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SPECTROSCOPIC OBSERVATIONS OF THE CATACLYSMIC VARIABLE PG 0917+342: AN ULTRA SHORT-PERIOD NOVA LIKE SYSTEM

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ABSTRACT

We present time-resolved spectroscopic observations of the cataclysmic variable PG 0917+342 which reveal it to be a nova-like system with an orbital period of 104 minutes. The spectra show lines of H, He I, and Ca I in absorption with variable emission cores, and Hα emission always above the continuum. Orbital parameters derived from our radial velocity data indicate a system inclination of $\sim 32°$, $M_2 = 0.2\ M_{\odot}$, and a likely, but not well determined, mass for the white dwarf of $\sim 0.3\ M_{\odot}$. PG 0917+342 appears to be the first non-magnetic nova-like star below the CV period gap.

Subject headings: binaries: spectroscopic — novae, cataclysmic variables — stars: individual (PG 0917+342)

1. INTRODUCTION

Cataclysmic variables (CVs) (novae, recurrent novae, dwarf novae, and nova-like systems) are close binaries containing white dwarf primaries and late-type main-sequence secondary stars filling their Roche lobes. The secondary loses mass through the inner Lagrangian point and in order to conserve angular momentum the transferred material usually forms an accretion disk around the white dwarf component. A hot spot originates at the place where the mass-transfer stream impacts the disk. For the systems in which the primaries have strong magnetic fields, the process of forming the accretion disk is disturbed. The transferred material is forced to follow the field lines and creates accretion columns near one or both of the white dwarf's magnetic poles.

Generally, the orbital periods of CVs range from a little over 1 hr to about 15 hr with a characteristic gap between about 2 and 3 hr. The shortest orbital periods imply typical dimensions for the systems to be of the order of a solar diameter. The spectra of CVs are very complicated. The accretion disk usually dominates the spectrum in the visible, producing, a blue continuum and typically broad emission lines of hydrogen, helium, and sometimes other elements. A contribution to the visible spectrum by the secondary late-type star is usually seen if the orbital period is more than about 6 hr, while the absorption lines of the white dwarf primary are rarely seen. Comprehensive reviews of cataclysmic variables can be found in Robinson (1976a), Warner (1976), Patterson (1984), and Wade & Ward (1985). PG 0917+342 was discovered in the Palomar-Green Survey (Green et al. 1982, hereafter GFLS) and tentatively identified as a nova-like object with a *B*-magnitude of 15.1. GFLS indicated that this system had been seen in both emission and absorption states. As part of their study Howell & Szkody (1990) noted that PG 0917+342 was a likely candidate for being a Galactic halo CV. Photometric observations of PG 0917+342 covering ~ 4 hr were obtained by Howell et al. (1991). The star was shown to have an average *V*-magnitude of 14.1, $R \sim 13.1$, and their photometric data revealed an almost constant light curve within the observational errors, but showed two ~ 0.1 mag humps. It was suggested by them that if these humps represented a periodic orbital modulation, then the orbital period would be about 2 hr. They also mentioned that such a light curve would be typical of a system containing a thick disk (i.e., optically thick). Nightly spectra of PG 0917+342 obtained by Szkody & Howell (1991, hereafter S&H) over three nights appear similar to those typical for dwarf nova following an outburst (Szkody, Piche, & Feinswog 1990) or a nova-like system, also indicating a thick accretion disk, due to the presence of strong Balmer absorption lines.

In this paper we present the first detailed study of spectroscopic observations of the cataclysmic variable PG 0917+342. We analyze these observations in order to determine the fundamental physical properties of the system. We began by describing the observations (§ 2), then we discuss our determined orbital period (§ 3), and in § 4 we derive the basic system parameters. Finally, we provide a discussion and some speculations on this interesting star in § 5.

2. OBSERVATIONS

The spectra presented here were obtained with the Perkins 1.8 m reflector of the Ohio State and Ohio Wesleyan Universities at the Lowell Observatory, equipped with a B&C spectrograph and a TI CCD detector. A 350 lines mm^{-1} grating was used in first-order for the lower dispersion spectra, and a 600 lines mm^{-1} was used in first-order for the higher dispersion data. A summary of our observations is presented in Table 1.

The lower-dispersion observations were obtained on 1990 December 9 UT. They represent a total elapsed time of about 4 hr and cover a wavelength range of $\sim$3400–5200 Å. A slit width of 2″ was used and yielded a spectral resolution of 4 Å FWHM. The weather conditions were good throughout the night with stable seeing of about 1″.5. Seventeen higher dispersion spectra were obtained on 1991 February 18, covering a region of 700 Å centered near Hα. A slit width of 2″ was used, giving a resolution of 2.7 Å FWHM. Unfortunately, the sky was not photometric during this entire night and the seeing was about 3″.

