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TESTING THE CRITERIA FOR STABLE MASS TRANSFER IN CATACLYSMIC VARIABLES

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About 2% of the CVs in the Ritter & Kolb catalogue have mass estimates for their components that suggest that they are undergoing unstable mass transfer, contrary to the canonical model of the evolution of CVs. We have previously revised the mass values for three of them, and found them to be stable. We review the observations for the other nine and find that two of them are in fact probably stable even with their published mass estimates. The remaining seven objects either have poorly determined properties or lie firmly in the unstable region, or both, and should be re-observed.

Introduction

In cataclysmic variable stars (CVs[1]), mass transfer from the secondary (usually a main-sequence star) to the primary (white dwarf) is driven by angular-momentum loss from the system. The mass loss affects the donor star's structure, and the star's thermal and dynamical responses provide the necessary adjustment.

However, these two response mechanisms have their limits. Politano[2] has expressed these limits for a CV in which the donor star (secondary) is a zero-age main-sequence star. This is presented as two curves representing the thermal radius–mass exponent, and the adiabatic radius–mass exponent, respectively. Stable mass transfer for a particular system occurs if its tidal radius–mass exponent (the logarithmic derivative of the Roche-lobe radius of the secondary with respect to mass) lies below both curves. As the tidal radius–mass exponent in a CV may be expressed in terms of the mass ratio $q = M_2/M_1$ only, the two criteria may be plotted to show the critical mass ratio as a function of the secondary's mass. Having such a clear-cut criterion for stable mass transfer in CVs, we decided to test it against the data provided in the 7th edition of the Ritter & Kolb[3] catalogue (update 7·4). Fig. 1 displays the two curves, together with the data for the 100 or so CVs included in the catalogue that have mass estimates given for both components*. It is clear that the great majority of systems lie in a stable region.

Twelve systems lie above at least one of the curves. The aim of this paper is to investigate which of these objects warrants further observation to determine whether they really breach the stability criteria on q *versus* M_2. We can readily eliminate three systems from further consideration: RW Tri, UX UMa, and LX Ser. Investigations reported by Vande Putte *et al.*[4] provide more recent data than are incorporated in the catalogue, and place the central values of the mass and mass ratios below, or just on, the curves. The values are given in Table I.

*The catalogue contains a total of 472 CVs, but most of them have at best a mass estimate for one component.

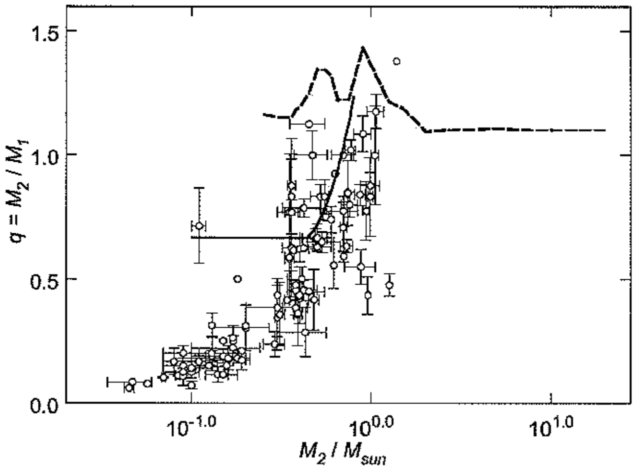

FIG. 1

Plot of mass ratio as a function of secondary mass, showing the limits for stable mass transfer (solid line, adiabatic, or dynamical; dashed line, thermal).

