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Aspects of observations and evolution of AM CVn stars

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Abstract. A brief history is given of the very earliest work on HZ 29 (aka AM CVn), during which it was demoted from quasar to cataclysmic variable via hot subdwarf. An overview of the steadily increasing number of known AM CVn stars is given, which are all helium transferring close binaries. It is suggested that more work is needed on the effects of irradiation on the secondaries both from the point of long term evolution and as a possible mechanism for producing short term unstable mass transfer. Apart from their own intrinsic interest, the general properties of AM CVn stars may teach us something about their hydrogen-rich cousins, the more populous normal cataclysmic variables.

Key words. binaries: interacting - general - stars - subdwarfs - magnetic

1. Introduction

In the beginning was a remark made by Henry Norris Russell (1948), who pointed out that for a pair of white dwarfs "each of half the sun's mass and 100 000 times its density, separated by four radii, the period of revolution comes out three minutes, and the duration of central eclipses thirty seconds! It is an entertaining puzzle to consider how such rapid variation could be discovered and, if so, how a reliable light curve could be obtained". Soon afterwards, photographic photometry of ten white dwarfs (Hossack & Hogg 1949), and later a photoelectric search among twelve white dwarfs (Lenouvel 1957), failed to find any brightness variations among them.

A blue star found in 1936 by Malmquist (1936) was rediscovered by Humason & Zwicky (1947), entered into their catalogue of faint blue stars as number 29 and had a chequered career. Greenstein (1956) initially thought he could see shallow hydrogen lines in the spectrum, but within a year Greenstein & Matthews (1957) reported HZ 29 to have broad and shallow absorption lines of He I, which suggested a classification as a DB white dwarf. But they also noticed that the absorption lines were too shallow for a normal white dwarf and that some lines were double (the first evidence of central emission, though not realised at that time). The identification with helium was at first disputed by Burbidge, Burbidge & Hoyle (1967). Because of some coincidences of HZ 29's lines with lines in two quasars (3C191 and PKS 0237-23) they declared HZ 29 to be a quasar with z = 1.95. Although the two other objects have continued their careers as successful quasars, HZ 29 has since been demoted in absolute magnitude from ~ -25 to ~ +10.

Joe Smak, in a routine survey of the colours and magnitudes of faint blue stars, noticed in his first observation of HZ 29 in 1962 that there seemed to be a low amplitude (0.05

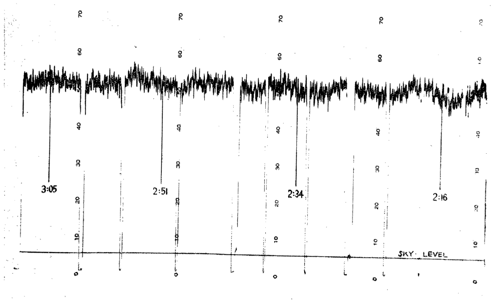

Fig. 1. The historic first light curve of HZ 29, later known as AM CVn. From Smak (1967).

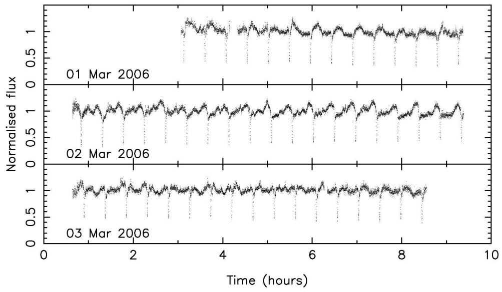

Fig. 2. Light curve of the first known eclipsing AM CVn star, SDSS J0926+3624. From Marsh et al., (2007).

mag) sinusoidal variability with a period ~ 9 min. Later observations by Krzeminski failed to confirm the variability and so the star was not observed further. It was only when Smak (1967) re-examined the old observations and made an autocorrelation analysis that the reality of variability, albeit at ~ 18 min period, was revealed. Considering that the available light curves were noisy chart recordings, and had to be hand digitized by measurements made at spacings of 43 s, this was no trivial task. He points out that "it was only due to a pure accident that the periodicity was so clearly visible on the first tracing and as a consequence more observations of the star were accumulated". Smak concluded that no definite interpretation could be made at that time, but a detached pair of white dwarfs was a possibility.

