Mon. Not. R. Astron. Soc. **356,** 773–777 (2005) doi:10.1111/j.1365-2966.2004.08509.x

Discovery of irradiation-induced variations in the light curve of the classical nova V2275 Cyg (N Cyg 2001 No. 2)

Ş. Balman,[1★] A. Yılmaz,[1] A. Retter,[2] T. Saygaç[3] and H. Esenoglu[3,4]

[1]*Department of Physics, Middle East Technical University, Ankara, 06531, Turkey*
[2]*Department of Astronomy and Astrophysics, Pennsylvania State University, 525 Davey Lab., University Park, PA 16802, USA*
[3]*Istanbul University, Department of Astronomy and Space Sciences, Istanbul, 34119, Turkey*
[4]*Istanbul Observatory, Research and Application Center, Istanbul, 34119, Turkey*

Accepted 2004 October 12. Received 2004 October 11; in original form 2004 August 3

ABSTRACT

We present charge-coupled device (CCD) photometry, light curve and time-series analysis of the classical nova V2275 Cyg (N Cyg 2001 No. 2). The source was observed for 14 nights in total in 2002 and 2003 using an R filter with the 1.5-m Russian–Turkish joint telescope (RTT150) at the TUBITAK National Observatory in Antalya, Turkey, as part of a large programme on the CCD photometry of cataclysmic variables. We report the detection of two distinct periodicities in the light curve of the nova: (a) $P_1 = 0.314\,49(15)$ d [7.6 h], and (b) $P_2 = 0.017\,079(17)$ d [24.6 min]. The first period is evident in both 2002 and 2003 whereas the second period is only detected in the 2003 data set. We interpret the first period as the orbital period of the system and attribute the orbital variations to aspect changes of the secondary irradiated by the hot white dwarf (WD). We suggest that the nova was a supersoft X-ray source in 2002 and, perhaps, in 2003. The second period could be a quasi-periodic oscillation originating from the oscillation of the ionization front (due to a hot WD) below the inner Lagrange point or a beat frequency in the system as a result of the magnetic nature of the WD if steady accretion has already been re-established.

Key words: accretion, accretion discs – binaries: eclipsing – stars: individual: V2275 Cygni – novae, cataclysmic variables – stars: oscillations – white dwarfs.

1 INTRODUCTION

Classical novae are a subset of cataclysmic variables that are interacting binary systems hosting a main-sequence secondary (sometimes a slightly evolved star) and a collapsed primary component, a white dwarf (Warner 1995). An outburst on the surface of the white dwarf as a result of a thermonuclear runaway in the accreted material causes the ejection of 10^{-3} to 10^{-7} $M_{\odot}$ of material at velocities up to several thousand kilometres per second (Shara 1989; Warner 1995). The classical nova V2275 Cyg (N Cyg 2001 No. 2) was discovered at a magnitude 7.0–8.8 on 2001 August 18 simultaneously by Nakamura, Tago & Abe (2001) and Nakano et al. (2001). Early optical spectroscopy showed hydrogen Balmer lines with P Cygni profiles and Hα lines indicating expansion velocities of 1700 km s^{-1} (Ayani 2001). At later stages, high-energy coronal lines were found to dominate the spectrum (e.g. [Si X], [Si IX] and [Al IX]). The nova was found to belong to the 'He/N' subclass of novae defined by Williams (1992), because of the broad lines of H, He and N in its spectrum (Kiss et al. 2002). In addition, Kiss et al. (2002) measured $t_2 = 2.9 \pm 0.5$ d, $t_3 = 7 \pm 1$ d and $M_V = -9.7 \pm 0.7$ mag, which were used to derive a distance of 3–8 kpc for the nova. An USNO star of $R = 18.8$ mag and $B = 19.6$ mag was suggested as a possible progenitor star (Schmeer 2001).

This paper is on the charge-coupled device (CCD) photometry of V2275 Cyg covering years 2002 and 2003 obtained with the 1.5-m Russian–Turkish joint telescope (RTT150) at the TUBITAK (Scientific and Technical Research Council of Turkey) National Observatory (TUG) in Antalya, Turkey. We present the discovery of a distinct period reported by Balman et al. (2003) (which we mark as P_1) and the detection of a highly coherent quasi-periodic oscillation (QPO) on six different nights in 2003 (using V, R and I filters). Fast variations from V2275 Cyg similar to this second period (which we mark as P_2) were also reported by Garnavich et al. (2004) derived from a data set of two nights obtained with a V filter.

