ANGULAR MOMENTUM LOSS AND THE FORMATION OF W UMa SYSTEMS

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Angular momentum loss (AML) may be introduced as part of the explanation of the peculiar overabundance of W UMa-type contact binaries (W UMS) (for a recent review, see Vilhu, 1981). Among the various possible mechanisms to achieve this are (i) overflow through the outer (L_2) Lagrangian point in a deep contact phase (Kuiper, 1941; Nariai, 1979), (ii) magnetic braking, where magnetic lines of force "stiffen" and thus enhance the efficiency of angular momentum loss associated with a stellar wind (Huang, 1966; Mestel, 1968). Such subjects have been investigated in a number of more recent detailed studies.

The existence of a common envelope for W UMS entitles us to regard them as being involved in some kind of mass transfer episode of their close binary evolution, since, in general, stars could not be both simultaneously filling adjoining Roche lobes and remain in thermal equilibrium (Kuiper, 1941). In the usual language, we may speak of Case A, in which the cores of both stars are still similar to those of the Main Sequence, or Case B, in which core hydrogen burning has already ceased prior to Roche lobe overflow (RLOF). Considerations of AML in Case A and Case B can be tested by observing "protomorph systems" (PS).

Even with a generous estimate of candidate systems, however, there still appear insufficient PS to account for W UMS, considering only Case A without AML on approach (Budding, 1982a). AML through magnetic braking may ease the pressure for a high PS supply under certain supposed conditions. This process should have a determinable effect on observed binary incidence at low period.

In Figure 1, Mestel's (1968) rather thorough description of AML by magnetic braking has been used to illustrate the variation of a characteristic braking time T_J ($= J/\dot{J}$) with P for some feasible range of PS parameters. Three basic parameters were involved; κ , the most significant one for the present context, denoting a normalized centrifugal force; ℓ , relating to the thermal energy of the source corona, and ζ , relating to the magnetic energy of the source. Okamoto (1974) generalized this discussion to allow for radial field structure in terms

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of an additional parameter λ. The existence of a power-law rise and "cut-off", in the response of AML to period (κ) variation, may have some bearing on the AML discussion of Ruciński and Vilhu (1982).

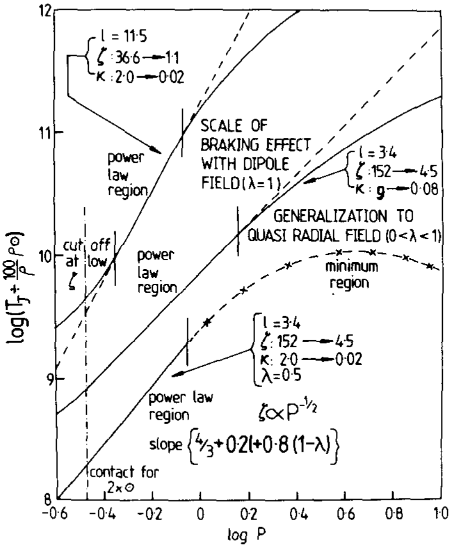

Figure 1

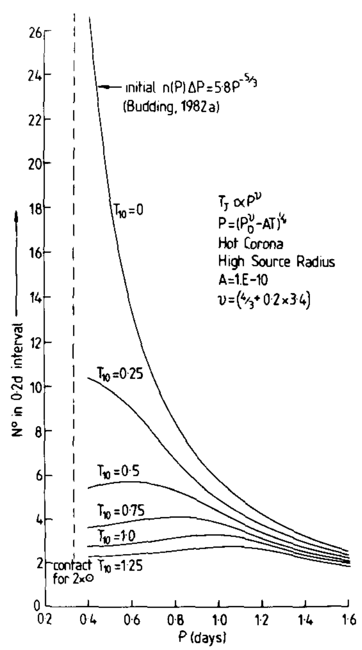

Figure 2

The power-law form for AML has been incorporated into a study of the evolution of n(P), with an initial form deduced from observations of detached close binaries of different spectral types (Budding, 1982a) and a constant rate of binary formation. Some results are shown in Figure 2. It is very difficult to understand the "bunching" effect of cool detached binaries on this basis (Budding, 1981), let alone the pronounced peak which occurs at contact.

Other problems with the Case A scenario can be noted as follows: (i) A number of W UMS are observed actually to exhibit period increases (Yamasaki, 1975). (ii) With Case A brought about by AML it is the more massive star which should first undergo RLOF. This should then tend towards equalising the masses, in contrast to the well-known inequality.

An alternative, Case B, picture will be presented in more detail elsewhere (Budding, 1982b). The basic premise is that PS are supposed to come from a large number of order $2M_\odot$ primaries accompanied by low mass secondaries ($q \lesssim 0.2$) at initial separations of order $10\ R_\odot$. There is evidence that such systems might indeed be very common (Trimble, 1978; Lucy and Ricco, 1979), despite strong selection effects against their discovery. Such PS could result from an initial fission process (Lucy, 1981). The contraction of the system, after RLOF starts, ensures overfilling of the outer critical Roche surface (whose volume is about twice that of the inner contact volume). AML by process (i), above, then appears as a necessary feature of this mode of binary evolution.

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Secondary overluminosity and period increases on a less than core nuclear timescale can both be quite naturally understood within this framework, while it is also possible to make the long sought connection with U Gem systems. A number ($\sim$ 10%) of semi-detached binaries of low mass, currently having extremely low mass ratio (e.g. AS Eri), may be noted here. It seems very likely that such systems have been in over-contact in the past (Refsdal, et al., 1974).

In this picture magnetic braking plays a secondary role up until the time when it might delay binary separation at low q. In Case A, magnetic braking is generally required to slow down once contact has been reached (Ruciński, et al., 1982). The depth of the secondary's convection zone may also be relatively large, particularly at higher mass ratio, though light curve asymmetries should still tend to have, as with classical Algols, a preferred sense.

In spite of such differences, there are sufficient encouraging points in the comparisons with observations to cause the Case B scenario to be taken seriously, at least for some W UMS.

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DISCUSSION

Rucinski: I just wanted to contest your initial statement about the frequency of these stars, that is one W UMa-type star per thousand stars seems to me to be a small number since almost every star is a binary. It is true, of course, that many stars are in wide binaries and you might have trouble with photomorphs.

Budding: Maybe we have to agree to differ about that. To me when one compares with other, detached close binaries, one in a thousand is about 5-10 times as much as one would expect. I am not the only one to have commented on this. The idea goes back to Shapley.

Rucinski: W UMa-type binaries are very easy to discover so they are over-represented with respect to other eclipsing binaries. If we consider all of the stars in the sky, most of them are in binaries. Among these W UMa stars are very rare although very interesting.