Dynamical Evolution of Dense Stellar Systems
Proceedings IAU Symposium No. 246, 2007
E. Vesperini, M. Giersz & A. Sills, eds.

doi:10.1017/S1743921308015743

The Formation of Contact and Very Close Binaries

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Abstract. We explore the possibility that all close binaries, i.e. those with periods <3 days, including contact binaries, are produced from initially wider binaries by the action of a triple companion through the medium of Kozai Cycles with Tidal Friction (KCTF).

Keywords. stars: evolution, stars: binaries: general

1. Introduction

Pribulla & Rucinski (2006) have noted that in a reasonably complete sample of 88 northern contact binaries, 52 show evidence of a third body. Given the difficulty of recognising the presence of a third body except in favorable circumstances, this argues for the likelihood that *all* contact binaries are in triples, and hence that 'triplicity' is *necessary* for the formation of a contact binary.

Tokovinin *et al.* (2007) found that in a sample of spectroscopic binaries with $P < 30\,\mathrm{d}$, among the 41 with $P < 3\,\mathrm{d}$, 32 were triple; and making allowance, by a maximum-likelihood procedure, for incompleteness they concluded that the fraction of triples must be $\sim 96\%$. For spectroscopic binaries with $P > 12\,\mathrm{d}$ the figure was much lower (34%).

Therefore there is a good case for the hypothesis that very close binaries form as a consequence of the presence of a third body. The most likely mechanism to do this is the combination of Kozai cycles with tidal friction (KCTF) – see Eggleton & Kisseleva-Eggleton (2006), Fabrycky & Tremaine (2007), and Kiseleva, Eggleton & Mikkola (1997). For contact binaries, the extra effects of magnetic braking and tidal friction will have to be included.

Fig. 1 shows an aspect of the behaviour of a reasonably close inner pair ($1.0 + 0.6\,M_\odot$, period $P_{\rm in}$) subjected to Kozai cycles by the presence of a third body in an orbit ($1.6 + 0.9\,M_\odot$, period $P_{\rm out}$) inclined at angle η to the inner orbit ($\cos\eta = 0.1$). Left of the boundary passing near the middle of the plot, and right of the boundary near the bottom right, there are no Kozai cycles. The symbols are explained in the legend. Plusses are systems where KCTF shortens the period to a few days in $<3\,\mathrm{Gyr}$, but not so rapidly that tidal energy release rivals stellar luminosity (ie. the Kelvin-Helmhotz timescale).

We believe the systems marked by plusses are computed reasonably reliably, and all should arrive at periods of $\sim 2-10\,\mathrm{d}$. We expect 10% of all triples to be inclined as much (or more) as the systems shown; but a lower inclination like $\cos\eta = 0.3$ is much the same, with a smaller patch of circles. The circled systems need more detailed evolution, because the two close components will be swollen by the tidal-friction energy release,

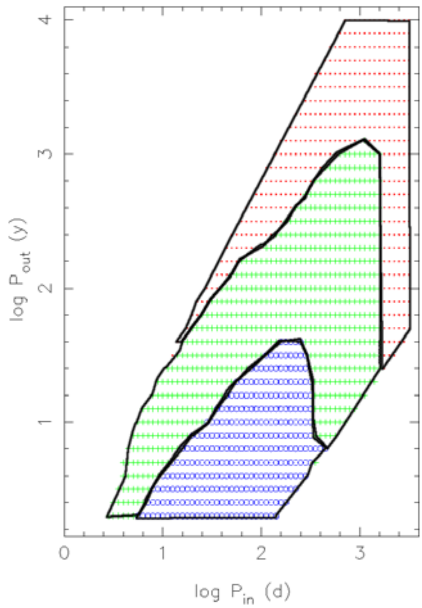

Figure 1. A sampling of systems with a range of both inner period (across) and outer period (up). Dots indicate Kozai cycling that is not significantly affected by tidal friction on a timescale $\lesssim 3\,$Gyr, and circles indicate systems so rapidly modified by tidal friction that the luminosites of the two close components should be affected. Plusses are systems affected on times between the thermal timescale and 3 Gyr.

their quadrupole moments will be increased, and it is not clear whether this can stabilise or destabilise the KCTF evolution.

We expect to use our stellar-evolution code to follow some cases illustrated with circles. Our treatment of tidal friction, in the equilibrium-tide approximation, gives a specific form for the energy-generation rate as a function of radius in the star. We suspect that internal heating may affect the rate at which the inner system approaches short period and circularity, but may not have much effect on the parameters of the final system without affecting the stellar luminosities strongly, i.e the timescale of KCTF evolution is longer than the Kelvin-Helmholtz time, while shorter then $\sim 3\,$Gyr.

Acknowledgements

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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