TABLE I

Information on systems already investigated

Object	$M_2/M_\odot$	q
RW Tri	0·59 ± 0·07	0·82 ± 0·10
UX UMa	0·47 ± 0·07	0·60 ± 0·09
LX Ser	0·37 ± 0·06	0·53 ± 0·14

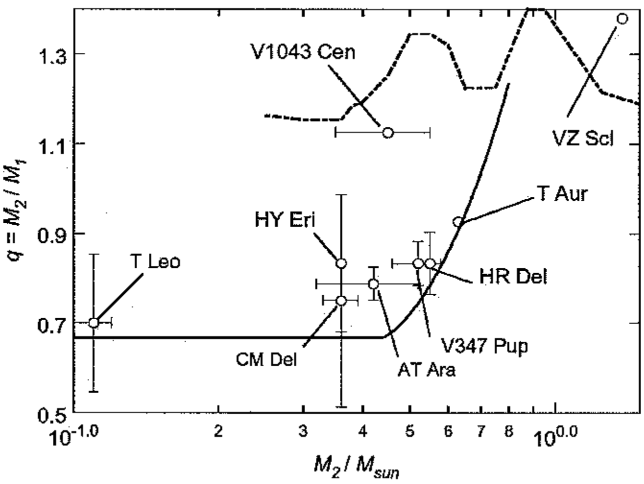

FIG. 2

Mass ratios as a function of secondary mass for CVs above either stability line.

This leaves nine objects for consideration, as shown in Fig. 2. (Two other objects in the catalogue have mass estimates for both stars and fall above the stability lines, but both are highly unusual objects. CI Aql is a recurrent nova with a very massive white dwarf[5] (1·2 $M_{\odot}$) and a rather long orbital period of 14·8 hr. V Sge appears to have a highly unusual mass ratio[6] of 3·8, a secondary mass of 3·3 $M_{\odot}$, and also a long orbital period, this time of 12·3 hr. We shall not discuss them further here.)

TABLE II

Properties of systems above the stability line.

Object	*Coordinates J2000*	*Period (hr)*	*mag1 mag2*	*mag3 mag4*	*EB SB*	*Type*	$M_1/M_{\odot}$	$M_2/M_{\odot}$	q	*Incl. (deg.)*
AT Ara	17 30 33·8	9	15·3	11·5		DN/UG	0·53	0·42	0·79	38
	−46 05 59 1				2		0·14	0·1	0·09	5
V347 Pup	06 10 33·6	5·6	13·4		1	NL	0·63	0·52	0·83	84
	−48 44 26 1		15·8		2		0·04	0·06	0·05	2·3
HR Del	20 42 20·4	5·1	11·9	3·5		Nb	0·67	0·55	0·83	40
	+19 09 40 1		13		1		0·08	0·03	0·07	2
T Aur	05 31 59·1	4·9	14·9	4·1	1	Nb	0·68	0·63	0·93	57
	+30 26 45 1		15·1		1					
V1043 Cen	13 13 17·1	4·2	14·6	16·3		NL/AM	0·4	0·45	1·13	40
	−32 59 12 1				1			0·1		
CM Del	20 24 56·9	3·9	13·4			NL/UX	0·48	0·36	0·75	73
	+17 17 54 1		15·3		1		0·15	0·03	0·22	47
VZ Scl	23 50 09·2	3·5	15·6	> 18	1	NL/VY	1	1·38	1·38	90
	−26 22 53 1		18·1		1					
HY Eri	05 01 46·3	2·9	17·5		1	NL/AM	0·43	0·36	0·83	75
	−03 59 21 1				1		0·08		0·15	3
T Leo	11 38 27·0	1·4	15·2	11		DN/SU	0·16	0·11	0·7	65
	+03 22 08 1		15·9	10	1		0·04	0·01	0·15	19

mag1 = maximum brightness of novae (Nb) in minimum, DN (UG, SU) in minimum, NL (UX) in normal state, NL (AM, VY) in high state.
mag2 = minimum brightness, in case of eclipses magn. at mid-eclipse, of novae (Nb) in minimum, DN (UG, SU) in minimum, NL (UX) in normal state, NL (AM, VY) in high state.
mag3 = maximum brightness of novae (Nb) in outburst, DN (UG) in outburst, DN (SU) in normal outburst, NL (AM, VY) in low state.
mag4 = brightness of SU in super-outburst.
EB: if blank, no eclipses observed; if n, n eclipses per orbital revolution. SB: if 1, single-lined spectroscopic binary; if 2, double-lined spectroscopic binary.

