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Observations and models of H2252 – 035

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Summary. We present observations of H2252–035 made in 1980 August and November, which span the wavelength range 1200–22 000 Å. The continuum is well represented by a blackbody of 12 500 K over most of this range. We discuss and reject a model for the optical flux in terms of reprocessing of high-energy radiation from the secondary, and propose a model in terms of reprocessing from the disc and bright-spot region.

1 Introduction

The X-ray source H2252–035 (= 3A 2254–033) has been identified with a 13-mag emission-line object whose spectrum resembles that of a cataclysmic variable (Griffiths *et al.* 1980). The X-ray flux shows a nearly sinusoidal modulation with a period of 805 s and with an amplitude (peak to mean) of between 40 (White & Marshall 1980) and 100 per cent (Patterson & Garcia 1980).

The optical radiation is modulated at three distinct frequencies (Warner 1980; Patterson & Price 1980). The light is modulated on a 3.59-hr period with an amplitude of about 10 per cent (Patterson & Price 1981; Warner, O'Donoghue & Fairall 1981). The emission lines show radial-velocity variations at this period with amplitude $K = 145 \text{ km s}^{-1}$ (Williams & Johns 1980; Patterson & Price 1981; Mochnacki, private communication), with superior conjunction occurring at photometric phase 0.06 ± 0.04. The light is also modulated with an amplitude of about 5 per cent with a period of 859 s, which is the beat period between the 805-s X-ray period and the 3.59-hr orbital period. This leads to a model put forward

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by Patterson & Price (1981) which identifies the source of 3.6-hr optical modulation and the emission lines as the face of the secondary star which is heated by the X-ray emitting primary. If the X-ray emitter is a magnetized star which emits beamed X-rays and rotates in a *prograde* sense with a period of 805 s, then the secondary sees the X-ray beam at the modified period of 859 s. In addition, Warner *et al.* detect the 805-s period in the optical at an amplitude of 2 per cent.

In this paper we present photometric, spectroscopic and spectrophotometric observations of H2252−035 made in 1980. The observations are presented in Section 2 and discussed in more detail in Section 3. In Section 4 we attempt to tie together all the data available so far, to provide constraints on the possible models for the system. We summarize our findings in Section 5.

2 Observations

Most of the observations reported here were made during the week 1980 August 5–13 (UT) at three separate observing sites. The infrared data were gathered in 1980 November. The Journal of Observations is given in Table 1(a) and (b).

Photoelectric photometry at *UBV* (Johnson) and *RI* (Kron–Cousins) wavelengths was obtained with the RGO two-channel travelling photometer attached to the 1.5-m flux collector on Tenerife. *UBV* standards were taken from the equatorial selected areas (Landolt 1973). The *RI* magnitudes for the same stars were taken from S20 response observations by Kunkel & Rydgren (1979) converted to appropriate *RI* band-passes following Bessell (1979). The effective wavelengths of our *R* and *I* bands are 6400 and 7900 Å respectively. BD $-4°$ 5787 was used as a local standard.

Table 1. (a) Journal of Spectroscopic Observations of H2252 − 035.

Date 1980	UT mid-exposure h m	Exposure time (min)	Wavelength range (Å)	Resolution (Å)	Comments
August 6	01 01	25	1900–3200	8	*IUE* LWR 8447
August 6	01 32	29	1250–1950	6	*IUE* SWP 9706
August 7	00 41	16.67	3400–7500	~30	SAAO 1.9-m + IPCS
August 11	00 59	16.67	3950–5050	2	SAAO 1.9-m + IPCS
	01 20	16.67	3950–5050	2	SAAO 1.9-m + IPCS

(b) Journal of Photometric Observations of H2252 − 035.

	Date 1980 (UT)	Start (UT) h m	Finish (UT) h m
UBVRI			
	August 5/6	23 47	01 07
	August 7	03 40	04 16
	August 10	04 55	05 06
	August 11	03 52	04 23
	August 12	03 25	04 00
	August 13	02 50	04 55
JHK		h m	
	November 21	09 20	

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Ultraviolet observations of H2252–035 were made using *IUE* from Vilspa on 1980 August 6. Well-exposed, low-resolution spectra were taken through the large aperture (for photometric accuracy) in the wavebands λλ1200–1950 and λλ1900–3100. The spectra were processed with the standard Vilspa Extlow package and converted to absolute fluxes with the UCL package provided by D. Carnochan and M. Snijders, modified for use on the Cambridge IBM 370 by C. Feather. The shortwave spectrum was also processed using the program described by Snijders (1980) which operates on the GPHOT image, and no significant differences were found.

