SPECTROSCOPY AND OPTICAL/IR PHOTOMETRY OF THE CATACLYSMIC VARIABLE CPD −48°1577 * **

W. WARGAU, A. BRUCH[a], H. DRECHSEL, J. RAHE, and R. SCHOEMBS[b]
Dr. Remeis Sternwarte Bamberg, Astronomisches Institut der Universität Erlangen, Nürnberg, F.R.G.

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Abstract. The photometric variability of CPD −48°1577 in the optical and IR ranges is discussed. The structure and variation of prominent emission line profiles are investigated. An estimate of the distance is given.

1. Introduction

CPD −48°1577 was recently discovered as a cataclysmic variable by Garrison *et al.* (1982). The optical spectra show extremely broad and shallow hydrogen absorption lines with emission cores. In this respect it resembles other novalike systems such as TT Ari (Cowley *et al.*, 1975), VY Scl (Burrel and Mould, 1973) or the old nova DI Lac (Kraft, 1964). The color indices and flickering behavior are also typical for cataclysmic systems. The UV spectra obtained by Böhnhardt *et al.* (1982) confirm the classification of CPD −48°1577 as a novalike system. The visual magnitude of $9\overset{m}{.}8$ (Garrison *et al.*, 1982) makes this star the brightest member of its class.

First spectrophotometric observations of CPD −48°1577 were discussed by Wargau *et al.* (1983; hereafter referred to as Paper I). From radial velocity measurements of the emission cores of the hydrogen lines, a tentative orbital period of 0.187 days was derived.

In the following we study the long-term photometric variability of CPD −48°1577, present results of first photometric measurements in the infrared, and discuss results of the spectroscopic observations published in Paper I in more detail. Finally, an estimate of the distance of CPD −48°1577 is given.

2. Photometric Observations

2.1. The long-term variability

The long-term photographic variability of CPD −48°1577 was determined from measurements of 92 plates of the Bamberg sky-survey series sampled between December 1963 and January 1973. An iris-diaphragm-photometer was used to measure the density of the stellar image. Seven SAO stars were used as calibration

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** Based on data collected at the European Southern Observatory in Chile.

[a] Astronomisches Institut der Westfälischen Wilhelms-Universität Münster, F.R.G.

[b] Institut für Astronomie und Astrophysik der Universität München, F.R.G.

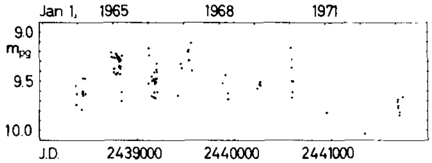

Fig. 1. Long-term variability of CPD $-48°1577$, as determined from photographic plates of the Bamberg sky-survey series, obtained between December 1963 and January 1973.

standards. The mean error for a single measurement can be estimated to be a few hundredths of a magnitude. The light curve is shown in Figure 1. During the nine years covered by the plates, CPD $-48°1577$ varies in the range between $m_{pg} = 9\stackrel{m}{.}1$ and $10\stackrel{m}{.}0$ around the mean value of $m_{pg} = 9\stackrel{m}{.}5$. A systematic trend is not detectable. The observed irregular long-term light variations are a common feature for many novalike systems. In particular, no indication for an outburst or for a temporary light depression like those of TT Ari (Krautter *et al.*, 1980), MV Lyr (Robinson *et al.*, 1981), or of some AM Her-type stars could be found for CPD $-48°1577$.

2.2. Infrared Photometry

Infrared observations of CPD $-48°1577$ were carried out between 25 January and 1 February 1983, with the 1 m-telescope of the European Southern Observatory at La Silla, Chile. The telescope was equipped with an InSb-photometer. The measurements were taken through the J (1.25 μm, H (1.65 μm), K (2.2 μm), and L (3.4 μm) filters. The integration time of a single measurement was 20 s; in each night about 4 $JHKL$ measurements were obtained.

