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C. Zurita
Instituto Astrofisico de Canarias

J. Casares
Instituto Astrofisico de Canarias

T. Shahbaz
University of Oxford

P. A. Charles
University of Oxford

R. I. Hynes
The Open University

See next page for additional authors

Authors
C. Zurita, J. Casares, T. Shahbaz, P. A. Charles, R. I. Hynes, S. Shugarov, V. Goransky, E. P. Pavlenko, and Y. Kuznetsova

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C. Zurita,[1★] J. Casares,[1] T. Shahbaz,[2] P. A. Charles,[2] R. I. Hynes,[3] S. Shugarov,[4] V. Goransky,[4] E. P. Pavlenko[5,6] and Y. Kuznetsova[7]

[1]*Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain*
[2]*Department of Astrophysics, Nuclear Physics Laboratory, Keble Road, Oxford OX1 3RH*
[3]*The Open University, Walton Hall, Milton Keynes MK7 6AA*
[4]*Sternberg State Astronomical Institute, 13 Universitetskiy Prospect, Moscow 119899, Russia*
[5]*Crimean Astrophysical Observatory, 334413, Nauchny, Crimea, Ukraine*
[6]*Isaac Newton Institute Chile, Crimean Branch*
[7]*Kiev University, Physical Faculty, 64 Volodymyrska Str., Kiev 252017, Ukraine*

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ABSTRACT

We present optical photometry of the X-ray transient XTE J2123−058, obtained in 1998 July–October. The light curves are strongly modulated on the 5.95-h orbital period, and exhibit dramatic changes in amplitude and form during the decline. We used synthetic models, which include the effect of partial eclipses and X-ray heating effects, to estimate the system parameters, and we constrain the binary inclination to be $i = 73° \pm 4$. The model is successful in reproducing the light curves at different stages of the decay by requiring the accretion disc to become smaller and thinner by 30 per cent as the system fades by 1.7 mag in the optical. From August 26 the system reaches quiescence with a mean magnitude of $R = 21.7 \pm 0.1$ and our data are consistent with the optical variability being dominated by the ellipsoidal modulation of the companion.

Key words: black hole physics – binaries: close – stars: individual: XTE J2123−058 – X-rays: stars.

1 INTRODUCTION

Soft X-ray transients (SXTs) are a subclass of low-mass X-ray binaries (LMXBs) that are characterized by episodic X-ray outbursts (usually lasting for several months), when the X-ray luminosities can increase by as much as a factor of 10^7 (van Paradijs & McClintock 1995). The observed optical flux is generated by X-ray re-processing in the accretion disc and the companion star. These outbursts recur on a time-scale of decades, but in the interim the SXTs are in a state of quiescence and the optical emission is dominated by the radiation of the faint companion star. This offers the best opportunity to analyse the properties of this star and obtain dynamical information which eventually enables us to constrain the nature of the compact object. There are currently 12 SXTs with identified optical counterparts, with eight dynamical black holes and three confirmed neutron stars: CenX-4, Aql X-1 and 1608−522 (van Paradijs & McClintock 1995). In addition, there are a few neutron star binaries exhibiting X–ray on and off states (EXO0748–676, 4U 2129+47 and SAX J1748.9–2021), although they are not classified as SXTs because they do not show the classic fast rise and slow exponential/linear decay.

The X-ray transient J2123−058 was discovered on 1998 June 29 by the *Rossi X-Ray Time Explorer* (*RXTE*) (Levine et al. 1998) reaching a peak X-ray flux of 100 mCrabs (2–12 keV). Its high Galactic latitude ($b = -36^{\circ}.2$) is unusual among transients, an indication that J2123−058 might be a member of the galactic halo population. The optical counterpart was promptly identified with a variable star of $R = 17.2$ (Tomsick et al. 1998a), which was only marginally visible on a digitized UK Schmidt plate, suggesting a pre-outburst magnitude $R \geq 20$ (Zurita, Casares & Hynes 1998). Spectra obtained early in the outburst showed strong high-excitation lines of He II λ4686, C III/N III λ4640 and weak Balmer emission embedded in broad absorptions (Tomsick et al. 1998a; Hynes et al. 1999). These features are frequently observed in SXTs during outburst (e.g. Callanan et al. 1995) and persistent LMXBs (e.g. Augusteijn et al. 1998). Type-I (thermonuclear) bursts have been detected both in X-rays (Takeshima & Strohmayer 1998) and optical (Tomsick et al. 1998b), a signature of a neutron star in the binary. The outburst light curve exhibited regular 0.7-mag deep triangular-shaped minima repeating every 6 h (Casares et al. 1998; Tomsick et al. 1998b), a strong indication of high inclination. This provided the first evidence for the system orbital period ($P = 5.957 \pm 0.003$) which was later confirmed by a radial velocity study of the He II λ4686 emission line (Hynes et al. 1998). In addition, Ilovaisky & Chevalier (1998) reported the

★ E-mail: czurita@ll.iac.es

presence of a 0.3-mag modulation with a period of 7.2 d, probably caused by the precessing disc. Since August 26 the system had settled down to its quiescent state at $R \simeq 21.7$ (Zurita & Casares 1998).