2 OBSERVATIONS AND DATA REDUCTION

V2275 Cyg was observed during eight nights in 2002 and six nights in 2003 using the standard R filters (Johnson and Cousins) at TUG (see Table 1 for a timetable of observations). The data were obtained with the imaging CCD (a Loral LICK3 2048 × 2048 pixel

★E-mail: solen@astroa.physics.metu.edu.tr

Table 1. The timetable of the observations. (All observations are obtained with standard *V*, *R* and *I* filters.)

UT date	Time of start (HJD − 245 2000)	Run time (h)	Number of frames	Filter
020610	436.484 518	1.8	30	*R*
020612	438.486 060	1.9	29	*R*
021001	549.246 533	7.1	88	*R*
021002	550.248 770	5.3	68	*R*
021003	551.256 457	5.9	99	*R*
021005	553.293 507	5.4	80	*R*
021201	610.238 175	1.5	40	*R*
021222	631.188 612	2.9	68	*R*
030825	877.367 836	5.8	136	*R*
030826	878.376 911	4.1	114	*R*
030827	879.299 621	7.5	204	*R*
031101	945.196 586	6.2	81, 82	*R*, *I*
031102	946.208 050	5.6	65, 64	*R*, *V*
031228	1002.221 443	2.0	23, 23	*I*, *V*

back-illuminated CCD chip at 0.26 arcsec pixel^{-1} resolution) on 2002 June 10 and June 12, and an Ap47p CCD (1024 × 1024 pixels with 13 μm pixel^{-1} resolution) on 2002 October 1–5, December 1 and December 22. The rest of the data are taken with the ANDOR CCD (2048 × 2048 pixels at 0.24 arcsec pixel^{-1} resolution) on 2003 August 25–27, and the imaging CCD on 2003 November 1–2. The exposure time is 90 s for each frame. A total of 1149 images were obtained in the *R* band and reduced using standard procedures calibrating the frames with the bias/dark current frames and dome flat fields. In addition, a total of 105 frames in the *I* band and 87 frames in the *V* band have been compiled for comparison (in 2003 November 1–2, and 2003 December 28). After the raw data were cleaned and calibrated, the instrumental magnitudes of the nova were derived by the point spread function (PSF) fitting algorithms DAOPHOT (Stetson 1987) and ALLSTAR in the MIDAS software package (version 02FEBpl1.0 and 03FEBpl1.0) using 25 stars as PSF stars. Also, another reference group of four constant stars close to the nova in the same field was formed in order to reduce the scintillation effects and to derive the relative magnitudes. The calibrated apparent magnitude of the nova in the *R* band varied in the range from 15.1 to 16.2 mag in 2002. The fading of the nova continued, changing this range to 17.3–19.0 mag in 2003.

3 ANALYSIS AND RESULTS

Using our reduced and calibrated *R*-band data, we constructed light curves for the nights given in Table 1. A collection of normalized light curves obtained from runs that are longer than 5 h is displayed in Fig. 1. The top panel is of 2002 October 1–5, the middle panel is of 2003 August 25–27 and the bottom panel is of 2003 November 1–2. A deep modulation of the light curve can be seen in Fig. 1. Fig. 2 shows the data obtained in the longest run (7.5 h) on 2003 August 27. This figure reveals not only the long period that is causing the deep modulation (which we mark as P_1), but also the other superimposed faster variations (which we mark as P_2) and humps that are observed in the system. We have also accumulated data using the standard *I* filter on 2003 November 1 and *V* filter on 2003 November 2 together with the *R* filter observations (see Fig. 3). The short time-scale variations (which we mark as P_2) are apparent in the figure. Subtraction of a linear trend from the *V*- and *I*-band light curves in Fig. 3 suggests that the long-period variations (i.e. P_1) are larger in amplitude in the *I* and *R* bands than the *V* band, which can be