On 1991 February 19 five additional spectra with resolution of 4 Å FWHM were obtained. The wavelength range from 5750 to 6900 Å was observed to allow a search for any contribution from the secondary at the Na I doublet (5890.0 and

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TABLE 1

JOURNAL OF OBSERVATIONS OF PG 0917+342

JD (UT)	Duration (hr)	Number of Spectra	Spectral Resolution FWHM (Å)	Integration Time (s)	Spectral Coverage ($\lambda\lambda$)
2448234.833 (1990 Dec 09)	4	20	4.0	600.0	4000–5200
2448305.793 (1991 Feb 18)	5	17	2.7	900.0	6250–6900
2448306.663 (1991 Feb 19)	1	5	4.0	600.0	5700–6800

5895.5 Å). The spectra were not of high S/N due to the sky conditions and strong night sky emission hampered accurate sky subtraction. We saw, however, no hint of secondary lines in our data, indicating that PG 0917+342 was likely to have a short orbital period. The spectral data were reduced using IRAF. Each night a number of bias and quartz lamp frames were taken and Fe-Ne arcs were obtained every 10–15 minutes during observations of PG 0917+342. Kitt Peak (IIDS and IRS) flux standard stars were observed throughout each night and used to provide flux calibration. All object and Fe-Ne lamp frames were bias subtracted and flat-field corrected, then reduced by IRAF routines available in the TWODSPEC and ONEDSPEC packages. Wavelength solutions were found to have a scatter of 0.1 pixels which is ~0.2 Å. The spectra of PG 0917+342 were then flux calibrated by using the standard stars.

A summed low-dispersion spectrum is presented in Figure 1. We see the presence of the Balmer lines as well as He I (4471 Å), possibly He I (4921 Å, 6678 Å), and Ca I (4227 Å). All these lines appear in absorption with variable emission cores. The Balmer decrement observed in the emission lines is consistent with that seen in UX UMa type nova-likes (Warner 1976). The He and Ca lines were too weak to measure in any individual spectrum. The Hα emission line was observed to always be strongly above the continuum, but the absorption wings are clearly visible. It was reported by GFLS that PG 0917 was observed in both emission and absorption states. S&H showed PG 0917+342 to have variable continuum flux and highly variable

TABLE 2

LINE FLUXES RELATIVE TO Hβ[a]

Line	SIT Spectra (Green et al. 1982)	This Work
Hα[b] (6563 Å)	...	1.27
Hβ[c] (4861 Å)	1.0	1.0
	−1.0	−1.0
He II (4686 Å)	0.53	...
C III, N II, N III (4650 Å)	0.48	...
He I (4471 Å)	−0.42	−0.19
Hγ (4340 Å)	0.56	0.49
	−0.83	−0.80
Hδ (4101 Å)	0.52	0.0–0.35
	−1.17	−1.29

[a] Negative signs denote absorption lines.

[b] The Hα data were obtained ~2 months after Hβ data.

[c] For our spectra the line flux of Hβ = 1.1×10^{-14} ergs cm^{-2} s^{-1} in emission and -5.1×10^{-14} ergs cm^{-2} s^{-1} in absorption.

emission cores on nightly time scales (for the lines in the range of λλ4200–4900) and Hα emission was above the continuum. In general, these previous observations have stronger emission than those presented here but have similar continuum magnitudes. GFLS listed mean fluxes in ratio to their observed Hβ emission line and we compare those to our measured values in Table 2. The accuracy of our relative fluxes is good to about 25%, the same as estimated by GFLS Our He I 4471 absorption line is broad (FWHM = 32 Å) and weaker, with an equiv-