Paczynski (1967) was quick to pick up on the implications of such possible very short period binaries as emitters of gravitational waves (WZ Sge had recently been identified as an 82 min binary, which was itself of unprecedented shortness, but HZ 29 would be even more extreme). He too thought of it only as a detached pair, with which evidence for the existence of gravitational waves could in principle be tested from detection of the predicted change in orbital period, which he showed would be quite easily measurable.

Smak's detection of variability in HZ 29 resulted in it being given the variable star designation AM CVn, which in time was to become the type star of a new kind of variable.

Ostriker & Hesser (1968) produced the first light curve from digital photometry, which enabled them to construct a mean light curve that clearly showed its double pulse nature. Curiously, though, they concluded "a binary-system interpretation seems unlikely, since maximum light occurs only during a small fraction of the total light curve. Also, the object is not on the main sequence, and, if it were instead a pair of eclipsing white dwarfs, the mass would have to be very low in order to have a close pair with a period as long as 10^3 sec. However, the period is not impossible for a pair of hot subdwarfs". With hindsight, we can point out that it is also not impossible for a pair of white dwarfs, only one of which has a very low mass and therefore relatively large radius. Ostriker and Hesser suggested that AM CVn was either a pulsating hot subdwarf or a rotating magnetic white dwarf. In this they were prophetic of two classes of variable star that would indeed eventually be discovered.

AM CVn was observed by Rob Robinson and myself in 1971 (Warner & Robinson 1972) as part of the study of rapid blue variables being conducted at McDonald Observatory. The observations were of sufficiently high signal/noise to show the presence of rapid flickering; this and other considerations led us to propose that "AM CVn represents a late stage of evolution of a cataclysmic variable star, in which all hydrogen has been removed from the system". In retrospect, there are two problems with even this conclusion - the best modern light curves show that almost all the observed rapid variability can be ascribed to orbital and superhump variations; there is very little evidence for the flickering that was deduced as the signature of mass transfer. And the system, according to later evolutionary theory, lost all of its hydrogen even before it became a CV. But, as I like to point out to students, it is important to be right, even if for the wrong reason.

I will now discuss a number of topics that I think have not been fully worked out in the observation and evolution of AM CVn stars. I want first to look at some relevant properties of the normal, hydrogen-rich cataclysmic variables (CVs). For compactness I will often refer to the latter as HCVs and the helium transferring systems as HeCVs; these are observationally determined characteristics.

2. Period gaps and VY Scl behaviour

In the HCVs there are several strong correlations established for systems with periods $P_{\rm orb}$ in the range 2 - 4 h:

(i) In the range 3 - 4 h the systems are predominantly high $\dot{M}$, i.e. they are mostly nova-like variables, and there is a paucity of dwarf novae, which require relatively low $\dot{M}$, this is unlikely to be due to an observational bias – dwarf novae call attention to themselves in outburst, whereas the nova-likes are more difficult to detect. Furthermore, the observationally estimated values of $\dot{M}$ in this region are about an order of magnitude larger than is derived from the standard (e.g. Verbunt & Zwaan (1981) magnetic braking law. This may require the existence of an $\dot{M}$ - enhancing mechanism for the 3 - 4 h range.