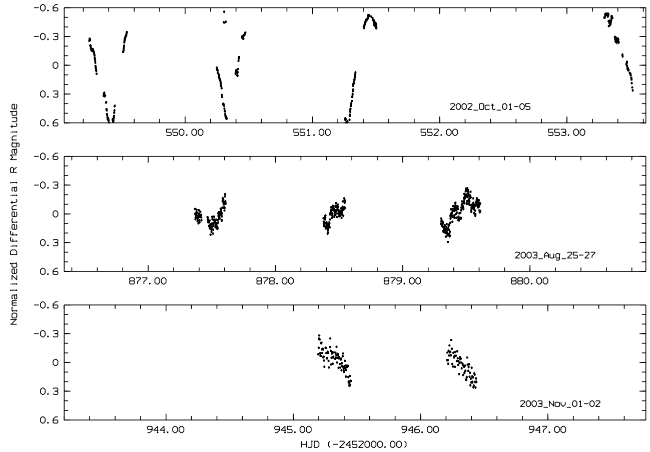

Figure 1. The normalized differential light curve of V2275 Cyg observed on 2002 October 1–5 (top panel); the light curve obtained on 2003 August 25–27 (middle panel); and the light curve obtained on 2003 November 1–2 (bottom panel). All data are taken with the TUG 1.5-m telescope using the standard *R*-band filters (Johnson and Cousins). The epochs of the observations are noted on the *x*-axis. The average magnitude errors are ±0.0083, ±0.0065 and ±0.0095 for the top, middle and bottom panels, respectively.

expected (see Discussion). We have performed Fourier analysis of the time series obtained from the data in order to derive the periods of these modulations. In general, several standard programs have been used, like the Scargle algorithm (Scargle 1982) and discrete Fourier analysis using Leahy normalization (Leahy, Elsner & Weisskopf 1983). Fig. 4 shows the power spectrum of the data for the year 2002 and Fig. 5 for the year 2003 where the Scargle algorithm is used to calculate the power spectra. The detection limit of a period at the 3σ confidence level (99 per cent) is a power of 14.2 in Fig. 4 (2002 data) and 15.6 in Fig. 5 (2003 data) (see also Scargle 1982). In order to correct for the effects of windowing and sampling functions on power spectra, synthetic constant light curves are created and a few very prominent frequency peaks that appear in these light curves are pre-whitened from the data in the analysis. Before calculating the power spectra, the individual or consecutive nights are normalized by subtraction of the mean magnitude. Moreover, when necessary, the red noise in the lower frequencies is removed by detrending the data.

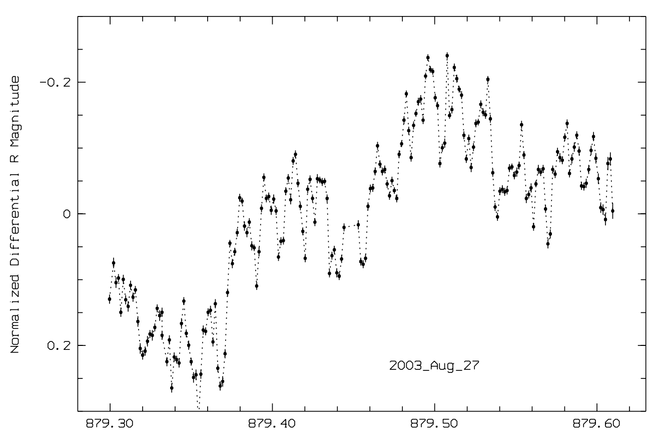

Figure 2. The light curve of the longest observing run (7.5 h) on 2003 August 27. The data are taken with the ANDOR CCD using a standard *R*-band filter (Cousins). The average magnitude error is ±0.0063.