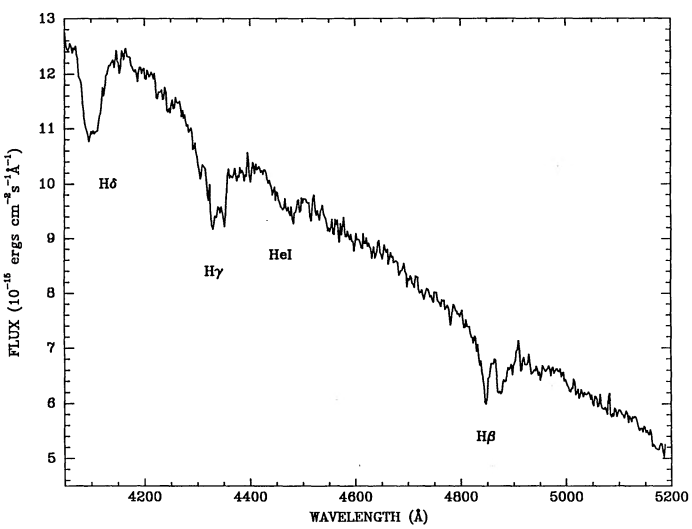

FIG. 1*a*

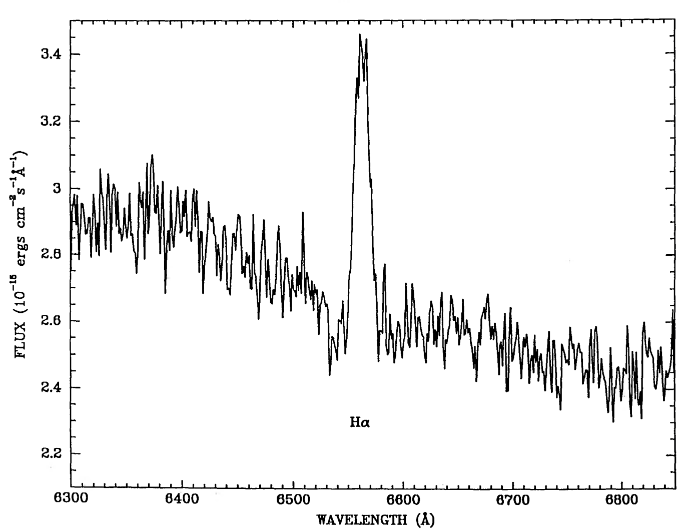

FIG. 1*b*

FIG. 1.—(*a*) Averaged low-dispersion spectrum of PG 0917+342 from 1990 December 9. Note the blue continuum, and the weak Hβ and Hγ emission lines inside the broad absorption profiles. (*b*) Averaged higher dispersion spectrum of PG 0917+342 obtained in the vicinity of Hα. In this case, the emission line is strong enough to stand above the continuum. There is still evidence of broad absorption wings, especially in the blue.

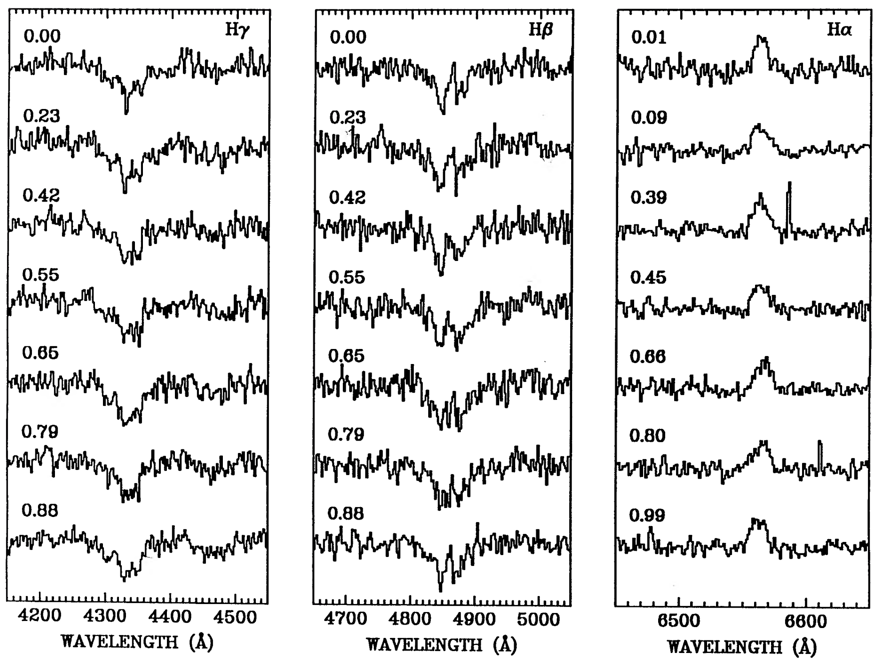

FIG. 2.—Balmer lines Hα, Hβ, and Hγ as a function of orbital phase. Note the presence of an s-wave component corresponding to the narrow peak clearly seen in Hα and maybe Hβ. Numbers above each spectrum refer to the orbital phase.

alent width of ~0.98 Å and we did not see evidence for He II or the 4650 Å CN blend. The weaker He I lines and Ca I (4227 Å) could not be reliably measured.

Figure 2 shows plots of the strongest line profiles as a function of orbital phase. Hα emission is always well above the continuum an only hints of its absorption wings can be seen. Its average FWHM is 650 km s^{-1} with wings extending to ~2400 km s^{-1}. The line profiles and level of emission change both with time and phase and a typical CV s-wave component is clearly seen in Hα and maybe in Hβ. The equivalent widths of the Balmer emission lines, however, show no correlation with orbital phase.

The Balmer emission line profiles vary significantly with time from single-peaked to possibly double-peaked shapes (see Fig. 2) and, at some phases, appears asymmetric with respect to the absorption line center. This asymmetry may be due to excess emission on the red side or extra absorption on the blue side. The latter possibility is intriguing, as it may indicate the presence of a wind similar to those seen in the ultraviolet (e.g., Woods 1989; Cordova & Mason 1984) and the visible (Hessman 1990). These data, however, are not of good enough S/N and do not provide multiple coverage at each phase to be certain of these asymmetries and what their cause might be.

3. THE RADIAL VELOCITY CURVE OF PG 0917+342

The photometric observations obtained by Howell et al. (1991) revealed dissimilar looking ~0.1 mag humps in an *R* band light curve of PG 0917+342. These features were not statistically significant in their data but it was suggested that if they represented an orbital modulation, the orbital period would be about 2 hr. As part of this study, one of us (SH) has reanalyzed the photometric data of Howell et al. (1991) and found that the *R* band humps are best fit by a period of $1.7^{+0.4}_{-0.2}$ hr. We will see that this value is in agreement with the radial velocity study presented here.