Optical spectroscopy was carried out at the SAAO Sutherland, using an IPCS attached to the Radcliffe unit-spectrograph mounted at the Cassegrain focus of the 1.9-m telescope. The instrumental set-up was broadly similar to that described by Warner *et al.* (1981). The low-resolution spectrum obtained on August 7 used a wide (10 arcsec) entrance-aperture in good seeing, to ensure accurate spectrophotometry. At the time of that observation, the quality of the night was photometric as judged by photometric observers on nearby telescopes. Absolute flux values were obtained by comparison with the white dwarf standard L870 – 2 and Oke's (1974) calibration. The reduction was carried out with a computer program written by Hassall which was checked by comparison with the program used by Bath, Pringle & Whelan (1980). Atmospheric extinction values for the SAAO site were obtained from Spencer-Jones (1980). Although the formal photon-count errors are about 2 per cent (0.6 per cent at the peak of the instrumental response), the accuracy of the spectrophotometry is limited by a slight saturation of the IPCS detector in the wavelength range λλ4050–5640. In this range the flux obtained is an overestimate by a maximum of 15 per cent at $\lambda = 4900$ Å (see Section 3). Higher-resolution spectra were obtained on 1980 August 11 through a narrow entrance slit, but with the same instrumental set-up.

Infrared observations (*JHK* photometry) were made on 1980 November 21 using the AAO infrared photometer (Barton & Allen 1980).

3 Results

In this section we describe the data in more detail and discuss what conclusions we may draw from them.

3.1 PHOTOMETRY

3.1.1 Optical

The optical photometric data were obtained in the successive filters *UBVRIIRVBU* over a time of about 10 min, during continuous observing sessions of about 1 hr on the different nights (Table 1b). Thus the data are not suitable for an analysis of the periods discussed by Patterson & Price (1980) and by Warner *et al.* (1981). However, on August 6, data were obtained simultaneously with *IUE* spectra, though in slightly imperfect observing conditions. In addition, on August 7, data were obtained almost simultaneously with optical spectrophotometry. We can therefore use the photometry to tie the ultraviolet and optical spectra together. Typical integration times were 60 s in U, 100 s in I and 20 s in each of V, B and R. The errors in the photometry are of order ±0.03 mag.

This photometry is summarized in Tables 1(b) and 2. We give the mean magnitudes of H2252–035 and observed full range, as well as the values derived for the local comparison star. Table 2 also gives the adopted *UBVRI* values at the times of our spectrophotometry. To obtain values where simultaneous observations were not made, an average was taken of the values on the same night at close to the same phase of the 3.6-hr period and values at

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Table 2. Photometry of H2252 – 035.

Object	V	$B-V$	$U-B$	$V-R$	$R-I$
H2252 – 035 average value	13.45	0.06	−0.97	0.10	0.13
H2252 – 035 range (max-min)	0.28	0.14	0.19	0.15	0.28
Comparison star BD – 4° 5787	9.78	0.59	−0.01	0.34	0.34
H2252 – 035 Simultaneous with *IUE* on August 6	13.49	0.08	−0.98	0.06	0.17
H2252 – 035 Appropriate for August 7 spectra	13.41	0.08	−0.96	0.10	0.11

the same phases on other nights. The ephemeris and period given by Warner *et al.* (1981) were used. Each quoted value is an average of at least four individual values, which in general showed little scatter (of order 0.1 mag in V, $U-B$ etc.).

3.1.2 *Infrared*

On the night of 1980 November 21, infrared photometry through J, H, K filters, and a J-band light curve, were obtained using the Anglo-Australian telescope with the AAO IRPS. The photometry through a 7-arcsec aperture yielded $J = 13.08$ mag, $(J-H) = 0.06$ and $(H-K) = 0.12$, with errors of ± 0.02 mag in the J, H, K bands. These colour values have been corrected to compensate for light-curve variation between measurements with separate filters. The light curve of H2252–035 obtained through a 10.5-arcsec aperture has the following characteristics. The period for the variations in J is consistent with that found in the optical (859 s), while the peak to mean amplitude of these variations is ~ 3 per cent.

3.2 SPECTROPHOTOMETRY

The ultraviolet (*IUE*) and optical spectrophotometric measurements were made on successive days. The *UBVRI* photometry of August 7 and the optical spectrophotometry of the same night agree to within a few per cent. From Table 2 we see that the difference between the *UBVRI* measurements on August 6 and 7 is, to within the errors, a systematic grey shift of about 8 per cent. We have therefore scaled the optical spectrophotometry of August 7 by a factor 0.92 in order to compare it with the *IUE* spectrophotometry of August 6. The results are shown in Fig. 1. The *IUE* data have been binned in 20-Å bins for $1250 < \lambda < 1900$ Å, and in 40-Å bins for $1950 < \lambda < 3100$ Å. The *UBVRI* fluxes shown are those obtained simultaneously with the *IUE* data. As can be seen from the figure, the scaled optical data join the *IUE* data very well. We have already commented that the slight hump in the optical data around 4900 Å was caused by a saturation of the detector.