This paper presents the results of a comprehensive set of observations that have led to detailed optical light curves from outburst through the decay into quiescence. Our spectroscopy will be the subject of a second paper (Hynes et al., submitted).

2 OBSERVATIONS AND DATA REDUCTION

We observed J2123−058 during the period 1998 July–September with the IAC80 and 1-m Optical Ground Station (OGS) in the Observatorio del Teide (Tenerife), the 1.25-m SAI Station and 0.5-m and 0.38-m telescopes at Crimea, the Mount Canopus 1-m telescope at Tasmania and the 1.2-m telescope at the Kryonerion Astronomical station of the National Observatory of Athens at Kryonerio of Korinthia. On the night of 1999 June 21, we obtained *VRI* images, using the 1-m Jacobus Kapteyn Telescope in the Roque de los Muchachos Observatory (La Palma). The integration times ranged from 1 to 40 min, depending on the telescope, atmospheric conditions and the brightness of the target. The observing log is presented in Table 1. All images were corrected for bias and flat-fielded in the standard way.

We applied aperture photometry to our object and several nearby comparison stars within the field of view, using IRAF. We selected four comparison stars which were checked for variability during each night, and over the entire data set. We calibrated the data was using nine standard stars from several fields (Landolt 1992), from which we constructed a colour-dependent calibration. The Crimean data in *R* were calibrated relative to the nearby comparison star from the US Naval Observatory (USNO) catalogue which was also in the previous calibrated data. White-light photometry was also obtained in Crimea using a 0.5-m telescope equipped with a TV detector. The TV camera operates in the range $\lambda\lambda 3500$–8000 with maximum sensitivity at $\lambda 4000$ and effective wavelength at $\lambda_{\rm eff}4851$. Magnitudes were measured relative to a nearby star from the USNO catalogue which was calibrated at *B* and *V* wavelengths. 'Equivalent *BV* magnitudes' were calculated by interpolating the fluxes in *B* and *V* to find the flux at the effective wavelength of the TV detector. For further details see Pavlenko, Prokofieva & Dolgushin (1989).

3 LIGHT CURVES

3.1 Long term light curve

Fig. 1 compares the overall light curve of J2123−058 in optical (*VR*-bands) and X-rays (2–12 keV). The long-term behaviour in X-rays shows a classical FRED (fast-rise exponential-decay) morphology, with characteristic e-folding times of 2.4 d (rise) and 19 d (decay). These time-scales coincide with the mean values of the distributions of SXTs (Chen, Shrader & Livio 1997). Twenty days after the peak of the outburst, the X-ray intensity reaches a secondary maximum (of less than half of the peak intensity). The secondary maximum is also suggested by our optical data.

We identify three different stages in the optical light curve: the outburst plateau (until ∼August 10), the decay phase (≃August 10–26) and quiescence (from ≃August 26). In the plateau phase the object brightness decays at a moderately slow rate of $\simeq 0.03$ mag d^{-1} although a modulation is clearly visible in the nightly mean magnitudes. The time-scale of this variability is

Table 1. Log of observations.