The sliding double-Gaussian technique developed by Schneider & Young (1980) and often used in various incarnations by others (e.g., Shafter 1983; Thorstensen 1986) is based on measuring the wings of emission lines. The wings are likely to be formed in the inner region of the accretion disk so should be closely related to the motion of the white dwarf. This technique was essentially impossible to apply in the case of PG 0917+342 as the emission lines are located within absorption lines. Even Hα shows, in some cases, absorption in the line wings. This made using the line wings a difficult and unreliable method for PG 0917+342. We therefore adopted using Gaussian fits to the entire profile (both absorption and emission) and used the center of these fits as the line center.

Two Gaussian functions were fit simultaneously to each line, one for the absorption and another for the emission. Only one Gaussian was used for the Hα emission and for the Hδ absorption lines. Figure 3 shows the radial velocity curves obtained for the Balmer lines.

We attempted to fit both the emission and absorption profiles in the Hγ line. In the former case, the emission was very weak or not present at all; for the absorption profile, it was very difficult to eliminate the large asymmetries caused by the underlying emission. Thus, in both cases, we could not get a reliable velocity solution.

We note here the presence of a high velocity component seen in all the radial velocity data (except the Hα s-wave component) near phase 0.7. This phenomena has been seen at this phase by others (Szkody, Shafter, & Cowley 1984; Wagner et al. 1991) and is generally attributed to viewing other velocity components in the binary such as the gas stream itself. The radial velocities of the Hα s-wave component were measured using the IRAF " d " (Gaussian fit) routine. The Gaussian function was fit only to the peak of the s-wave component (see Fig. 2). We found the s-wave to be shifted by 0.15 in phase (55°) with respect to the radial velocity curves of other lines, with its peak at phase 0.9. If we interpret the s-wave component in the usual manner, i.e., due to a region of enhanced emission somewhere

