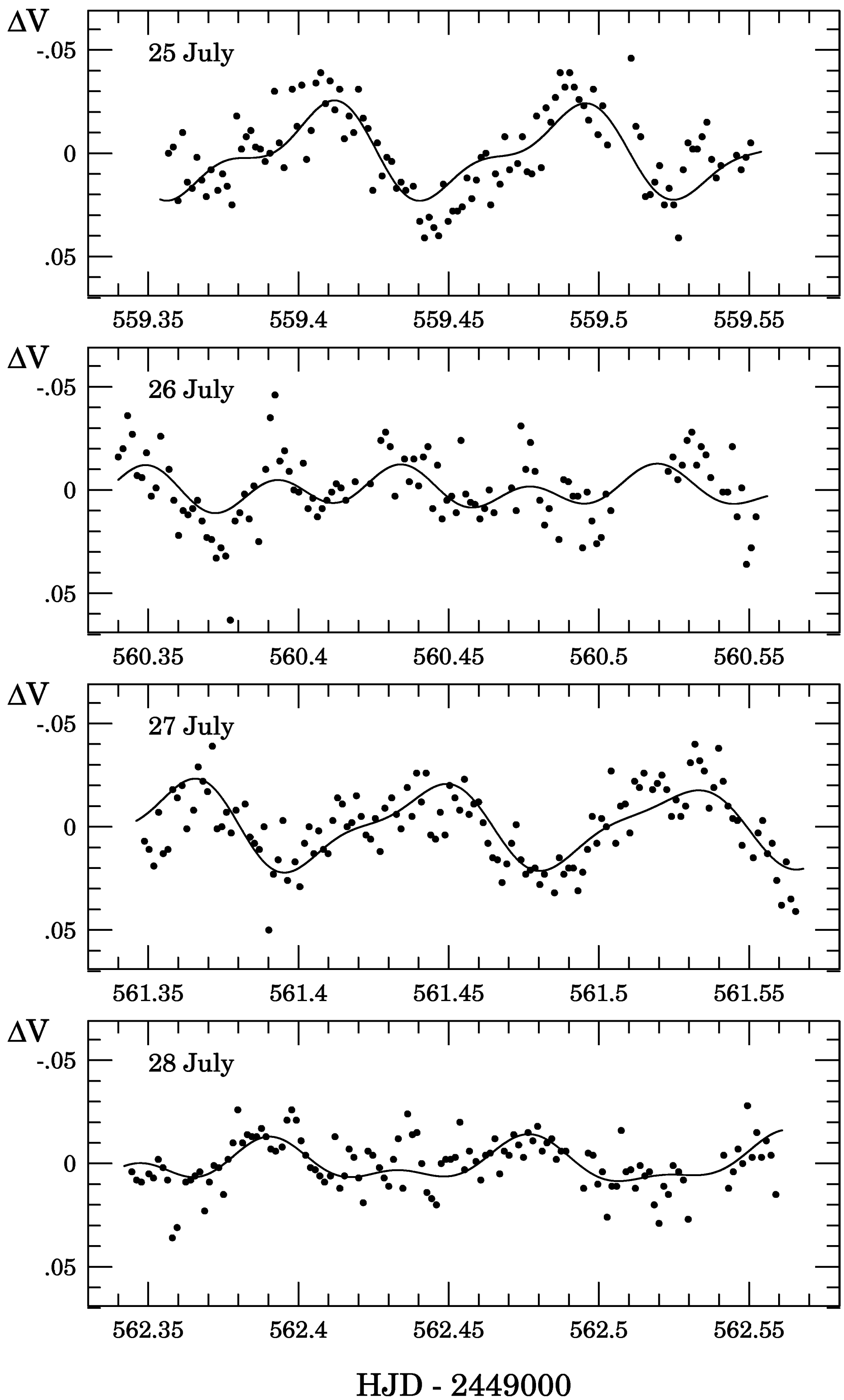

Fig. 6. As in Fig. 5 for the V light curves of V1974 Cygni observed during four consecutive nights of July 1994.

1994, after removing the longer-scale change from each individual run. In Fig. 6 we can also see that a night with well marked 0.08-day modulation is followed by the night when two types of extrema with smaller amplitudes can be traced alternately in the light curves.