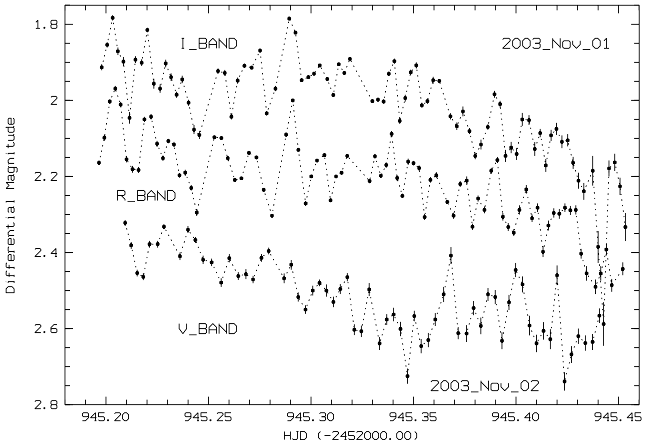

Figure 3. The light curve of V2275 Cyg obtained with the standard *I* and *R* filters on 2003 November 1, and with the *V* filter on 2003 November 2. The data are taken with the imaging CCD. The average magnitude errors are ±0.015, ±0.008 and ±0.011 for the *V*, *R I* light curves, respectively.

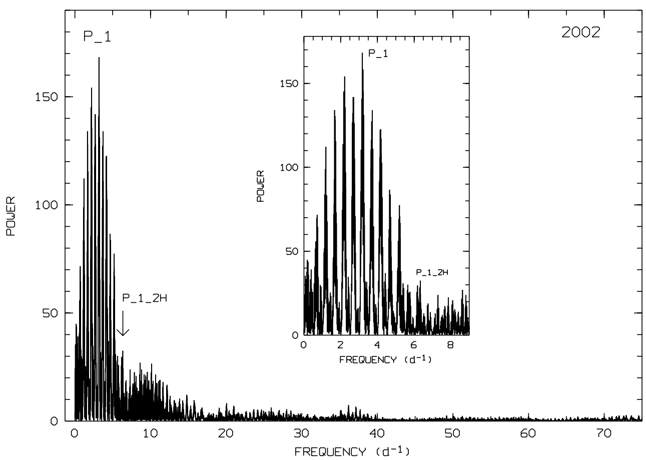

Figure 4. The power spectrum of V2275 Cyg, derived from the 2002 data set (eight nights), using the Scargle algorithm. The new period is indicated as P_1 and its weak (but significant) second harmonic is also noted.

We find a prominent period at $P_1 = 0.314\,49(15)$ d using the whole data set. The power spectra in Figs 4 and 5 show the highest peak at this period and the group of peaks around it are some of the ±1/3, ±1/2, ±1 and ±2 d aliases of the detected period. In Fig. 4 (2002 data), a weak second harmonic of P_1 ($P_1/2$) is present (it is significant). In Fig. 5 (2003 data), the third harmonic of P_1 ($P_1/3$) is also present, but the second harmonic is not significantly detected. The period (P_1) shows an amplitude variation of 0.42 ± 0.06 mag in 2002 (measured by fitting a sine wave). The amplitude of the variations is decreased significantly in 2003 to 0.22 ± 0.12 mag. The decrease in modulation depth is about 50 per cent (in magnitude). The ephemeris for P_1 determined by fitting a sine curve is

$$T_{\min} = \mathrm{HJD}\ 245\,2549.4163(\pm 0.0154) + 0.314\,49(\pm 0.000\,15)\,E.$$

We also detect a second periodicity at $P_2 = 0.017\,079(17)$ with an amplitude of 0.03 ± 0.01 mag. These rapid variations are revealed in all the nights in 2003 with varying intensity. They are also clearly seen in Figs 2 and 3 (in the *V*, *R* and *I* bands). We do not recover the beat period between P_2 and P_1 in the 2003 data set.

Figs 6 and 7 display the mean light curves folded on P_1 using the 2002 and 2003 data set, and P_2 using the 2003 data set, respectively.

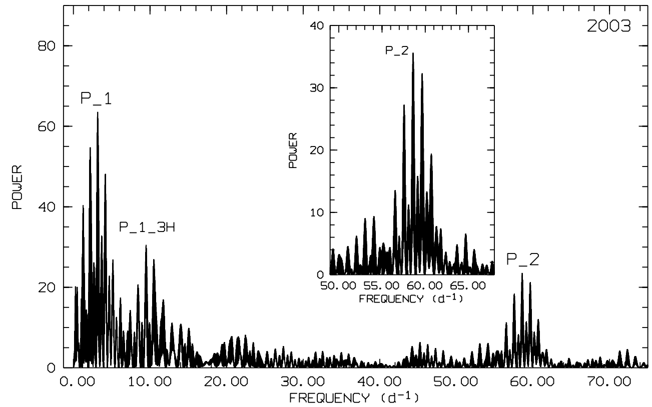

Figure 5. The power spectrum of V2275 Cyg obtained using the 2003 data set (five nights). P_1 is noted on the figure. The inset is a normalized power spectrum of V2275 Cyg in the frequency range centred around P_2 where P_1 is removed. A Scargle algorithm is used for the analyses.