Table II summarises the main characteristics of the nine systems. The values of M_2 and q are taken from the original papers referred to in the catalogue. These are usually identical to the values in the catalogue. The only significant difference is for VZ Scl, where a typographical error in the catalogue gives a secondary mass of 0·4 $M_{\odot}$, instead of 1·38 $M_{\odot}$.

Discussion of the systems

In this section we discuss the basis for attributing the system parameters. This helps to decide whether a case can be made to observe a system again, to ascertain whether a system really violates the criteria for stable mass transfer.

AT Ara. The catalogue lists AT Ara as a dwarf nova (DN) of the U Gem sub-class.

The sub-class corresponds to all DN that are neither Z Cam nor SU UMa objects. Around 14% of catalogue entries are members of the sub-class. Initial observations took place in the mid to late seventies, but did not include detailed photometric and spectroscopic results (Bruch[7]). Bruch's paper contains the first detailed study of AT Ara. He finds that the secondary makes a significant contribution to the optical spectrum, and classifies it as a K2 star. Bruch's work is also the basis for the catalogue entry. A 1·6-m telescope was used for the spectroscopic measurements. Using the double-Gaussian-fit method, first proposed by Schneider & Young[8] and refined by Shafter[9] (his Appendix II), applied to the Hα emission line, the author finds $K_1 = 78 \cdot 9 \pm 3 \cdot 1$ km s^{-1}. Cross-correlation with a suitable red-dwarf template shows the secondary to have a radial velocity $K_2 = 99 \cdot 5 \pm 3 \cdot 2$ km s^{-1}. From estimating how far out the wings of the Hα emission line extend, the author concludes that the projected radial velocity of disc particles close to the surface of the white dwarf is 1690 ± 230 km s^{-1}. Balancing centrifugal and gravitational forces at the surface of a white dwarf of mass M_1 and radius R_1, for a particle of mass m and linear velocity v, we obtain

$$M_1 G = v^2 R_1. \qquad (1)$$

Knowing that $v \sin i = 1690$ km s^{-1} leads therefore to

$$M_1 G = \left[\frac{1690 \text{ km s}^{-1}}{\sin i} \right]^2 R_1. \qquad (2)$$

Nauenberg's[10] mass–radius expression for a white dwarf,

$$R/R_\odot = \frac{0 \cdot 0225}{\mu_e} \frac{[1 - (M/M_3)^{4/3}]^{1/2}}{(M/M_3)^{1/3}}, \qquad (3)$$

where μ_e = mean molecular weight per free electron, and $M_3/M_\odot = \dfrac{5 \cdot 816}{\mu_e^2}$, can be combined with Eqn. (2) to give a relation between M_1 and the inclination. As q is known, this is in effect a relation between M_2 and i. On the other hand, Kepler's laws imply for a circular orbit:

$$\frac{P_{orb} K_1^3}{2\pi G} = M_2 \left(\frac{q}{1+q} \right)^2 \sin^3 i. \qquad (4)$$

This provides a second relation between M_2 and i. Solving the two relations provides the required system parameters reported in Table II.

From these results, we calculate that the white-dwarf radius[10] is $9 \cdot 42 \times 10^6$ m, for the central values of the parameters. If the point representing AT Ara in Fig. 2 were to move horizontally to the right as far as the critical curve, the white-dwarf radius would decrease to $9 \cdot 20 \times 10^6$ m. Given that the initial determination of R_1 neglected the existence of a boundary layer, and/or of a gap between the inner edge of the disc and the surface of the white dwarf, it is conceivable that the primary radius could in fact equal, or be less than, this second value. In the light of this, it would be difficult to make a case for re-observing, even though the representative point is slightly above the curve, and the error bars do not quite reach the stability line. The recent provenance of the data reinforces this conclusion.