Table I gives the mean J-magnitude and the $(J–H)$, $(H–K)$, and $(K–L)$ colors for each night. During the observing period, CPD $-48°1577$ was essentially constant in the infrared light. In order to check a possible dependence of the IR brightness and colors on the orbital phase, the light and color curves are plotted versus orbital

TABLE I

Mean J brightness and IR colors of CPD $-48°1577$

Date 1983	J	$(J–H)$	$(H–K)$	$(K–L)$
26 Jan.	$9\stackrel{m}{.}199 \pm 034$	$0\stackrel{m}{.}208 \pm 019$	$0\stackrel{m}{.}084 \pm 017$	$0\stackrel{m}{.}322 \pm 217$
27 Jan.	$9\stackrel{m}{.}402 \pm 057$	$0\stackrel{m}{.}285 \pm 067$	$0\stackrel{m}{.}145 \pm 052$	$0\stackrel{m}{.}332 \pm 278$
29 Jan.	$9\stackrel{m}{.}313$	$0\stackrel{m}{.}267$	$0\stackrel{m}{.}120$	$0\stackrel{m}{.}421$
30 Jan.	$9\stackrel{m}{.}180 \pm 042$	$0\stackrel{m}{.}191 \pm 035$	$0\stackrel{m}{.}130 \pm 012$	$0\stackrel{m}{.}155 \pm 184$
31 Jan.	$9\stackrel{m}{.}379 \pm 134$	$0\stackrel{m}{.}346 \pm 108$	$0\stackrel{m}{.}127 \pm 013$	$0\stackrel{m}{.}323 \pm 097$
1 Feb.	$9\stackrel{m}{.}293 \pm 050$	$0\stackrel{m}{.}297 \pm 070$	$0\stackrel{m}{.}085 \pm 071$	$0\stackrel{m}{.}080 \pm 278$
Mean	$9\stackrel{m}{.}29 \pm 11$	$0\stackrel{m}{.}26 \pm 08$	$0\stackrel{m}{.}12 \pm 04$	$0\stackrel{m}{.}26 \pm 21$

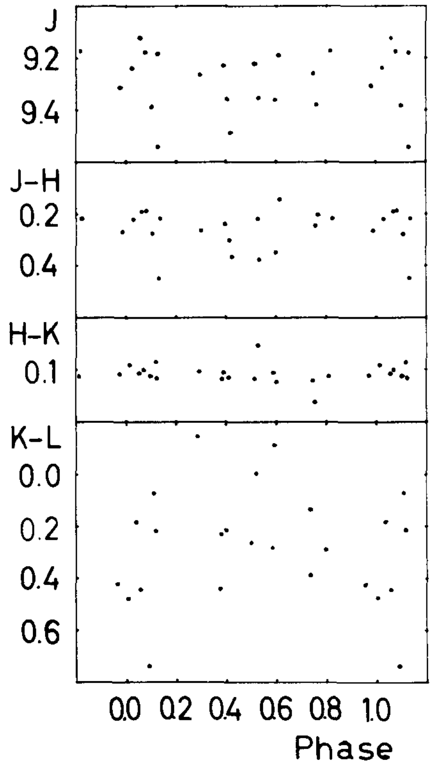

Fig. 2. Infrared light and color curves. The J (1.25 μm) filter curve together with the color curves $(J-H)$, $(H-K)$, and $(K-L)$ are drawn as a function of orbital phase.

phase in Figure 2. The appearance of these curves suggests that the system shows no occultation or eclipse effects, though this statement is somewhat uncertain due to the large amount of scattering. An upper limit of roughly 65–70° can be put on the orbital inclination of the system. This is consistent with the estimate of $i = 63°$ given in Paper I on the basis of the cataclysmic variable model.

The infrared colors of CPD $-48°1577$ are similar to those of other novalike variables such as UX UMa ($(J-K) = 0\overset{m}{.}50$: Szkody (1977)), and RW Tri ($(J-K) = 0\overset{m}{.}5$: Longmore *et al.* (1981)); whereas the colors of most dwarf novae at minimum are considerably redder (SS Cyg: $J-K = 0\overset{m}{.}76$; RX And: $J-K = 0\overset{m}{.}77$; AH Her: $J-K = 0\overset{m}{.}93$: Szkody (1977); OY Car: $J-K = 0\overset{m}{.}75$: Sherrington *et al.* (1982)), which might reflect different contributions to the IR light by accretion discs in nova-like systems and dwarf novae.