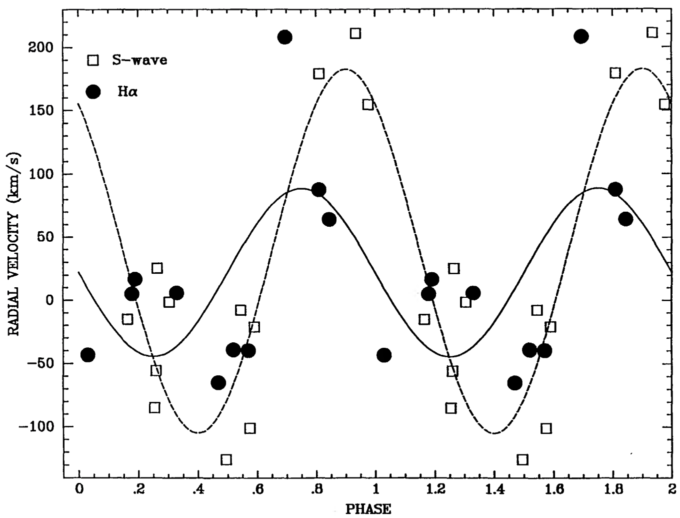

FIG. 3a

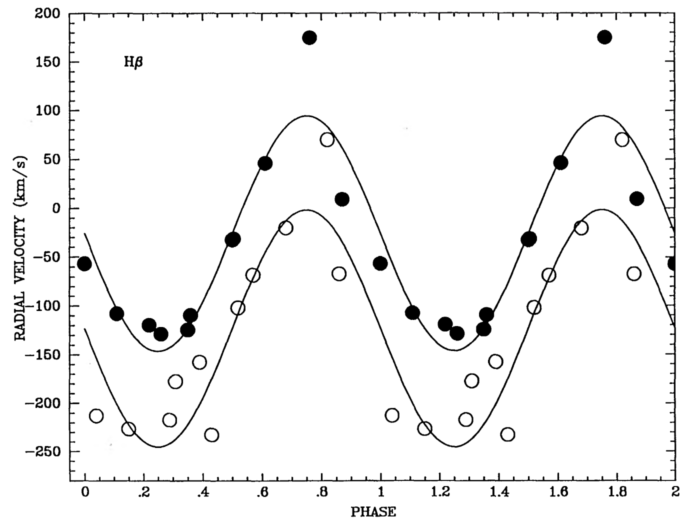

FIG. 3b

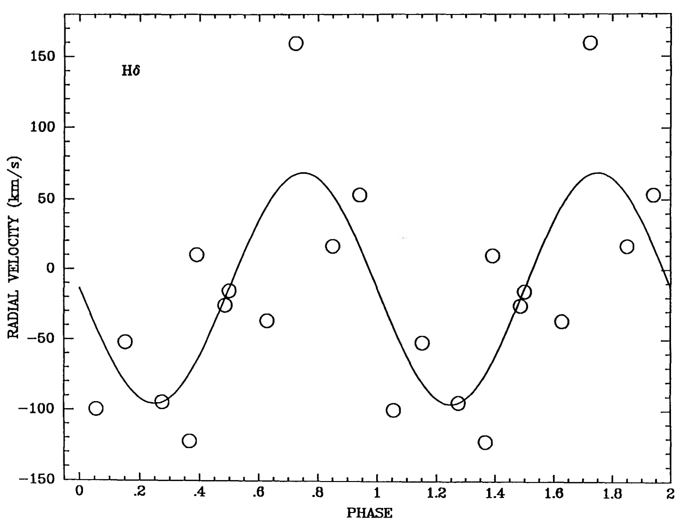

FIG. 3c

FIG. 3.—(*a*) Radial velocity curve derived from the phased Hα emission-line data (*solid curve*). The 1 σ error of the velocity measurements with respect to the sine curve fit is ± 33 km s^{-1}. Dashed curve is the best-fit sinusoid to the velocities of the s-wave component which is about 55° out of phase with the Hα emission data. (*b*) Phase-binned radial velocities derived from Hβ emission (*filled circles*) and absorption (*open circles*) lines. The 1 σ error of the velocity measurements with respect to the sine curve fit is ± 10 km s^{-1} for those measured from emission lines, and ± 19 km s^{-1} for those measured from absorption lines. No offset has been aplied to the two curves. (*c*) Phase binned radial velocities for the Hδ absorption lines. The 1 σ error of the velocity measurements with respect to the sine curve fit is ± 26 km s^{-1}.

on the accretion disk, this would imply that this region directly faces the observer near phase 0.6–0.7, which would be slightly earlier in phase than expected by the standard hot spot models which place the spot facing the observer near phase 0.8. It is likely that the *s*-wave component had some biasing effect on the measured Hα emission line centroids.

Using a least-squares procedure, we fit the individual velocities with sinusoids of the form

$$V(t) = \gamma_0 + K_1 \sin [2\pi(t - t_0)/P] , \quad (1)$$

where γ_0 is the systemic velocity in km s^{-1}, t is the time of observation, t_0 corresponds to the time of phase 0, and P equals trial orbital periods fit to the radial velocity curve. Table 3 contains the heliocentric corrected results for these parameters. Once an orbital period was determined, we were able to phase average spectra in pairs to increase the S/N and obtain the radial velocity solutions shown in Figure 3 and listed in Table 4.

TABLE 3

HELIOCENTRIC RADIAL VELOCITIES OF PG 0917+342

Orbital Phase	$V_{\mathrm{H}\alpha\ \mathrm{em}}$ (km s^{-1})	$V_{\mathrm{s\text{-}wave}}$ (km s^{-1})	$V_{\mathrm{H}\beta\ \mathrm{em}}$ (km s^{-1})	$V_{\mathrm{H}\beta\ \mathrm{abs}}$ (km s^{-1})	$V_{\delta\ \mathrm{abs}}$ (km s^{-1})
0.03.........	−43	118	−57	−213	−99
0.15.........	5	−15	−108	−227	−52
0.26.........	12	−56	−129	−217	−94
0.33.........	6	−2	−124	−178	−122
0.48.........	−65	−101	−33	−104	−26
0.51.........	−39	−105	−32	−103	−15
0.60.........	−38	−21	46	−65	−36
0.69.........	208	79	172	−20	155
0.82.........	88	182	84	70	50
0.85.........	65	189	39	−67	17

NOTE.—Phase 0.0 corresponds to HJD 2448234.88721.

TABLE 4

DETERMINED ORBITAL PARAMETERS FOR PG 0917+342

Line	γ (km s^{-1})[a]	K_1 (km s^{-1})[a]	Orbital Period (hr)	C.L.[b]
Hα em	22 ± 24	67 ± 33	$1.82^{+0.11}_{-0.14}$	97.5
Hα (s-wave)	39 ± 11	144 ± 15	$1.70^{+0.12}_{-0.05}$	97.5
Hβ em	-26 ± 7	121 ± 10	$1.85^{+0.05}_{-0.19}$	97.0
Hβ ab	-124 ± 10	122 ± 19	$1.66^{+0.2}_{-0.5}$	97.5
Hδ ab	-13 ± 19	82 ± 26	$1.94^{+0.17}_{-0.02}$	99.0
Adopted	12.2[c]	107[d]	1.73 ± 0.17[e]	...

[a] 1 σ errors are quoted and came from a formal χ^2 test of the fitted sinusoid radial velocity core.

[b] C.L. = confidence level as defined in Stellingwerf 1978.

[c] Adopted value is a weighted mean (in proportion to the inverse of the variance) with the Hβ ab value not used.

[d] Adopted value is a weighted mean (in proportion to the inverse of the variance) excluding the Hα s-wave value.

[e] Adopted value is a straight mean of all values ± 1 σ error.

Each radial velocity curve was independently searched for periodic modulations using the technique of phase dispersion minimization (PDM) developed by Stellingwerf (1978). The PDM technique provides the user with a statistical test for each determined period that yields a confidence interval via an (two-sided) F-test. Our results are presented in Table 4. Almost the same value of the orbital period was derived from each radial velocity curve (both emission and absorption lines), all with high confidence levels of $\geq 97\%$. Since we have two independent data sets, covering over two cycles each and giving the same result for the orbital period, we feel it is very unlikely we have any cycle count ambiguities. We show one of our typical PDM θ transform periodograms in Figure 4. We therefore adopt an orbital period for PG 0917+342 to be a straight average of the obtained results and equal to 104 ± 8 minutes.