Date	HJD[a]	Exp/Filter	Telescope
1998 July 02	−3	1 × R	IAC80 0.8 m[b]
1998 July 04	−1	1 × B, 1 × V, 1 × R	IAC80 0.8 m
1998 July 06	01	80 × R	OGS 1 m[c]
1998 July 07	02	79 × R	OGS 1 m
1998 July 08	03	20 × R	OGS 1 m
1998 July 09	04	33 × R	OGS 1 m
1998 July 10	05	20 × R	OGS 1 m
1998 July 12	07	42 × R	OGS 1 m
1998 July 13	08	24 × R	OGS 1 m
1998 July 14	09	2 × V	M. Canopus 1 m[d]
1998 July 16	11	2 × V	M. Canopus 1 m
1998 July 18	13	1 × B, 1 × V, 1 × R	M. Canopus 1 m
1998 July 19	14	40 × BV	Crimean 0.5 m[e]
		36 × R	Crimean 1.25 m[f]
		2 × B, 2 × V, 2 × R	M. Canopus 1 m
1998 July 20	15	42 × BV	Crimean 0.5 m
		74 × R	Crimean 1.25 m
		1 × B, 5 × V, 1 × R	M. Canopus 1 m
1998 July 21	16	36 × BV	Crimean 0.5 m
		94 × R	Crimean 1.25 m
1998 July 22	17	25 × BV	Crimean 0.5 m
		43 × R	Crimean 1.25 m
1998 July 23	18	48 × BV	Crimean 0.5 m
		45 × R	Crimean 1.25 m
1998 July 24	19	61 × R	Kryonerion 1.2 m[g]
		55 × BV	Crimean 0.5 m
1998 July 26	21	70 × R	OGS 1 m
		46 × BV	Crimean 0.5 m
1998 July 27	22	77 × R	OGS 1 m
		33 × BV	Crimean 0.5 m
1998 July 28	23	77 × R	OGS 1 m
		40 × BV	Crimean 0.5 m
1998 July 29	24	74 × R	OGS 1 m
		49 × BV	Crimean 0.5 m
1998 July 30	25	81 × R	OGS 1 m
		33 × BV	Crimean 0.5 m
1998 July 31	26	40 × BV	Crimean 0.5 m
1998 August 01	27	23 × BV	Crimean 0.5 m
		4 × R	Crimean 0.38 m
1998 August 02	28	1 × R	IAC80 0.8 m
1998 August 03	29	1 × R	IAC80 0.8 m
1998 August 04	30	2 × R	Crimean 0.38 m
		1 × R	IAC80 0.8 m
1998 August 05	31	2 × R	Crimean 0.38 m
1998 August 12	38	1 × R	IAC80 0.8 m
1998 August 15	41	12 × R	IAC80 0.8 m
1998 August 16	42	26 × R	IAC80 0.8 m
1998 August 17	43	8 × R	IAC80 0.8 m
1998 August 19	45	3 × V, 1 × R	M. Canopus 1 m
1998 August 26	52	18 × R	OGS 1 m
		1 × V	IAC80 0.8 m
1998 August 27	53	14 × R	OGS 1 m
1998 September 02	59	4 × R	IAC80 0.8 m
1998 September 23	80	11 × R	OGS 1 m
1998 September 24	81	8 × R	OGS 1 m
1998 September 25	82	5 × R	OGS 1 m
1998 September 26	83	5 × R	OGS 1 m
1999 June 21	351	1 × R, 1 × V, 1 × I	JKT 1 m[h]

Notes to table.
[a] HJD−2451000.
[b] IAC80 – 80-cm Telescope in the Observatorio del Teide (Tenerife).
[c] 1-m Optical Ground Station in the Observatorio del Teide (Tenerife).
[d] Mount Canopus 1-m telescope at Tasmania.
[e] 0.5-m telescope at Crimea.
[f] 1.25-m reflector of SAI Crimean Station.
[g] 1.2-m telescope at the Kryonerion Astronomical station of the National Observatory of Athens at Kryonerio of Korinthia.
[h] 1-m Jacobus Kapteyn Telescope in the Roque de los Muchachos Observatory (La Palma).

