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NOVA OUTBURSTS ON MAGNETIC WHITE DWARFS

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ABSTRACT

We examine the question of nova outbursts on magnetic white dwarfs among AM Her systems. We study in particular the effects of the presence of a strong magnetic field on the development of a thermonuclear runaway (TNR). The magnetic field is capable of weakening the outburst both through the inhibition of shear and diffusion mixing (which results in lower enrichments by heavy elements) and by interference with the development of convection during the TNR (which results in lower ejection velocities). The apparent absence of classical novae among AM Her systems may nevertheless have been due to selection effects, which are a consequence of the lower accretion rates below the period gap and the very narrow range in mass ratios capable of producing novae below the gap.
Subject headings: stars: novae — stars: magnetic — stars: stellar statistics

I. INTRODUCTION

The existence of magnetic fields in the white dwarf components of cataclysmic variables has by now been established for ~ 24 objects (see e.g., Schmidt and Liebert 1986 for a recent review). Of these, 12 objects are of the AM Herculis type (polars) and ~ 10 are of the DQ Herculis type (intermediate polars). It has also been recognized that the presence of the magnetic field can have important consequences for the evolution of cataclysmic binaries (e.g., Lamb and Melia 1986; Hameury *et al.* 1987, and references therein). The evolution of magnetic fields in white dwarfs has recently been calculated (Wendell, Van Horn, and Sargent 1987).

Two DQ Her systems have exhibited nova outbursts: DQ Her (in 1934) and V533 Her (in 1963). Recently it has been suggested that the light curve of V1500 Cyg shows a striking resemblance to that of AM Her stars. In addition, the strength of its He II $\lambda4686$ line is also characteristic of magnetic systems (Kaluzny and Semeniuk 1987; Chlebowski and Kaluzny 1987). Polarization measurements revealed a significant ($\sim 3\%$) circular polarization in the system's optical light (Schmidt, Smith, and Elston 1987). If these observations are confirmed, then V1500 Cyg will be the first classical nova (CN) among AM Her systems (with CP Pup being another likely candidate; Warner 1985). In fact, it was the apparent absence (until now) of CN among polars that led Livio (1983) to examine the question whether the presence of a strong magnetic field could prevent nova outbursts from occurring. He found that the funneling of the material onto a small polar cap area could have the effect of increasing the effective accretion rate (see also Ferland and Truran 1980). If matter were to remain confined to the polar cap, this would result in strong compressional heating, ignition under very weakly degenerate conditions, and no strong outbursts. Livio (1983) has also shown that, *if boundary instabilities are neglected*, the field in AM Her systems is sufficiently strong to prevent the diffusion of matter perpendicular to the field lines (see also Hameury and Lasota 1985). However, *it is very unlikely that instabilities can be ignored*, once the pressure in the accreted material becoms comparable to the magnetic field pressure. It can therefore be expected that material will eventually spread over the entire white dwarf surface.

Rose and Scott (1976), using qualitative arguments, first commented on the effect of a magnetic field on the nova outburst. In the present work, we examine the question of nova outbursts occurring on the surface of magnetic white dwarfs using a hydrodynamic stellar evolution code. We study, in particular, the influence of the magnetic field on convection, during the development of the thermonuclear runaway. The basic assumptions and method of calculation are described in § II, and the results are presented in § III. A discussion and conclusions follow.

II. ASSUMPTIONS AND METHOD OF CALCULATION

The presence of a strong magnetic field can influence the development of a TNR through the following main processes. (i) The funneling of the accreted material onto the polar caps increases the effective accretion rate over the cap area. As we shall see, however, matter is very likely to spread at later stages over the entire white dwarf surface. (ii) The absence of accretion disks in the AM Her systems (Lamb and Melia 1986) prevents shear mixing from occurring (Livio and Truran 1987; Fujimoto 1986), and thus enrichment by heavy elements can take place only via diffusion (Prialnik and Kovetz 1984) or overshooting induced by flame propagation (Woosley 1987). (iii) The magnetic field interferes with the development of convection during the TNR.

Let us now examine the processes described in (i)–(iii) above.

a) Funneling and Spreading

The magnetic fields of AM Her stars are found to lie in the range $B \approx (2\text{–}4) \times 10^7$ G (Schmidt and Liebert 1986) corresponding to magnetic moments $\mu \approx 10^{33}\text{–}10^{34}$. The condition for the existence of an accretion disk is given roughly by (Lamb and Melia 1986)

$$R_{\rm A}^{\rm disk} \lesssim X^2 R_{\rm L_1} , \tag{1}$$

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where $R_A^{\rm disk}$ is the Alfvén radius for the disk, R_{L_1} is the radius of the Lagrangian point L_1, and $X \approx 0.3$–0.4 depends on the stream angle (Lubow and Shu 1975), although from observations X is inferred to be somewhat larger. Condition (1) translates into $\mu \gtrsim 10^{33}$ G cm^3 (for the largest white dwarf mass, 1.4 $M_\odot$) below the period gap, and thus AM Her systems are not expected to have accretion disks. Instead, the accreted material is channeled onto the polar cap. The fractional polar cap area f, can be estimated very crudely using a kinematic model and a dipole field (e.g., Davidson and Ostriker 1973)

$$f \approx 2.6 \times 10^{-3}\left(\frac{B}{10^7\ \rm G}\right)^{-4/7}\left(\frac{M_{\rm WD}}{M_\odot}\right)^{3/7}\left(\frac{R_{\rm WD}}{6 \times 10^8\ \rm cm}\right)^{-5/7} \times \left(\frac{\dot{M}}{10^{-9}\ M_\odot\ \rm yr^{-1}}\right)^{2/7} . \quad (2)$$

The hydrogen-rich accreted material accumulates at the pole for as long as the energy density at the base of the accretion column remains small compared to the magnetic energy density (e.g., Livio 1984). When the gas pressure becomes comparable to the magnetic pressure, however, the field lines become distorted, and matter is expected to break the confinement, because the center of curvature is within the plasma, via the operation of interchange instabilities (e.g., Roberts 1967. p. 244) and spread over the entire white dwarf surface. The time scale to build up the necessary pressure can be estimated using equation (2) to be

$$\tau \approx 2 \times 10^3\left(\frac{B}{10^7\ \rm G}\right)^{10/7}\left(\frac{M_{\rm WD}}{M_\odot}\right)^{-4/7}\left(\frac{R_{\rm WD}}{6 \times 10^8\ \rm cm}\right)^{23/7} \times \left(\frac{\dot{M}}{10^{-9}\ M_\odot\ \rm yr^{-1}}\right)^{-5/7} \rm s , \quad (3)$$