Griffiths *et al.* (1980) have argued from radio observations of the column density in the direction of H2252–035 that the reddening is small ($E_{B-V} < 0.06$). The lack of a 2200-Å dust feature in the *IUE* data allows us to estimate an upper limit to the reddening of $E_{B-V} < 0.05$, in agreement with Griffiths *et al.* For this reason we have applied no de-reddening correction to the data presented in Fig. 1.

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The optical continuum in Fig. 1 can be fitted roughly with a power law of the form $f_\lambda \propto \lambda^{-2.4}$, which agrees well with the value $f_\lambda \propto \lambda^{-2.5}$ found by Griffiths *et al.* The *IUE* data can be roughly approximated as a power law of the form $f_\lambda \propto \lambda^{-1.2}$.

We have attempted to fit the continuum spectrum with blackbody curves and with the spectra obtained from steady accretion discs in the manner described by Bath *et al.* (1980). No disc spectrum provided a satisfactory fit to all the data, the best fit being obtained with a disc of maximum temperature ~25 000 K and a ratio of outer to inner radii of 6. The *IUE* data alone can be fitted reasonably well by a 16 000-K blackbody, but the optical data diverge significantly. A good fit (Fig. 1) to the optical and most of *IUE* data can be obtained with a blackbody of 12 600 ± 1500 K.

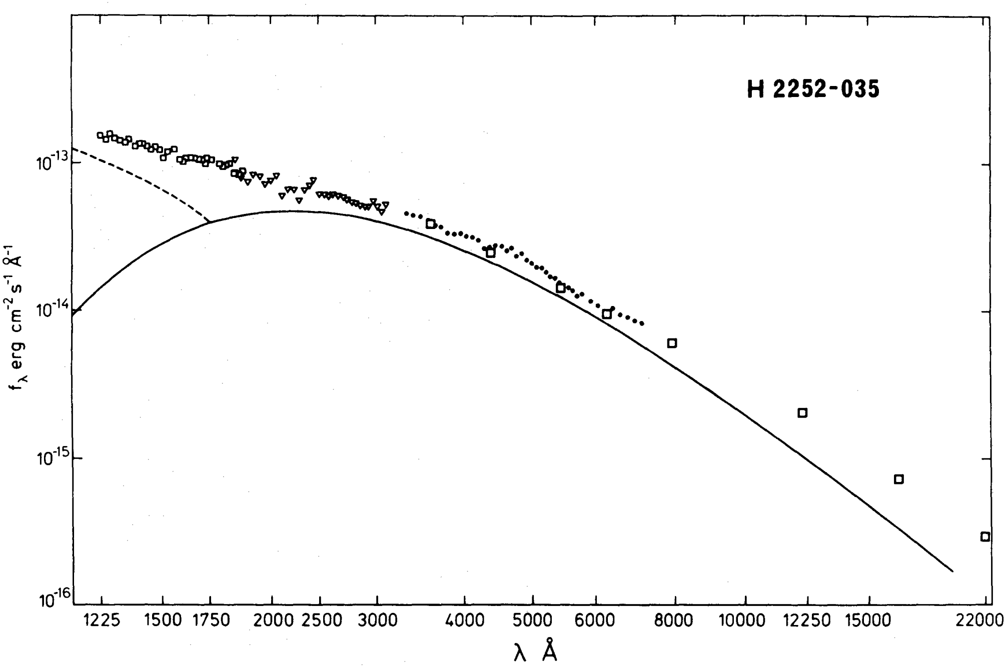

Figure 1. The spectrum of H2252 – 035. The *IUE* observations (small squares SWP and triangles LWR) and the *UBVRI* photometry (large squares) were made simultaneously on 1980 August 6. The optical spectrophotometry (filled circles) was taken on 1980 August 7 and has been scaled down by 8 per cent (see text). The *JHK* photometry was made on 1980 November 21. The solid curve is the best blackbody fit to the optical and ultraviolet data, and corresponds to T = 12 600 K. The ultraviolet excess is sketched as a dashed curve. Both these curves have been displaced downwards by 20 per cent so that they do not interfere with the data points.