V347 Pup. V347 Pup is a nova-like CV. Around 40 percent of the CVs in the catalogue belong to this class. Negligible polarization appears to exclude any strong magnetism[11]. On the other hand, Still *et al.*[12] identify a disc in this deeply eclipsing binary. They also conclude that the disc shows spiral-armed asymmetries. Thoroughgood *et al.*[13] find the secondary to be of spectral type M0·5 V. They show evidence of substantial irradiation of the secondary, probably mainly by the disc.

The study by Thoroughgood *et al.* provides the entry for the catalogue. They were able to observe with a 1·9-m telescope for spectroscopy, and a 1-m for photometry. They recognized the difficulty of using the Hα line to fix the primary's radial velocity. Instead, they relied on the behaviour of the secondary's spectrum. They initially determined K_2 by skew-mapping. Thereafter they modelled the secondary-star flux by varying the extent of the region irradiated by the primary, and used this to adjust K_2, obtaining a value of 198 ± 5 km s^{-1}. Next, they rotationally broadened the templates, and determined the rotational velocity of the secondary by optimal subtraction, to find the value of $v_2 \sin i = 130 \pm 5$ km s^{-1}. They used two well-known relations:

$$\frac{R_2}{a} = \frac{0{\cdot}49q^{2/3}}{0{\cdot}6q^{2/3}+\ln(1+q^{1/3})} \tag{5}$$

(Eggleton[14]), and

$$\frac{R_2}{a}(1+q) = \left(\frac{v \sin i}{K_2}\right) \tag{6}$$

(from Smith & Dhillon[15]), to calculate R_2/a from the two measured quantities $v_2 \sin i$ and K_2. The authors also presented a relation between R_2/a and the eclipse duration and the inclination:

$$\left(\frac{R_2}{a}\right)^2 = \sin^2(\pi\Delta\phi_{1/2}) + \cos^2(\pi\Delta\phi_{1/2})\cos^2 i. \tag{7}$$

As the eclipse duration is measured, this set of equations provides the value of the inclination and the mass ratio. Using the expression of Kepler's third law,

$$\frac{K_2{}^3 P_{\mathrm{orb}}}{2\pi G} = \frac{M_1 \sin^3 i}{(1+q)^2}, \tag{8}$$

M_1 can be determined, as well as M_2. Having measured K_2, $v \sin i$, $\Delta\phi_{1/2}$, and their uncertainties, the authors proceeded with repeated calculations of the system parameters by sampling the measured values from normal distributions centred on the nominal values. Results leading to $\sin i > 1$ were rejected. This produced distributions of calculated parameter values from which to determine the system parameters shown in Table II. The recent vintage of the work, the closeness to the curve, and the fact that the uncertainty given on M_2 could place the point on the stability line, mean that it would be difficult to make a case for re-observing.

HR Del. The catalogue describes HR Del as a slow nova (decline from maximum by 3^{m} in more than about 100 days). Nine percent of entries in the catalogue are novae (slow or fast). It erupted[1] in 1967 and reached a peak brightness of $m_v = 3^m \cdot 4$, followed[16,17] by a slow decline to its pre-eruption brightness of $m_v = 12^m$. The UV observations[17] show evidence for a disc, and they estimate its temperature at $\sim 33\,900$ K.