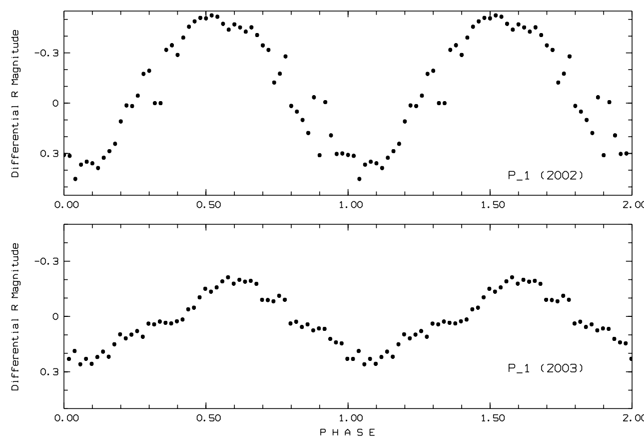

Figure 6. The light curve of the 2002 data set (top panel) and 2003 data set (bottom panel), folded on the period P_1 [0.314 49(15)]. The first data point in time (start HJD in 2002) is taken as the reference and a grouping (averaged over) of 50 phase bins is used for the folding process (i.e. the 2002 and 2003 data are phase-locked). The average error of a phase bin is ±0.0021 mag for the top panel and ±0.0024 mag for the bottom panel.

The shapes of the profiles are sinusoidal for both P_1 and P_2 (in 2002–2003), with a slight asymmetry. Hump-like features are apparent on both profiles, as well. The ingress in the mean light curve of P_1 and P_2 is shorter by 10 per cent of the photometric phase than the egress. In addition, we have constructed $V - R$, $I - R$ and $I - V$ colour diagrams to search for colour variations over the photometric phases of the periods (light curves are calibrated before the construction of the colour diagrams). The right-hand panel of Fig. 8 shows the existence of a significant modulation of the colour difference $I - V$ over the photometric phase of P_1. The $I - R$ magnitude plotted in the left-hand panel of Fig. 8 indicates colour variation over the photometric phase of the second period as well.

4 DISCUSSION

We present 14 nights of data on V2275 Cyg obtained with the TUG 1.5-m telescope using mainly standard *R* filters in 2002 and 2003. We discover large modulations $\Delta m_r = 0.42$ at $P_1 = 0.314\,49(15)$ d in the light curve of the classical nova in 2002, the amplitude of

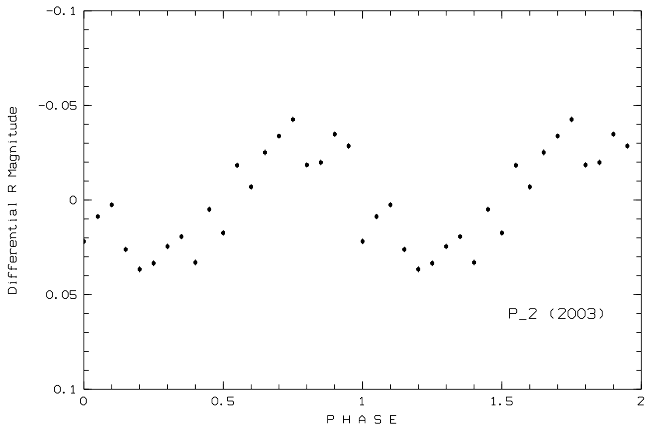

Figure 7. The light curve of the 2003 data set, folded on the period P_2 [0.017 079(17)]. The first data point in time (start mid-HJD in 2003) is taken as the reference and a grouping (averaged over) of 20 phase bins is used for the folding process. The average error of a phase bin is ± 0.0015 mag. The small oscillations superimposed on the mean light curve are due to the time windows of the data.