The systemic velocity is found to be roughly consistent in all cases, except for the Hβ absorption lines, with our adopted value of 12.2 km s^{-1}. We find that our K_1 values show a range of 67 to 121 km s^{-1}, excluding the s-wave component which is notorious for giving an erroneously high semi-amplitude (e.g., Shafter, Szkody, & Thorstensen 1986). We therefore have adopted a K_1 value of 107 km s^{-1} but will comment on this issue further in § 5.

Two general sources of errors exist in our radial velocity measurements. The first one is an uncertainty of the fit of the Gaussian function into the line profile. Although the χ^2 value of each fit was satisfactory the uncertainty of each fit was about 0.5 Å which gives an error of ± 23 km s^{-1} at Hα and ± 37 km s^{-1} at Hδ. Secondly, the absorption line of Hβ typically had asymmetric profiles that cause the fitted Gaussian functions to be systematically shifted toward the blue. This effect is much smaller in Hδ. Estimating the shift that these asymmetries caused was difficult, but it is likely that this is the cause for the discordant systemic velocity derived from the Hβ absorption lines.

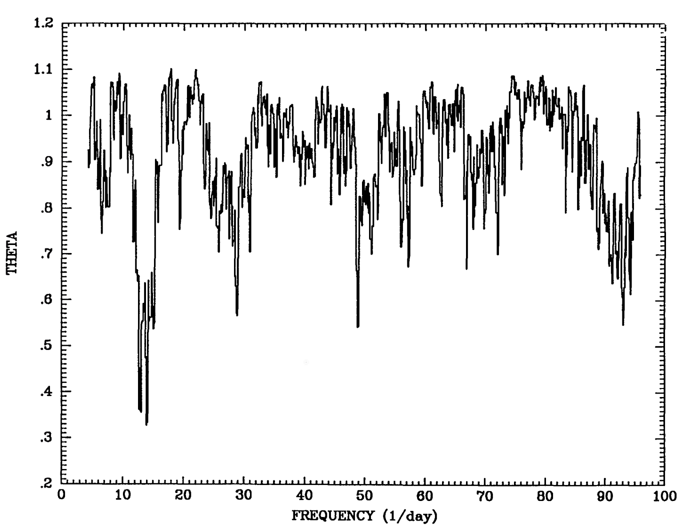

FIG. 4.—Typical PDM θ transform periodgram for PG 0917+342. This one is for the Hα emission line, but all were similar. The weak periods seen at 28 days^{-1}, 48 days^{-1}, and larger frequencies are simply the data sampling time and associated harmonics. The very weak period at ~ 7 days^{-1} (~ 4 to 5 hr) is due to the length of the data sets. The only significant period in the entire plot is that of the orbital period at 13.8 days^{-1}.

4. THE SYSTEM PARAMETERS

We can use our spectroscopic data to determine the basic system parameters of PG 0917+342. In our analysis, we will assume that the secondary star is on the zero-age main sequence. This assumption was briefly discussed by Patterson (1984) and is usually adopted for determining parameters of CVs (e.g., Shafter 1983; Penning et al. 1984; Downes et al. 1986). If we assume that the secondary roughly obeys a linear relation for the lower main sequence ($R/R_\odot = \beta M/M_\odot$), then from Kepler's third law we have (e.g., see Shafter 1983)

$$\frac{M_2}{M_\odot} = 0.998 \times 10^{-4}\left(\frac{1+q}{q}\right)^{1/2} P\beta^{-3/2}\left(\frac{R_2}{a}\right)^{3/2} , \quad (2)$$

where M_2 and R_2 are the mass and radius of the secondary P is the orbital period in seconds, q is the mass ratio M_2/M_1, and a is the separation between the centers of the stars, The parameter β is always close to 1 and in further computations we adopt its value as 0.96, following Warner (1976, eq. [4]).

In order to eliminate dependence of R_2/a from equation (2), we make the usual assumption that the secondary's Roche lobe is spherical and that R_2 is equal to its mean radius. With this assumption we can use the formula derived by Paczyński (1971), which is correct to $\sim 2\%$:

$$\frac{R_2}{a} = \begin{cases} 0.38 + 0.2 \log q & 0.5 < q < 20 , \quad (3a) \\ 0.462\left(\dfrac{q}{1+q}\right)^{1/3} & 0 < q < 0.5 . \quad (3b) \end{cases}$$

By applying equation (3) to equation (2) we have a relation between M_2 and q only. Now, if we want to obtain a value for M_2, we can use the above if we can estimate q. It was proposed by Warner (1973, 1976) that an estimate of q can be found from its relation to potentially observable quantities:

$$\frac{K_1}{V_d \sin i} = qf^2(q) , \quad (4)$$

where K_1 is the semi-amplitude of the primary's radial velocity curve in km s^{-1}, $V_d \sin i$ is the projected rotational velocity of the outer edge of the accretion disk (km s^{-1}), and $f(q)$ is the distance from the center of the primary to the inner Lagrangian point (in units of a). Warner (1976) gives a convenient formula for $f(q)$, deduced from the tabulations of Plavec & Kratochvil (1964), accurate to 1%. By applying this to equation (4) we obtain

$$\frac{K_1}{V_d \sin i} = q(0.5 - 0.227 \log q)^2 \quad 0.1 \leq q \leq 1.0 . \quad (5)$$

Equation (5) depends on measuring $V_d \sin i$ which is difficult, somewhat subjective and not everyone agrees on its precise or correct usage (e.g., see Robinson 1976b; Ritter 1976). For single-lined CVs an estimate of this parameter can however be found and this method is in fact the only one available directly from observable quantities.

