Cataclysmic Variable Evolution: The Role of the White Dwarf Magnetic Field

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Abstract. I review the current knowledge of the long-term evolution of CVs and discuss the possible influence of a magnetic white dwarf on properties determining the observable orbital period distribution.

1. Introduction

The study of the long-term evolution of cataclysmic variables (CVs) considers changes of system parameters on timescales $\gtrsim 10^8 - 10^9$ yr. Such changes, generally too slow to be observable in individual systems, critically determine observed collective properties where systems of any age contribute. As in most cases the orbital period P is the only accurately measured system parameter the period distribution became the prime diagnostic tool to test theories of the long-term evolution. Similarly, the period distributions of various CV subtypes provide clues to the physical interrelation of these subclasses.

Magnetic CVs (mCVs) where the white dwarf (WD) has a sufficiently strong magnetic field to affect the accretion geometry form such a distinctive subclass: the high-field polars (or AM Her systems) and the low-field intermediate polars (IPs) are characterized by well-defined observational properties (see e.g. Cropper 1990, Patterson 1994, Warner 1995). The polars are strong soft X-ray emitters, show optical/IR polarization and have a synchronously rotating WD, the IPs are harder X-ray sources and show a second periodicity due to the asynchronously rotating WD.

The emission property of polars made them to ideal targets for the ROSAT satellite which is most sensitive in the soft X-ray band. In fact, the ROSAT all-sky survey and optical follow-up studies increased the number of polars with determined period from ~ 17 previously known systems to over 50 (Beuermann & Schwope 1994; Beuermann, this volume). The "time evolving" polar period distribution stimulated recently a controversial discussion on a possible pecularity of polars and their relation to IPs. A similar observational boost for IPs is still missing.

Two recent reviews (King 1994, Chanmugam 1995) summarized concepts useful for understanding mCV evolution. This article adopts a different viewpoint by discussing evolutionary aspects in the light of what is known about non-magnetic evolution, and is organized as follows: Section 2 presents the observed period distribution for various subgroups of CVs and comments on the statistical significance of possible differences. Section 3 summarizes briefly the

