THE ASTROPHYSICAL JOURNAL, 327: L77–L79, 1988 April 15

THE PERIOD DISTRIBUTION OF CATACLYSMIC VARIABLES

J. M. HAMEURY, A. R. KING,[1,2] AND J. P. LASOTA
Observatoire de Paris, Section de Meudon

AND

H. RITTER
Universitätssternwarte München
Received 1987 November 13; accepted 1988 January 8

ABSTRACT

In a recent paper, Warner and Livio claim that the AM Her and SU UMa cataclysmic variables (CVs) with periods $P < 2$ hr show a tendency to cluster in disjoint period ranges. We show that the statistical significance of this result is entirely due to the large accumulation of AM Her systems in the range 113.5–114.8 minutes. We have shown elsewhere that this period spike is probably caused by the resumption of mass transfer after the systems cross the 2–3 hr period gap. We emphasize that the "synchronization-induced gap" mechanism of Lamb and Melia is based on an incorrect assumption about the contraction time scale of a mass-losing secondary star and cannot produce any significant gap in the period distribution of AM Her systems or lead to the formation of ultrashort-period CVs, as claimed by Lamb and Melia.

Subject headings: stars: accretion — stars: binaries — stars: evolution — stars: magnetic

I. INTRODUCTION

Most CVs with $P < 2$ hr are in either the SU UMa or AM Her subclasses. The distribution of the AM Her systems is far from uniform, as no less than six out of the 10 systems lie in the range 113.5–114.8 minutes. Morris *et al.* (1987) already showed that this spike was statistically significant when only five members were known. Warner and Livio (1987, hereafter WL) analyze the combined distribution of AM Her and SU UMa systems and claim that this shows a tendency for the two classes to lie in disjoint period ranges. Recently, we (Hameury *et al.* 1987*a*, hereafter HLKR) have shown that the period spike of the AM Her's can be explained as a result of the short adiabatic expansion episode undergone by the secondary star when mass transfer restarts after the systems have crossed the 2–3 hr period gap. The sharpness of the spike probably follows from the restricted range of white dwarfs masses favored by selection effects (Ritter and Burkert 1986), which are particularly strong for X-ray–selected objects, as many of the AM Her's (unlike SU UMa's) are. If correct, this explanation is very strong support for the proposal that the period gap occurs when the driving angular momentum loss mechanism for $P > 3$ hr is drastically reduced, possibly when the secondary becomes fully convective (Rappaport, Verbunt, and Joss 1983; Spruit and Ritter 1983). We show below that the clustering claimed by WL disappears if the period spike is removed from the distribution. Thus, if our explanation for the spike is correct, there is no evidence for any tendency for the AM Her's and SU UMa's to avoid each other's period ranges. WL discuss the possibility that the "synchronization-induced period gap" mechanism (hereafter abbreviated to SIG) proposed by Lamb and Melia (1987*a*, *b*, *c*) might produce clustering of AM Her periods. HKLR point out that this mechanism cannot produce observable effects; we indicate here the basic argument.

[1] Also Université Paris 7, France.
[2] Also Astronomy Department, Leicester University, UK.

II. PERIOD CLUSTERING

To establish the importance of the AM Her period spike for the result claimed by WL, we reanalyze the data they give (their Table 1) in the following ways:

1. In order of increasing period, WL data give the distribution

ASSSASSSSSSAASSSSSSSSSSAAAAAASS

in an obvious notation. This has a probability of 4.8×10^{-3} of occurring by chance if the underlying distribution were uniform. However, it is apparent that this result must depend strongly on the string of six As near the upper end of the period range. The probability of such a string is only 6.3×10^{-3}. Considering only systems with periods shorter than those in the spike (which then forces the longest period to be that of an S), we find a probability of 0.11 that the distribution could occur by chance.

2. WL suggest that EX Hya and V2051 Oph may be classed as S and A, respectively. Adding these systems gives a probability for the full distribution of 3.1×10^{-3}. The AM Her period spike has now a probability of 0.010. Considering again only periods below the spike gives a probability of 0.026 (i.e., about 2 σ). This result depends very strongly on the presence of an A at the shortest period of all: a single S at a shorter period would increase the probability to 0.20. We note that the catalog of Ritter (1987*a*) lists two systems at shorter period than EF Eri, WL's shortest period system (A). One (HV And) may bé an AM Her; the shortest period is now that of AF Cam, tentatively classified as a U Gem dwarf nova. In the past, all such systems discovered below the period gap have later been reclassified as SU UMa's following the observation of one or more superoutburst from them.