Smak (1969) has discussed difficulties with this procedure, pointing out that $V_d \sin i$ may not provide an accurate measurement of the motion of the outer accretion disk, and may in fact strongly depend on the spectrograph, measurement and fitting technique, and any possible unresolved multiple line components. Following Warner (1973), we use a value given by the HWHI value of the observed emission line to estimate

$V_d \sin i$. For the Hα emission line, $V_d \sin i \sim 325$ km s^{-1}. Applying this value and a semi-amplitude of $K_1 = 67$ km s^{-1} to equation (5), we obtain $q = 0.7$. Using this value in equations (3) and (2), we find $M_2 = 0.22\ M_\odot$ and $M_1 = 0.30\ M_\odot$. Taking the HWHI of the Hβ emission line (~ 510 km s^{-1}) together with its K_1 value of 120 km s^{-1}, we obtain $q = 0.92$. Inserting these values into equation (3) and (2) gives M_2 of $= 0.23\ M_\odot$, and M_1 of $= 0.24\ M_\odot$.

The obtained lower mass estimate for the primary is very small and lies very near the observed range for white dwarf masses in cataclysmic binaries 0.2 to 1.4 $M_\odot$ (Politano, Ritter, & Webbink 1985; Weidemann & Yuan 1989). Even the higher limit barely makes it into the observational arena.

As can be seen by the above results, M_2 depends little on the measured quantities, though it depends weakly, on q, while M_1 is, of course, strongly dependent on the q-value determined which in turn depends strongly on the estimated $V_d \sin i$ value. We return to this point and the use of emission lines in nova-like variables for parameter determination in § 5. If we indeed did the use extreme limits of K_1 (i.e., $K_1 \pm 1\ \sigma$) in the above two calculations we find that $M_2 \sim 0.2\ M_\odot$ in all cases and M_1 lies between 0.18 and 0.8 $M_\odot$. Therefore, our adopted K_1 value of 107 km s^{-1} seems reasonable and we thus adopt the values of $M_2 = 0.2\ M_\odot$ and $M_1 = 0.3\ M_\odot$ for PG 0917+342, although M_1 is *not* well constrained.

Table 5 summarizes our calculated parameters. As already discussed by Shafter (1983), there is no straightforward quantitative way to estimate the errors in the values derived above, in particular in the masses. Our value of M_2 is likely to be more accurate than that of M_1 because its calculation is only weakly dependent on the uncertain value of q derived from equation (5) and is essentially dependent on believing it is a normal main-sequence star and fills its Roche lobe.

We can now use the relation between the observed quantities and the inclination of the system (see e.g., Warner 1976; Downes et al. 1986).

$$\sin^3 i = \frac{K_1^3 P}{2\pi G M_2}\left(\frac{q+1}{q}\right)^2 , \qquad (6)$$

where G is the gravitational constant. Use of equation (6) (and using the range of K_1) gives i to be in the range of 19° to 44° for PG 0917+342. The photometric behavior of PG 0917+342 observed by Howell et al. (1991) allows us to place a conservative upper limit of $\sim 65°$ on the orbital inclination since the system does not show eclipses and is consistent with the i-value estimated by equation (6).

Equation (3) and those in Patterson (1984) can also be used to estimate R_2 and a (see Table 5). We can also use the parameters for the secondary star to assign it a spectral type of $\sim$M5, surface temperature of $T_{\rm eff} \sim 3000$ K, and an M_V of +15.2.

TABLE 5

ADOPTED SYSTEM PARAMETERS FOR PG 0917+342

Parameter	Value
M_1	$0.3^{+0.5}_{-0.12}\ M_\odot$
M_2	$0.2\ M_\odot$
i	19°–44°
R_2	$0.21\ R_\odot$
a	$0.57\ R_\odot$

5. DISCUSSION

It would appear that PG 0917+342, both photometrically and spectroscopically, behaves like a nova-like system. The characteristic appearance of a thick disk (e.g., Ferguson, Green, & Liebert 1984) and its small amplitude variability are all typical of the class. The V-magnitudes seen by S&H and Howell et al. (1991) were obtained 6 months apart, but agree well within the limits of the stars variability. Using these values, the $B-V$ color of PG 0917+342 can be determined from the data of S&H and equals +0.1, typical of the class of nova-likes (Warner 1976), PG 0917+342 so far shows no indications of a strong magnetic field and the fact that the emission and absorption lines give the same *period and phase* seems to rule out the possibility that we are simply seeing magnetic spot modulations and not orbital motion. PG 0917+342 may be the first nonmagnetic nova-like system below the period gap.