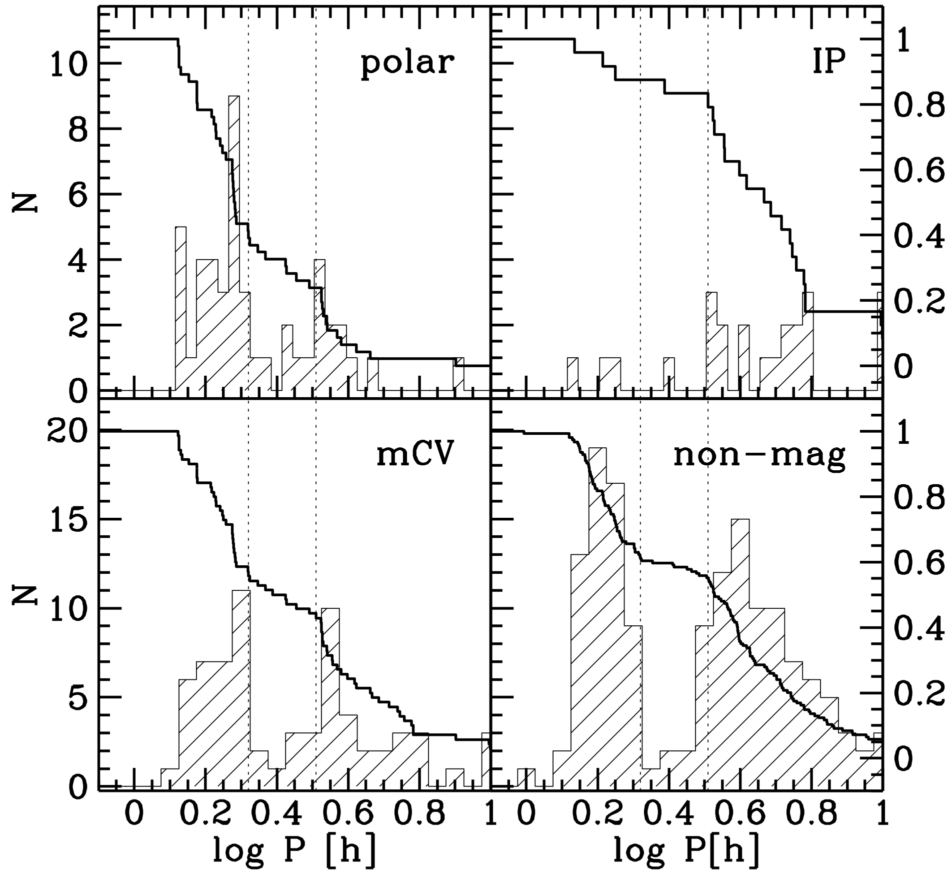

Figure 1. Period histogram (hatched; scale on the left) and cumulative period distribution (scale on the right), defined by Eq. (1), for various CV subgroups. The vertical dotted lines mark the period gap of non-magnetic CVs.

physical mechanisms determining the shape of the period distribution of CVs in general, and reports on attempts to reproduce it by population synthesis techniques. Finally Sec. 4 tries to identify the factors within this framework which may introduce differences between non-magnetic CVs and mCVs.

2. The data

Figure 1 shows the period histogram $N(P)$ and corresponding cumulative period distribution $N_\Sigma(>P)$ for polars (46 systems), IPs (24), non-magnetic CVs (155), and mCVs (polars and IPs taken together). Note that the cumulative distribution, defined by

$$N_\Sigma(>P) = \frac{1}{N_{\rm CV}} \int_P^\infty N(P')\mathrm{d}P' \,, \qquad (1)$$

where $N_{\rm CV}$ is the total number of systems in the sample, is independent of any binning and normalized to 1. The data are taken from the present version of Ritter's CV catalog (Ritter 1995, priv. comm.; see Ritter & Kolb 1995 for the most recent published version of the catalog).

The main features of the period distribution both for non-magnetic and magnetic CVs are the deficiency of systems with P between ~ 2 h and ~ 3 h (the period gap), visible in N_Σ as a period interval with smaller slope, and a short-period cut-off at $P_{\rm min} \simeq 80$ min (the mimimum period). IPs are preferentially above the gap, polars below. Until recently there was no polar known with $P > 4.6$ h, but the discovery of RXJ0515+0105 (e.g. Shafter et al. 1995; Shafter, this volume) with $P \simeq 8$ h now weakens this upper period limit.

Although the non-magnetic and magnetic CV distribution appear to be very similar, a closer inspection by eye may suggest that the relative number of systems in the period gap is higher for mCVs, clearly due to the large number of polars in the gap. This speculation does not pass a strict Kolmogorov Smirnov test: Wheatley (1995) finds no statistically significant difference between the polar and the non-magnetic period distribution and points out that the apparent overabundance of polars in the gap is partly a consequence of the small number of polars above the gap.

The polar distribution shows a further peculiar feature: 9 out of 43 systems cluster within a period interval of 3 min width at $P \simeq 114$ min, close to the lower edge of the period gap. This so-called period spike was more prominent in the pre-ROSAT sample (6 out of 17 systems, e.g. Ritter & Kolb 1992) and its statistical significance is unclear.

Apart from the orbital period a quantitative determination of the WD's surface magnetic field strength B is possible for a number of systems. In polars $7 \lesssim B/{\rm MG} \lesssim 70$ (e.g. Beuermann, this volume). In IPs the fields are believed to be significantly weaker in most cases. The only IPs with detectable polarization give B-values close to the smallest ones observed in polars: ~ 4 MG for BG CMi (Chanmugam et al. 1990), and $8 - 18$ MG for RE0751+14 (Piirola, Hakala & Coyne 1993). In contrast, about 4% of all isolated WDs are magnetic and show a much wider range of field strengths, $0.03 \lesssim B/{\rm MG} \lesssim 1000$. The distribution in $\log B$ space is almost uniform (Schmidt & Smith 1995; see also Liebert, this volume).

3. Theoretical concepts for interpreting the period distribution

The main features of the CV period distribution can be understood in terms of the standard model for the secular evolution. The following paragraphs summarize basic concepts.