(ii) The same 3 - 4 h range contains most or all of the high $\dot{M}$ systems that show instabilities of $\dot{M}$, i.e. the VY Scl stars, which vary in accretion luminosity by up to two orders of magnitude on time scales of months or years. A list of VY Scl stars and their properties can be found in Table 4.1 of Warner (1995a), with additional information in Table 2 of Kato, Ishioka & Uemura (2002). Note, however, that in the latter list the type star VY Scl is listed with the period of 5.56 h found spectroscopically by Martinez-Pais et al., (2000), which is in conflict with the photometric period of 4.456 h found by Patterson (quoted in Downes et al., 2005). This may therefore be another case of spectroscopic and photometric periods that differ for unknown reasons (Woudt, Warner & Pretorius 2004, Araujo-Betancor et al., 2005).
An interesting observational fact is that, with one exception, in intermediate and low $\dot{M}$ states VY Scl stars show no convincing evidence of dwarf nova outbursts. The exception is V425 Cas which has shown a $\sim$ 2.65 d variation, with a range of only 0.7 mag, when the system was 1 - 2 mag below maximum (Kato et al., 2001c).
It is probably correct to say that while not every nova-like CV in the 3 - 4 h range has been seen to be a VY Scl star, this is possibly due to under-sampling of the long-term light curves of many of the candidates. It would be a useful project to check archival plates for some of the brighter systems that have been inadequately observed. In this way, for example, it was long ago established that the two intermediate polars, V1223 Sgr and AO Psc, both of which are in the 3 - 4 h range, have dramatic low states (Belserene 1981).

(iii) The orbital "period gap" from $\sim$ 2 - 3 h, known since 1975 (Warner 1976), now contains some CVs most of which are (or are suspected) magnetic systems (e.g. Thorstensen & Fenton 2002; Warner 2002). There is no doubt, however, that for non-magnetic HCV systems there is a very low space density in the 2 - 3 h range.

There are as yet no agreed interpretations of these properties, but they are of relevance to HeCVs, so I will describe some aspects of the status quo.

(i) The high $\dot{M}$ for 3 h to 4 h HCVs can be attributed to irradiation-enhanced mass transfer: when the orbital separation becomes small enough there is a positive feed-back mechanism inherent in the accretion luminosity, such that the higher luminosities of the central region (inner disc and surface of the primary) heat and expand the irradiated surface of the donor star, increasing mass transfer. This is a self-limiting process because higher $\dot{M}$ thickens the disc, which increases shielding of irradiation of the secondary. As the orbit shrinks, irradiation begins to be important at $P_{\rm orb}$ = 4 h and is the dominant process at $P_{\rm orb}$ = 3 h; the maximum $\dot{M}$ calculated from this process agrees with the highest values observed in the 3 - 4 h range (Wu, Wickramasinghe & Warner 1995a,b). This same irradiation process appears necessary to explain the maintenance of high $\dot{M}$ for times in excess of 100 y after nova outbursts (Warner 2002). Note that the time scales that appear in this theory are much shorter than those introduced in long-term orbital evolution, e.g. Ritter (1985), which use the thermal time scale of the entire outer envelope of the secondary rather than that of the region which provides the immediate mass transfer (see King & Cannizzo (1998) for further comment on this).

(ii) The $\dot{M}$ instability, which in non-magnetic HCVs appears an almost exclusive property of the 3 - 4 h range, also appears in the irradiation-enhanced mass transfer process (Wu et al., 1995a,b). In essence, the feed-back mechanism generates a deterministic chaos process with two attractors - one at high $\dot{M}$ and one at low $\dot{M}$. That there is additional physics present is shown by the absence of dwarf nova (DN) outbursts during the $\dot{M}$ low states; Lasota & Hameury (2004, 2005) infer from this that the primaries must have weak magnetic fields that clear out the inner disc. In addition, to prevent DN outbursts at intermediate levels of $\dot{M}$ a magnetic field strong enough to prevent the formation of a disc is required. This requires fields at least as strong as those of the lowest field intermediate polars.
An alternative hypothesis for the variability of $\dot{M}$ from the secondaries in VY Scl stars has been given by Livio & Pringle (1994), wherein they envisage star spots passing by the inner Lagrangian point. An obvious problem with this idea is that it provides no explanation of why it should occur predominantly in the 3 - 4 h range.

(iii) The period gap in HCVs has for long been hypothesized as a diminution or restructuring of the magnetic field of the secondary when the latter becomes fully convective. There have been a number of criticisms of this conjecture and the modeling by Tout & Pringle (1992) and by Ivanova & Taam (2003) of angular momentum loss from rapidly rotating lower main sequence stars finds no observational or theoretical evidence for a change of behaviour above and below this boundary; the letter conclude that "other mechanisms [than discontinuous braking] should be sought to prevent systems entering into the period gap". The existence of a "large-scale and stable magnetic field" in the fully convective very low mass L-type star (Burger et al., 2005) is further evidence in this arena.