Which is extremely short compared to the time scale for the runaway to occur: $\sim 10^4$–10^5 yr (at 10^{-9} $M_\odot$ yr^{-1}; e.g., Truran and Livio 1986). The picture that emerges, therefore, is one in which matter accretes onto the poles, but then at short intervals breaks the confinement and spreads over the whole white dwarf surface, building one spherical shell on top of another. The exact form of the development of the instability is at present unknown, since most existing studies either treat only the magnetostatic configuration (e.g., Hameury and Lasota 1985) or treat simplified problems (e.g., Basko and Sunyaev 1976). However, since the time scale on which spreading is expected to occur is many orders of magnitude shorter than the time scale on which the TNR conditions are achieved, the exact form of the spreading is not important for the TNR development.

b) *The Interaction of Convection with the Magnetic Field*

The influence of magnetic fields on convection has been recently examined by Tayler (1986), following the original work by Gough and Tayler (1966). The effect of the magnetic field is to impede convective motions perpendicular to the field lines. In the context of the mixing length theory, the introduction of the magnetic field transforms the difference between the actual temperature gradient and the adiabatic one, $\nabla - \nabla_{\rm ad}$ into (Tayler 1986)

$$\nabla - \nabla_{\rm ad}^1 = \frac{\nabla - \nabla_{\rm ad}}{1 + (B^2/16\pi v_{\rm con}^2)} , \quad (4)$$

Where $v_{\rm con}$ is the average convection velocity and we have assumed a mixing length to pressure scale height ratio of 1. In addition, the instantaneous convective velocities are changed by

$$v_{\rm con} = \left(v_0^2 - \frac{B^2}{16\pi\rho}\right)^{1/2} , \quad (5)$$

where v_0 is the velocity in the absence of the magnetic field. The changes represented by equations (4) and (5) have been incorporated into the treatment of convection and into the calculation of the convective flux. The critical value for the onset of convection becomes (λ_1 is a parameter of order unity).

$$\nabla_{\rm crit} = \nabla_{\rm ad}^1 + \lambda_1 \frac{B^2}{4\pi P} . \quad (6)$$

For our numerical calculations, we have used the one-dimensional hydrodynamic code described by Kutter and Sparks (1972) and by Starrfield, Truran, and Sparks (1978), augmented by the treatment of spherical accretion described by Starrfield, Sparks, and Truran (1985). The spherically symmetric treatment is probably quite adequate for the long accretion time scales associated with TNRs, as explained in § II*a* above. In the absence of an accretion disk and its associated shear mixing in AM Her systems, the only mechanisms that can produce enrichment by heavy elements, in principle, at least are diffusion and convective overshoot. For a constant accretion rate of 10^{-9} $M_\odot$ yr^{-1} onto a white dwarf of mass 1 $M_\odot$, a heavy-element mass fraction of $Z \approx 0.1$ was achieved in the calculations of Kovetz and Prialnik (1985). Higher enrichments are obtained for lower accretion rates. In view of the considerable uncertainties involved and because enrichment by convective overshoot has not yet been fully explored, we have decided to perform calculations for a range of assumed values of Z in the envelope.

III. NUMERICAL COMPUTATIONS

Most of the calculations were performed on a 1.25 $M_\odot$ white dwarf; several representative calculations for a 1.0 $M_\odot$ white dwarf were included for comparison. In addition, we performed calculations with parameters appropriate for V1500 Cyg, in view of the fact that this system may be an AM Her system. The accretion rate in most cases was taken to be $\dot{M} = 1.58 \times 10^{-9}$ $M_\odot$ yr^{-1}. This value is higher than typical accretion rates observed in AM Her systems (Patterson 1984; Warner 1987) but is typical for nova calculations. It was chosen to allow a comparison to be made with calculations performed in the absence of a magnetic field. In addition, we have performed calculations with $\dot{M} = 1.58 \times 10^{-10}$ $M_\odot$ yr^{-1} (and the parameters of V1500 Cyg). In order to maximize the strength of the outburst and to study the net effect of the magnetic field on convection, with its associated implications for mass ejection, we first performed a series of calculations for matter of assumed composition $Z = 0.5$ (actually $X_{\rm C} = 0.5$). As we shall emphasize later, much lower enrichment levels are in fact expected in the presence of a magnetic field. The results obtained for different field strengths are summarized in Table 1. The maximum field strength we have chosen (3×10^8 G) is larger than any observed in AM Her systems, but it is not larger than the largest fields observed in isolated white dwarfs (Schmidt and Liebert 1986; Schmidt 1986). The light curves for the different models M0, M2E7, M5E7, M3E8 (corresponding to $B = 0$, 2×10^7, 5×10^7 and 3×10^8 G, respectively) are presented in Figures 1–4. As can be seen, increasing the field