Kürster and Barwig[16], whose work provides the HR Del entry to the catalogue, relied on spectral data recorded with a 1·5-m telescope. They quote work by Bruch, who concluded, from the broadening of the He II and Hβ lines, that the inclination of the system is at least 22°, with a most likely value of 41°. This value is bolstered by the fact that the cast-out nebular shell has an inclination of 38°–39°. On this basis, they adopt an inclination of 40°± 2°. The authors noted that of all lines recorded, the He II line was the only one to appear single-peaked (*i.e.*, not a double-peaked disc feature), and to be strongly broadened, while exhibiting a periodic variation consistent with the system period. From this, they conclude that its behaviour reflects the orbital motion of the white dwarf. They use this to construct a radial-velocity curve, and find $K_1 = 109 \cdot 8 \pm 2 \cdot 3$ km s^{-1}. Combining Paczynski's[18] expression for the Roche-lobe radius

$$\frac{R_2}{a} = 0 \cdot 46224 \left(\frac{M_2}{M_1+M_2}\right)^{1/3} \tag{9}$$

with Kepler's law

$$P_{\text{orb}}{}^2 = \frac{4\pi^2 a^3}{G[M_1+M_2]}, \tag{10}$$

results in

$$\frac{M_2}{R_2{}^3} = \frac{4\pi^2}{9 \cdot 876 \times 10^{-2}\, G P_{\text{orb}}{}^2}. \tag{11}$$

The authors solve (11) for M_2, using two alternative expressions for the mass–radius relation by Lacy[19], and by Patterson[20], both based on a main-sequence assumption. From what is known so far, Eqn. (4) can then be used to determine the mass ratio q, and M_1. The catalogue takes the average system parameters found from using the two expressions for the mass–radius relation. These are the values in Table II. However, it is worth noting the age of the observations (1978–1980), and the fact that photographic recording was used. In addition, we note that the nova shell radiates in the region of the He II and Hβ lines relied on for the mass determinations. These elements and the fact that the shell will have abated in the twenty-five years since Kürster and Barwig's observations make HR Del worth re-observing.

T Aur. The catalogue describes T Aur as a slow nova (see HR Del). T Aur erupted in 1891, went through a minimum 7–10^m deep, then brightened and followed the extrapolation of its early decline[1]. T Aur's secondary has sufficient magnetic activity to affect flow near the L_1 point. This in turn affects the 4·91-hour orbital period, in the form of a 23-year quasi period[21]. Bianchini[22] recorded a light curve (*B* filter) and found a hump near phase 0·9. Further evidence for a hump appears in his analysis of the Hβ line. Szkody & Feinswog[23] recorded an infrared light curve which shows a hump over phase 0·6–0·8, which they also believe originates from the hot spot. Bianchini found evidence for a disc, in the form of a doubling of the He II lines. This means that accretion is continuing, *via* a disc.

The catalogue refers to the work of Bianchini, who utilized a 1·8-m telescope for his spectroscopic observations. He relied on a main-sequence-based relation between the mass and the period given by Warner[24] to determine the secondary star's mass M_2. The author noted that the outer edge of the He II emission line exhibited a variation with orbital phase, and took this as representative of the white-dwarf radial velocity. The resulting radial-velocity curve yields a $K_1 = 154 \pm 34$ km s^{-1}. He further uses the He II line profile to measure the projected velocity of the edge of the disc, $v_d \sin i = 640$ km s^{-1}, with no uncertainty estimate. Warner[24] shows that there is a relation between the projected velocity of the edge of the disc, K_1, and the mass ratio:

$$\frac{K_1}{v_d \sin i} = q(0 \cdot 5 - 0 \cdot 227 \log q)^2. \qquad (12)$$

Hence from the measured quantities, one can find q, and therefore M_1. Eqn. (4) then provides the inclination, leading to the system parameters in Table II. The use of the extreme wing of emission lines to create a radial-velocity curve is open to error, and this is manifest in this case. In addition, the age of the data and the absence of error estimates make this a possible candidate for re-observing.

