ROTATION IN CLOSE BINARIES

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ABSTRACT

It has been demonstrated (Zahn 1966 a, b, c; 1975, 1977) that turbulent viscous dissipation of tides can brake the rotation of stars having convective envelopes, while radiative dissipation can do likewise for those having radiative envelopes. The time scales for the former are very small whereas those for the latter depend sensitively on the ratio r/R where r is the radius of the star and R, the binary separation. For most systems these turn out to be much less than their main sequence lifetimes. This fact affords a natural explanation for the preponderance of synchronous systems.

The parameter which quantifies the tidal braking is the ratio of t_{ms}, the main sequence lifetime (a measure of the star's age) to t_{syn}, the synchronisation time scale (a measure of the rotational deceleration). A plot of the ratio of orbital period P_o to spin period P_s of the star versus such a parameter is shown in figure 1. Rotational velocities of the eclipsing binary systems were obtained from Levato (1974). The fractional radii and inclination of the orbit were taken from the Graded Catalog of Photometric Systems (Koch et al., 1970) while the Seventh Catalog of Spectroscopic Binary Systems (Batten et al., 1978) was our source for the orbital parameters and mass functions. These were utilised to derive the masses, radii and separation of the components of eclipsing binary systems. For Am spectroscopic binaries, the vsini values were obtained from Abt (1975) and Abt and Moyd (1973). The masses of these systems were taken from Allen (1973) which corresponded to their hydrogen spectral types (whenever available) or colours. The synchronisation time scale was calculated according to Zahn's (1977) formula whereas t_{ms} was calculated from Iben (1964).

Figure 1 shows possibly two sequences of stars. The upper sequence behaves "normally" in the sense that it shows asynchronous rotation when the tidal actions are not strong enough to act within its lifetime ($t_{ms}/t_{syn} < 1$). The lower sequence continues to remain near

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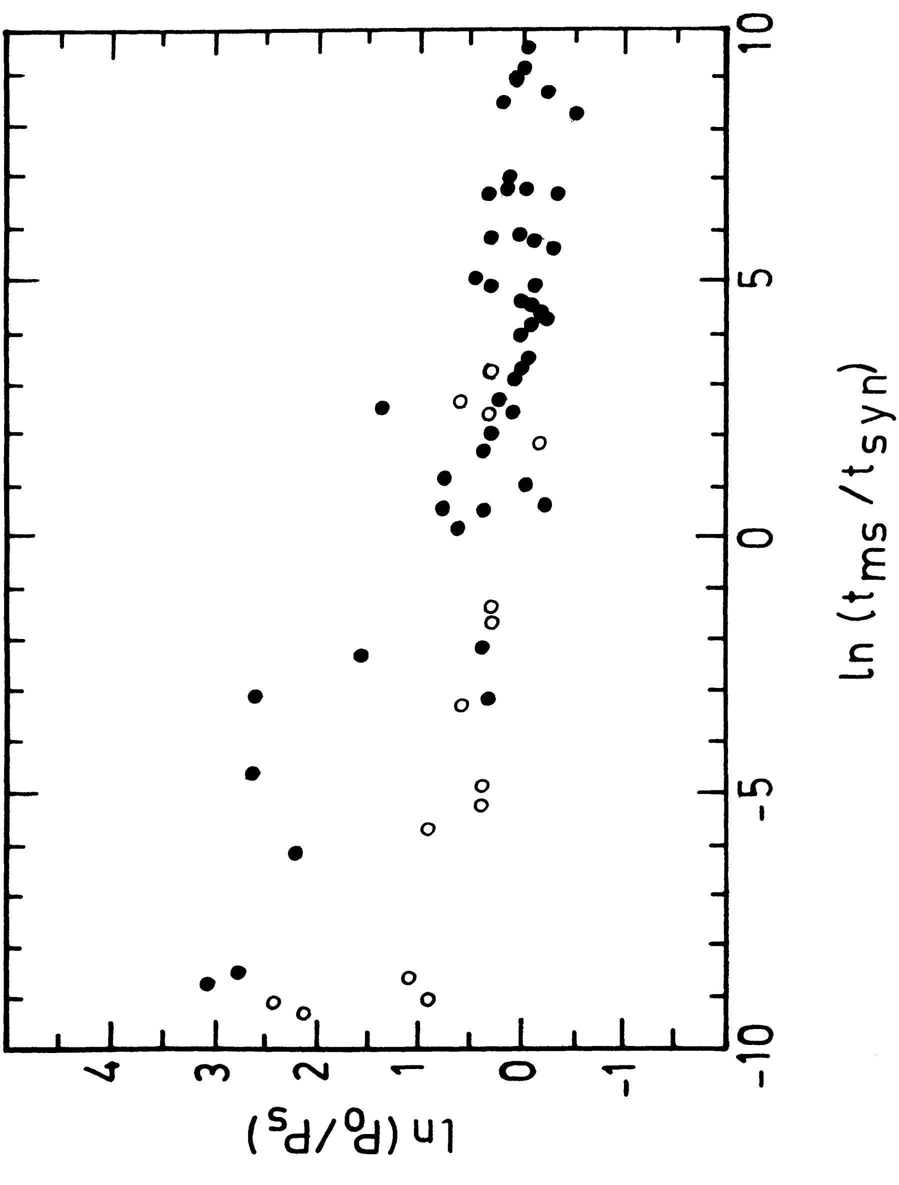

Fig. 1: Plot of the ratio of the orbital to spin period versus the ratio of the main-sequence life-time to the synchronisation time scale. Open circles refer the Am binaries. Based on Iben (1964).

synchronism even when $t_{ms}/t_{syn} < 1$. A majority of these happen to be Am binaries. The possibility of magnetic braking was tested using equation 12 of Joss et al. (1979) but enormous fields ($\approx 10^5$G) seem necessary for this. Such fields could hardly have escaped detection. Angular momentum transport by magneto acoustic waves may not be a good idea purely because of the difficulty of generating these waves in the almost convection-free surfaces of early type stars. A third alternative would be that these had been born with an intrinsically slow rotation. The question which one would now like to ask is whether the Am phenomenon, rather than being isolated among a fraction of the binaries, could be a manifestation of some more general properties of close binaries with the surface peculiarities being wiped out by tidal effects in closer systems. In such a case the equivalent Am stars amongst the close binaries must exist. Then we would be forced to look for two modes of binary star formation.

Finally, when one considers the mass transfer picture for semi-detached systems, one would expect these to be conspicuous in a background of detached systems for the following reasons: Any mass transfer on such large scales as envisaged would, most probably, spin up the recepient. The fact that the donor becomes less massive, coupled with the fact that hardly a fraction of the synchronisation time has elapsed since the mass transfer took place, makes it impossible for the donor to brake the spun up companion. Hence primaries of Algol systems ought to appear with non-synchronous rotation on any plot consisting of a mixture of detached and semi-detached systems. Except for U Cephei, however, the rest of the Algol systems appear quite synchronous in Figure 1.

If one considers the rotational velocities of Algol systems, it is found that, excepting for a few fast rotators, the mean value is about 70 kms^{-1}. Interestingly enough, this value is similar to those of Ap and Am stars.

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