The fact that the ultraviolet points for $\lambda \lesssim 2200$ Å and the infrared points for $\lambda \gtrsim 10\,000$ Å lie systematically above this curve indicates that the overall spectrum is produced by a range of temperatures. The closeness of the fit at the long-wavelength end of the spectrum indicates, however, that either the excess infrared radiation is confined to infrared wavelengths (e.g. a cool blackbody), or any temperature associated with the excess is close to 12 500 K. In either case, the lowest temperature which could contribute significantly to the optical is probably not much cooler than 10 000 K. For example, *I*, *J*, *H* and *K* points can be fitted by a 7000-K blackbody which would contribute ~50 per cent at *B*, but then the optical continuum remaining after subtraction of such a 7000-K blackbody is steeper than the $f_\lambda \propto \lambda^{-4}$ blackbody line. The infrared excess remaining after subtraction of a 12 500-K blackbody is poorly fitted by a blackbody of order $T \sim 4500$ K.

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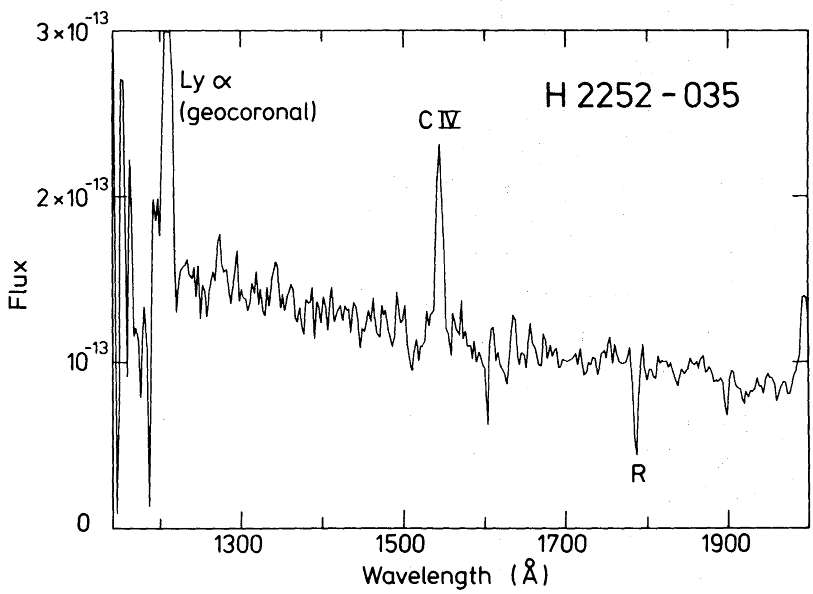

Figure 2. *IUE* shortwave spectrum of H2252 – 035 taken on 1980 August 6. The flux is in units of erg cm^{-2} s^{-1} $Å^{-1}$.

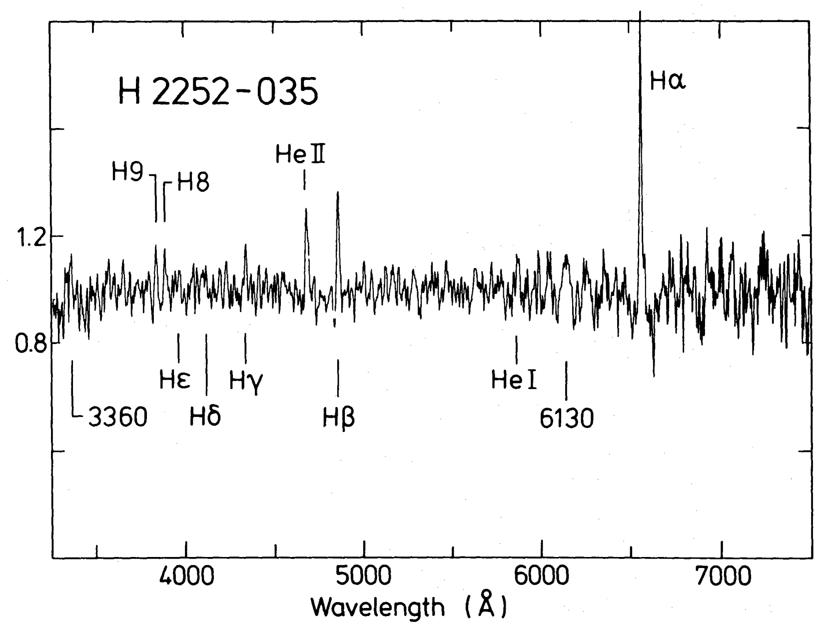

Figure 3. Spectrum of H2252 – 035 taken on 1980 August 7. The continuum has been normalized to unity everywhere.

3.3 LINE SPECTRUM

The ultraviolet spectrum shows emission at C IV (1550 Å) with equivalent width 4.7 Å (Fig. 2). Apart from geocoronal Lyα, no other features could be certainly identified, although there are peaks slightly above the local noise at λ1640 (He II) and λ1335 (C II).