3.1. Long-term evolution

Roche geometry of the secondary with mass M_2, radius R_2 and Kepler's 3rd law imply that the orbital period $P \propto R_2^{3/2} M_2^{-1/2}$. Thus

$$\frac{\dot P}{P} \propto \frac{1}{2}(3\zeta - 1)\frac{\dot M_2}{M_2}, \tag{2}$$

where ζ is the effective mass–radius exponent, defined by $\zeta = (\dot{R}_2/R_2)/(\dot{M}_2/M_2)$ $= \mathrm{d}\ln R_2/\mathrm{d}\ln M_2$. As long as ζ is close to the thermal equilibrium exponent $\zeta_{\rm eq} \simeq 1$ characterizing the ZAMS the period *decreases* on the mass loss timescale $t_{\rm M} = M_2/|\dot{M}_2|$.

Mass transfer in CVs is stable and can be sustained only by a steady extraction of angular momentum J from the orbit on a timescale $t_{\rm J} = J/|\dot{J}| \simeq t_{\rm M}$. In the generally accepted standard model (see King 1988 for a review, for more recent references see e.g. Kolb & Ritter 1992) $\dot{J}$ is due to gravitational radiation (GR, $t_{\rm J} \simeq 10^9 - 10^{10}$ yr) and, for secondaries with a radiative core ($M_2 \gtrsim 0.3 M_\odot$), magnetic stellar wind braking (MB, $t_{\rm J} \simeq 10^8$ yr, see e.g. Verbunt & Zwaan 1981, Verbunt 1984, Mestel & Spruit 1987).

The main effect of mass loss on the secondary is to perturb its equilibrium structure and to change its radius from the ZAMS value $R_{\rm eq}$ to a somewhat larger (for $M_2 \lesssim 0.6 M_\odot$) or smaller value (for $M_2 \gtrsim 0.6 M_\odot$). Establishing thermal equilibrium is associated with the Kelvin–Helmholtz time $t_{\rm KH}$, so that $t_{\rm M}/t_{\rm KH}$, the ratio of the competing timescales, is the key quantity determining the evolution. By applying simple homolgy relations to describe the secondary's reaction, Stehle, Ritter & Kolb (1995) show that the evolution is governed by the first-order differential equation

$$\zeta - \zeta_{\rm ad} = c\frac{t_{\rm M}}{t_{\rm KH}}(r^3 - r^{-8})\,, \tag{3}$$

where $c \simeq 2.5$, $r = R/R_{\rm eq}$, and $\zeta_{\rm ad}$ is the secondary's adiabatic mass–radius exponent (a function of M_2 only, $\zeta_{\rm ad} \simeq -1/3$ for $M_2 \lesssim 0.5 M_\odot$). Here $t_{\rm KH}$ refers to the star in thermal equilibrium. The most important property of Eq. (3) is the existence of an attractor solution $\zeta \simeq \zeta_{\rm eq}$, caused by the specific r–dependence of the term in parentheses. Any solution $\zeta(M_2(t))$ of Eq. (3) converges on a very short timescale $\simeq 0.05 t_{\rm KH}$ to this attractor solution if the time variability of $\tau_{\rm J}$ is reasonably small.

The period gap is identified with a detached phase the systems pass (unrecognizable as CVs) when the secondary becomes fully convective (Rappaport, Verbunt & Joss 1983; Spruit & Ritter 1983). At this moment it is believed that the secondary's surface magnetic field strength drops, or the field configuration changes (Taam & Spruit 1989), both of which would lead to a discontinuous decrease of magnetic braking. As a consequence the secondary detaches from its Roche–lobe, contracts and regains thermal equilibrium. Mass transfer resumes on a much smaller rate when gravitational radiation has shrunken the orbit enough that the secondary fills its Roche lobe again.

The existence of an attractor in Eq. (3) guarantees that CVs with different initial configurations (i.e. different initial WD mass $M_{1,\rm i}$ and secondary mass $M_{2,\rm i}$) evolve in a uniform way and that the detached phases of individual systems appear as period gap in the distribution of the whole population of CVs.

One of the more serious problems of this standard model is that observationally derived values for the mass transfer rate $\dot{M}$ (e.g. Patterson 1984, Warner 1987) suggest a considerable intrinsic scatter of $\dot{M}$ (on factors 10–100) for a given orbital period, whereas the attractor property of Eq. (3) enforces an almost unique $\dot{M}$–P relation. Although oscillations of $\dot{M}$ about the secular mean value on timescales $\simeq 10^6$–10^7 yr too short to change the mean evolution were invoked as standard explanation (e.g. Hameury, King & Lasota 1989a), it is only now that a plausible physical mechanism causing such oscillations has been found (King et al. 1995; Ritter, Zhang & Kolb 1995a,b): under the weak, anisotropic irradiation of the secondary by the WD the system alternates between high states in which irradiation forces the mass donor to expand slowly, driving an elevated mass transfer rate, and low states in which the secondary contracts.