5. Amplitudes of the Short-Term Modulations

Table 2 gives the full amplitudes (in magnitudes) of the short-term modulations in filters I and V as a function of time. The amplitude of the two modulations was generally estimated from the power spectra calculated for succeeding subsets of observations. The JD epoch in the first column presents a mean epoch for a subset. For the three July 1994 subsets of consecutive nights (JD 536, 546 and 560 in Column 1) and for the subset of the five November 1994 nights (JD 661 in Column 1), we preferred to include in Table 2 the values obtained from the sinusoidal fits described in the previous Section, as they present a better estimate of the amplitudes than the values estimated from power spectra. For time intervals represented by one observational run only (as for example JD 471), we have placed in Table 2 a total (combined) amplitude of both modulations determined directly from the light curve. Such an amplitude was also given for the last subset of the 1993 I observations.

Table 2

Amplitudes in magnitudes of the $0.^d0813$ and $0.^d085$ modulations of Nova V1974 Cygni

JD	FILTER V		FILTER I	
2449000.+	$0.^d0813$	$0.^d085$	$0.^d0813$	$0.^d085$
185	>.11			
272			.149	<.04
288			.125	<.05
303			.142	<.06
322			.16	
471	.06			
536	.020	.019		
546	.021	.023	.07	
560	.015	.023		
588			.12	
603			.14	
636	.042	.053	.051	.046
661	.034	.034	.035	.044
694			>.06	
714			.032	<.02

Table 2 confirms the earlier conclusions that in 1993 the only significant short-term periodicity in the observations of Nova V1974 Cygni was the 0.0813-day modulation, while the 0.085-day modulation, if present, was not discernible amidst noise. A total amplitude of the two modulations visible in the V 1994 data prior to August was generally twice as small as in the 1993 I data. Later on, from August through the beginning of December, a total amplitude of the two modulations – in both filters – was comparable to that observed in 1993. The I observations from the end of December 1994 and the beginning of January 1995 indicate again a decrease of the total amplitude of the modulations.

Particularly interesting data in Table 2 are the values of the separate amplitudes of each of the two modulations. We can see that, on the average, the 0.085-day modulation contributes to the total (combined) amplitude of the short-term periodicities a bit more than the 0.0813-day modulation, both in V as in I filters. The last entry of Table 2 indicates, however, that at the end of December 1994 the 0.085-day modulation is not discernible from the noise.

6. $O-C$ Analysis of Times of Extrema

Table 3 contains 28 times of minima of the 0.0813-day modulation determined from the 1993 observations of Nova V1974 Cygni. However, in the 1994 observations, maxima were more distinctly pronounced than minima. Thus, for the $O-C$ analysis comprising all our observations we decided to take the maxima rather than minima. They are collected in Table 4. The 1994 maxima, coming generally from a superposition of maxima of the two modulations, are less precisely determined than the 1993 maxima.

Table 3

Times of minima of the $0\overset{d}{.}0813$ periodicity observed in 1993

HJD 2449000.+	FILTER	E	HJD 2449000.+	FILTER	E
185.4923	V	– 1010	286.5009	I	233
267.5595	I	0	289.4979	I	270
268.5396	–	12	289.5871	I	271
268.6227	–	13	293.4834	I	319
271.5441	I	49	293.5653	I	320
271.6306	I	50	299.4977	I	393
273.5743	I	74	300.5520	I	406
273.6553	I	75	302.5101	I	430
276.5033	I	110	304.5338	I	455
276.5800	I	111	306.4834	I	479
276.6630	I	112	313.4765	I	565
284.5458	I	209	314.5281	I	578
284.6262	I	210	330.457	I	774
285.5939	I	222	331.52	I	787

Column 2 of Table 4 indicates that among our maxima we have twelve observed simultaneously in two colors and two in three colors. For those maxima we have