3. WL find a probability 1.4×10^{-4} for the observed distribution in the range 90–115.2 minutes where most of the systems lie. The probability of six consecutive As is 2.1×10^{-3}; again, considering only periods below the spike (in this range) raises the probability to 0.10.

4. The full list of systems (Ritter 1987*a*) below the gap and

above the minimum period gives 10 AM Her among 35 systems in all. The probability of six consecutive As is 3.8×10^{-3}. Removing these systems as before raises the probability to 0.43.

5. Counting as before V2051 Oph and EX Hya as A and S respectively, the six consecutive As have a probability of 7×10^{-3}; removing them gives a probability of 0.15.

We finally note that the latest (unpublished) version of Ritter's catalog contains three more systems with periods below the gap: BR Lup, NSV 12615, and FS Aur, with periods of 113.6, 88.45, and 85 minutes, respectively. BR Lup appears to be inside the AM Her 114 minute spike, and the inclusion of these three systems strengthens our conclusions. We conclude that the low probability found by WL results from the presence of the AM Her period spike. This is highly significant, whereas the absence of SU UMa's in the 6.67 minute period range 98.45–105.12 minutes is not, having a probability of 0.55. There is no evidence that the SU UMa and AM Her systems avoid each others' period ranges.

III. SYNCHRONIZATION-INDUCED PERIOD GAP?

WL consider the possibility that the SIG mechanism of Lamb and Melia (1987*a*, *b*, *c*) might lead to period clustering but conclude that this is unlikely. In fact this mechanism can produce neither clustering nor the formation of ultrashort-period CVs claimed by Lamb and Melia. The mechanism appeals to the idea that synchronizing the white dwarf with the binary orbit in a magnetic CV must increase the binary separation, by injection of the spin of the white dwarf angular momentum directly to the orbit. Lamb and Melia claim that this is sufficient to bring the secondary star out of contact and turn off mass transfer, and that this can lead to a prolonged gap. They further claim that for short ($P < 1.5$ hr) periods the secondary has time to cool to the hydrogen degenerate sequence, and thus leads to the formation of an ultrashort-period binary. None of these claims is correct. The basic reasons for this are as follows (HKLR):

1. The increase in orbital separation which synchronization can produce is at best of the order of the surface scale height of the secondary star. As repeatedly emphasized in the literature (see, e.g., Ritter 1987*b* for a fuller discussion), the "rim" of the secondary is not infinitely steep, so that the mass transfer is sensitive to Roche lobe movements of at least a scale height.

2. Even if sufficient separation is achieved, a prolonged gap does not follow unless the basic driving angular momentum loss mechanism is drastically reduced, as is indeed postulated in the standard explanation for the 2–3 hr period gap (Rappaport, Verbunt, and Joss 1983; Spruit and Ritter 1983). Point (1) is fairly obvious on calculating the maximum angular momentum of the white dwarf prior to synchronization, taking account of the fact that there is an upper limit to the spin rate if the star is to go on accreting. The result is that the ratio of the variation of the stellar radius R_2 to the atmospheric scale height $\Delta R_2/H$ is usually less than 1 for typical values of the parameters, so that the mass transfer rate will not be affected.

Even allowing that $\Delta R_2/H$ may be >1, no significant gap will result. The reason is that, unlike the standard gap formation mechanism, the SIG mechanism does not change the rate at which the Roche lobe shrinks down on the surface of the secondary star; it merely gives the stellar surface a small start in a race which it must inevitably lose. HKLR show that the Roche lobe radius R_L shrinks faster than the stellar radius during the detached phase because of the dynamical stability condition, and that the detached phase lasts a time

$$t_{\text{detached}} = \frac{\Delta R_2}{R_L}\left(\frac{2}{t_J} - \frac{\Delta L}{L}\frac{1}{t_{\text{KH}}}\right)^{-1} , \tag{1}$$