3.2. Discovery probability

As was pointed out already by Ritter & Burkert (1986) observational selection plays an important role for the discovery probability of a given CV system.

The discovery probability $p(x) \propto V/\dot{x}$ for a system with given initial configuration ($M_{1,\mathrm{i}}$, $M_{2,\mathrm{i}}$) and evolution $[P(t), \dot{M}(t)]$ at a certain configuration x within the bin Δx depends on the time $\propto 1/\dot{x}$ spent in Δx and the space volume V over which systems with configuration x can be observed. To lowest order $V \propto L^{\gamma}$, where L is the system's luminosity. Note that $L \propto \dot{M}$ since accretion is the dominant energy source. The selection exponent γ depends on the source distribution in physical space and on the CV's brightness in the waveband used to detect the source. For an isotropic source distribution a $\mathrm{m_{bol}}$–limited sample is characterized by $\gamma = 3/2$, whereas $\gamma \simeq 1$ for a $\mathrm{m_{vis}}$–limited sample of accretion disk systems (Dünhuber 1994, Dünhuber & Ritter 1993). As an example, the discovery probability over orbital period reads

$$p(\log P) \propto \frac{P}{\dot{P}} \left(\frac{M_2}{t_{\mathrm{M}}} \right)^{\gamma} \propto \frac{M_2^{\gamma}}{3\zeta - 1} t_{\mathrm{M}}^{1-\gamma} \,, \tag{4}$$

where Eq. (2) was used. Since observed samples like CVs with determined orbital period may represent a mixture of systems detected by different methods (or even by chance), a prescription for V (or L) is difficult to find. Moreover, any variability of the source increases its detectability, an effect even harder to describe in quantitative terms.

The sum of individual discovery probabilities (4) over all possible initial component masses, weighted by the corresponding birth rate b, and integrated over the past star formation history finally yields the observable period distribution for the present CV population (see e.g. Kolb 1993):

$$N(\log P) = \int_0^{T_{\mathrm{G}}} \int \int b(t')\, V\, \frac{P}{\dot{P}}\, \mathrm{d}M_{1,\mathrm{i}} \mathrm{d}M_{2,\mathrm{i}} \mathrm{d}t \,, \tag{5}$$

where T_{G} is the age of the Galaxy. To compute $N(\log P)$ further input describing the formation of CVs is needed.

3.3. Formation of CVs

In the currently accepted picture CVs form from initially much wider main–sequence binaries which undergo dynamically unstable mass transfer when the more massive primary fills its Roche lobe as an evolved giant. This gives rise to a common envelope (CE) phase: energy is extracted from the orbit to eject the giant's envelope, leading to a spiral–in of the secondary (see e.g. Iben & Livio

1993 for a review). The exposed core of the giant (the future white dwarf) and the low–mass secondary may either coalesce during this process, or survive the CE phase as a close detached binary with a short orbital period, subsequently evolving into contact by orbital angular momentum losses.

The statistics of CV formation have been studied by a number of authors (Politano 1988, 1990; Tutukov, Yungelson & Iben 1992, and references therein; de Kool 1992; Han, Podsiadlowski & Eggleton 1995), using simple analytic approximations to stellar evolution models. One of the most uncertain ingredient in these calculations is the description of the CE phase itself, usually parameterized in terms of the envelope ejection efficiency $\alpha_{\rm CE}$ (see e.g. de Kool 1990). Typically, the models predict an intrinsic CV space density $\sim 10^{-4}$ pc^{-3}.

A detailed CV population synthesis (Kolb 1993) shows that the *shape* of the period distribution is mainly determined by the secular evolution $\dot{P}(t)$ (hence by equilibrium properties of low-mass stars, cf. Eq. (3)), whereas the total number of CVs in the sample and the number ratio of systems below to above the gap is strongly influenced by selection effects and parameters entering the determination of the formation rate (such as $\alpha_{\rm CE}$).

These remarks, summarized in Eq. (5), call for a cautious interpretation of observed data like the period distributions of CV subgroups, since any of the determining factors — evolution, formation and selection — may cause differences between the samples.