Historically, the first suggestion of a reason for the period gap was stimulated by the VY Scl phenomenon that is common just above the gap (Robinson et al., 1981) - it being argued that zero $\dot{M}$ is a possible ultimate evolutionary outcome of the evident $\dot{M}$ instability in the 3 - 4 h range. The irradiative feedback mechanism described above provides just such an outcome.

3. VY Scl and dwarf nova activity in HeCVs

The AM CVn stars have long-term luminosity variations that parallel those of the HCVs. Table 1 lists the 40 known AM CVns. The period P is the orbital period where known.

The systems are arranged in order of increasing $P_{\rm orb}$, from which it is seen that the shortest and longest period systems have stable $\dot{M}$, but for $\sim 1300 < P_{\rm orb} < 2500$ s there are wide ranging variations, which I have in-

Table 1. The AM CVn Stars

Star	P(s)	mv	Refs
HM Cnc	321.25	21.1	1,2
V407 Vul	569	19.9	3
ES Cet	620	16.9	4,5
SDSS J1908	936	26	
AM CVn	1028.7	14.1- 14.2	6,7
HP Lib	1102.7	13.6	8
PTF1 J1919	1347	18.0 -20.2	42
CR Boo	1471.3	13.0 -18.0	9,10, 11,12
KL Dra	1500	16.8 - 20	13
PTF1 J0719	1608		27,39
V803 Cen	1612.0	13.2 -17.4	14,15,16
SDSS J0926	1698	16.6 - 19.6	25
CP Eri	1701.2	16.5 - 19.7	17
PTF1 0943	1810	16.9- 20.7	39
CSS 0105	1899	16.3 - 19.6	37
V406 Hya	2041.5	14.5 - 19.7	18
PTF1 J0435	2059		39
SDSS J1730	2110		44,45
2QZ J1427	2194	15.1 - 20.2	19
SDSS J0129	2253	14.5 - 20.0	25,28, 29,38
SDSS J1240	2237.5	19.0 -19.8	20
SDSS J1411		19.4-19.7	26
ASASSN	2575	12.3 - 18	36
SDSS J1525	2659	19.8-20.2	32,38
SDSS J0804	2670	17.8-19.9	31
GP Com	2794	15.9 - 16.3	21,22
SDSS J0902	2898		32,40
SDSS J1208	3178	18.9 - 19.4	34,38
SDSS J1642	3252		32
SDSS J1552	3378	20.2 - 20.6	33
SDSS J1137	3576	19.2	41
V396 Hya	3906	17.0 - 17.4	23,24
SDSS J1721		20.4 - 20.7	32
SDSS J2047		17.0-17.4	35
PTF1 J0857		19.5 - 21.7	39
PTF1 J1523		17.6 - 23.5	39
PTF1 J1633		17.9 - 23.0	39
PTF1 J2219		16.2 -20.7	39
SDSS J1505		19.2	41
SDSS J1043			45

References 1. Israel et al. (2002); 2. Ramsay, Hakala & Cropper (2002); 3. Cropper et al. (1998); 4. Warner & Woudt (2002); 5. Espaillat et al. 2005; 6. Skillman et al. (1999); 7. Solheim et al. (1998); 8. Patterson et al. (2002); 9. Kato et al. (2000a); 10. Kato et al. (2001b); 11. Patterson et al. (1997); 12. Provencal et al. (1997); 13. Wood et al. (2002); 14. Kato et al. (2000a,b); 15. Kato et al. (2001a); 16. Patterson et al. (2000); 17. Abbott et al. (1992); 18. Woudt & Warner (2003); 19. Woudt, Warner & Rycoff (2005); 20. Roelofs et al. (2004); 21. Nather, Robinson & Stover (1981); 22. Morales-Rueda et (2003); 23. Ruiz et al. (2001); 24. Woudt & Warner (2001); 25. Anderson et al. 2005; 26. Fontaine et al. (2011); 27. Levitan et al. (2011); 28. Barclay et al. (2009); 29. Shears et al. (2011); 31. Roelofs et al. (2009); 32. Rau et al. (2010); 33. Roelofs et al. (2007a); 34. Anderson et al. (2008); 35. Prieto et al. (2006); 36. Woudt et al. (2014); 37. Motsoeledi (2014); 38. Kupfer et al. (2013); 39. Levitan et al. (2013); 40. Kato et al. (2014); 41. Carter et al. (2014); 42. Levitan et al. (2014a); 43. Levitan et al. (2014b); 44. Carter et al. (2014); 45. Carter et al. (2013)

