ORBIT CIRCULARIZATION TIME IN BINARY STELLAR SYSTEMS

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Summary: We have analyzed the orbital parameters of 33 red dwarf and 17 red giant spectroscopic binaries belonging to open clusters to deduce the time-scale for orbital circularization. The dynamical evolution of BD $+23^{o}635$, a short period binary member of the Hyades, should result in the formation either of a cataclysmic binary or a WUMa system.

Zahn (1966, 1977) and Lecar et al. (1976) have studied the process of circularization of spectroscopic binaries orbits induced by tidal effects. Such a mechanism is especially effective for late-type stars because of the turbulent viscosity associated to the convective envelope. But owing to difficulties inherent to the treatment of convection, the time-scale for circularization is rather ill-defined. Although it has been known for a long time that the orbits of short period binaries are circular, this fact has not yet been used, mainly because of difficulties in assigning a proper age to late-type stars.

Late-type (Sp. Type $\gtrsim$F5) binaries in open clusters offer an opportunity of determining the time-scale of orbit circularization. The measurement of radial velocities by photoelectric techniques (Griffin, 1967; Baranne et al., 1979) has recently improved our knowledge of stellar duplicity in nearby open clusters. The 29 orbits obtained so far with the radial velocity scanners (Griffin and Gunn, 1978, 1981; Griffin et al., 1982; Mermilliod and Mayor, Coravel unpublished measurements) display the capabilities of these instruments as compared to the classical photographic techniques which yielded up to now only four orbits for late-type dwarfs in open clusters. As concerns the red giants, the present state is similar, being one classical orbit against 16 photoelectric orbits.

Figure 1 shows the eccentricity vs period diagram on the one hand for red dwarf stars in the Hyades, Pleiades, Praesepe and Coma Ber open clusters (left part), and on the other hand for red giants belonging to several open clusters (right part).

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 411–414.

https://doi.org/10.1017/S0074180900031223 Published online by Cambridge University Press

Late-type dwarfs. The diagram for the late-type dwarfs shows a strong discontinuity near a value of the period equal to 5.7 days. The orbits with periods shorter than this critical value are circular, while all orbits with longer periods have non-zero eccentricities. Lecar et al. (1976) give the following expression for the characteristic time of circularization:

$$t_{circ,1} = 0.08\ (M_1/M_2)(a/R)^5(g/g_{\odot})\ P^2/\lambda\eta v$$

The circularization time of the system is taken as the harmonic mean of the times associated to each component. The circularization time needed for the eccentricity to become as low as 0.01 to 0.02 is assumed to be of the order of one-third of the cluster age. Thus, for systems composed of two stars of one solar mass with ages equal to the Hyades or Praesepe ages, the limiting period should be about 5.1 days. The circularization time depends on spectral types of both components through the value of radii, masses, relative thickness λ and mass η of the convective envelope. Thus only a detailed study of systems with period close to the limiting period will provide a significant test of the circularization time-scale. Using the three systems[1] nearest to the discontinuity we can restrain the uncertainty to a factor of two around the circularization time-scale proposed by Lecar et al. (1976).

Red giants. By considering the two systems[2] whose periods are on both sides of the discontinuity in the (e,P) diagram, we can estimate the value of the viscous energy dissipation necessary to account for the circularization of the red giant orbits. Expression (2) may be written in the form:

$$t_{circ} = R_{LWK}\ (M_1/M_2)(a/R)^5(g/g_{\odot})\ P^2 \qquad \text{(P in days)}$$

where $R_{LWK}=0.08/\lambda R\theta$. For solar type dwarf stars, the value of R_{LWK} is about 16 y. For giant stars we estimate a value of R_{LWK} between 0.015 and 0.025 y, in good agreement with a direct estimate of $R_{LWK}=0.08/\lambda\eta v$ from KO III models (R_{LWK}(KO III) ~0.09 y).

It should be noticed that we have tried to explain the discontinuity in the (e,P) plane for dwarf stars in terms of orbital circularization during the main sequence lifetime of the stars. However, since the radii of the proto-stars are larger than those of the main sequence stars, the convective zone more developed and the gravity lower, the circularization

[1] (VB 22, P=5.60d, e=0.0 in the Hyades, McClure 1982; VB 121, P=5.75d, e=0.35 in the Hyades, Griffin and Gunn 1978; KW 181, P=5.87d, e=0.35 in Praesepe, CORAVEL unpublished orbit.)

[2] (NGC 752-110, P=127d, e=0.0 and NGC 7092-95, P=178d, e=0.23, both CORAVEL unpublished orbits.)

time during the pre-main sequence evolution is considerably shorter for a given period. One cannot reject the possibility that the limiting period at 5.7 d results entirely from the star evolution prior to arrival on the main sequence.

The system BD +23°635

The Hyades member system BD +23°635 presents an interesting problem: although it has a short period, P = 2.4 d, the eccentricity is significantly different from zero: e = 0.057 ± 0.005 (Griffin and Gunn, 1981). These authors also discovered that a third star belongs to this system. This fact enables us to explain the observed orbital parameters by invoking the mechanism studied by Mazeh and Shaham (1982): the non-zero eccentricity most probably results from the perturbation created by the third companion. The simultaneous action of the energy dissipation (by tidal interaction) and of the perturbation (which maintains a non-zero eccentricity) induces a secular evolution of the close binary. The orbital period shrinks, with a characteristic time ($\tau_a = \tau_{circ}/2<e_{1,2}>\simeq 2\cdot 10^9$ y) shorter than the nuclear lifetime of the stars. Therefore, such a system appears as a probable progenitor of WUMa or small mass cataclysmic systems.

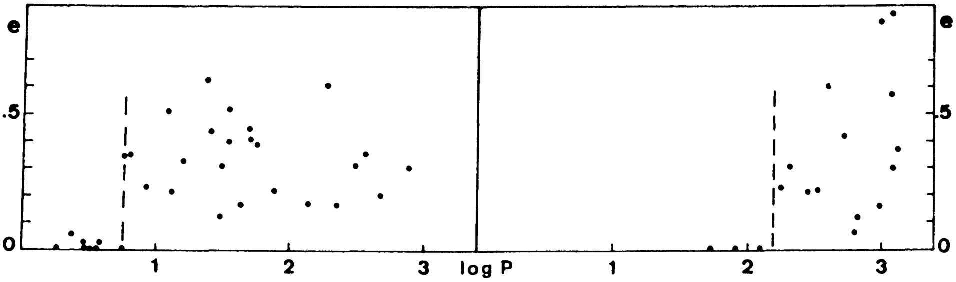

Fig. 1. (e,P) diagram for dwarfs (left) and giants (right)

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https://doi.org/10.1017/S0074180900031223 Published online by Cambridge University Press

DISCUSSION

Spruit: Is the formation of a cataclysmic system from a triple likely to be a rare event?

Mayor: With T. Mazeh we are conducting a search of triple systems through the precession of the nodes effect. Preliminary results show the existence of a non-negligible percentage of triple systems exhibiting this effect. Evidently not all of them will have a contraction time τ_a shorter than the evolutionary time τ_e.

https://doi.org/10.1017/S0074180900031223 Published online by Cambridge University Press