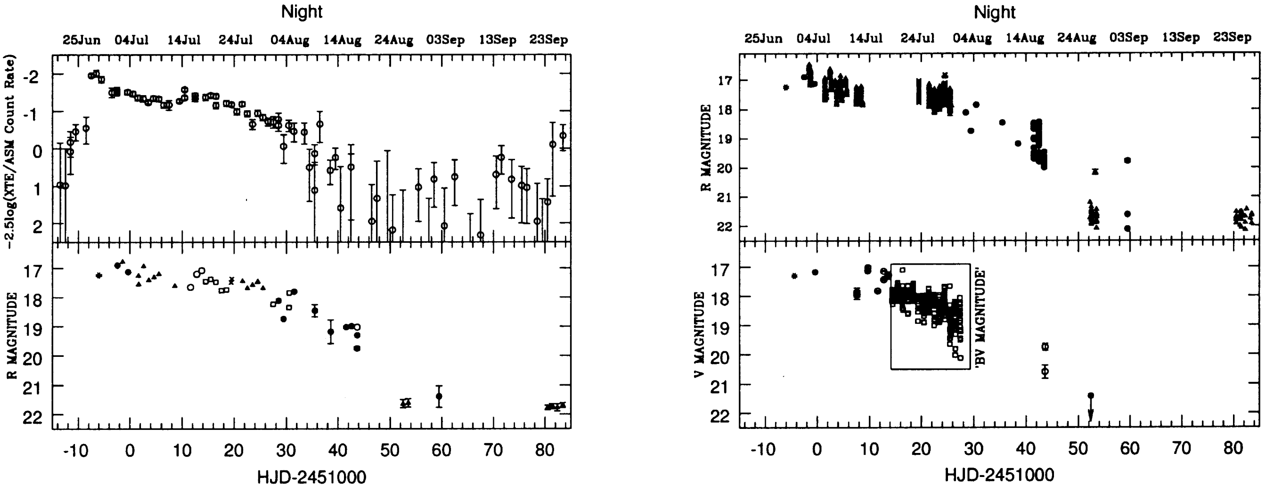

Figure 1. Left: temporal evolution of J2123−058 plotted as 'X-ray magnitudes' (top) and *R*-band magnitudes averaged per day (bottom). Note that 1 Crab equals an ASM count rate of 75 count s^{-1}. The X-ray data are provided by the ASM/*RXTE* teams at MIT and at the *RXTE* SOF at NASA's GSFC. Right: temporal evolution plotted as *R*-band magnitudes (top) and *V* and '*BV*' magnitudes (bottom). The optical data points have been obtained with the following telescopes/sites: OGS (triangles), IAC80 (filled circles), Crimean telescopes (open squares), Kryoneri Astronomical Station (diagonal crosses) and Tasmania (open circles). Asterisks mark the magnitudes reported by Tomsick et al. (IAUC 6957).

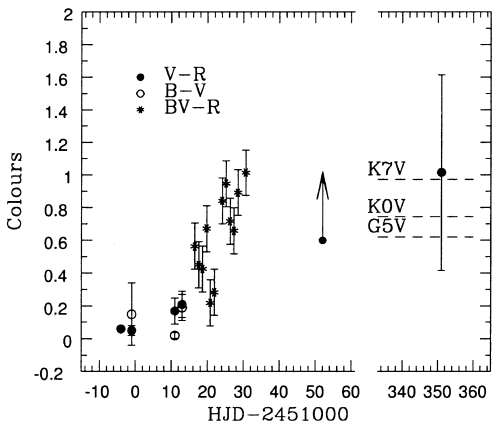

Figure 2. $(BV - R)$, $(B - V)$ and $(V - R)$ colours of J2123−058 as a function of time. Indices $(B - V)$ and $(V - R)$ were obtained from single simultaneous points. $(BV - R)$ were calculated averaging magnitudes simultaneous within 3 min. Horizontal lines mark $(V - R)$ colours for different spectral types.

consistent with the 7-d modulation attributed to disc precession by Ilovaisky & Chevalier (1998). From ~August 10 the optical light curve began an abrupt fall at a rate of $\simeq 0.2\,\mathrm{mag\,d^{-1}}$ before reaching quiescence on August 26 at $R = 21.7$ (see Fig. 1).

Taking $V(\mathrm{peak}) \simeq 17.2$ and $V(\mathrm{quiescent}) \simeq 22.9$, we estimate a total outburst amplitude of 5.7 mag. Using the empirical relation $\Delta V = 14.36 - 7.6 \log P_{\mathrm{orb}}$ (h) (Shahbaz & Kuulkers 1998), we would expect a total amplitude $\Delta V \simeq 8.4$, 2.7 mag larger that what is observed. This difference can be explained by three effects: (1) the outburst brightness of the disc being reduced by a factor cos (*i*), since the disc would be foreshorted by the high binary inclination angle, (2) we are also assuming that the quiescent flux is completely dominated by the companion star with no veiling from the accretion disc and (3) if the secondary star is sufficiently evolved for it to be degenerate it would appear intrinsically fainter. We believe the discrepancy is due to a combination of these effects and can only be resolved by obtaining optical spectroscopy in quiescence.

We see evidence for optical bursts both during outburst (July 29 with an amplitude of 0.3 mag) and at the onset of quiescence (August 27 and September 2 with amplitudes larger than 1 mag). The optical bursts observed during the ourburst decay is most probably caused by re-processing of X-ray bursts. However, the origin of the optical bursts observed during the onset of quiesence is more puzzling, given that the source had almost reached its quiescent (low luminosity) X-ray state. Note that no simultaneous X-ray observations exist, which might shed light on the origin of these optical flashes observed during quiescence.

Our *V* and '*BV*' (Fig. 1), show that the *BV* magnitudes drop faster than *R*. Moreover the amplitudes in *BV* and *R* increase during the decay. Fig. 2 presents colour information of J2123−058 as a function of time. Although we cannot directly compare the '*BV*' − *R* colour with *V*−*R* it is clear from the plot that the system reddens as the outburst decays and the secondary's contribution increases. In quiescence, we obtained an upper limit to the quiescent *V* magnitude through 2 × 2400-s images of J2123−058 with the IAC80 telescope. We also have a marginal detection in *V* on the night of 1999 June 21 using the JKT telescope. Our colours are consistent with the spectral type of a late-K main sequence star.