V1043 Cen. V1043 Cen is a member of the AM Her sub-class of nova-like CVs. Thirteen percent of the CVs in the catalogue belong to the sub-class. They are also called polars, and as such, display a strong magnetic field located at the white dwarf. An interesting characteristic of the sub-class is that the white dwarf rotates with the same period as the orbital motion. The variability in magnitude is linked to variation in the rate of mass transfer from the secondary. Thomas *et al.*[25] examined the orbital variations in the 3800–9100 Å range while V1043 Cen was in a low state. They find the spectral type of the secondary to be M3, a result in line with van der Heyden *et al.*'s finding[26] of M3·5 V. Subtracting an M3 spectrum from the object's spectra reveals the cyclotron flux. This in turn yields a magnetic field of 56 MG at the white dwarf. Further analysis reveals a white-dwarf photosphere at ~14 000 K.

Gänsicke *et al.*[27] used *IUE* data obtained during a low state to arrive at a similar value (~15 000 K) for the 'base' temperature, with a hot spot of 34 000 K. The latter may originate from the accretion area. They point out that V1043 Cen has the fourth-longest period of a polar, which suggests a young system. Its relatively low white-dwarf temperature is, however, comparable to that of short-period polars. They speculate that one of two scenarios may be in play. V1043 Cen may be a recently formed CV with mass transfer in the process of turning on. Alternatively, it could be a 'normal' system that recently experienced an abnormally long (> 10^4 yr) low state. The papers by Thomas *et al.* and Gänsicke *et al.* form the basis of the catalogue entries for this object. The observations were undertaken mainly with *IUE*, *ROSAT*, and 1-m and 2·2-m telescopes. The authors provide an estimate of distance by using the spectral type of the secondary and a relation between spectral type and surface brightness F_{TiO}, which is compared with flux measurements. The result is a distance of 200 ± 17 pc. To calculate the flux, a base temperature of the WD is taken to be 15 000 K, with a spot at 34 000 K. Knowing the flux from the WD and its distance, its radius is inferred as $1 \cdot 1 \times 10^9$ cm. The Hamada–Salpeter relation[28] establishes the mass from this radius: $M_1 \sim 0{\cdot}40\ M_\odot$. The spectral type of the secondary referred to above and the main-sequence assumption provide a mass estimate: $M_2 \approx 0{\cdot}45 \pm 0{\cdot}1\ M_\odot$. The value of K_2 is determined by constructing a radial-velocity curve for three absorption lines in the secondary's spectrum, leading to $K_2 = 185 \pm 9$ km s^{-1}. The latter is consistent with van der Heyden *et al.*'s finding[26] of $K_2 = 169 \pm 10$ km s^{-1}. These values allow Eqn. (8) to be applied to calculate the inclination. The system parameters are given in Table II. The position on the diagram (Fig. 2) and the absence of error estimates for the WD mass and for the inclination make this a candidate for re-observing. The relatively low mass of the primary is a further reason for re-visiting V1043 Cen (Smith & Dhillon[15] provide averages for the WD mass in the range 0·7 to 0·8 $M_\odot$).

CM Del. CM Del is a member of the UX UMa sub-class of nova-likes. The sub-class makes up eleven percent of CVs in the catalogue. Shafter[29] detected a high mass transfer, typical of CVs in the 0·13–0·17-d period range. Lyons *et al.*[30] used *HST* and *IUE* data for CM Del in quiescence; they determined the white-dwarf temperature to be 22 000 K. Shafter's observations at a 3-m telescope[9] and their processing provide the catalogue entries for this object. He examines the Hα line wings and their orbital behaviour to determine a radial-velocity curve that gives $K_1 = 155 \pm 24$ km s^{-1}. He also deduces the value of $v_d \sin i = 740 \pm 73$ km^{-1}, based on a specially devised calibration relation. Shafter provides an expression for M_2 as a function of P (in seconds) and q, based on the assumption that the secondary is approximated by a main-sequence star:

$$\frac{M_2}{M_\odot} = \left[\frac{9{\cdot}96 \times 10^{-10}\,(1+1/q)\,P^2 q^2}{[0{\cdot}6q^{2/3} + \ln(1+q^{1/3})]^3}\right]^{0{\cdot}582}. \qquad (13)$$