Table 4

Times of maxima of V1974 Cygni

HJD 2449000.+	FILTER	$0\overset{d}{.}0813$ E	$0\overset{d}{.}0813$ O − C	$0\overset{d}{.}085$ E	$0\overset{d}{.}085$ O − C
267.5140	I	0	–0.004		
268.5757	–	13	0.061		
271.4950	I	49	–0.015		
271.5756	I	50	–0.023		
273.5287	I	74	0.012		
273.6119	I	75	0.035		
283.5948	I	198	–0.117		
284.5833	I	210	0.048		
285.5483	I	222	–0.077		
286.5292	I	234	–0.007		
289.5365	I	271	0.001		
293.5244	I	320	0.075		
293.5981	I	321	–0.018		
300.5088	I	406	0.024		
302.5373	I	431	–0.014		
304.5625	I	456	–0.092		
314.4821	I	578	–0.023		
321.554	I	665	0.003		
471.540	V			–751	–0.290
535.438	V	3297	0.021	0	0.074
537.390	V	3321	0.042	23	0.028
537.470	V	3322	0.027	24	–0.032
546.406	$V+R+I$	3432	–0.008	129	0.045
546.487	$V+R+I$	3433	–0.011	130	–0.002
547.424	V			141	0.016
548.448	V	3457	0.120	153	0.057
548.524	V	3458	0.055	154	–0.050
559.407	V	3592	–0.020	282	–0.079
559.490	V	3593	0.001	283	–0.103
560.437	V			294	0.033
561.367	V	3616	0.099	305	–0.031
561.445	V	3617	0.059	306	–0.114
561.533	V	3618	0.142	307	–0.079
562.395	V			317	0.057
562.479	V			318	0.044
588.658	I	3952	–0.062	626	–0.122
603.607	I	4136	–0.102	802	–0.339
625.547	I			1060	–0.351
627.495	$V+I$	4430	–0.141	1083	–0.445
637.262	$V+I$	4550	0.050	1198	–0.597
637.341	$V+I$	4551	0.022	1199	–0.668
637.432	$V+I$	4552	0.142	1200	–0.598
642.534	I	4615	–0.074	1260	–0.604
646.269	$V+I$	4661	–0.112	1304	–0.685
646.358	$V+I$	4662	–0.016	1305	–0.639
659.356	$V+I$	4822	–0.065	1458	–0.798
659.440	I	4823	–0.031	1459	–0.810
659.526	I	4824	0.027	1460	–0.799
661.220	$V+I$	4845	–0.127	1480	–0.879
661.306	$V+I$	4846	–0.069	1481	–0.868
661.392	$V+I$	4847	–0.011	1482	–0.857
663.263	$V+I$	4870	0.013	1504	–0.856
663.344	I	4871	0.010	1505	–0.904
663.435	I	4872	0.130	1506	–0.834
669.284	$V+I$	4944	0.107	1575	–1.056
694.359	I			1870	–1.204
713.476	I	5488	–0.074		
717.463	I	5537	–0.011		

determined the times of maxima for each filter independently and come to the conclusion that there is no systematic difference between the observed times of V, R and I maxima. A partial $O-C$ analysis performed independently for the corresponding V and I maxima gave the same conclusion. Therefore, for a complete $O-C$ analysis we have taken the mean values from V and I, or from V, R and I times of maxima, and these values are placed in Table 4. The lack of a systematic difference between times of maxima for different filters justifies also inclusion into Tables 3 and 4 three times of extrema obtained from observations performed without any filter.

6.1. The 0.0813-day Period

Using the minima of Table 3, except for the first one, DeYoung and Schmidt (1994) determined the period of the 0.0813-day modulation as equal to 0.081263 ± 0.000003 days and they came to the conclusion that the period is stable and that it is the orbital period of the system. We have repeated the calculation including also the first V minimum and obtained, within the error limits, the same value of the 0.0813-day period. Next, the $O-C$ analysis performed independently for the 1993 maxima of Table 4 and for the 1994 maxima of the Table resulted in the period values not differing, within the error limits, from the first value.

Analyzing the 1994 maxima for the 0.0813-day period, we have rejected seven maxima of Table 4 (those without cycle numbers in Column 3). Those maxima do not fit to the ephemeris for the 0.0813-day periodicity, but fit well to the 0.085-day periodicity. The well-defined 1994 maxima come generally from superposition of both types of maxima. The rejected maxima are not so distinctly pronounced. They appear on the light curve because the 0.085-day modulation has a little bit greater amplitude in these epochs and overcomes the opposite phase of the 0.0813-day modulation. Therefore, we are justified rejecting those maxima in the analysis of the 0.0813-day modulation.

The least-squares method employed for all maxima of Table 4 with their cycle numbers in Column 3 gives the following linear ephemeris for the 0.0813-day periodicity:

$$\begin{aligned} \mathrm{HJD}_{\mathrm{Max}} = &2449267.5143 + 0.0812623\,E \\ &\pm 0.0014 \pm 0.0000004 \end{aligned} \quad (1)$$

The $O-C$ residuals from this ephemeris contained in Column 4 of Table 4 are plotted in Fig. 7. The Figure fully confirms the conclusion of DeYoung and Schmidt (1994) that the 0.0813-day period is stable and it can be interpreted as the orbital period of Nova V1994 Cygni.