TABLE 1

CHARACTERISTICS OF MODEL CALCULATIONS

Model	M_{WD} ($M_\odot$)	E^{nuc}_{max} (erg g^{-1} s^{-1})	Z	B (Gauss)	$\dot{M}$ ($M_\odot$ yr^{-1})	M_{env} ($M_\odot$)	M_{ej} ($M_\odot$)	v (km s^{-1})	$K.E.$ (erg)
M0	1.25	1.28×10^{16}	0.5	0	1.58×10^{-9}	7.8×10^{-6}	5.3×10^{-7}	2077	...
M2E7	1.25	1.28×10^{16}	0.5	2×10^7	1.58×10^{-9}	7.8×10^{-6}	5.3×10^{-7}	1924	...
M5E7	1.25	1.27×10^{16}	0.5	5×10^7	1.58×10^{-9}	7.8×10^{-6}	5.3×10^{-7}	1595	...
M3E8	1.25	1.26×10^{16}	0.5	3×10^8	1.58×10^{-9}	7.8×10^{-6}	...	...	...
M03A	1.25	5.47×10^{15}	0.3	0	1.58×10^{-9}	1.1×10^{-5}	5.3×10^{-7}	843	3.8×10^{42}
M03B	1.25	5.39×10^{15}	0.3	2×10^7	1.58×10^{-9}	1.1×10^{-5}	1.5×10^{-7}	911	1.2×10^{42}
M02A	1.25	4.17×10^{15}	0.2	0	1.58×10^{-9}	1.3×10^{-5}	1.7×10^{-6}	1200	2.4×10^{43}
M02B	1.25	4.08×10^{15}	0.2	3×10^7	1.58×10^{-9}	1.3×10^{-5}	3.2×10^{-7}	809	2.0×10^{42}
M02C	1.25	4.07×10^{15}	0.2	5×10^7	1.58×10^{-9}	1.3×10^{-5}	1.5×10^{-7}	1180	1.6×10^{42}
M1A	1.00	1.38×10^{15}	0.3	0	1.58×10^{-9}	3.0×10^{-5}	6.4×10^{-6}	754	...
M1B	1.00	1.36×10^{15}	0.3	3×10^7	1.58×10^{-9}	3.0×10^{-5}	...	...	...
M01	1.00	4.02×10^{14}	0.1	2×10^7	1.58×10^{-9}	4.7×10^{-5}	...	...	...
M(−10)1	1.00	2.75×10^{15}	0.3	0	1.58×10^{-10}	4.1×10^{-5}	1.0×10^{-5}	1680	...
M(−10)2	1.00	2.71×10^{15}	0.3	2×10^7	1.58×10^{-10}	4.1×10^{-5}	8.6×10^{-6}	1580	...
MCyg1	1.25	3.70×10^{16}	0.3	0	7.00×10^{-12}	1.3×10^{-5}		2018	...
MCyg2	1.25	3.59×10^{16}	0.3	2×10^7	7.00×10^{-12}	1.3×10^{-5}		1954	...
MCyg3	1.25	4.73×10^{15}	0.15	2×10^7	7.00×10^{-12}	2.0×10^{-5}	2.1×10^{-6}	1500	...

strength results in lower ejection velocities in this case, through to the point at which no mass ejection takes place. Since the maximum energy generation rate is essentially the same (and large) in all models, it is clear that it is the interference of the magnetic field with the transport of energy and of beta unstable nuclei to the outer mass layers (at the right moment) that influences mass ejection. This is demonstrated in Figure 5, in which the mass involved in the convective region as a function of time is plotted for the different models. The abundance of the beta unstable nuclei in the outermost convective zone drops, as one goes from the $B = 0$ case to the models with magnetic fields, and, since the energy release provided by the decay of these nuclei is quite essential for mass ejection (Truran, Shankar, and Livio 1987), the drop in the ejection velocities is quite understandable. The results for $Z = 0.5$ indicate that, while the magnetic field does influence the violence of

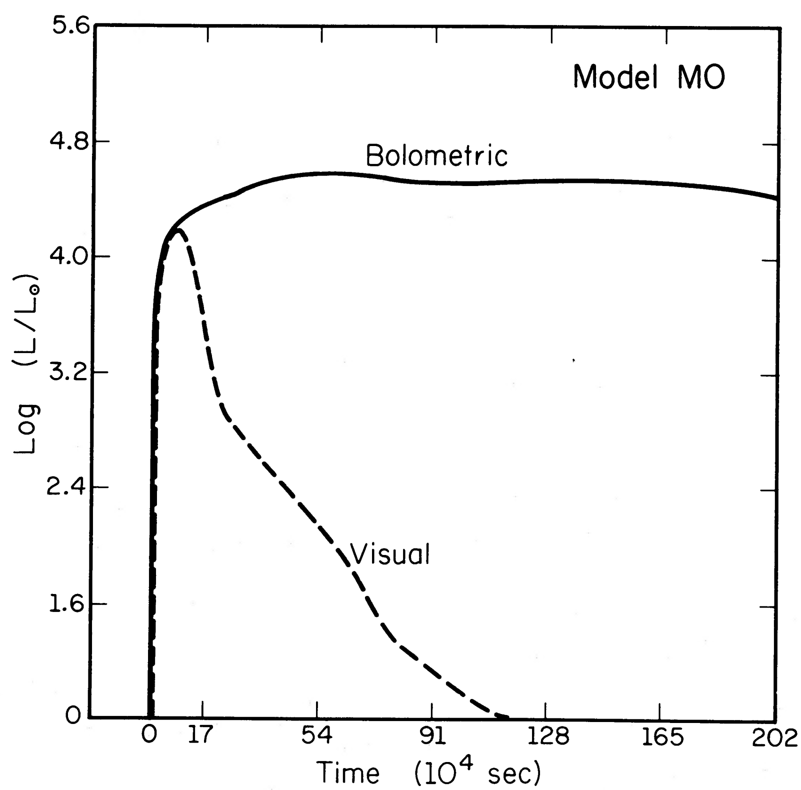

FIG. 1.—Bolometric and visual light curves obtained for model M0 (see Table 1)

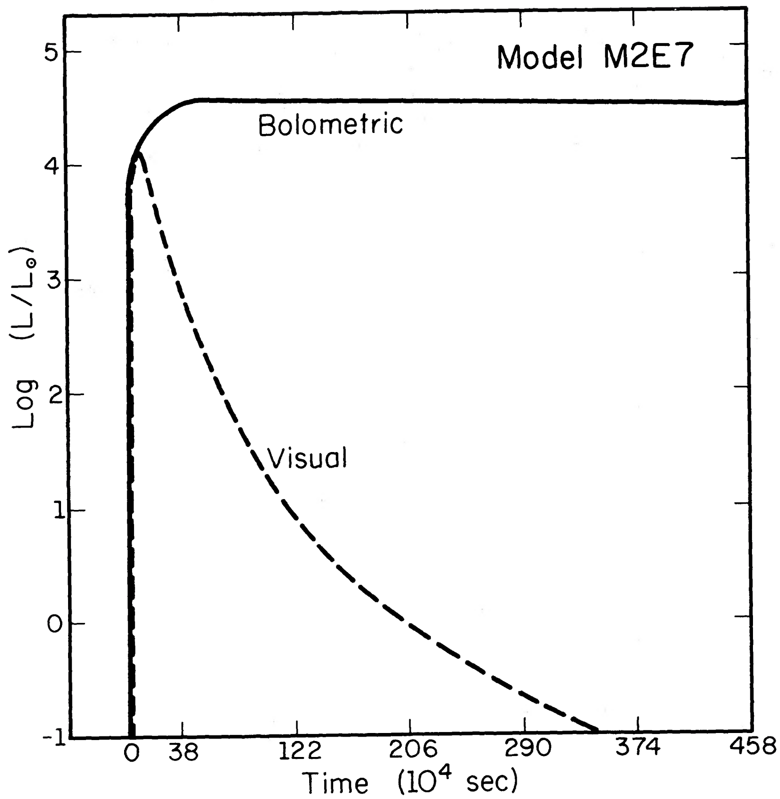

FIG. 2.—Bolometric and visual light curves obtained for model M2E7 (see Table 1)