Eqns (12) and (13) provide the values of q and M_2. The values of M_1 and the inclination follow from this, leading to the system parameters in Table II. The white-dwarf mass is relatively low[15], so there is some doubt about these parameters. We have therefore re-examined the basis for the calibration relation for $v_d \sin i$. Shafter essentially uses a method devised by Warner[31], who first uses the assumption that the secondary fills its Roche lobe, together with a main-sequence mass–radius relation, to derive a relationship between the secondary mass, the orbital period, and the mass ratio. He then uses an approximation for the Roche-lobe radius of the primary to derive a relation between K_1 (measurable from emission-line wings using the usual double-Gaussian method), $v_d \sin i$, and q. Thus, if $v_d \sin i$ can be measured, the mass ratio is known and hence the secondary mass from Eqn. (13).

However, it is by no means straightforward to measure $v_d \sin i$ directly from line profiles, as Shafter recognizes. Instead, he determines it empirically by observing systems with known K_1 and q, computing $v_d \sin i$ for these systems, and defining the position in the line profile corresponding to this value in terms of a shape parameter, f. He then claims that f has the same value for all his calibration systems, and assumes that the same value applies to the systems where q is not known, and can be used to determine $v_d \sin i$ for these systems. However, his data show that there is a scatter of about 25% in the values of f (ref. 9, Fig. 3). This means that his results may be statistically reliable for his selection of systems but casts doubt on the results for any particular system.

Given the low white-dwarf mass, and the fact that K_1 was determined from a radial-velocity curve that only covered half the orbit (ref. 9, Fig. 8g), it appears that the results for CM Del are sufficiently in doubt to make it worth re-observing.

VZ Scl. VZ Scl is a member of the VY Scl sub-class of the nova-likes. Some 8% of CVs in the catalogue belong to this sub-class, which shows reductions in brightness from an approximately constant maximum, caused by rapid, temporary lowering of the mass-transfer rate from the secondary. The drop in this case is in excess of $2^{m}\cdot5$. It also exhibits a $2^{m}\cdot5$ drop in magnitude when in eclipse, suggesting a very high inclination. Warner[1] indicates that VZ Scl may be a member of the SW Sex sub-class, or even a Z Cam in extended standstill. There is evidence[32] of a disc, obtained by mapping the Hβ line through eclipse. However, Williams[32] also indicates that this object may to some degree be an intermediate polar. Observational evidence for a disc is also given by O'Donoghue *et al.*[33] and by Sulkanen *et al.*[34], who report on the size of the disc in the high and low states, respectively; it is larger in a high than in a low state. In parallel, Warner[1] reports flickering near the centre of the disc, rather than from the bright spot, and this may point to two sources of flickering in CVs, with the centre being the dominant one in VZ Scl. O'Donoghue *et al.* speculate that the outer part of the disc may be rotating at non-Keplerian velocities. Sherrington *et al.*[35] find that in the high state, the infrared radiation is dominated by the disc, whereas in the low state, this is dominated by the secondary.

Warner & Thackeray[36] observed this object with a 5-m telescope (photographic spectroscopy), and a 2-m (photometry). They examined the He I and He II emission lines and combined their variation with phase to produce a radial-velocity curve of roughly sinusoidal appearance. From this they derive $K_1 \approx 275$ km s^{-1} (no error estimates). From emission-line broadening, they find $v_d \sin i = 900$ km s^{-1} (no error estimates). Examination of the eclipse depth and duration shows $i = 90°$. These results combined with Eqns. (4) and (12) provide the values of the system parameters in Table II. The position of the object above the thermal-stability limit makes this an object worth re-observing.