The low-resolution optical spectrum taken on August 7 is shown in Fig. 3. The continuum has been roughly normalized to unity so that the ordinate is in arbitrary units. The Balmer lines are apparent in emission from Hα to H9. He II λ4686 is comparable in strength to Hβ. There are several weaker emission-features, which include He I λλ7065, 5876, a broad feature

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Table 3. Equivalent widths and line fluxes of H2252 – 035.

Line	EW (Å)	F_λ (continuum) 10^{-13} erg cm^{-2} s^{-1} Å^{-1}	Line flux 10^{-13} erg cm^{-2} s^{-1}	Line/Hβ
Hα	23	0.104	2.4	1.4
Hβ	6.8	0.246	1.7	1
Hγ	3.6	0.290	1.0	0.6
λ4686	7.4	0.265	2.0	1.2

near 6130 Å, and weaker features near 5630 Å and 3360 Å. Further data are needed to confirm the existence of these. We note that our low-resolution data did not obviously show the lines at λ5090 and at λ4640 (C III/N III) reported by Warner *et al.*

In Table 3 we give the equivalent widths and line fluxes for Hα, Hβ, Hγ and He II λ4686, which may be compared with those found by Griffiths *et al.* The Balmer decrements obtained are in rough agreement, although there is evidence for variability in the Balmer-line equivalent widths and in the Hβ/He II (4686) ratio. The upper limit to the flux in the 1640-Å He II line implies that the ratio of fluxes $F_{\lambda 1640}/F_{\lambda 4686}$ is less than 1. This should be compared with the theoretical ratio of ~6.6 (Seaton 1978), which is obtained by assuming the lines to be optically thin, and is not very sensitive to temperature or density. If this is taken to be a reddening effect, we would require $E_{B-V} > 0.5$, in clear contradiction to other information (Section 3.2). We conclude that the He II lines are optically thick and/or variable.

The sum of the two higher-resolution spectra is shown in Fig. 4. The ordinate is detected photon counts, and the shape of the spectrum reflects the instrumental response. The Balmer series Hβ to H9 and He II λ4686 can be seen in emission. Also seen in emission on both individual spectra were lines at $\lambda\lambda$4921, 4471 (He I), λ4642 (N III?) and λ4652 (C III?). Other candidate features must await confirmation by better data. The equivalent widths were larger by 10–20 per cent on the second of the two high-resolution scans, although the average value is close to the value in Table 3. The Hβ emission appears to be in a broad shallow absorption-trough, which makes estimates of the equivalent width difficult. The Ca II *K* line is probably present in absorption in the first scan. These spectra provide further

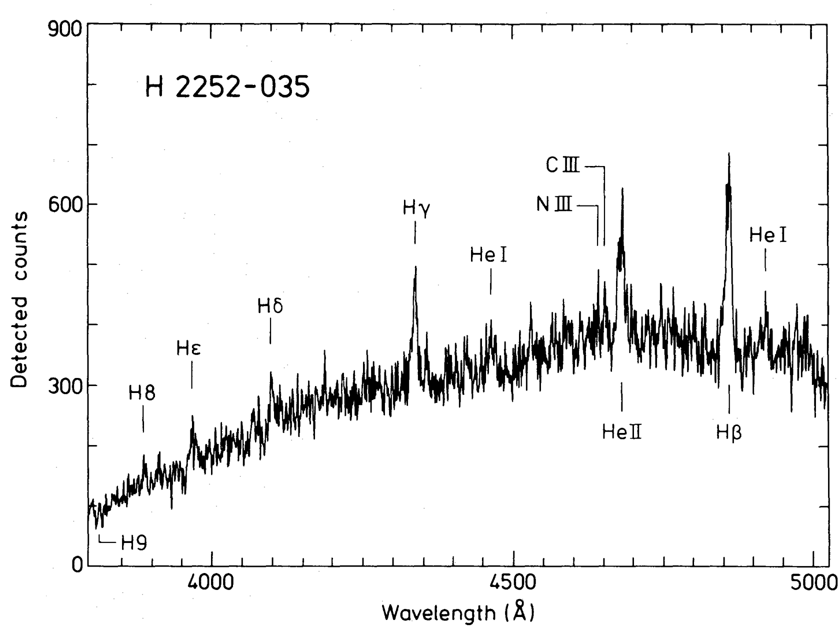

Figure 4. Spectrum of H2252 – 035 taken on 1980 August 11. The shape of the continuum is due to the detector response.