6.2. The 0.085-day Period

Unlike the 0.0813-day period, the 0.085-day period is not stable. This conclusion was already obtained by Semeniuk *et al.* (1994) from the 1994 observations made prior to August 1994. They could not, however, determine conclusively the sign of the period derivative. The new maxima observed during 1994 and collected

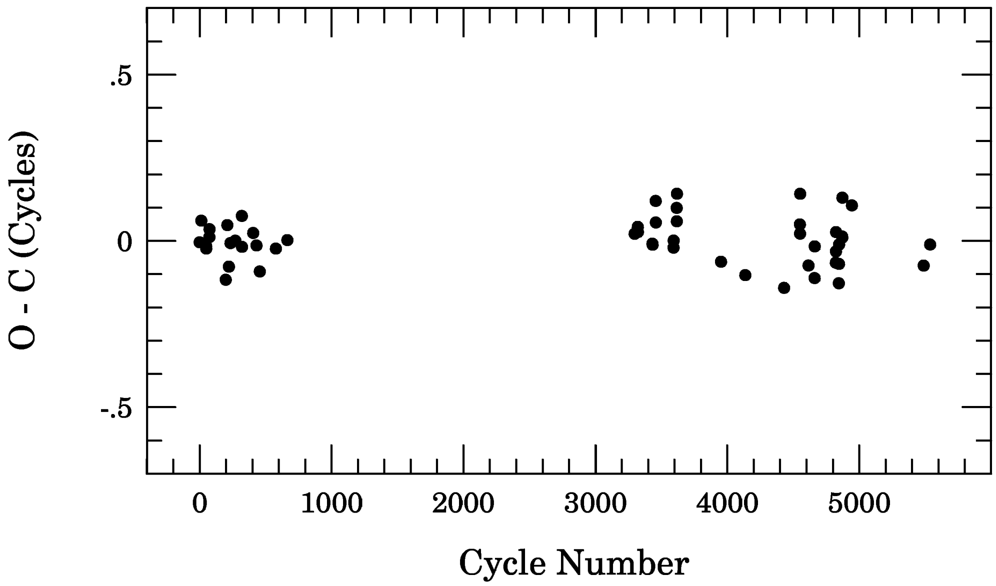

Fig. 7. $O - C$ diagram for times of maxima of the 0.0813-day modulation calculated from the ephemeris (Eq. 1).

in Table 4 did allow the sign of the derivative to be determined. The 0.085-day period appeared to decrease. To describe the times of maxima of the 0.085-day modulation we have calculated two ephemerides, a quadratic one and an exponential one. In these calculations we rejected the two last maxima of Table 4, as we have no convincing evidence for presence of the 0.085-day periodicity in the power spectrum obtained for the last runs of December 1994 and it is not excluded that the last maxima come only from the 0.0813-day modulation.

The quadratic ephemeris obtained as the best least squares fit to 38 maxima of Table 4 is the following:

$$\begin{aligned} \mathrm{HJD}_{\mathrm{Max}} = & 2449535.4316 + 0.085043\,E - 3.3\times10^{-8}E^2 \\ & \pm 0.0014 \pm 0.000003 \quad \pm 0.2 \end{aligned} \tag{2}$$

An analogy with Nova V1500 Cygni suggests that the quickly changing 0.085-day period may be the spin period of the white dwarf component of the system. Therefore, it is possible that the 0.085-day period is not decreasing linearly with time, but evolves exponentially to the orbital value $P_{\mathrm{orb}} = 0.0813$ days according to the formula:

$$P = P_{\mathrm{orb}} + (P_0 - P_{\mathrm{orb}})\exp(-E/\tau), \tag{3}$$

where P_0 is the value of P for the epoch zero and τ is e-decay time scale of the difference $P_0 - P_{\mathrm{orb}}$. In that case the corresponding exponential ephemeris describing times of maxima of the 0.085-day periodicity is of the following form:

$$\mathrm{HJD}_{\mathrm{Max}} = M_0 + P_{\mathrm{orb}}E + (P_0 - P_{\mathrm{orb}})(1 - \exp(-E/\tau))\tau. \tag{4}$$

The parameters M_0, P_0 and τ in the formula were determined using the differential corrections method and have the following values:

$$M_0 = 2449535.4317 \pm 0.0013$$
$$P_0 = 0.085043 \pm 0.000003$$
$$\tau = 57165 \pm 3830$$

The ephemeris (Eq. 4) with these parameters gives an equally good fit to the maxima as the quadratic ephemeris (Eq. 2).