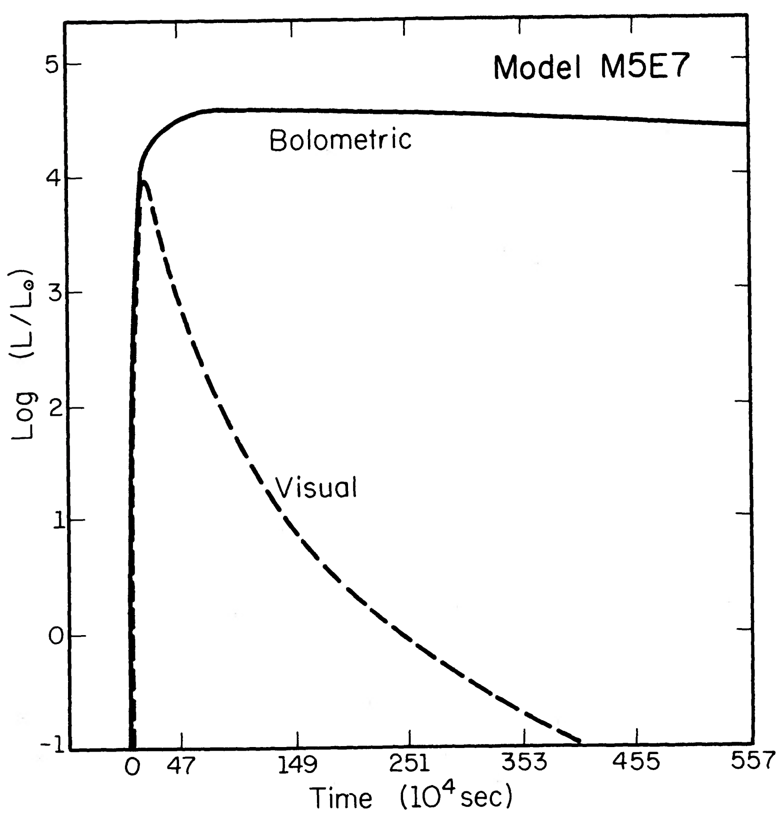

FIG. 3.—Bolometric and visual light curves obtained for model M5E7 (see Table 1)

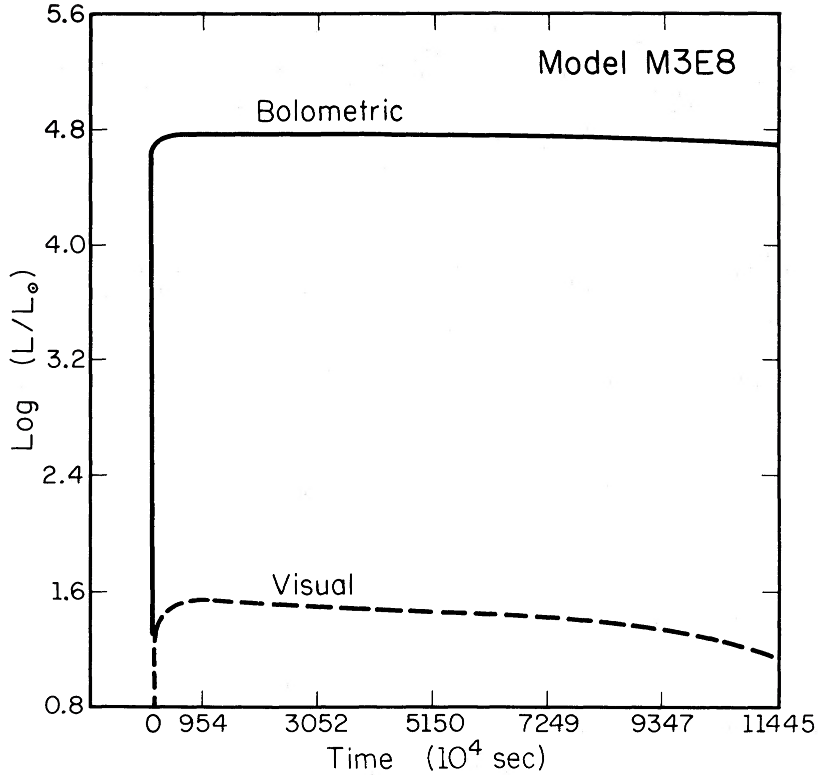

FIG. 4.—Bolometric and visual light curves obtained for model M3E8 (see Table 1)