3.2 The orbital light curve

Representative light curves of J2123−058 in different stages of the outburst cycle are presented in Fig. 3. The data have been folded on the updated ephemeris given by Zurita & Casares (1998): HJD 2451042.639(5) + 0.24821(3) E. Note the dramatic changes in amplitude and morphology of the light curves as the outburst decays.

The July light curves are flat topped with broad triangular minima. They have a full amplitude of 0.7 mag and are reminiscent of the 5.1-h period eclipsing transient EXO 0748–676, although its long term behaviour is characterized by high and low X-ray/optical states rather than transient outbursts. We also find similarities with the eclipsing LMXB source 2A1822–371 whose complex optical light curve has been successfully modelled by X-ray heating and partial occultation of a thick non-axisymmetric

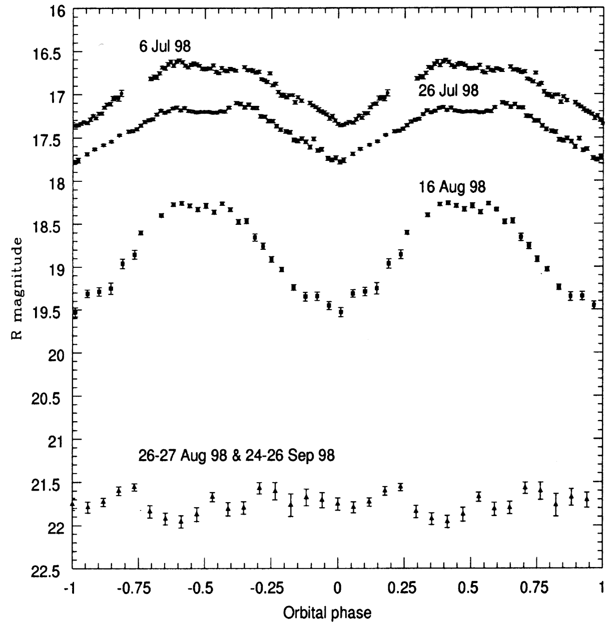

Figure 3. Optical light curves of J2123−058 taken during 1998 July–September, covering outburst, decay and quiescence (bursts have been suppress in the averaged curves). They show spectacular variations, evolving from a strong triangular shape to sinusoidal and double-hump modulations. The light curves are folded on the 5.95-h period and are shown twice for clarity

accretion disc and a faint companion (Mason et al. 1980). Asymmetries in the eclipse minima are also seen in J2123−058 on individual nights and also in the curves by Tomsick et al. (1998b).

On the other hand, the light curve of August 16 is almost sinusoidal and shows a peak-to-peak amplitude of ~1.4 mag. It resembles the outburst light curve of the 5.2-h neutron star system 4U 2129+47, where the large amplitude has been attributed to reprocessed X-ray radiation from the heated face of the optical star (Thorstensen et al. 1979). Note, however, that at the onset of the fast optical decay (≃August 10) the X-ray flux had already dropped by a factor ≥10 with respect to the outburst peak. Note also the presence of two narrow 0.2-mag dips at phases 0 and 0.5 which suggest the presence of grazing eclipses.

Finally, the quiescent light curve displays a characteristic ellipsoidal modulation from the secondary star: a double-humped variation with a full amplitude of ~0.4 mag. This light curve was produced by phase binning the entire quiescent data (from August 26 on) after detrending the night-to-night variability using a linear fit.

4 DISTANCE ESTIMATE

In the context of King & Ritter (1998), the X-ray exponential decay seen in J2123−058 indicates that irradiation is strong enough to ionize the entire accretion disc. Also, a secondary maximum is expected for one irradiated-state viscous time after the onset of the outburst and it can be used to calibrate the peak X-ray luminosity and hence the distance to the source $D_{\rm kpc}$ through

$$D_{\rm kpc} = 4.3 \times 10^{-5} t_{\rm s}^{3/2} \eta^{1/2} f^{1/2} F_{\rm p}^{-1/2} \tau_{\rm d}^{-1/2},$$

where $F_{\rm p}$ is the peak X-ray flux, $t_{\rm s}$ is the time of the secondary maximum after the peak of the outburst in days, $\tau_{\rm d}$ is the e-folding time of the decay in days, η is the radiation efficiency parameter and f is the ratio of the disc mass at the start of the outburst to the maximum possible mass (Shahbaz, Charles & King 1998). In our case, $\tau_{\rm d} = 19$ d, $t_{\rm s} \simeq 20$ d and $F_{\rm p}$ can be estimated from the XTE count rate (6 count s^{-1} in the energy range 2–12 keV) which corresponds to 1.84×10^{-9} erg cm^{-2} s^{-1}. Assuming $\eta = 0.15$ and $f = 0.5$ we find $D_{\rm kpc} = 5.7$.