Ritter's Catalogue (1990) lists all CVs, including nova-likes, with known orbital periods. All the nova-like systems contained within it with orbital periods below the CV period gap are magnetic systems. The only listed exception is V1193 Ori (Hamuy's blue variable). Warner & Nather (1988) suggest that this object may be similar to EX Hya, based on their own and other referenced photometry, with a possible period near 1.4 hr. Ringwald (1991), however, has obtained time-resolved spectroscopy and has found that the orbital period for V1193 Ori is 3.97 hr.

Hertzog (1986) noticed that PG 0917+342 was located in the sky roughly near the likely position of Nova Lyncis 101 A.D. and speculated that possibly it was the remnant of this nova. Current models of novae require massive white dwarfs in the range of 0.8–1.24 $M_\odot$ (Ritter et al. 1991), and as yet no models predict a scenario that would leave a small ($\leq 0.5\ M_\odot$) white dwarf behind. If the white dwarf in PG 0917+342 is really near 0.3 $M_\odot$, then it would seem unlikely that PG 0917+342 is the remnant of that old nova. However, the white dwarf mass is so poorly determined that this intriguing possibility should be studied further.

We have assumed that the standard analysis techniques developed for systems in which the emission lines are thought to represent the true motion of the primary, either by using the wings or the approximation that the HWHI $V_d \sin i$, apply to nova-like systems. This is actually unlikely to be the case. The continuum level and absorption lines tends to "hide" the true emission profile from the observer and, as pointed out by Hessman (1990), observations of the same nova-like, made over time, show very different measured values for the system components based on emission-line components, thus making it unlikely that the central emission features are really a good probe of the inner disk. In fact, the emission cores are likely to be formed in the transition layer between the optically thick and thin parts of the disk. This transition region, or chromosphere, is likely to change in location and extent with time.

Therefore, if we indeed believe that the masses can be roughly derived by this type of analysis, then we must allow for an additional uncertainty in using it in nova-likes, for which the true emission-line profile is unknown. In this analysis it is unlikely that one can confine the white dwarf mass to better than the range of 0.1–0.5 $M_\odot$, so any of the assumptions about K_1 and estimates of $V_d \sin i$ all give values that lie within acceptable limits. The derived system parameters for PG 0917+342 agree better with those listed for ultra-short-period dwarf novae (e.g., VW Hyi, SW UMa, and T Leo; Szkody et al.

1984), as compared with typical nova-like values (Warner 1976; Wade & Ward 1985).

Models of accretion rates in nova-likes are discussed in Wade & Ward (1985) and a relation between $\dot{M}$ and orbital period is given in Patterson (1984). Values of $\dot{M}$ from both these estimators, for typical nova-likes with orbital periods of $\sim$4 hr, lie between 10^{-8} to 10^{-10} $M_\odot$ yr^{-1}. These values are in agreement with observations of nova-like systems. Applying Patterson's relation to PG 0917+342 predicts $\dot{M} \sim 5 \times 10^{-11}$ $M_\odot$ yr^{-1}, an order of magnitude or two too low for a typical nova-like. The spectroscopic and photometric observations of this star seem to indicate that $\dot{M}$ should be $\sim 10^{-8}$ to 10^{-9} $M_\odot$ yr^{-1}, apparently placing PG 0917+342 in disagreement with Patterson's empirical relation between $\dot{M}$ and orbital period, as it has too large an $\dot{M}$ for its period. We note, however, that Patterson's relation has a very large scatter in it and the $\dot{M}$-value one assumes from observations is likely to be influenced by the system's inclination or possibly its evolutionary state, even for systems of similar period.

PG 0917+342 appears to be a typical nova-like system and may be the first such system below the CV period gap without a significant magnetic field. We note here that GFLS did see He II 4866 and C III/N IV in emission at one epoch. He II emission is sometimes thought to be associated with systems containing a highly magnetic white dwarf. Szkody et al. (1990) showed, however, that is is more likely an indication of a relatively high $\dot{M}$ and a constant disk. The apparent high $\dot{M}$ and short orbital period are, however, in contrast with the typical values. We therefore do not know if using nova-like parameters, like $M_V = +4$, are valid for this system. If we assign PG 0917+342 an absolute magnitude of $M_V = +4$ (typical for nova-like variables), we find that it is at a distance of 1 kpc from us or a z distance of 700 pc, i.e., not a member of the Galactic disk.

PG 0917+342 appears to be a unique object which certainly requires further study. In particular, searching for possible magnetic fields, determining the mass transfer rate, higher resolution spectroscopy to further investigate the possibility of an outflowing wind (in the optical part of the spectrum!), and simultaneous photometry and spectroscopy to understand the s-wave seen in the system are necessary. The white dwarf mass is also critical to determine accurately. A detailed study of PG 0917+342 promises to make an important contribution to our understanding of the nature of the nova-like objects.

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