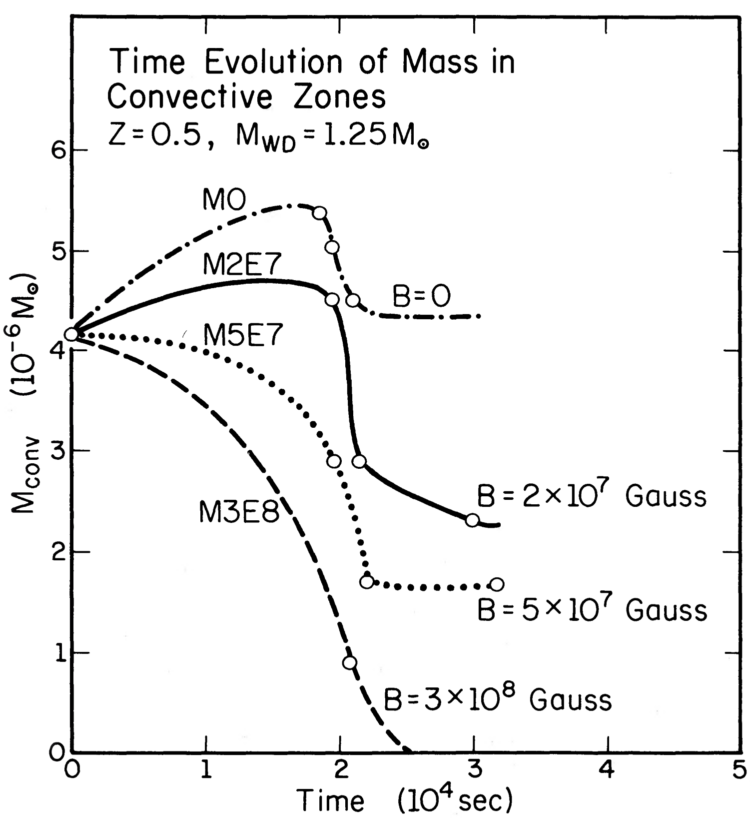

FIG. 5.—Mass involved in the convective regions as a function of time for the models in Figs. 1–4

the outburst (as reflected in the ejection velocities), the TNR for this (heavy-element–rich) configuration is sufficiently strong to ensure that a nova-type outburst is obtained for all but the largest field strengths.

The situation becomes somewhat more ambiguous as the TNR strength is reduced, in the presence of lower levels of enrichment of heavy elements. For example, for $Z = 0.3$, in the $B = 0$ case (model M03A) a mass of $M_{ej} = 5.3 \times 10^{-7}\ M_\odot$ is ejected at 843 km s^{-1}, while in the $B = 2 \times 10^7$ G case (model M03B) a much lower mass, $M_{ej} = 1.5 \times 10^{-7}\ M_\odot$ is ejected at a somewhat higher velocity $V_{ej} = 911$ km s^{-1} (see Table 1). A similar situation is obtained for $Z = 0.2$, for which case, in the transition from $B = 0$ (model M02A) to $B = 3 \times 10^7$ G (model M02B), less mass is ejected at a lower velocity (see Table 1); however, increasing the magnetic field strength to $B = 5 \times 10^7$ G (model M02C) results in a still lower mass ejected at a higher velocity. The kinetic energy of the ejecta, however, shows a monotonic decrease (with increasing field strength), as can be seen from Table 1. The issue of this seemingly arbitrary increase in the maximum ejection velocities with increasing field strength is a complex one. An exhaustive analysis of the $Z = 0.2$ case (sequence M02A → M02B → M02C) was nevertheless carried out. The evolution of the light curves and radius for this sequence is presented in Figures 6–7. The observed shift of the visual peak (and of radial expansion) later in time with increasing field strength can be understood in terms of the delayed beta-decay activity in the outer layers of the envelope. Further work is clearly required to allow us to understand fully this phenomenon.

The effect of the magnetic field is demonstrated perhaps in the most dramatic way in calculations of accretion onto a 1 $M_\odot$ white dwarf (models M1A, M1B). In this case, the calculation with no magnetic field (for $Z = 0.3$, $\dot{M} = 1.58 \times 10^{-9}\ M_\odot$ yr^{-1}) resulted in the ejection a mass of $6.4 \times 10^{-6}\ M_\odot$ at a velocity of 754 km s^{-1}. A calculation with $B = 3 \times 10^7$ G resulted in no mass ejection, but nevertheless a visually bright nova (Fig. 8). The influence of the magnetic field on the development of convection for this case is presented in Figure 9. Here again, the transport of the beta unstable nuclei was significantly inhibited in the $B = 3 \times 10^7$ case.

A calculation with $Z = 0.1$ and a magnetic field of $B = 2 \times 10^7$ G for a 1.0 $M_\odot$ white dwarf (model M01), resulted in no mass ejection and a very weak TNR (see Fig. 10). When Z approaches the solar value, we reach the situation in which only very weak TNRs are obtained for models involving a 1.0 $M_\odot$ white dwarf. This is a result of the fact that for accretion rates above $\sim 10^{-9}\ M_\odot$ yr^{-1}, only weak TNRs ensue, due to the strong compressional heating and ignition under weakly degenerate conditions. Thus the weakness of the flash in this situation can be attributed much more to the mass of the white dwarf and the relatively high accretion rate (and lower Z), than to the presence of magnetic field. In order to demonstrate that this is indeed the case, we evolved a model for the conditions $M_{WD} = 1\ M_\odot$, $\dot{M} = 1.58 \times 10^{-10}\ M_\odot$ yr^{-1} and $Z = X_C = 0.3$. We found that a mass $1.0 \times 10^{-5}\ M_\odot$ was ejected at a velocity $V_{max} = 1680$ km s^{-1} in the $B = 0$ case [model $M(-10)$1], while a mass $\Delta M_{ej} = 8.6 \times 10^{-6}\ M_\odot$ was ejected at $V_{max} = 1580$ km s^{-1} in the $B = 2 \times 10^7$ case [model $M(-10)2$]. Thus, the magnetic field had very little effect in this case.

The next model we calculated involved parameters that can be appropriate for the V1500 Cyg system. We considered a white dwarf of mass 1.25 $M_\odot$, since there are indications that the white dwarf in this system is massive (Lance, McCall, and Uomoto 1987). The magnetic field was taken to be