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evidence of line variability in H2252−035 as noted by Warner *et al.* The Balmer lines and λ4686 are resolved, although the structure apparent in Fig. 4 is consistent with noise. The mean FWZI of Hβ is 1100 ± 200 km s^{-1} and of He II λ4686 is 1200 ± 200 km s^{-1}.

4 Discussion

In this section we discuss the constraints imposed by the observations on possible models for H2252−035. We assume that the X-ray flux is produced by accretion on to the poles of a magnetized star which rotates with period $P_X \equiv 2\pi/\omega_X = 805$ s, though we bear in mind the possibility that the actual rotation period may be twice this value if both poles are equally strong and/or visible. We argue below (Section 4.6) that the bulk of the accretion luminosity is emitted outside the 2–10 keV band, probably at EUV/XUV energies. We assume that, as proposed originally by Patterson & Garcia (1980), the 859-s optical period is produced by reprocessing of the X-ray flux absorbed by some component of the binary system which remains stationary in the rotating frame. We consider the possibilities that the stationary component is either (Section 4.2) the secondary mass-transferring star (proposed by Patterson & Price 1981), or (Section 4.3) the bright-spot region where the stream of transferred matter strikes the outer edge of the disc.

4.1 CONSTRAINTS IMPOSED BY PHOTOMETRY

Suppose that the X-ray flux $L_X(t)$ varies with time as

$$L_X(t) = \bar{L}_X(1 + f \cos \omega_X t), \tag{4.1}$$

where f is observed to vary between 0.4 and 1, and $\bar{L}_X$ is the mean X-ray flux. We may take the reprocessed radiation in the optical $L_2(t)$ to be of the form

$$L_2(t) = L_2(\phi)\,(1 + \epsilon \cos \omega t), \tag{4.2}$$

where $\omega \equiv (2\pi/859)$ rad s^{-1} and $L_2(\phi)$ is the mean light observed at photometric phase of ϕ. We expect $\epsilon \leqslant f$. Finally we may assume the possibility of an additional optical light source L_3, which may, for example, come from an accretion disc. The observation by Warner *et al.* (1981) of a 2 per cent modulation of the optical flux with the 805-s period indicates that there is some additional flux present.

Over the 3.6-hr period the mean light varies by about 0.2 mag which implies (in obvious notation) that

$$\frac{L_2(\max) + L_3}{L_2(\min) + L_3} = 1.2. \tag{4.3}$$

This implies further that $L_2(\max)/L_2(\min) \geqslant 1.2$ and that $L_3 \leqslant 5L_2(\max)$.

From the observations of Warner *et al.* it is clear that the 859-s period is visible at all binary phases. From their Fig. 1 we estimate that the average amplitudes of the 859-s period at photometric maximum and minimum do not differ by more than 35 per cent. The amplitude of modulation at photometric phase ϕ is given by $\epsilon L_2(\phi)/(L_2(\phi) + L_3)$ so that, using (4.3), we deduce, after a little algebra,

$$\frac{L_2(\max)}{L_2(\min)} < (1.35) \times (1.2) = 1.6. \tag{4.4}$$

We conclude therefore that $L_2(\max)/L_2(\min)$ lies between about 1.2 and 1.6, and that the upper limit to $L_3/L_2(\max)$ correspondingly lies between 5 and 1.2.

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According to Warner *et al.*, the mean amplitude of the 859-s modulation is 0.04 mag, although it can on occasions become as large as 0.18 mag. Also apparent from runs 2800 and 2815 in Fig. 1 of Warner *et al.* is that the mean light-level is correlated with the size of the 859-s modulation, in the sense that when the mean light increases briefly by about 15 per cent, the amplitude increases briefly by a factor of 2. This cannot be achieved by just changing ϵ (or f) but can be achieved if L_3/L_2 changes briefly from about 4 to about 2.

4.2 THE MODEL BY PATTERSON & PRICE

In the model by Patterson & Price the light source $L_2(t)$ is identified as the heated face of the secondary star, and the radial velocity then corresponds to the orbital motion of the secondary. If the secondary mass M_2 is less than the primary M_1, then an orbital period of 3.6 hr and the assumption that the secondary is a main-sequence lobe-filling star yields $M_2 = 0.39\,M_\odot$ (Whyte & Eggleton 1980). For an evolved (subgiant) secondary, M_2 is less than this. In any case, the normal surface temperature of the secondary T_2 is likely to be of order 4000 K which is much less than the 13 000 K temperature indicated by our optical observations. In Section 4.1 we argued that L_2 and L_3 are comparable, and since the colour variations in the system correspond more or less to a grey shift (Section 3), we deduce that the heated side of the secondary is at about 13 000 K. The constraint (equation 4.4) that $L_2(\text{max})/L_2(\text{min}) \lesssim 2$, say, then implies that the angle of inclination $i \lesssim 12°$, almost independent of the mass ratio. This assumes heating of the secondary by the white dwarf, using the program described by Strittmatter *et al.* (1973), and also that heat transfer around the stellar surface is negligible. However, the demand that $K_2 = 145\ \text{km s}^{-1}$, and that for a white-dwarf primary $M_1 < 1.4 M_\odot$, requires $i > 19°$ for all values of M_2. For compatibility between these two constraints, we require $M_1 \geqslant 6\,M_\odot$, which is above the mass limit even for a neutron star.