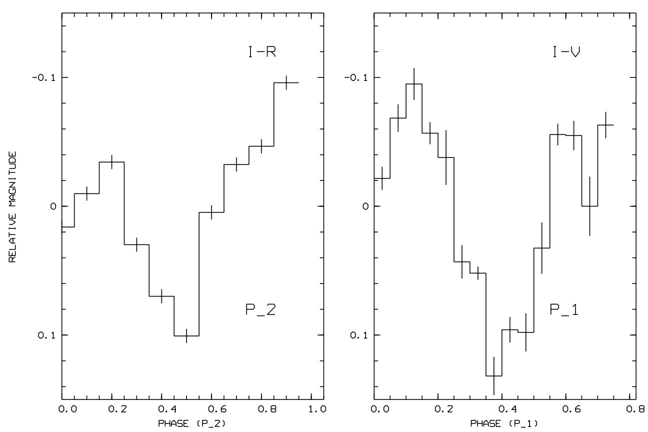

Figure 8. Colour variations of the detected periodicities. The left-hand panel is the normalized colour magnitude $(I - R)$ curve versus photometric phase of P_2. The total light curve is folded on P_2 using 10 phase bins. The right-hand panel shows $I - V$ colour variation over the photometric phase of P_1. The total light curve is folded on P_1 using 15 phase bins.

this modulation decreasing to $\Delta m_r = 0.22$ in 2003. This period was discovered in the V and the I bands as well. Since the periodicity is persistent and coherent, we propose that this is the binary period of the system. The orbital period can be detected as a result of the aspect variations of the secondary due to heating from the hot white dwarf (WD) (Kovetz, Prialnik & Shara 1988). The decrease in the modulation depth from 2002 to 2003 and the colour variations $(I - V, I - R, R - V)$ support a scenario where the heated secondary is the source of the light and the colour variation rather than a hotspot on the disc. The mass–period relation $M_2 \simeq 0.11 P_{\rm hr}$ (Warner 1995) yields a secondary mass of about 0.83 $M_{\odot}$ for V2275 Cyg using the discovered binary period in this paper, which is in accordance with the fact that a massive secondary will be hot and prone to irradiation effects. In addition, the mean light curves (Figs 6 and 7) indicate an asymmetry in the R band as would be expected from the differential rotation of the secondary spreading the heated atmosphere into a non-spherical shape (tear-drop model). An eclipse can be ruled out because the modulation amplitude would be larger in time as observed for some other novae (e.g. V838 Her, Leibowitz et al. 1992; V1494 Aql, Kato et al. 2004). A recent search for variations/periodicities in the light curve of faint cataclysmic variables (CVs) (including old novae) reveals that irradiation yields larger amplitude for modulations (Woudt & Warner 2003a,b) as detected in our study.

After a nova explosion, the hot WDs are candidates for heating their cooler companion. Some classical nova systems were recovered to show this irradiation effect like: (1) V1500 Cyg (N Cyg 1975), which showed an unperturbed temperature of 3000 K for the secondary and 8000 K for the heated side (Schmidt, Liebert & Stockman 1995; Somers & Naylor 1999); (2) DN Gem (N Gem 1912) (Retter, Leibowitz & Naylor 1999); (3) WY Sge (N Sge 1783), which indicated that the accretion luminosity from the disc could even be responsible for the irradiation of the secondary (Somers, Mukai & Naylor 1996). However, only one such system resembles V2275 Cyg closely: orbital modulations due to aspect variations of the heated face of the secondary was detected for V1974 Cyg (N Cyg 1992) at the outburst stage (about a year and a half after outburst) by DeYoung & Schmidt (1994) before the WD cooled to a point where it was no longer a strong X-ray source. The orbital variations in V1974 Cyg were $\sim$0.1 in the I band and $<$0.05 in the V band when the hydrogen burning had just turned off (the WD temperature was about 3–4 $\times$ 10^5 K; Balman, Krautter & Ögelman 1998). V1974 Cyg was discovered as a supersoft X-ray source (SSS) while burning the hydrogen over its surface (Balman et al. 1998, and references therein) consistent with the fact that most novae are expected to be an SSS at a certain point during their outburst stage (see Krautter 2002 for a review). A hot WD at a temperature above 1 $\times$ 10^5 K (i.e. emits mostly in the soft X-ray wavelengths) with a radiative wind can be the source of an ionization front irradiating the secondary star. Therefore, we suggest that V2275 Cyg was also an SSS during 2002–2003, and the radiative winds/ionization front of an SSS reaching out well into the photosphere of the secondary can explain the observations of V2275 Cyg in 2002. The decrease of 50 per cent in the modulation depth from 2002 to 2003 is another indication of the changing conditions in the ionization front. The strong third harmonic of P_1 detected in 2003 could support the existence of several hot zones over the total surface of the secondary along with the significantly heated inner face resulting in the higher harmonics becoming prominent.