where $\Delta L/L$ is the relative luminosity deficit, and t_J and t_{KH} are the angular momentum loss and Kelvin-Helmholtz time, respectively. The term in parentheses is positive provided that mass transfer was stable prior to synchronization. It is seen that t_{detached} is much less than the time t_{KH} for the star to shrink to the degenerate sequence in the way suggested by Lamb and Melia (1987*a*, *b*, *c*), if the mass transfer is to be dynamically stable prior to synchronization. They appear to have assumed that the star shrinks on a time scale t_{KH}, whereas it actually reacts on the longer time scale $(L/\Delta L)t_{\text{KH}}$. HKLR discuss other rather remote possibilities for making the mechanism work, such as a hypothetical decrease in angular momentum losses when the secondary detaches from the Roche lobe. They conclude that possible nonlinearities are never strong enough in a binary system to make it unstable to finite amplitude perturbations, while it must be stable to infinitesimal perturbations.

The recently discovered AM Her system V1500 Cyg (Schmidt and Stockman 1987) probably has a white dwarf spin period 1.5% shorter than the orbital period. It is clear that the ultimate synchronization of this system, as envisaged by Hameury *et al.* (1987*b*), will not cause any long-term interruption of mass transfer.

IV. CONCLUSION

We have shown that the only significant peculiarity in the distribution of short-period CVs is the period spike of the AM Her systems. There is no evidence that the AM Her and SU UMa systems avoid each other's period ranges as suggested by Warner and Livio (1987). We emphasize that the "synchronization-induced–gap" mechanism of Lamb and Melia (1987*a*, *b*, *c*) is founded on two incorrect assumptions and cannot lead to the effects claimed.

We thank Mario Livio for stimulating discussions. J. P. L. thanks the SERC for support under the short-term visit program of the Astronomy Department/X-Ray Astronomy group at the University of Leicester. H. R. acknowledges support by the Deutsche Forschungsgemeinschaft, grant Ku 474/8-2.

REFERENCES

Hameury, J. M., King, A. R., Lasota, J. P., and Ritter, H. 1987*a*, *M.N.R.A.S.*, in press (HKLR).
———. 1987*b*, *Ap. J.*, **316**, 275.
Lamb, D. Q., and Melia, F. 1987*a*, *Ap. Space Sci.*, **131**, 511.
———. 1987*b*, in *The Physics of Accretion onto Compact Objects*, ed. K. O. Mason, M. G. Watson, and N. E. White (Berlin: Springer-Verlag) p. 113.
Lamb, D. Q., and Melia, F. 1987*c*, *Ap. J.* (*Letters*), **321**, L133.
Morris, S. L., Schmidt, G. D., Liebert, J., Stocke, J., Gioia, I., and Maccacaro, T. 1987, *Ap. J.*, **314**, 641.
Rappaport, S., Verbunt, F., and Joss, P.C. 1983, *Ap. J.*, **275**, 713.
Ritter, H. 1987*a*, *Astr. Ap. Suppl.*, **70**, 335.
———. 1987*b*, *Astr. Ap.*, submitted.

Ritter, H., and Burkert, A. 1986, *Astr. Ap.*, **158**, 161.
Schmidt, G. D., and Stockman, H. S. 1987, *IAU Circ.*, 4458.
Spruit, H. C., and Ritter, H. 1983, *Astr. Ap.*, **124**, 267.
Warner, B., and Livio, M. 1987, *Ap. J.* (*Letters*), **322**, L95 (WL).

J. M. HAMEURY: Département d'Astrophysique Extragalactique et de Cosmologie, Observatoire de Paris, Section de Meudon, F-92195 Meudon Principal Cedex, France

A. R. KING: Department of Astronomy, University of Leicester, Leicester LE1 7RH, England, UK

J. P. LASOTA: Groupe d'Astrophysique Relativiste (CNRS), Département d'Astrophysique Relativiste et de Cosmologie, Observatoire de Paris, Section de Meudon, F-92195 Meudon Principal Cedex, France

H. RITTER: Universitätssternwarte München, Scheinerstrasse 1, D-8000 München 80, Federal Republic of Germany