Alternatively, we can estimate the distance to the source by comparing the quiescent magnitude with the absolute magnitude of a main sequence star which fits within the Roche lobe of a 6-h period orbit. Combining Paczynski's (1971) expression for the averaged radius of a Roche lobe with Kepler's Third Law we get the well-known relationship between the secondary's mean density and the orbital period: $\rho = 110/P_{\rm h}^2$ (g cm^{-3}). Substituting the orbital period of J2123−058 we obtain $\rho = 3.1$ g cm^{-3} which corresponds to a K7V secondary star with mass $\simeq 0.6\,M_{\odot}$ and absolute magnitude $M_R \simeq 7$. The dereddened quiescent magnitude is $R = 21.4$ (using $A_V = 0.37 \pm 0.15$ as derived from the Na D 1 line; see Hynes et al. 1998) which yields $D_{\rm kpc} = 7.7$. Strictly speaking, this is a lower limit to the distance as we are neglecting any contribution by the accretion disc to the quiescent optical flux. However, note that the true distance is probably not too far off 8 kpc since our quiescence light curve does not show strong evidence for disc contamination (see Section 5 and Fig. 6). A conservative limit can therefore be provided by assuming a 50 per cent contribution by the accretion disc to the continuum light. Allowing for 50 per cent disc contamination (as observed in J0422+32, a black-hole transient with comparable orbital period; see Casares et al. 1995) we obtain $R = 22.2$ for the companion star and hence $D_{\rm kpc} = 10.8$. Hereafter we will adopt $D_{\rm kpc} = 8 \pm 3$ which is consistent, at the lower end, with other estimates based on photospheric expansion models of the X-ray bursts (Homan et al. 1999; Tomsick et al. 1999). A spectral type determination of the companion star is essential to refine this distance estimate.

5 MODELLING

In an attempt to interpret the different light curves and derive the system parameters, we have used a model based on the work by de Jong, van Paradijs & Augusteijn (1996, also see references therein). The model assumes a flared accretion disc of the form $h \propto r^{9/7}$ (with h and r the disc height and radius respectively) and a Roche lobe filling secondary and accounts for X-ray heating, shadowing effects and mutual eclipses of the disc and the secondary. The disc is assumed to radiate as a blackbody with a radial temperature distribution calculated according to Vrtilek et al. (1990). The intensity distribution on the secondary star is computed using Kurucz model atmospheres. The albedo of the accretion disc and the companion star are fixed to 0.95 and 0.40 respectively, following the results of de Jong et al. (1996). The model parameters are the binary inclination (i), mass ratio ($q = M_1/M_2$), the accretion disc radius ($R_{\rm disc}$) defined as a fraction of the distance to the inner Lagrangian point ($R_{\rm L_1}$), the flaring angle of the accretion disc (α) and the X-ray luminosity ($L_{\rm x}$).

In order to model the outburst light curve we have averaged our best quality light curves of the plateau phase (July 26–30) in 29 phase bins. Using $L_{\rm x} = 1.3 \times 10^{37}$ erg s^{-1} (for $D_{\rm kpc} = 8$) and $M_2 = 0.6\,M_{\odot}$ we performed a least-squares fit to the data. Our best fit solution gave a reduced chi squared, χ^2_ν, value of 1.36 for $i = 76.0 \pm 1.0°$, $R_{\rm disc} = 0.75^{+0.06}_{-0.03}$, $R_{\rm L_1}$, $\alpha = 7.6^{+1.0}_{-0.2}$ deg and

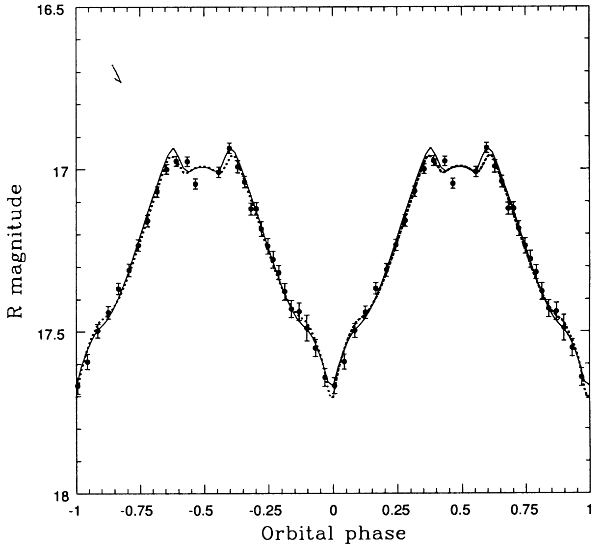

Figure 4. Outburst light curve (July 26–30) (points) and model fits (solid line) for $L_x = 1.3 \times 10^{37}$ erg s^{-1}, $i = 76°$, $q = 4.6$ ($M_2 = 0.6\,M_\odot$), $R_{disc} = 0.75$, R_{L_1} and $\alpha = 7°.6$. The dotted line shows the best fit using $M_2 = 0.1\,M_\odot$ (see text).