We also detected another periodicity $P_2 = 0.017\,079(17)$ d in the light curve of 2003. We suggest that this is a highly coherent QPO from the system. The power of the signal varies on different nights (independent of length of the observation) together with the small changes of the periodicity, which differ according to the colour (i.e. filter). The characteristics of the oscillations revealed in 2003 does not strongly support a WD spin period as the origin. The time-scale and characteristics of the QPOs ($\sim$1475 s) resemble flickering, or reprocessing from blobs orbiting within the inner regions/magnetosphere of the accretion disc in accreting CVs. It could also be the beat period between the spin period and the orbital period of the system (P_1). However, since the nova is still in its early outburst stage during the TUG observations, it is not clear whether the disc is completely disrupted, or if re-established, the accretion is steady, sporadic or unstable. For example, the existence of an accretion disc was revealed in V1974 Cyg two years after the outburst (Retter, Leibowitz & Ofek 1997), which was long after the discovery of the variations due to irradiation of the secondary.

There have been recent detections of oscillations in classical nova systems of about 2500 s (V1494 Aql, Drake et al. 2003) and $\sim$1300 s (V4743 Sgr, Ness et al. 2003) in the X-ray wavelengths.

These oscillations are attributed to expected WD pulsations (i.e. non-radial, non-adiabatic modes) from the $\sim 1.5 \times 10^5$ K and $L \sim 2000\,L_\odot$, hot WDs (Starrfield et al. 1985). The P_2 detected in V2275 Cyg is similar to these in time-scale. However, it is expected that the higher luminosity (a factor of 10) and the temperature (a factor of 4–5) of the WDs, as the hydrogen is burned over the surface, should decrease the pulsational time-scale (Starrfield et al. 1985), which makes this scenario unfavourable for V2275 Cyg. In addition, the 2002 data set should have revealed the same oscillations, if they were solely due to WD pulsations.

A more plausible explanation for the origin of P_2 is, yet again, the effect of an ionization front (IF) resulting from an alleged SSS phase and the radiative winds of the WD in the outburst stage. If the IF reaches well into the photosphere of the secondary, favourable conditions could result in ionization over the face of the secondary (the IF penetrates the photosphere) resulting in 'boiling off' (may be 'ripping off') material from a dense static/neutral medium, which could be the case in 2002. If the IF does not reach as far as the photosphere, it could still reach out below the inner Lagrangian point (L_1, a sonic point) where conditions cannot be steady and the IF then oscillates on a time-scale of the order of the dynamical time-scale of the secondary near L_1, which could result in QPOs as suggested by King (1989). This oscillation time-scale is proportional to $t_{\rm qpo} \simeq H/c_{\rm s}$ (scaleheight/sound speed), which is equivalent to $t_{\rm qpo} \simeq (R^3/GM)^{1/2} \simeq 176 P_{\rm hr}$. Given the orbital period derived in this paper (P_1), the predicted oscillation period of L_1 is similar to P_2 (assuming the size R of the secondary will be larger on the equatorial plane). By late 2003 the IF could be withdrawn towards the WD, irradiating only the inner Lagrangian point (L_1), which yields the QPOs.