4. Application to magnetic CVs

Guided by the fact that CVs evolve towards shorter orbital periods, and that the WD synchronizes against accretion torques essentially when the orbital distance becomes comparable to the WD magnetospheric radius (Hameury et al. 1987), early models for mCV evolution identified the IPs as long-period progenitors of polars, implicitely assuming that IPs and polars have similar field strengths (Chanmugam & Ray 1984; King, Frank & Ritter 1985). It is now believed that IPs generally have weaker fields — consistent with the non-detection of polarization. Hence the high-field non-synchronously rotating progenitors of polars at longer orbital periods are still to be identified, the only bona-fide pre-polar candidate amongst IPs known so far being RE0751+14 ($P \simeq 5.6$ h; see Sec. 2).

The following paragraphs address this progenitor problem and other puzzles discussed in Sec. 2 in the context of how the WD magnetic field affects the way CVs form, evolve and appear.

4.1. Formation

It is usually assumed that the strong WD magnetic field has its origin in a much weaker field, amplified during previous contraction phases by magnetic flux conservation (e.g. Chanmugam 1992). These weaker fields generated e.g. by dynamo processes in the earlier stellar evolution would have little influence on stellar structure, so that the evolution prior to the CE phase is likely to be the same for mCVs and non-magnetic CVs. Similarly for the CE phase itself: assuming that the WD magnetic field was already frozen into the red giant's core at the onset of the CE, simple estimates show that a field with a magnetic moment $\mu_1 \simeq 10^{34}$ Gcm^3 typical for polars becomes dynamically important only when the CE is essentially over (King et al. 1994). Thus one expects no influence of the magnetic field on the outcome of the CE phase. On the other hand, mCVs could belong to a certain subset of the progenitor population, e.g. to binaries with an Ap star primary. Such a subset, however, would still produce the standard features in the period distribution of CVs.

Regös & Tout (1995) take a completely different view: they point out that the late CE phase gives rise to a magnetic dynamo capable to generate the WD's later magnetic field even if the core was initially not magnetic at all. Their model predicts a correlation of field strength with post-CE orbital separation, such that systems leaving the CE in an almost semi-detached state have the strongest fields. This implies a maximum field strength $B_{\rm max}(P)$ for any mCV with orbital period P, $B_{\rm max}$ being the larger the smaller P, providing a natural explanation for the observed upper field-limit of ~ 70 MG in polars. Isolated WDs with stronger fields could be interpreted as products of an "unsuccessful" CE phase leading to coalescense. A further consequence of this model is to bring $\alpha_{\rm CE}$ close to 1.

4.2. Selection effects

As mCVs are X-ray sources they are usually considered as essentially X-ray selected. Although this is certainly true for the post-ROSAT sample of polars, Patterson (1994) raises doubts about this view for IPs. X-ray selected samples, in turn, may be described to lowest order as $m_{\rm bol}$–limited samples, as opposed to non-magnetic CVs which are believed to be closer to a $m_{\rm vis}$-limited sample. In the $m_{\rm bol}$–selected distribution the high mass transfer systems above the period gap attain a stronger weight due to the higher value of γ in Eq. (4). Consequently the relative number of systems above the gap increases from $\simeq 50\%$ for $m_{\rm vis}$-limited samples to roughly 90%. Surprisingly this is consistent with the observed IP distribution, but not with the polar or the combined mCV distribution. Clearly a more sophisticated description for the selection effects has to account for the detailed emission properties of mCVs. This would require a more complete understanding of the complex processes involved (e.g. King 1995, this volume). As an example, King & Lasota (1993) explain the "missing" long-period polar progenitors by blobby accretion inhibiting the production of X-rays.

4.3. Evolution

The speculations concerning mCV evolution usually aim at the strength of magnetic braking in polars and fall into three groups, obviously reflecting the lack of our present understanding: 1) models with enhanced MB, 2) models with standard MB, and 3) models with reduced MB. In this context it is interesting to note that the secondary's magnetic moment expected from dynamo relations, $\mu_2 \simeq 650$ G/(P/h) (e.g. Hameury, King & Lasota 1989a), is comparable to the observed magnetic moment of the WD in polars, $\mu_1 \simeq 10^{34}$ Gcm^3.