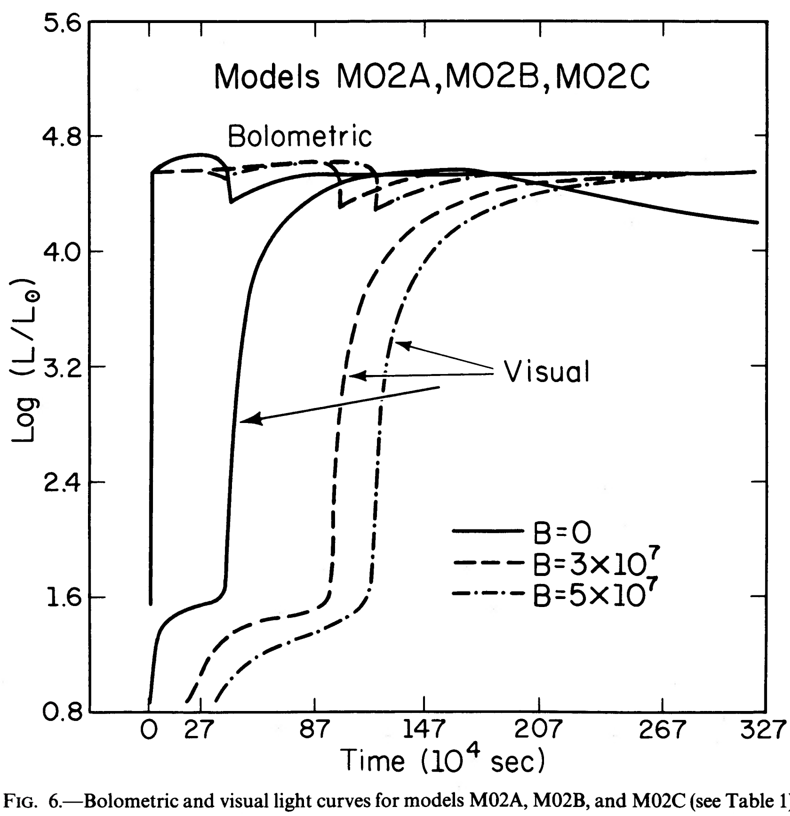

FIG. 6.—Bolometric and visual light curves for models M02A, M02B, and M02C (see Table 1)

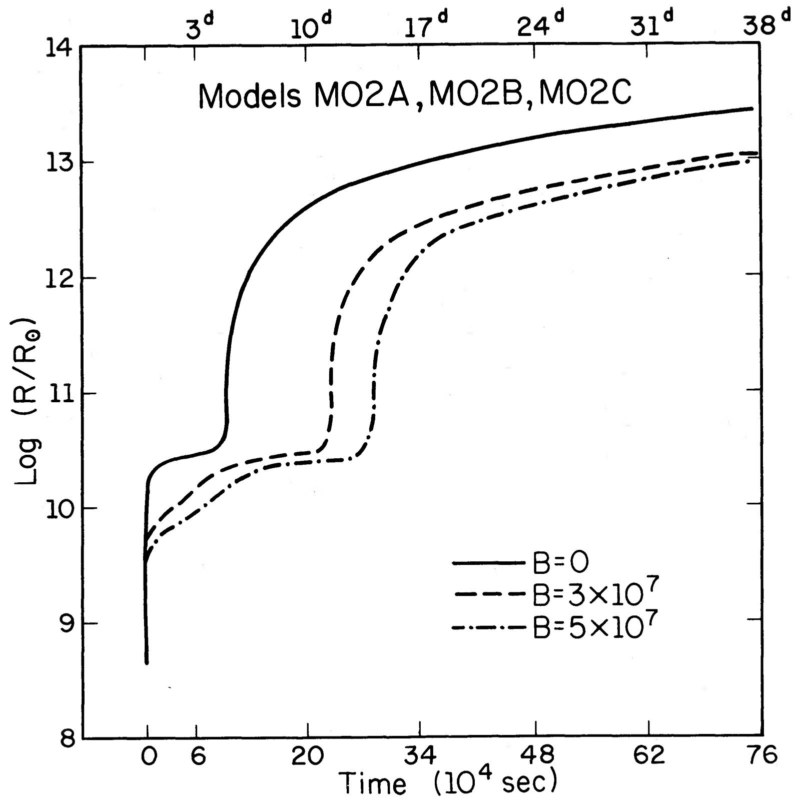

FIG. 7.—Radius of the accreted envelope as a function of time for models M02A, M02B, and M02C

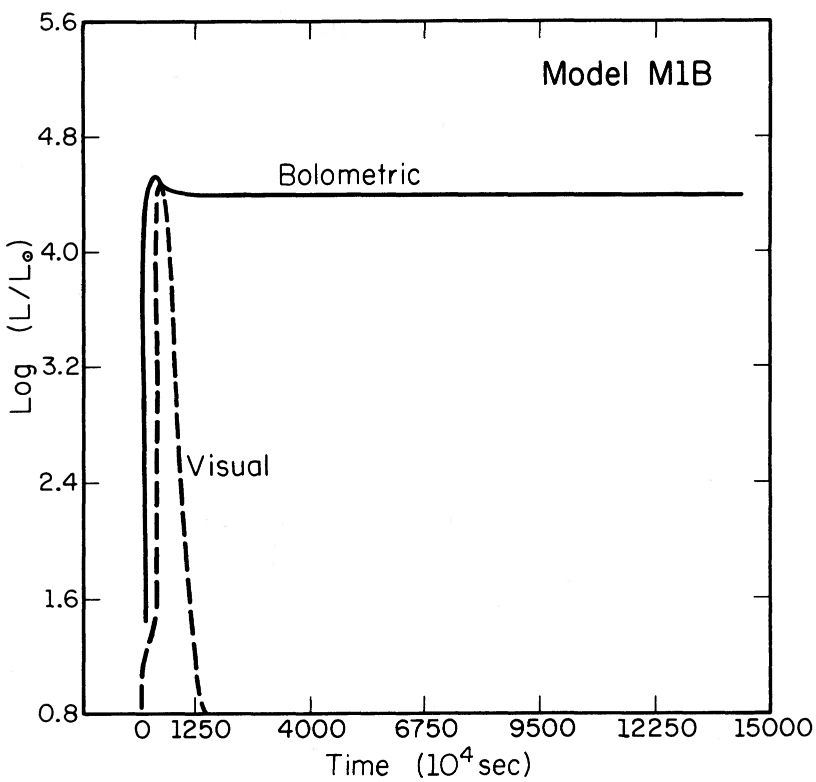

FIG. 8.—Bolometric and visual light curves obtained for model M1B (see Table 1)