terpreted as VY Scl type behaviour (Warner 1995b). More recently there have been alternative interpretations - for CR Boo Kato et al. (2000a) find evidence of quasi-periodic superoutbursts with time scale 46 d, and at another epoch superoutbursts on time scale 15 d (Kato et al. 2001b), whereas in V803 Cen there are claims of a 77 d supercycle at one epoch but a "standstill" and no superoutbursts at a later epoch (Kato et al. 2000a,b, 2001a). This variety of behaviour, and the light curves themselves, do not convincingly support their interpretation as dwarf nova outbursts - except for the $\sim$ 1 d outbursts following an evident superoutburst of V803 in June 2003 (Kato et al. 2004), and more recently the new AM CVn star ASASSN had a superoutburst followed by at least 6 short "echo outbursts" (Woudt et al. 2014) in close analogy of what WZ Sge did in 2001 (Patterson et al. 2002). In addition, the rise and fall time scales of many of the putative outbursts are too long to be generated by the small and hot discs of AM CVn stars. Rather, the light curves are more characteristic of VY Scl behaviour, and therefore more likely arise in $\dot{M}$ variations from the secondary. For results of a systematic survey of AM CVn star outbursts see Ramsay et al. (2012).

But there is a stronger argument against the decaday variations among AM CVn stars arising from disc instabilities, which is the observed presence of true dwarf nova outbursts on the expected time scales. In V803 Cen Patterson et al. (2000) found persistent brightness modulations when the system was at intermediate $\dot{M}$ states, with quasi-period $\sim$ 0.94 d when the mean magnitude was V $\sim$ 14.5 and $\sim$ 5 d when V $\sim$ 17.2. The rising part of the light curve has the short timescale (0.5 d rise time: Warner 1995a) expected of small helium discs, and the relatively small outburst amplitude ($\sim$ 1 mag) is a result of the high $\dot{M}$ not allowing the system to reach quiescence before the next outburst starts, as in the ER UMa type of HCV or in CN Ori (Schoembs 1982). Furthermore the increase in outburst interval TDN at lower luminosities agrees with the expectation that $T_{\rm DN} \propto 1/\dot{M}$. Similar short time scale apparent DN outbursts have been seen in CR Boo (Patterson et al. 1997), SN2003aw (Woudt & Warner

2003) and SDSS1240 (Woudt & Warner 2005). Nevertheless, it is doubtless true that the long term light curves of the "unstable" AM CVn stars have features in them (Kato et al. 2005) that have not been seen in HCVs.

The fact that, unlike the HCVs, the HeCVs can have DN outbursts when they are at intermediate levels of $\dot{M}$, is an example of behavioral difference that is of importance to the general interpretation of CVs. For example, if the absence of DN outbursts in HCV VY Scl stars is indeed due to significant magnetic fields on the primaries, then such fields appear to be absent in HeCVs. And if the VY Scl behaviour itself is due to magnetic spottedness of the secondaries, then the very low mass semi-degenerate companions in AM CVn stars suffer amazingly from acne and one would expect that magnetic braking could be a significant addition to GR braking.

I don't know what the theoreticians' attitude is to magnetic, very low mass, semi-degenerate donors, but perhaps of relevance is the rapid rotation (tens of minutes) and the fact that a kilogauss self-acting dynamo has been inferred from asteroseismology, and post-dicted, for the He white dwarf GD 358 which is a slow rotator (Winget et al. 1994; Bradley & Winget 1994; Markiel, Thomas & van Horn 1994).