Enhanced magnetic braking Liebert & Stockman (1985) and King (1985) independently suggested that the secondary's stellar wind couples to the WD

magnetic field, making magnetic braking the more effective the larger μ_1. The consequences of such enhanced MB would be a rapid evolution, making high-field systems short-lived and unobservable (Schmidt, Stockman & Grandi 1986; Hameury, King & Lasota 1989b). Qualitatively the expected evolution is (in order of decreasing WD magnetic moment):
a) "catastrophic", i.e. the induced mass transfer rate is so high that a CE forms and the system coalesces,
b) very fast, leading to increasing orbital periods (ζ is close to $\zeta_{\rm ad} < +1/3$),
c) fast, with high mass transfer rate; the system does not detach when the secondary becomes fully convective, crosses the period gap as a bright system and may reach a minimum period significantly longer than 80 min.; it may even evolve back into the gap,
d) faster than for non-magnetic CVs, leading to a wider period gap (Hameury et al. 1987) and possibly a broader period spike at turn-on below the gap (see below), filling the short-period part of the gap,
e) as for non-magnetic CVs.

The attractive features of this picture are the explanation for the upper field limit in polars and a mCV overabundance in the period gap (although no systematic investigation exists to underline these findings in a more quantitative way). However, there is no detailed physical model supporting the assumption that a strong WD field increases MB.

Standard magnetic braking The only physical explanation for the 114 min. period spike proposed so far attributes the feature to the turn-on of mass transfer below the period gap within the framework of the standard model (Hameury et al. 1988). At turn-on the initial adiabatic response of the secondary onto mass transfer ($\zeta = \zeta_{\rm ad} \simeq -1/3$) leads to a short phase of increasing orbital period, until thermal relaxation restores the usual period decrease ($\zeta \simeq \zeta_{\rm eq} \simeq 0.8$). As a consequence the systems pass each period twice, and are brighter as the usual secular mean during the first passage, both increasing the discovery probability. Certain restrictions of the systems' initial parameters are required in order not to smear the spike to unrecognizable width: these are surprisingly mild for the progenitor MS+MS binary (Ritter & Kolb 1992). Both numerical simulations (Ritter & Kolb 1992) and analytical approximations (Stehle, Ritter & Kolb 1995) show that the relative width of the spike $\Delta P/P$ is proportional to $t_{\rm KH}/t_{\rm J}$, and that $\Delta P \simeq 3$ min. is expected for $\dot{J} = \dot{J}_{\rm GR}$.

Neither the enhanced nor the reduced MB concept provides any model for the period spike, which of course poses no problem as long as one believes that the spike is statistically insignificant and needs no further explanation.

Reduced magnetic braking Li, Wu & Wickramasinghe (1994a) considered the situation of a synchronously rotating WD in a CV where both the secondary and the WD have counteraligned dipolar fields perpendicular to the orbital plane. From an analytical analysis (see also Li et al. 1995, this volume) in the spirit of the Mestel & Spruit (1987) description for magnetic stellar wind braking they find that the field lines of WD and secondary star connect and produce extended dead zones where the stellar wind is trapped. The corresponding reduction of flux along open field lines leads to a considerable reduction of the magnetic braking efficiency. Although the situation considered is clearly idealized (counteraligned dipoles are presumably not stable, see e.g. King, Frank & Whitehurst 1990; neither the secondary nor the WD field is a pure dipole) the differential effect — reduced MB for high-field WDs — seems plausible. On the other hand the quantitative estimates by Li, Wu & Wickramasinghe (1994a, b; see also Wickramasinghe, this volume) should be taken with caution; note that in the limit of vanishing WD field these authors fail to reproduce the magnitude of MB needed to explain the period gap for non-magnetic CVs. Instead, a systematic study of the effect of reduced MB (adequately parameterized) on the period distribution of a mCV population might provide further insight.

The most extreme assumption is to assume that polars synchronize almost instantly when they emerge from CE (Wickramasinghe & Wu 1994), and that GR is the only sink of orbital angular momentum (the "non-MB scenario"). The resulting period distribution, calculated easily using a population synthesis technique, cannot account for the observed reduced number density of polars in the period gap and for the long-period cut-off (Kolb & deKool 1993, 1994). The attempt to explain the maximum field-strength in polars within this framework requires the *additional* assumption that all polars emerge from CE at periods longer than $\simeq 8$ h (King et al. 1994). This is hard to justify in view of standard model predictions for CV formation — consistent with the observed distribution of orbital period and secondary mass in known pre-cataclysmic binaries — that the majority ($\gtrsim 70\%$) of the present CV population has formed with a fully convective secondary (King et al. 1994), and therefore at periods short enough to turn-on mass transfer (below the period gap) under the influence of GR only.