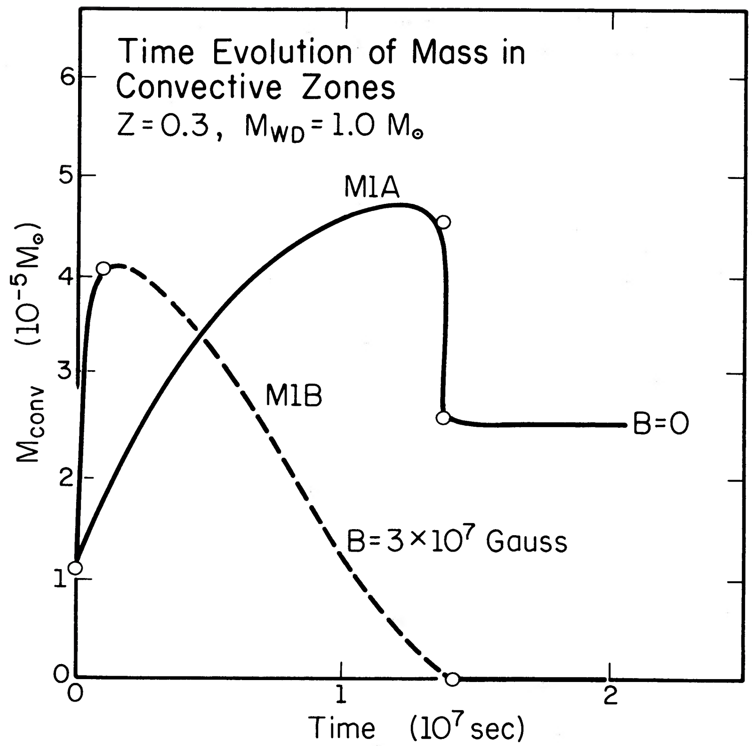

FIG. 9.—Mass involved in the convective regions as a function of time for models M1A, M1B

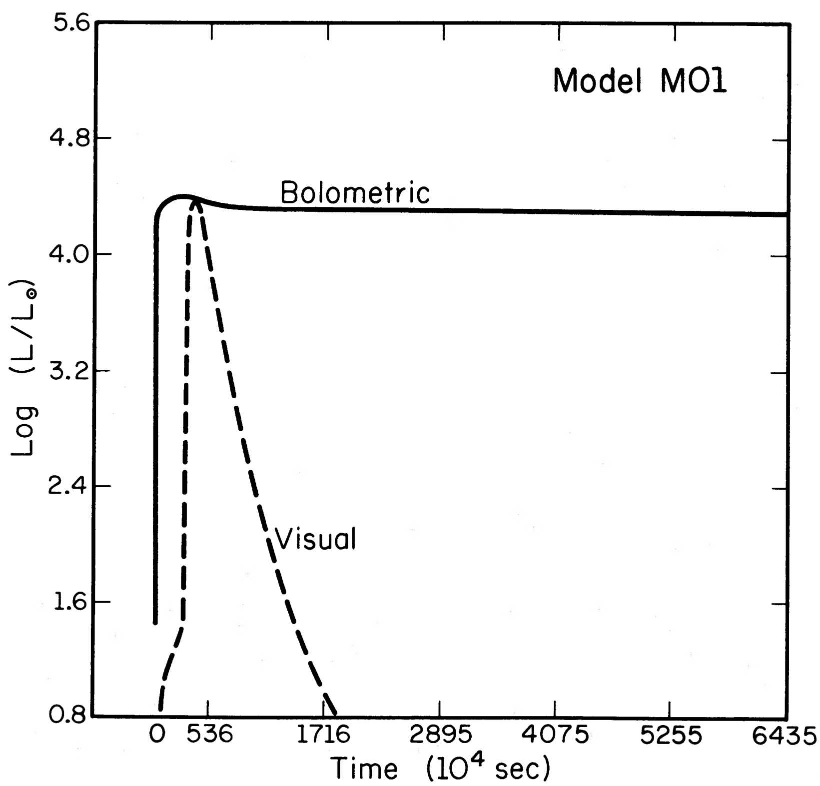

FIG. 10.—Bolometric and visual light curves for model M01 (see Table 1)

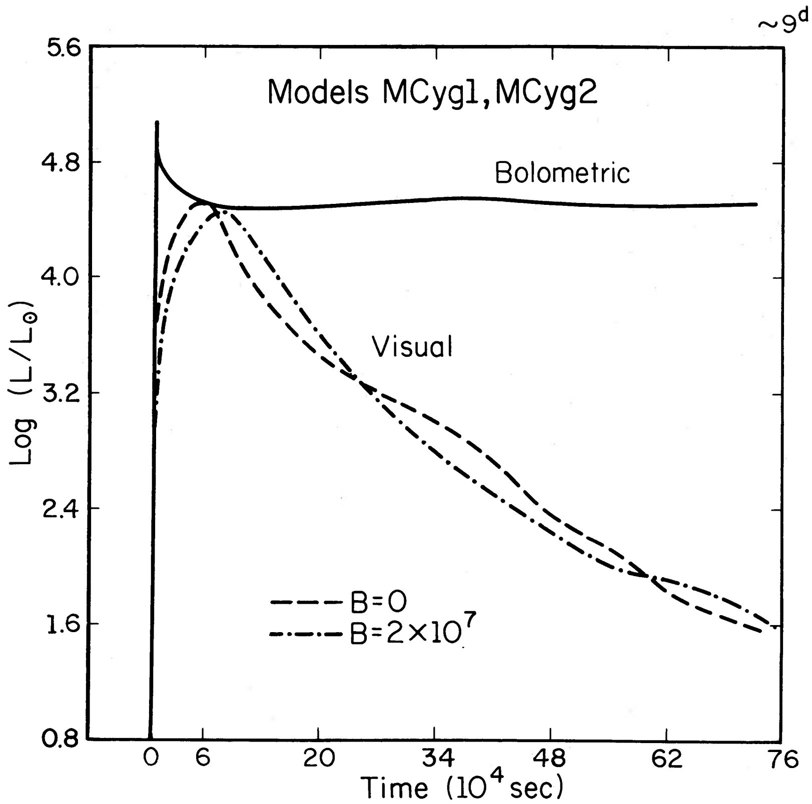

FIG. 11.—Bolometric and visual light curves for models MCyg1 and MCyg2 (see Table 1)

$B = 2 \times 10^7$ G, a typical value for AM Her systems. We used an accretion rate, implied by observations at quiescence (Livio and Shara 1987), of $\dot{M} = 7 \times 10^{-12}\ M_\odot\ \mathrm{yr}^{-1}$. There is some ambiguity concerning the mass fraction of the heavy elements in the ejecta. While Ferland and Shields (1978) found $Z = 0.3$, a more recent analysis concludes that $Z = 0.15$ (Lance *et al.* 1987). We calculated models for both choices of compositions. The results show (models MCyg1, MCyg2, MCyg3, and Fig. 11) that, *for massive white dwarfs and low accretion rates, strong outbursts are produced irrespective of the presence of the magnetic field.*

In the next section, we discuss classical nova outbursts on magnetic white dwarfs in the light of the present and previous results.