4. Irradiation revisited

On the other hand, if the idea of irradiation-induced mass transfer in the HCVs is correct, we may expect to find analogous effects in the HeCVs. I have previously pointed this out (Warner 1995b), but it seems to have had little impact (despite 101 citations in the ADS list - these are to other aspects of the paper) so I reiterate and update the argument here.

That irradiation must have a significant effect on the atmospheres of the secondaries of at least the shorter period AM CVn stars is seen from the fact that at only about 1.5×10^{10}cm ($\sim$ 0.2 $R_{\rm sun}$) from the one side of the secondary there is a white dwarf with a temperature $\sim$ 5×10^4 K and luminosity $\sim$ 1 $L_{\rm sun}$. Ignoring shadowing by the disc, the fraction of the primary's radiation that is intercepted by the secondary is $R^2(2)/4a^2$, and this is re-radiated as $2\pi R^2(2)\sigma T_{\rm ir}^4$. Using the $\dot{M}$ for semi-degenerate secondaries (eqn 9.61 of Warner 1995a), a primary mass of 0.6 $M_{\rm sun}$, a mass ratio q = 0.05 and the assumption that all accretion luminosity is radiated from near the surface of the primary leads to the irradiated temperatures $T_{\rm ir}$ given in Table 2. In fact, because of the relatively small disc radii, shadowing of the secondary is less important in HeCVs than in HCVs: the ratio of total thickness to disc radius at the outer edge of the disc is 0.048 in the high model of AM CVn (Nymark & Solheim 1995), whereas in HCVs it is 0.1 - 0.15 (Smak 1992).

Table 2. Temperature of the irradiated side of the Secondary

Porb(s)	500	1000	1500	2000
Tir (K)	52 000	16 400	8340	5165

The temperatures given in Table 2 show that for the early evolution of AM CVn stars irradiation is likely to have an important effect on the internal structure of the secondaries, which as far as I know has not so far been evaluated.

Now consider the effects of irradiatively enhanced in HCVs and HeCVs. The mass transfer rate for HeCVs is only moderately sensitive to the partially degenerate structure of the mass donor. Two examples, for the Savonije, de Kool & van den Heuvel (1986) and Tutukov & Fedorova (1989) evolutionary tracks respectively, evaluated for M(1) = 0.7 and q = 0.05, are (Espaillat et al. 2005)

$$\dot{M} = 4.6 \times 10^{-12} P_{\rm orb}^{-5.21}({\rm h}) M_{\odot}{\rm y}^{-1} \quad (1)$$

$$\dot{M} = 2.3 \times 10^{-12} P_{\rm orb}^{-6.07}({\rm h}) M_{\odot}{\rm y}^{-1} \quad (2)$$

At the shortest orbital periods $\dot{M}$ is high enough to maintain the accretion disc in a high viscosity state independent of the effect of irradiation. But as $P_{\rm orb}$ decreases the relative importance of irradiation increases; when it begins to dominate there is the possibility of VY Scl behaviour as in the case of HCVs. The secular mass transfer rate predicted for HCVs, from the Verbunt & Zwaan braking law (equation 9.18b of Warner 1995a), is

$$\dot{M} \; = \; 2.0 \times 10^{-11} P_{\rm orb}^{3.2}({\rm h}) M_{\odot} {\rm y}^{-1} \qquad (3)$$

The irradiative flux $F_{\rm ir}$ on the surface of the secondary is $\propto L(1)/a^2$. Using Kepler's Third Law, L(1) $\propto$ M(1)$\dot{M}$/R(1), and R(1) $\propto$ M(1)$^{-2/3}$, we find

$$F_{\rm ir} \; \propto \; M(1)^{2/3} \dot{M} (1+q)^{2/3} P_{\rm orb}^{-4/3}. \qquad (4)$$

If a particular $F_{\rm ir}$ is required to generate the irradiation feed-back instability (but a helium atmosphere, with its lower opacity, will not react in exactly the same way as a hydrogen atmosphere) then the above equations show that we should expect the 3 - 4 h instability range in HCVs to appear at ∼ 2000 s in HeCVs, which is indeed observed.