Relaxing some of the pure "non-MB" assumptions leads to a more complex situation. First of all, the torques acting to synchronize *detached* systems (pre-CVs emerging from CE) are poorly known. Any non-trivial (non-neglibible) synchronization timescale would influence the CV formation rate distribution. Second, CVs which synchronize *during* their evolution at a period $P_{\rm sync}$ enter a detached phase provided $\dot{J}_{\rm MB}$ drops sharply (see e.g. King & Kolb 1995 for a general criterion for when a system detaches). An ensemble of CVs with a range of magnetic field strengths could then cause a period distribution like the one observed for polars: the low-field systems would evolve uniformly, producing the standard period gap, whereas the high-field systems disturb this pattern by detached phases located at individual periods $P_{\rm sync}$ determined by the respective field strength.

This synchronization induced detached phase requires a discontinuous decrease of $\dot{J}_{\rm MB}$ by at least a factor ~ 3 when synchronism is achieved. In reality the transition could be more gradual, depending on the velocity of fieldline reconnection for non-synchronous rotation, or the drop in $\dot{J}_{\rm MB}$ could be much less than proposed by Li et al. A related problem concerns the strength of MB in systems driven out of synchronism, either by a nova explosion (as observed for V1500 Cyg, see e.g. Schmidt, Liebert & Stockman 1995), or at turn-on of mass transfer when accretion torques spin up the WD.

Further effects Apart from MB there are at least two further potential ways a magnetic WD could influence the long-term evolution.
1) Nova explosions (discussed in detail by Livio 1995, this volume; see also Livio 1994): The WD magnetic field could inhibit mixing on the WD surface, thereby reducing the strenghth of the outburst, the ejecta mass and metalicity. For

such slow novae frictional drag of the secondary orbiting in the nova envelope can cause substantial orbital angular momentum losses (Livio, Govarie & Ritter 1991), leading to an accelerated evolution similar to the enhanced MB case.
2) Irradiation-induced mass transfer cycles (see Sec. 3.1): these may or may not exist in polars: the radiation generated by the accretion column is more anisotropic and much harder than for non-magnetic CVs, it may miss the secondary, or be absorbed before it can affect the secondary. There are, however, observations showing clear signs of an illuminated secondary in some mCVs (e.g. V834 Cen; Schwope et al. 1993). If the cycles occur, it is likely that the WD cannot maintain synchronism during the high state where the mass transfer rate may be 10 times larger than the secular mean. Since the predicted cycle length $\sim 10^6$ yr is comparable to estimated values for the synchronization time ($10^5 - 10^6$ yr; Hameury, King & Lasota 1989a) the WD may never synchronize. The irradiation instability found by Ritter, Zhang & Kolb (1995) disappears for $M_2 \lesssim 0.5 M_\odot$ since the sub-photospheric superadiabatic convection zone acting as valve controlling the secondary's reaction becomes too thin. Taken at face value these results would explain the absence of long-period synchronous systems (but of course not the non-detection of non-synchronous polar progenitors).

5. Conclusions

The evolution of mCVs is far from being understood. Not surprising, results from recent satellite missions, in particular ROSAT, shed light on many aspects of mCV physics, but at the same time reveal an even larger number of new problems.

Although the number of factors determining the shape of the CV period distribution seems to be confusingly large, all concepts proposed for understanding mCV evolution share one common feature: polars, IPs and non-magnetic CVs do not form disjunct classes, rather they represent members of a CV population characterized by a wide and continous range in WD magnetic field strength B. To determine whether critical values of B separating groups with very different evolutionary behaviour really exist, or whether the differences in the observed system properties can be understood by continuously varying selection effects on top of a more or less uniform evolutionary picture, progress in the theoretical understanding of emission properties for a given system configuration, magnetic braking in the presence of a magnetic WD, as well as a systematic investigation of its influence on the resulting period distribution, is needed. A further increase in the number of known mCVs is of similar importance, since, after all, only improved statistics can finally decide about the significance of specific features in the magnetic field and orbital period distribution of CVs.

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