3. Optical Spectroscopy

Spectroscopic observations of CPD $-48°1577$ have been obtained on 1982, 30 and 31 December with the 1.5 m-telescope of the European Southern Observatory at La Silla,

TABLE II

Orbital parameters of CPD $-48°1577$[a]

$P = 0\overset{d}{.}187 \pm 0\overset{d}{.}002$
$T_0{}^{b} = JD\,2\,445\,334\overset{d}{.}609 \pm 0\overset{d}{.}003$
$K_1 = (135 \pm 8)\ \mathrm{km\,s^{-1}}$
$\gamma_0 = (-6 \pm 7)\ \mathrm{km\,s^{-1}}$
$a_1 \sin i = (3.5 \pm 0.2)\,10^{10}\ \mathrm{cm}$
$f(m) = (0.047 \pm 0.006)\,M_\odot$

[a] An eccentricity of $e = 0$ is assumed.
[b] T_0 is the time of inferior conjunction.

Chile, using the Image Dissector Scanner. Five spectra covering the wavelength range from 4080 to 5260 Å, and 2 spectra between 4450 and 6730 Å were taken at a dispersion of 59 Å mm^{-1} and 114 Å mm^{-1}, respectively. For details of the observations and reduction procedure, see Paper I.

The most important result of the preliminary analysis was the determination of the orbital period which could be derived from radial velocity measurements (see Paper I). Table II gives the orbital parameters resulting from a least squares fit to the radial velocity data. The investigation of a possibly small eccentricity is difficult due to the relatively small number of spectra. It must be emphasized that the parameters given in Table II can only be tentative, because they were derived from only 7 spectra. However, they lie in the typical range for cataclysmic variables.

The appearance of the spectral lines is described in Paper I. The most prominent features are the emission cores in the center of the hydrogen absorption troughs. The structure of these lines is strongly variable. Figure 3 shows tracings of Hβ and Hγ of the 5 spectra taken on 30 December 1982, ordered with orbital phase. The line profiles contain different peaks with irregularly variable relative intensities. In particular, no systematic variations with phase can be inferred from these data.

The intensities of the Hα, Hβ, Hγ, and He II (λ 4686 Å) emission lines and the equivalent widths of the hydrogen absorption troughs have been measured and are given in Table III. The errors quoted result from the deviations of the individual measurements from the mean value. The actual errors (in particular of the equivalent widths) may be larger, because the determination of the continuum in the spectra of CPD $-48°1577$ is rather difficult. The line intensities of the hydrogen emission components confirm the shallow Balmer decrement derived by Garrison *et al.* (1982).

4. Distance

Bailey (1981) derived a method to determine the distance of cataclysmic variables. His approach makes use of an empirical relation between the K-surface brightness and $(V-K)$ colors for nearby late-type stars, and anticipates that the red component of cataclysmic systems contributes most of the light in the K (2.2 μm) filter.

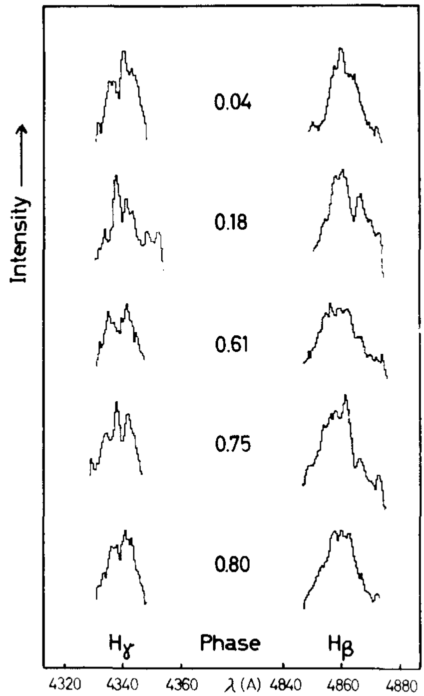

Fig. 3. Emission line profiles of Hβ and Hγ. Tracings of 5 spectra taken on 30 December, 1982, are shown; corresponding orbital phases are given.