The above argument is weakened if $T_2 \simeq 13\,000$ K, but the orbital period of a particle grazing the surface of a hydrogen-burning main-sequence star with temperature $T_2 \simeq 13\,000$ K is about 4.5 hr. A helium main-sequence star, which would have a smaller radius, is excluded by the observation of hydrogen emission in the spectrum. We note further that, if $i < 12°$ and the rotation axis of the magnetized star is aligned, then it is difficult to obtain a strong modulation of the X-ray flux.

We conclude that the modulated optical light is not due to reprocessed X-ray flux from the surface of the secondary.

4.3 REPROCESSING IN THE BRIGHT-SPOT REGION

We now consider the possibility that the 859-s period is due to reprocessing of the X-ray flux at the raised rim of the disc where the incoming stream strikes it. There is evidence from the phase variation of the pulsation in DQ Her that the edge of the disc in this region is thicker than elsewhere (Alpar 1979; Chester 1979; Petterson 1980). The geometrical model we have in mind is similar to that proposed (and since superseded) for AM Her by Fabian *et al.* (1977). We note that the solid angle subtended from the primary by the bright-spot region can exceed that subtended by the secondary, especially if M_2/M_1 is small. In addition, the disc can shadow the secondary, so reducing its contribution to the reprocessing. In view of the uncertainties of the geometry of the bright-spot region, the constraint imposed by equation (4.4) no longer implies a corresponding constraint on the inclination angle. We can now associate the 145-km s^{-1} radial velocity with typical velocities in the bright-spot region, so that the radial-velocity variation corresponds to the *S*-wave variations of the type seen in

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WZ Sge (Krzeminski & Kraft 1964). This gives the right relative phases of the photometry and radial velocity curve, if we assume maximum light occurs when we are facing the heated side of the bright spot and that the radial velocity corresponds to the orbital motion of bright-spot material around the primary (see also Section 4.5).

4.4 THE NATURE OF THE PRIMARY

There is no direct evidence as to whether the primary is a white dwarf or a neutron star. Patterson & Price (1981) argue in favour of a white dwarf by analogy with other cataclysmic variables, in which it is also found that the ratio of X-ray to optical luminosity is of order unity. In this case, however, the argument is not compelling, since the bright spot which is heated by flux from the primary will only intercept a few per cent of the primary's flux. This implies an unseen flux from the primary, probably in the EUV region of the spectrum, in order to give rise to the observed magnitude of the optical modulation (see Section 4.6).

For a given accretion luminosity, the spin-up time-scale for a white dwarf is about 10^3 larger than that for a neutron star. For a rotation period of 805 s, the corotation radius in the primary's magnetosphere is at

$$R_\Omega = 1.3 \times 10^{10} (M_1/M_\odot)^{1/3}\,\mathrm{cm}.$$

If the inner disc radius is at $R_{\rm in}$, we require $R_{\rm in} < R_\Omega$ for accretion to take place (Pringle & Rees 1972). For a 1-$M_\odot$ white-dwarf primary accreting at the rate of $10^{-9}\,M_\odot\,\mathrm{yr}^{-1}$, the spin-up time-scale is $\sim 10^7 \times (R_{\rm in}/R_\Omega)^{1/2}$ yr, and further monitoring of the rotation period will be important for ascertaining the nature of the compact object in this system.

We note further that, if no change in period is observed on a $\sim 10^7$-yr time-scale, it is probable that rotation balance has been achieved between the primary and the disc, that is $R_{\rm in} = R_\Omega$.

4.5 THE EMISSION-LINE PROFILES

The FWZI of the emission lines measured from our data is $1100\,\mathrm{km\,s^{-1}}$, a value which agrees with a width of ~ 20 Å given by Patterson & Price 1980, and which is much larger than the K-velocity of $145\,\mathrm{km\,s^{-1}}$. The breadth of the lines is too large to be produced in the atmosphere of the secondary star (thus further excluding the model discussed in Section 4.2). A straightforward S-wave model is also unlikely, since the velocity spread in the neighbourhood of the bright spot is less than the local velocity there – that is to say the observed S-wave of a spectral line shows a radial-velocity variation which is greater than the intrinsic width of the feature. We conclude that the breadth of the emission line is produced by Doppler motion of the disc as a whole, with the $\pm 550\,\mathrm{km\,s^{-1}}$ corresponding to the innermost emitting-disc elements. If the line is also produced in response to the fluctuating X-ray flux, we would expect the line profile to be modulated with a period 805 s. The two possible causes of the measured K-velocity are now:

(i) The radial velocity of the disc as a whole, in which case the 805-s period should show a corresponding orbital modulation. This interpretation is in conflict with the relative phasing of photometry and radial velocity.