HY Eri. HY Eri is a member of the AM Her sub-class of nova-likes (the sub-class is described above). Information on the system is sparse. No light curve has been located in the literature. Burwitz *et al.*[37] surmise that the system was born into the period gap and therefore the secondary is not much evolved. They also tentatively ascribe a white-dwarf magnetic field of ~ 25 MG, based on what may be cyclotron humps in the orbital spectra. Ramsay & Cropper[38] report *XMM–Newton* data showing that the soft-to-hard X-ray flux ratio is among the highest in their survey of seventeen polars. This was measured with the system in a high accretion state.

Burwitz *et al.*[37] observed this object with a 2·2-m telescope for spectroscopy, with *ROSAT*, and with 0·9 and 3·5-m telescopes for photometry. The Hβ, Hγ, and He II emission-line behaviour is combined to provide a radial-velocity curve from which $K_1 = 73\cdot6 \pm 25$ km s^{-1}. Furthermore, they rely on a main-sequence mass–period relation to determine $M_2 = 0\cdot36\ M_\odot$ (no error estimates). From these results, Eqn. (4) provides a relation between q and i. The photometry data allow the eclipse duration to be measured. This in turn provides another relation between q and i (see, for example, ref. 1, p. 71). The two constraints combined yield the values of q and i, and thus also M_1 shown in Table II. The position of the object relative to the curve and the absence of error estimates for M_2 make this object worth re-observing. In addition, the white-dwarf mass is relatively low[15].

T Leo. T Leo is a member of the SU UMa sub-class of dwarf novae; the sub-class represents twenty-three percent of catalogue entries. These objects undergo super-outbursts. Belle *et al.*[39] studied the object during such an event, using *IUE* spectra. From disc-model fitting, they conclude that $M_1 = 0.6\, M_\odot$. Howell *et al.*[40] based their investigation on X-ray, EUV, optical, and IR spectra, from which they conclude that in super-outburst, the WD boundary layer heats up to 71 000–97 000 K. Szkody *et al.*[41] find evidence for a disc. Vrielmann *et al.*[42] used *XMM–Newton* spectra to conclude that, although there may be a disc, the WD is probably spinning at a different period of ~ 414 s, so T Leo may be an intermediate polar. Shafter[9] studied this object in a manner similar to that applied to CM Del. He examines the Hα line wings and their orbital behaviour to determine a radial-velocity curve that gives $K_1 = 135 \pm 11$ km s^{-1}. The orbital phase coverage is much better than for CM Del, but there is considerable scatter in the radial-velocity curve. He also deduces the value of $v_d \sin i = 673 \pm 69$ km s^{-1}, based on the same calibration relation as for CM Del. Shafter uses Eqn. (13) for M_2 as a function of P (in seconds) and q, based on the assumption that the secondary is approximated by a main-sequence star. Eqns (12) and (13) provide the values of q and M_2. The values of M_1 and the inclination follow from this, leading to the system parameters in Table II.

As argued for CM Del, the basis for the calibration relation on $v_d \sin i$ is open to question for particular systems. In addition, the white-dwarf mass of $0.16\, M_\odot$ is even more extreme than for CM Del. We also note Belle *et al.*'s quite different WD mass estimate[39] of $0.6\, M_\odot$. Taken together, these points make T Leo worth re-observing.

Conclusion and proposed observations

Of the nine objects in Table II, only two (AT Ara and V347 Cen) seem to be close enough to the stability line and to have reliable enough data that they can be taken to be stable with some confidence. The remaining seven objects warrant further study, either because their parameters have great uncertainty or because the catalogue values place them firmly in the unstable region. Since it would be surprising if any of them actually turned out to be unstable, the catalogue values are likely to be wrong. We plan to observe them to establish the correct values and to place appropriate error bars on all the parameters.

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Dr M. Politano was kind enough to point out that the thermal stability data for the critical values of q in M. Hjellming's thesis[43] are in fact more recent than the data in his own paper[2]. We thus used the data from Hjellming in drawing Figs. 1 and 2.

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