It is possible that, as may happen in the HCVs, the low $\dot{M}$ state visited during the VY Scl phase may last long enough that the primary (whose outmost layers have been maintained hot by accretion) cools to the point where irradiation can no longer raise $\dot{M}$ to the high state again. In that case the "period gap" low state starts. In HCVs the consequence is that orbital evolution continues in the same direction as it has already followed - i.e. towards shorter orbital periods. But in HeCVs the direction is reversed - if mass transfer ceases $P_{\rm orb}$ decreases. The secondary will relax towards the smaller radius implied by the mass/radius relationship for fully degenerate secondaries (e. g. equation 2a of Espaillat et al. 2005). For $\dot{M}$ = 0 the time scale of gravitational braking (equation 9.4 of Warner 1995a) is $t_{\rm GR}$ ∼ 7 × 10^{8}y at $P_{\rm orb}$ = 2000 s. Kelvin-Helmholtz time scales for the low mass semi-degenerate secondaries of HeCVs aren't yet known (Lars Bildsten, private communication), but if they are greater than $t_{\rm GR}$ no period gap will occur. Nevertheless, there could be considerable time spent at low or zero $\dot{M}$ waiting for the Roche Lobe to shrink and catch up with the retreating surface of the secondary.

In conclusion, it is amusing to note that, just as AM CVn itself started out in life classified briefly as a quasar, two other members of the class have initially been thought of as objects of extraordinary luminosity – supernova 2003aw, which was found to be a non-supernova in a non-existent galaxy (Woudt & Warner 2003), and 2QZ J1427 which is not the Blazar that it was thought it could be (Woudt, Warner & Rykoff 2005).

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References

Abbott, T. M. C., et al. 1992, ApJ, 399, 680
Anderson, S. F., et al. 2005, AJ, 130, 2230
Anderson, S. F., et al. 2008, AJ, 135, 2108
Araujo-Betancor, S., et al. 2005, A&A, 430, 629
Belserene, E. P. 1981, BAAS, 13, 524
Bradley, P. A., & Winget, D. E. 1994, ApJ, 430, 850
Burbidge, G., Burbidge, E. M., & Hoyle, F. 1967, ApJ, 147, 1219
Burger, E., et al. 2005, ApJ, 627, 960
Carter, P.J., et al. 2013, MNRAS, 429, 2143
Carter, P.J., et al. 2014, MNRAS, 437, 2894
Cropper, M., et al. 1998, MNRAS, 293, L57
Downes, R., et al. 2005, Journal of Astronomical Data, 11, 2
Espaillat, C., et al. 2005, PASP, 117, 1189
Faulkner, J., Flannery, B. P., & Warner, B. 1972, ApJL, 175, 79
Greenstein, J. L. 1956, in Proc. 3rd Berkely Symp. Mathematical Statistics and Probability, ed. J. Neyman (Univ. California Press, Berkeley), 3, 11
Greenstein, J. L., & Matthews, M. S. 1957, ApJ, 126, 14
Hossack, W. R., & Hogg, F. S. 1949, AJ, 54, 189
Humason, M. L., & Zwicky, F. 1947, ApJ, 105, 85
Israel, G. L., et al. 2002, A&A, 386, L861
Ivanova, N., & Taam, R. E. 2003, ApJ, 599, 516
Kato, T., et al. 2000a, MNRAS, 315, 140
Kato, T., et al. 2000b, IBVS, 4915, 1
Kato,T., et al. 2001a, IBVS, 5091