Fig. 8 shows the change of the period. The $O-C$ deviations plotted in the Figure are taken from the last column of Table 4. They were calculated using the linear ephemeris $\mathrm{HJD_{Max}} = 2449535.4317 + 0.085043E$. The solid line in Fig. 8 presents the fit corresponding to the exponential ephemeris (Eq. 4). The quadratic fit (Eq. 2) in the epochs interval covered by Fig. 8 does not differ visibly from the exponential fit.

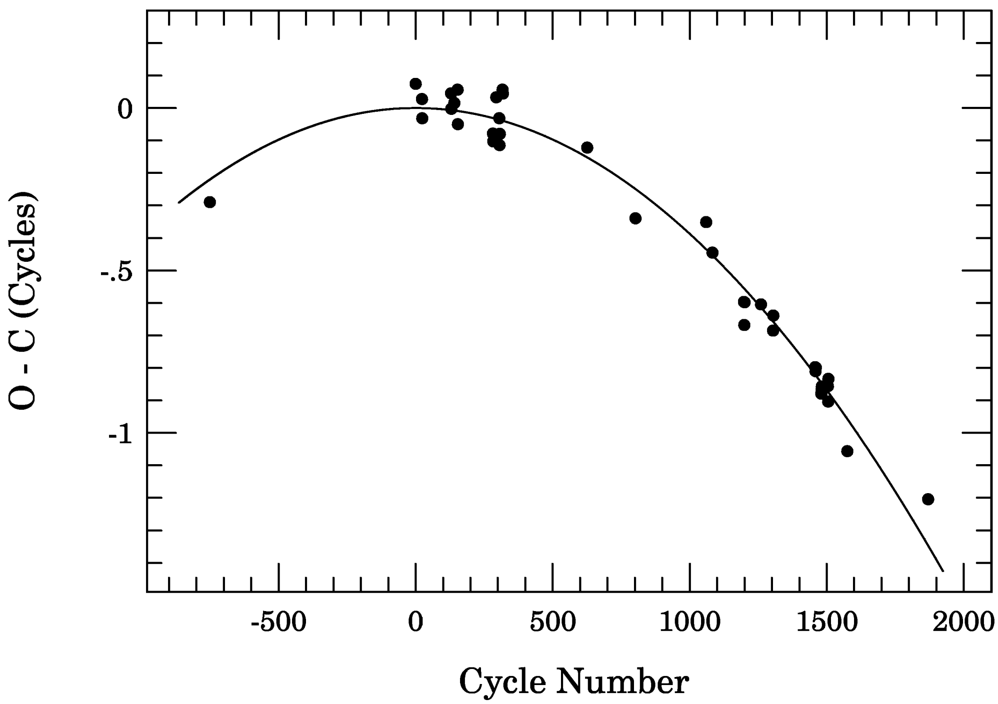

Fig. 8. $O-C$ values for times of maxima of the 0.085-day modulation calculated with the linear ephemeris $\mathrm{HJD_{Max}} = 2449535.4317 + 0.085043E$. The solid line is the fit corresponding to the exponential ephemeris (Eq. 4).

7. Conclusions and Discussion

Our extensive analysis of the CCD photometric observations of Nova V1974 Cygni obtained during 1993–1994 has convincingly proved that two short-term modulations of periods 0.0813-day (117 min) and 0.085-day (122 min), whose values are close to 2-day aliases of one another, are really present in the light curve of the nova.

The 0.0813-day period was observed both in the 1993 and in the 1994 observational seasons and appears to be stable. Therefore, we interpret it – as originally proposed by DeYoung and Schmidt (1994) – as the orbital period of the system. The amplitude of the 0.0813-day periodicity decreased by a factor of about two in the 1994 season in comparison with the 1993 season.

The 0.085-day periodicity appeared to be present only in the 1994 observations of the nova, while no convincing trace of the period was found in the 1993 observations. The mean amplitude of the 0.085-day modulation in 1994 was comparable or even a little bit greater than the amplitude of the 0.0813-day modulation.

We have found no phase shift between times of extrema of both modulations observed in different filters.

We have demonstrated that the 0.085-day period is decreasing, and we suggest that it may be the period of rotation of the white dwarf component of the binary system. The temporal evolution of the period in the time interval covered by our observations is equally well described with a parabolic ephemeris as with an exponential one. A larger baseline is obviously needed to decide which of two is correct.