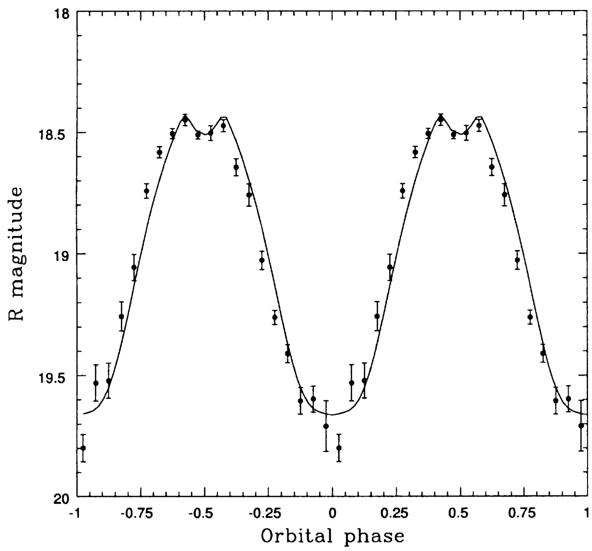

Figure 5. Decay light curve (August 16) (points) and model fits (solid line) for $L_x = 1.3 \times 10^{36}$ erg s^{-1}, $i = 72°$, $q = 4.2$ ($M_2 = 0.6\,M_\odot$), $R_{disc} = 0.6$, R_{L_1} and $\alpha = 5°.7$.

$q = 4.6^{+0.5}_{-0.2}$. The uncertainties quoted are at the 99 per cent confidence level and were obtained by grid searching the parameter of interest whilst optimizing the other model parameters. We have also rescaled the χ^2_ν values so that the minimum χ^2_ν is 1. The best model fit to the outburst data is shown in Fig. 4 (solid line). In order to examine the effects of changing M_2, we fitted the outburst data with $M_2 = 0.1\,M_\odot$ (Fig. 4 – dotted line). We find that the derived parameters are the same, within the errors: $\chi^2_\nu = 1.5$, $i = 75.3^{+0.8}_{-1.2}$ deg, $R_{disc} = 0.83 \pm 0.05$, R_{L_1}, $q = 3.4 \pm 0.4$, $\alpha = 8.8^{+0.8}_{-1.2}$ deg. Regarding the decay stage, we have fitted the light curve of 16 Aug binned into 20 phase bins, when the X-ray luminosity was an order of magnitude lower, $L_x = 1.3 \times 10^{36}$ erg s^{-1}. We fitted the decay stage data with this X-ray luminosity and $M_2 = 0.6\,M_\odot$. Our best fit solution gave a reduced χ_ν of 1.51 for $i = 72.0 \pm 3.0°$, $R_{disc} = 0.56 \pm 0.06\,R_{L_1}$, $\alpha = 5.7 \pm 0.5°$ and $q = 4.2$ (q could not be constrained with this data set). The best model fit to the decay-stage data is shown in Fig. 5. Again 99 per cent confidence levels are quoted.

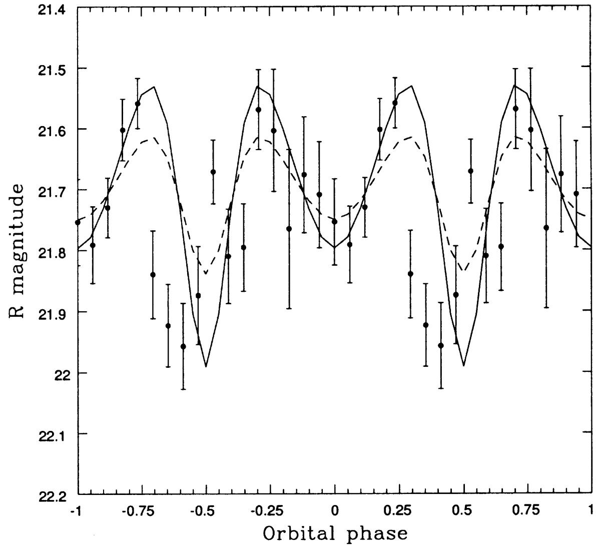

Figure 6. Quiescent light curve (1998 August 26–27 and 1998 September 24–26) (points) and model plot (solid line) for $i = 73°$, $q = 4.6$ and no X-ray heating. The dashed line shows a model plot assuming 50 per cent contamination by the accretion disc.