IV. DISCUSSION AND CONCLUSIONS

For the past several years, the apparent absence of classical nova eruptions among AM Her systems has been considered somewhat puzzling. If future observations should confirm the suggestion by Chlebowski and Kaluzny (1987) and Schmidt *et al.* (1987) that V1500 Cyg is an AM Her system, however, then it becomes clear that this was *entirely due to selection effects.* Accretion rates in CVs below the period gap (where mass transfer is probably driven by gravitational radiation) are considerably lower (and show a narrower range) than above the gap (where mass transfer may be driven by magnetic braking), as can be seen from the accretion rates deduced by Patterson (1984) and Warner (1987). If we adopt the mass transfer rate from the Verbunt and Zwaan (1981) prescription for magnetic braking, we obtain for the ratio of the recurrence time of nova outbursts above and below the gap (Livio 1987)

$$\frac{\tau_{\mathrm{above}}}{\tau_{\mathrm{under}}} \approx 2.3 \times 10^{-2} M_{\mathrm{WD}}^2 M^{-2/3} P_4^{-2.18} P_2^{-0.26}\ , \qquad (7)$$

where M_{WD} and M are the white dwarf and total mass, respectively (in solar units), P_4 is the orbital period above the gap (in 4 hr units), and P_2 is the orbital period below the gap (in 2 hr units). Since almost all AM Her systems are found below the period gap, this immediately introduces a strong selection effect against observing nova eruptions in these systems. Furthermore, only a narrow range in mass ratios $0.12 \lesssim q \lesssim 0.22$ is allowed for nova systems below the gap (Livio and Shara 1987). This is a consequence of the fact that violent classical nova-like outbursts are not obtained on white dwarfs less massive than $\sim 0.6\ M_\odot$. The narrow range in mass ratios provides a second constraint, acting against finding classical novae among AM Her systems under the period gap (see, however, Livio 1987).

In the present work, we have examined the influence of the presence of a strong magnetic field on the TNR development. This is of practical interest since Nova Cygni 1975 provided an extremely spectacular outburst. We found that, as long as the accreted material is sufficiently enriched in heavy elements, mass ejection may be affected by the magnetic field, but a visually bright nova outburst can still be obtained. The magnetic field interferes with the development of convection in such a way as to impede the transport of beta unstable nuclei and of energy (at the critical time) to the outermost mass zones, which are the ones to be ejected. In very extreme cases, the magnetic field can inhibit mass ejection completely, although the light curve is only slightly affected (in enriched Z configurations).

The effect of the presence of a strong magnetic field can become more pronounced (in principle at least), if its possible consequences for the process of envelope enrichment in heavy elements are taken into consideration. The accretion flows in

AM Her systems are channeled onto the polar caps, thus eliminating shear induced turbulence as an effective source of mixing (Livio and Truran 1987; Fujimoto 1986). This leaves only diffusion and convective overshoot at the bottom of the accreted layers as possible mechanisms for mixing heavy elements into the accreted envelope (Prialnik and Kovetz, 1984; Woosley 1987). However, diffusion operates by introducing small amounts of hydrogen into the core, where it can ignite and burn and drive convection, which in turn is the real agent by which mixing takes place. Therefore, if inhibition of convection by the magnetic field occurs, it can significantly reduce the degree of mixing by diffusion. This, as we have seen, has the effect of considerably weakening the TNR. In fact, for low white dwarf masses ($\lesssim 0.7\ M_{\odot}$), thermonuclear runaways proceeding in accreted envelopes of solar composition do not result in classical nova-type outbursts (for accretion rates $\dot{M} \lesssim 10^{-10}\ M_{\odot}\ \mathrm{yr}^{-1}$). It is thus possible for very strong magnetic fields (in fact larger by a factor 10 from the ones in AM Her systems) to prevent more violent nova eruptions from occurring (for low mass white dwarfs), through the inhibition of mixing of heavy elements into the accreted material. This argument does not apply if significant mixing can occur via various flame propagation mechanisms (Woosley 1987). Such a mixing was not obtained, however, in recent calculations that did not assume mixing length theory (Hillebrandt 1987). It is perhaps important to note that the level of enrichment determined by the recent analysis of the ejecta of V1500 Cyg (Lance *et al.* 1987) is in fact lower (by more than a factor 2) than the one expected even by mixing induced by diffusion alone (Kovetz and Prialnik 1985). This may reflect the inhibiting effects of the presence of the magnetic field.

We note, in conclusion, that the apparent absence of classical novae among AM Her systems was very probably entirely due to selection effects which result from lower accretion rates below the period gap and the relatively narrow range of mass ratios capable of producing nova eruptions. Strong magnetic fields, however, can also affect nova eruptions. The magnetic field interferes with the development of the TNR mainly through the channeling of the accreted material onto the polar caps and by impeding convection at crucial stages of the runaway. This in itself can result in somewhat lower ejection velocities (for relatively low mass white dwarfs) but not in a total suppression of the TNR, as long as heavy elements are allowed to mix into the envelope. The prevention of shear-induced mixing (by inhibiting disk formation) and possibly the reduction of diffusion mixing (by interfering with convection) can have the important consequence of weakening the TNR, in particular for relatively low-mass white dwarfs. Nevertheless, *For massive white dwarfs, in the presence of low accretion rates and some degree of heavy-element enrichment, the strength of the outburst is almost unaffected by the presence of a magnetic field.* In particular, we have demonstrated that for parameters appropriate for V1500 Cyg, an extremely strong outburst can indeed be obtained with high ejection velocities.

It should be noted that a magnetic field of $B \sim 6 \times 10^5$ G, as suggested for DQ Her (Lamb, and Patterson 1982), is too low to have any significant effect on convection (this has been confirmed by a full numerical calculation), and thus DQ Her stars with similar fields can definitely exhibit normal nova outbursts. If, however, DQ Her stars have fields of the same strength as AM Her stars, as suggested by King *et al.* (1985), then some weakening of the TNR should occur for relatively low mass white dwarfs. This does not appear to be the case for DQ Her itself (see also Livio and Truran 1987 for discussion).

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