(ii) A combination of a narrow S-wave feature moving to and fro within the disc emission-line profile with a velocity amplitude of some 200–400 $\mathrm{km\,s^{-1}}$. This is not an unreasonable value for the S-wave amplitude (*cf.* 700 $\mathrm{km\,s^{-1}}$ in WZ Sge – Krzeminski & Kraft 1964) if the inclination $i \simeq 30°$.

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If the overall width of the emission lines is due to Doppler motion of the inner disc elements, we may obtain some idea of the inclination of the system. For example, if we demand that $R_{in} \lesssim R_{\Omega}$ (see Section 4.4), then the assumption that the halfwidth of the emission lines corresponds to a Keplerian velocity at R_{in} implies

$$\sin i \lesssim 0.54\ (M_1/M_\odot)^{-1/3}(P_x/805)^{1/3}.$$

Thus the observations are consistent with a moderate inclination angle.

4.6 ESTIMATES OF LUMINOSITY AND DISTANCE

The total integrated flux received in the wavelength region λλ1200–7500 is 2.5×10^{-10} erg cm^{-2} s^{-1}, and the flux due to the 12 500-K blackbody illustrated in Fig. 1 is 2.0×10^{-10} erg cm^{-2} s^{-1}. The 2–10 keV X-ray flux reported by Griffiths *et al.* (1980) is 3.1×10^{-11} erg cm^{-2} s^{-1}. Unless the X-ray flux varies greatly, it is thus already clear that there must be a substantial unseen component of luminosity from the magnetized star, if the optical and UV light is due to a reflection effect. Since the fraction of flux from the primary that is intercepted and re-radiated by the disc and/or secondary is likely to be less than 10 per cent, there may be up to 100 times as much flux emitted by the primary in the hard X-ray (> 10 keV) or in the EUV/XUV bands as is detected in the range 2–10 keV.

An absolute upper limit to such an EUV/XUV flux can be obtained by assuming that it is emitted according to the blackbody law and that it is consistent with the observations at 1200 Å and at 2 keV. This limit is 5×10^{-7} erg cm^{-2} s^{-1}, corresponding to a blackbody temperature of 1.9×10^6 K. This radiation would, however, contribute to the optical flux (V band) at the 7 per cent level. Since the X-ray flux is strongly (> 40 per cent) modulated, and since the optical modulation on the 805-s period is 2 per cent, the upper limit should be correspondingly reduced to 2×10^{-7} erg cm^{-2} s^{-1}. A further constraint from observations at soft X-ray energies would be important.

If we assume that the 12 500-K blackbody is radiated by an accretion disc in the system, then by estimating the size of the disc we may estimate the distance to H2252–035. For a period of 3.6 hr, the binary separation is 8.3×10^{10} $[(M_1 + M_2)/M_\odot]^{1/3}$ cm. If the disc has an outer radius of 3×10^{10} cm and radiates at a uniform temperature, the distance to the object would be ~750 pc and the total observed luminosity would be ~10^{34} erg s^{-1}. The corresponding values in the case that the 12 500-K blackbody originates by reprocessing in the hot-spot region are distance ~100 pc and observed luminosity ~10^{32} erg s^{-1}.

5 Conclusions

We have presented observations of H2252–035 over the wavelength range 1200–22 000 Å. The continuum is well represented by a blackbody of 12 500 K over most of this range. The infrared points (JHK) show evidence for a slightly cooler contribution. There is a significant excess at wavelengths λ < 2200 Å. We have argued that the optical flux does not come from reprocessing in the atmosphere of the secondary star (as proposed by Patterson & Price 1981) and put forward the alternative suggestion that most of the optical flux comes from an accretion disc in the system, with the 859-s modulation coming from the bright-spot region. In this model, the broad emission-lines come from the disc as a whole, and the reported radial-velocity measurements are probably due to a narrow S-wave feature moving within the overall line-profile. Thus high spectrally and temporally resolved observations of the lines are important. Any reprocessing model requires the flux from the primary to exceed substantially the 2–10 keV flux reported by Griffiths *et al.* (1980). Observations at soft X-ray energies are required.

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