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BINSTAR : A new Binary Stellar-Evolution Code

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Abstract. We introduce our new stellar evolution code, BINSTAR, which has been developed in order to study interacting binaries. We describe the state-of-the-art input physics which includes treatments of tidal interactions, mass transfer and angular momentum transport within each stellar component. Finally, we compare the tidal timescales resulting from the full integration of the tidal interaction equations from Zahn (1977) and from the analytical fit provided by Hurley et al. (2002)

1. Physics of BINSTAR

BINSTAR is an extension of the stellar evolution code STAREVOL, which handles the simultaneous calculation of both stellar components, and of the binary orbit. The stellar input physics is described in detail in Siess (2006). A further key ingredient within BINSTAR is a detailed modelling of tidal interactions following the formalism of Zahn (1977, 1989). The code is also able to follow the evolution of the eccentricity following the Hut (1981) prescription. The mass transfer rate is recomputed at each iteration during the convergence process and accounts for Roche lobe overflow and wind accretion. Stellar rotation also contributes to total angular momentum budget.

2. Tidal circularization in radiative stars

For radiative stars, Zahn (1977) provides expressions for the circularisation ($\tau_{\rm circ}$) and synchronization ($\tau_{\rm sync}$) timescales which are inversely proportional to the parameter E_2 which describes the structure of the star. Because the determination of this parameter is non-trivial, Hurley et al. (2002) suggested a fit to E_2 in terms of the stellar mass M, according to

$$E_2 = 1.592 \times 10^{-9} \left(\frac{M}{M_\odot}\right)^{2.84} . \quad (1)$$

Fig. 1 shows that Eq. 1 provides a rather poor approximation to the values of E_2 obtained from BINSTAR. The E_2 fit values are initially at least a factor of 5 larger than the computed ones. Furthermore the deviations increase significant towards the end of the stars' hydrogen burning phase. Hence, Eq. (1) greatly over-estimates E_2 leading to a large under-estimate of both $\tau_{\rm circ}$ and $\tau_{\rm sync}$ ($\propto E_2^{-1}$). The assumption that tides are

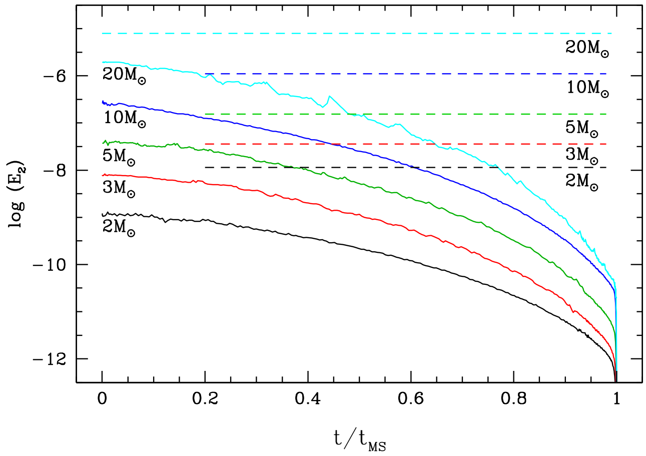

Figure 1. A comparison of the values of E_2 as a function of the relative main sequence lifetime for a 2, 3, 5, 10 and 20 $M_{\odot}$ star with a solar composition (Z = 0.02) and no overshooting, as calculated using BINSTAR by solving the full set of the tidal interaction equations (solid lines) and from Eq. 1 (dashed lines).

important and lead to rapid circularization and synchronization as the stellar components evolve off the main sequence may not always hold. The Roche-lobe filling star may thus be rotating asynchronously with the orbit which may also have a non-zero eccentricity, by the time mass transfer commences.

3. Summary

BINSTAR incorporates detailed physics describing mass transfer, tidal interaction and orbital evolution. It also inherits a detailed nucleosynthesis network, treatments of chemical and angular momentum transport within the star, semi-convection, thermohaline and rotationally induced mixing.

Values of E_2 from the fit suggested by Hurley et al. (2002) are compared with those obtained from the full set of tidal structure equations using BINSTAR. The fit formula greatly over-estimates E_2 and hence will under-estimate the circularization and synchronization time-scales. Hence, the assumption that binary orbits are circularised, and that stellar components are rotating synchronously with the orbit by the time Roche-lobe overflow occurs, may not be necessarily valid in all cases.

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References

Hurley, J. R., Tout, C. A., & Pols, O. R. 2002, MNRAS, 329, 897
Hut, P. 1981, Astronomy and Astrophysics, 99, 126
Siess, L. 2006, A&A, 448, 717
Zahn, J. 1989, A&A, 220, 112
Zahn, J.-P. 1977, Astronomy and Astrophysics, 57, 383