The presence of the two short-term modulation periods suggests the existence of a third period equal to 1.85 days – a beat period of the two short periods. The presence of this period reveals itself in the direct photometry of the nova as a difference between appearance of the light curves from two consecutive nights. We have managed to model the resulting, characteristically changing shape of the light curve with a superposition of sinusoids with frequencies corresponding to the two periods and their overtones. We have also attempted to find the 1.85-day period in a Lomb-Scargle power spectrum obtained for the appropriate frequency domain. We have used for this purpose the three July 1994 subsets of consecutive nights and the November 1994 subset of five consecutive nights (after first removing the general decreasing trend from combined observations of each subset). However, no significant peak corresponding to a 1.85 day period was found in the calculated power spectrum. The highest peak in these low frequencies corresponds to 3.75 days, which is approximately double value of the 1.85 days.

Semeniuk *et al.* (1994) noticed the resemblance of V1994 Cygni to intermediate polars and particularly to Nova V1500 Cygni. We are prone to believe that Nova V1974 Cygni, prior to its outburst in 1992, was a magnetized, synchronously rotating AM Her binary like Nova V1500 Cygni (Semeniuk *et al.* 1977). The explosion has broken down the spin/orbit synchronism, and the quickly decreasing 0.085-day period observed in 1994 may be the spin period of the white dwarf evolving now into synchronism with the orbital cycle.

However, we should also stress a difference between the two objects. In the case of V1500 Cygni, during the first two observational seasons only the decreasing spin period was visible in the light curve of the nova, while in the third observational season it disappeared and instead, a more stable orbital period appeared in photometry (Patterson 1979). Its value was a little bit shorter than an initial value of $P_{\rm spin}$, but longer than its value observed just before disappearance. The spin period was rediscovered in polarimetry only 12 years after outburst with a value about 2% shorter than the orbital 0.1396-day period (Stockman, Schmidt and Lamb 1988) and appeared to be increasing (Schmidt and Stockman 1991).

In the case of V1974 Cygni, the orbital period $P_{\rm orb}$ was first observed in the light curve and the decreasing 0.085-day period appeared in photometry only about two years after outburst, with a value still about 5% longer than the orbital period. Recently, Retter, Ofek and Leibowitz (1995) reported that the two periods obey exactly the linear relation of Stolz and Schoembs (1981) for SU UMa stars. This fact could serve as an argument that the 0.085-day period of Nova V1974 Cygni might not be a rotation period of the white dwarf component of the system, but rather a superhump period. Additionally, the 117-min orbital period of V1974 Cygni places the nova at the short-period side of the period gap populated mainly by polars (AM Her stars) and SU UMa stars. A counterargument against including V1974 Cygni into SU UMa-type stars is, however, the fact that generally during their superoutbursts we do not observe orbital modulations, but only superhumps. Therefore, we are more inclined towards the hypothesis that the 0.085-day period is a spin period of the white-dwarf component of an AM Her star which was thrown off synchronism by the nova outburst and now evolves back into synchronization. A screening effect of envelope might cause that the period was not observed during the first two years after eruption.

Here one should perhaps shortly mention potential physical mechanisms commonly considered to be related to change and evolution of periods of the short-term modulations in cataclysmic variables. The most important among them seem to be: 1) mass loss from the system affecting generally the orbital period, 2) increase of the white dwarf radius in the process of expansion following detonation, 3) increase of the white dwarf radius due to decrease of its mass, 4) shrinking of the white dwarf due to cooling, 5) magnetic synchronization of the white dwarf due to magnetic interaction with the companion, 6) acceleration of the white dwarf rotation due to mass accretion from the companion, 7) magnetic braking of the white dwarf due to interaction with the common envelope, 8) friction exerted on the orbital motion due to interaction with common envelope.

We do not attempt to express opinion which of the above mentioned factors dominated at different evolutionary stages of Nova V1974 Cygni.

Applying our ephemerides (Eq. 2) and (Eq. 4), we can make some predictions on the future temporal behavior of the 0.085-day period P. If its decrease is linear then according to the ephemeris (Eq. 2), we get $\dot{P} = -7.8 \times 10^{-7}$. In this case a predicted time scale for equalization of the decreasing period P with the orbital period is $(P_{\rm orb} - P)/\dot{P} = (13 \pm 1)$ yr. On the other hand, the exponential ephemeris (Eq. 4) predicts that the e-folding time for the difference $P - P_{\rm orb}$ is also (13 ± 1) yr. A longer baseline is necessary to discern between the two cases.

Further photometric, spectroscopic, and, particularly, polarimetric observations, are clearly needed to confirm or disprove our interpretation and predictions concerning this very interesting object.

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