Bailey (1981) expressed the K-surface brightness $S(K)$ by

$$S(K) = K + 5\log\left(\frac{R_2}{R_\odot}\right) - 5\log d + 5,$$

where K is the observed magnitude in the K filter, R_2 is the radius of the late-type component, and d is the distance of the system in parsecs.

The calibration of the K-surface brightness as a function of $(V-K)$-colors, which represents an effective temperature sequence, gives two line segments of different slopes, separated by $(V-K) = 3\overset{m}{.}5$. The spectral type of the late component of CPD $-48°1577$, which would immediately yield a $(V-K)$ value, is not known. On the other hand, we know the almost constant K-brightness of CPD $-48°1577$ during our observations, which is $8\overset{m}{.}91 \pm 0\overset{m}{.}04$. For the V-magnitude we use the value of $V = 9\overset{m}{.}5 \pm 0\overset{m}{.}2$ by Böhnhardt *et al.* (1982), which is in agreement with the mean brightness of the historical light curve. This gives a $(V-K)$ value of $0\overset{m}{.}59$. From Bailey's (1981) relation, we obtain

$$S(K) = 2.56 + 0.508(V-K) \quad \text{(valid for } (V-K) < 3\overset{m}{.}5).$$

The radius R_2 of the secondary can be approximated from Kepler's third law and from the geometry of the Roche model, assuming that the secondary fills its lobe

TABLE III

Emission line intensities and equivalent widths of absorption lines

Date 1982	Emission line intensities ($\times 10^{-12}$ erg cm^{-2} s^{-1} Å^{-1})				Equivalent widths of absorption lines (Å)	
	Hα	Hβ	Hγ	He II	Hβ	Hγ
30 Dec.	–	1.6 ± 0.3	1.1 ± 0.2	1.1 ± 0.1	1.4 ± 0.4	2.2 ± 0.5
31 Dec.	1.4 ± 2	1.40 ± 0.02	–	0.57 ± 0.03	3.4 ± 0.3	

(Paczynski, 1971), and from the mass-radius relationship for the lower Main-Sequence stars (Lacy, 1977). Then we find

$$\frac{R_2}{R_\odot} = 1.970 \times 10^{-5}\, P^{1.0474},$$

where P is expressed in seconds.

This leads to a distance of $d = 82$ pc. This value is compatible with the small amount of interstellar reddening of $E(B-V) = 0\overset{m}{.}02$ found by Böhnhardt *et al.* (1982). Allowing for variations of the visual magnitude, we derived the distances corresponding to the upper and lower bounds of the photographic light curve of Figure 1. The results are $d = 90$ pc and 73 pc, respectively.

The main uncertainty of the distance determination arises from the $(V-K)$ value. In particular, the V magnitude does not represent the secondary star, since it is dominated by the light of the accretion disc and hot spot. Wade (1979) showed that the red component in the U Gem system, which has a period of $P = 0\overset{d}{.}177$, dominates the radiation of the system at wavelengths longer than about 0.7 μm. Fortunately, Bailey's method is not very sensitive to errors in the $(V-K)$ value, i.e., an error of 1 mag in $(V-K)$ only leads to an 25% error in distance.

5. Conclusions

During a time interval of 9 y, the photographic brightness of CPD-48°1577 showed irregular variations with a maximum amplitude of about 1 mag with undetermined time-scale. IR photometric measurements revealed essentially constant brightness in the J-, H-, K-, L-bands during the observing time. The IR color indices lie in a typical range of novalike systems. The Balmer line profiles are composed of broad absorption throughs with central emission cores which show irregular structure and intensity variations. Making use of the K-magnitude of the secondary, a distance of 82 pc is derived. The absolute visual magnitude of $M_V = 4\overset{m}{.}9$ is typical for a nova-like variable. The mean visual brightness of $9\overset{m}{.}5$ makes CPD $-48°1577$ the brightest known cataclysmic system. Due to the relatively small distance, an attempt to measure the parallax appears promising.

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