CONCLUSIONS

We detected two periodicities in the light curve of the classical nova V2275 Cygni (2001). The first one is 0.314 49(15) d, which we attribute to the orbital period of the binary system. The modulation depth of the mean light curve folded on this period indicates a change from 0.42 ± 0.06 mag to 0.22 ± 0.12 mag over the course of one year. We propose that these variations are due to the illumination of the secondary by the hot WD where the aspect variations of the heated/irradiated secondary reveals the binary period of the system. The reduction in the modulation depths indicates the changing conditions in the ionization front at the location of the secondary. This highly ionizing radiation could originate from a hot WD which went through a supersoft X-ray phase while burning hydrogen on its surface. We also detect a second period of 0.017 079(17) d in the year 2003, which we interpret as a QPO from our data in 2002–2003. For the origin of this period we propose either a magnetic cataclysmic variable scenario (e.g. the interaction of blobs with the magnetosphere) or a scenario where the QPOs are a result of oscillations of the inner Lagrangian point (L_1) due to irradiation from a cooling hot WD. Both scenarios indicate that some form of accretion is being established in the nova system after the outburst. Our preliminary analysis reveals that both periods exist in 2004 data and the modulation depth of the first period is further reduced. The photometric observations of V2275 Cyg in 2004 (still being conducted at TUG) should reveal the changing shape and depth of the orbital modulations and QPOs which will, in turn, portray the evolution of the WD itself.

ACKNOWLEDGMENTS

We would like to thank an anonymous referee for critical reading of the manuscript. We also thank the TUBITAK National Observatory Institute and Ü. Kızıloğlu for support of the observations. We thank Tansel Ak for obtaining data for us. SB also acknowledges support by the Turkish Academy of Sciences TUBA-GEBIP fellowship (Distinguished Young Scientist Award). AR was partly supported by a postdoctoral fellowship from Penn State University.

REFERENCES

Ayani K., 2001, IAU Circ. 7686
Balman S., Krautter J., Ögelman H., 1998, ApJ, 499, 395
Balman S., Yilmaz A., Retter A., Ak T., Saygac T., Esenoglu H., Aslan Z., 2003, IAU Circ. 8074, 3
DeYoung J. A., Schmidt R. E., 1994, ApJ, 431, L47
Drake J. et al., 2003, ApJ, 584, 448
Garnavich P. M., Macdonald A. J., Wu B., Easterday S. M., Libal A. J., Palumbo A., Quinn M. A., 2004, Inf. Bull. Var. Stars, 5519
Kato T., Ishiuka R., Uemura M., Starkey D. R., Krajci T., 2004, PASJ, 56, 125
King A. R., 1989, MNRAS, 241, 365
Kiss L. L., Gogh N., Vinko J., Furesz G., Csak B., DeBond, H., Tompson J. R., Derekas A., 2002, A&A, 384, 982
Kovetz A., Prialnik D., Shara M. M., 1988, ApJ, 325, 828
Krautter J., 2002, in Hernanz M., Jose J., eds, AIP Conf. Proc. Vol. 637, Classical Nova Explosions. Am. Inst. Phys., New York, p. 345
Leahy D. A., Elsner R. F., Weisskopf M. C., 1983, ApJ, 272, 256
Leibowitz E. M., Mendelson H., Mashal E., Prialnik D., Seitter W. C., 1992, ApJ, 385, L49
Nakamura A., Tago A., Abe H., 2001, IAU Circ. 7686, 2
Nakano S., Hatayama K., Kato T., Takao A., Sano Y., 2001, IAU Circ. 7687, 3
Ness J.-U. et al., 2003, ApJ, 594, L127
Retter A., Leibowitz E. M., Ofek E. O., 1997, MNRAS, 286, 745
Retter A., Leibowitz E. M., Naylor T., 1999, MNRAS, 308, 140
Scargle J. D., 1982, ApJ, 263, 835
Schmeer P., 2001, IAU Circ. 7688, 2
Schmidt G. D., Liebert J., Stockman H. S., 1995, ApJ, 441, 414
Shara M., 1989, PASP, 101, 5
Somers M. W., Naylor T., 1999, A&A, 352, 563
Somers M. W., Mukai K., Naylor T., 1996, MNRAS, 278, 845
Starrfield S., Cox A. N., Kidman R. B., Pensnell W. D., 1985, ApJ, 293, L23
Stetson P. B., 1987, PASP, 99, 191
Warner B., 1995, Cataclysmic Variable Stars, Cambridge Univ. Press, Cambridge
Williams R. E., 1992, AJ, 104, 725
Woudt P. A., Warner B., 2003a, MNRAS, 339, 731
Woudt P. A., Warner B., 2003b, MNRAS, 340, 1011

This paper has been typeset from a TEX/LATEX file prepared by the author.