In Fig. 6, we show the quiescent light curve which exhibits the characteristic ellipsoidal modulation of the secondary star: i.e. two equal maxima and two unequal minima. The minimum at phase 0.5 is expected to be deeper than the minimum at phase 0.0 because gravity darkening is more pronounced near the inner Lagrangian point L_1. This effect is important for high inclination systems (see e.g. Avni & Bahcall 1974). In the figure we also show model plots using $i = 73°$, $q = 4.6$ (values which are consistent with those derived from the decay and outburst data), and no X-ray heating. The solid and dotted lines show plots with zero and 50 per cent disc contamination. The former model probably best describes the data.

6 DISCUSSION

XTE J2123−058 is a remarkable neutron star binary. Our optical light curve shows marked orbital modulations with dramatic variations as the outburst declines. These are very similar to the modulations observed in accretion disc corona (ADC) sources of comparable orbital periods (e.g. 4U 2129+47 and 2A 1822−371; see e.g. McClintock et al. 1981; Mason & Cordova 1982) although none of these are transient systems.

The X-ray light curve displays the classic SXT properties, namely a FRED morphology with typical e-folding rise and decay times and secondary maximum. Furthermore, the ratio of X-ray to optical luminosity [$\xi = B_0 + 2.5 \log F_x(\mu\mathrm{Jy})$] is also in excellent agreement with the observed distribution of LMXBs. Taking $B = 17.28$ (Tomsick et al. 1998a) and F_x(2–12 keV) $\simeq$ 100 mCrab (Levine et al. 1998) at the outburst peak and assuming $A_V = 0.37$ (Hynes et al. 1998) we obtain $\xi = 21.9$, whereas the distribution peak of LMXBs gives $\xi = 21.8 \pm 1.0$ (see van Paradijs & McClintock 1995). This result implies that, despite its high inclination, the X-ray source in J2123−058 is not hidden by the accretion disc (i.e. $\alpha \geq 90°–i$). This is consistent with the values our model favours for the binary inclination ($i = 73°$) and disc flaring angle ($\alpha = 5°.7–7°.6$).

The long-term evolution of the optical light curve can be compared to those of other SXTs (e.g. GRO J0422+32, A0620−00, N. Muscae 91). They show a slow linear decay followed by a steeper fall. We find that J2123−058 also reproduces this behaviour, although the total amplitude and time-scales are a factor of ~2 shorter (see e.g. Callanan et al. 1995).

We have modelled our *R*-band light curves of J2123−058 at different stages of the outburst including the obscuration effects and X-ray heating of the secondary star accretion disc. This led us to constrain the system inclination to $i = 73 \pm 4°$. We find encouraging the excellent agreement between the inclination values obtained for the two independent light curves (July 26–30 and August 16) during which L_x has dropped by one order of magnitude. The light curves at the plateau phase (July) are very similar to those of EXO 0748–676 and 2A 1822–371 with an extended depression of the luminosity from phase ~0.7 until the eclipse and a steeper rise to maximum (see Mason et al. 1980; Schmidtke & Cowley 1987). Our model fit indicates that the accretion disc is the dominant source of light and the triangular shaped minima can be interpreted as eclipses of the accretion disc by the secondary star together with the changing aspect of the heated polar caps of the companion star. The dramatic changes observed in the light curves during decline, are triggered by large changes in the disc size and geometry. Our fit to the decay data (August 16) demands a thinner and smaller accretion disc which implies a smaller fraction of the disc is X-ray heated. Conversely, the secondary star is more exposed to the X-ray radiation and therefore the total amplitude of the modulation increases by a factor of 2 (to ~1.4 mag). The resulting light curve has a sinusoidal-like shape and is reminiscent of the LMXBs 4U 2129+47(=V1727 Cygni) and HZ Her. Our model fit implies a change of ~30 per cent in the disc size, as the system fades by 1.7 mag in the optical. The change in the radius of the disc size is what one expects. If angular momentum is transported outwards in the disc through viscous processes, then at outburst, since matter diffuses inwards, the angular momentum of that matter has to be transferred to the outer parts of the disc, and the radius of the disc is expected to expand. When the system is decaying, after the end of the mass transfer enhancement, the disc shrinks to its original radius (Livio & Verbunt 1988; Ichikawa & Osaki 1992). Observations of U Gem, Z Cha, OY Car, HT Car show that the accretion discs are indeed larger in outburst than in quiescence (Smak 1984b; O'Donohuge 1986; Harrop-Allin & Warner 1996). Comparing our results with disc-radius variation in U Gem (Smak 1984a), we find approximately the same rate of decrease.

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