Kato, T., et al. 2001b, IBVS, 5120
Kato, T., et al. 2001c, PASJ, 53, 1185
Kato, T., et al. 2004, PASJ, 56S, S89
Kato, et al. 2014, arXiv:1407.4196
King, A.R., & Cannizzo, J. K. 1998, ApJ, 499, 348
Kupfer, T., et al. 2013, MNRAS, 432, 2048
Lasota, J.-P., & Hameury, J.-M. 2004, ASP Conf. Ser., 315, 46
Lasota, J.-P., & Hameury, J.-M. 2005, astro-ph/0506382
Lenouvel, F. 1957, J. Obs., 40, 15
Levitan, D., et al. 2013, MNRAS, 430, 996
Levitan, D., et al. 2014a, ApJ, 785, 114
Levitan, D., et al. 2014b, AAS, 223, 154.16
Livio, M., & Pringle, J. 1994, ApJ, 427, 956
Malmquist, K. G. 1936, Stockholm Ann., 12, part 7
Markiel, J. A., Thomas, J. H. & van Horn, H. M. 1994, ApJ, 430, 834
Marsh, T.R., et al. 2007, ASP Conf. Ser., 372, 431
Martinez-Pais, I. G., et al. 2000, ApJ, 538, 315
Morales-Rueda, L., et al. 2003, A&A, 405, 249
Nather, R. E., Robinson, E. L., & Stover, R. J. 1981, ApJ, 244, 269
Nymark, T. K., & Solheim, J. -E. 1995, Baltic Astronomy, 4, 386
Ostriker, J. P., & Hesser, J. E. 1968, ApJL, 153, 151
Paczynski, B. 1967, Acta Astron., 17, 287
Patterson, J., et al. 1997, PASP, 109, 1100
Patterson, J., et al. 2000, PASP, 112, 625
Patterson, J., et al. 2002, PASP, 114, 65
Provencal, J.L., et al. 1997, ApJ, 480, 383
Ramsay, G., Hakala, P., & Cropper, M. 2002, MNRAS, 332, L7
Ramsay, G., et al. 2012, MNRAS, 419, 2836
Rau, A., et al. 2010, ApJ, 708, 456
Ritter, H. 1985, A&A, 145, 227
Robinson, E. L., et al. 1981, ApJ, 251, 611
Roelofs, G. H. A., et al. 2004, IAU Coll., 194, 254
Roelofs, G. H. A., et al. 2007a, MNRAS, 382, 1643
Roelofs, G. H. A., et al. 2009, MNRAS, 394, 367
Ruiz, M. T., et al. 2001, ApJ, 552, 679
Russell, H. N. 1948, Harvard Observatory Monographs, 7, 181
Savonije, G. J., de Kool, M. & van den Heuvel, E. P. J. 1986, A&A, 155, 51
Schoembs, R. 1982, A&A, 115, 190
Skillman, D. R., et al. 1999, PASP, 111, 1281
Smak, J. 1967, Acta Astron., 17, 255
Smak, J. 1992, Acta Astron., 42, 323
Solheim, J.-E., et al. 1998, A&A, 332, 939
Thorstensen, J. R., & Fenton, W. H 2002, PASP, 114, 74
Tout, C. A., Pringle, J. E. 1992, MNRAS, 256, 269
Tutukov, A. V., & Fedorova, A. V. 1989, AZh, 66, 1172
Warner, B. 1976, IAU Symp., 73, 85
Warner, B. 1995a, Cataclysmic Variable Stars (Cambridge Univ. Press, Cambridge)
Warner, B. 1995b, Ap&SS, 225, 249
Warner, B. 2002, AIP Conf. Ser., 637, 3
Warner, B., & Robinson, E. L. 1972, MNRAS, 159, 101
Warner, B., & Woudt, P. A. 2002, PASP, 114, 129
Winget, D. E., et al. 1994, ApJ, 430, 839
Wood, M. A., et al. 2002, MNRAS, 334, 87
Woudt, P. A., & Warner, B. 2001, MNRAS, 328, 159
Woudt, P. A., & Warner, B. 2003, MNRAS, 345, 1266
Woudt, P. A., Warner, B., Pretorius, M. L. 2004, MNRAS, 351, 1015
Woudt, P. A., Warner, B., & Rykoff, E. 2005, IAU Circ., 8531
Woudt, P. A., et al. 2014, in preparation
Wu, K., Wickramasinghe, D. T., Warner, B. 1995a, PASA, 12, 60
Wu, K., Wickramasinghe, D. T., Warner, B. 1995b, Astrophysics and Space Science Library, 205, 315