RevMexAA (Serie de Conferencias), **20**, 95–96 (2004)

REALISTIC MODELS FOR DONORS IN ULTRACOMPACT BINARIES

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RESUMEN

Presentamos el primer conjunto realista de modelos estelares arbitrariamente degenerados, apropiados para donadores en binarias ultracompactas. Las relaciones masa - radio, M-R, de estos objetos son parametrizadas por la entropía y la composición del donador. Enfatizamos que nuestra comprensión de la configuración actual de binarias ultracompactas y sus potenciales trazas evolutivas pueden estar afectadas por este hecho.

ABSTRACT

We present the first realistic set of arbitrarily degenerate stellar models appropriate for donors in ultracompact binaries. The mass-radius M-R relations for these objects are parameterized by the donor's entropy and composition. We highlight how this fact can affect our understanding on the current configuration of ultracompact binaries today and their potential evolutionary tracks.

Key Words: **BINARIES: CLOSE — WHITE DWARFS — X-RAYS: BINARIES**

1. MODELS FOR ARBITRARILY DEGENERATE DONORS

Ultracompact binaries (UCBs) are mass-transferring systems with orbital periods, $P_{\rm orb}$, below the minimum which binaries with predominantly H donors can reach ($\approx$ 70 − 80 min) (Rappaport, Joss, & Webbink 1982). The donors in UCBs have evolved (He or C/O) compositions (Nelson, Rappaport, & Joss 1986; Fedorova & Ergma 1989; Podsiadlowski, Rappaort, & Pfahl 2002) and most likely have masses $M_2 \lesssim 0.1 M_\odot$ (e.g., Markwardt et al. (2002); Galloway et al. (2002)). Although, typically the donors in UCBs are modeled as fully degenerate objects, we expect the donors to have core temperatures, T_c, between 10^5-10^7 K, depending on the binary's formation channel and the donor's composition (Bildsten 2002; Nelson & Rappaport 2003; Serenelli, Althaus, Rohrmann, & Benvenuto 2001; Salaris et al. 2000). This make them far from fully degenerate in most cases and has implications for the current states of UCB systems and their potential evolutionary histories, past and future. In particular, approximating these donors as fully degenerate is *not* sufficient for understanding the properties of the UCB population.

To address the impact of partial degeneracy on the structure of UCB donors, we have calculated the first realistic set of arbitrarily degenerate models relevant to these objects. A sample of the resulting M-R relations are shown in Figure 1. We emphasize that these relations are not single-valued, but parameterized by the donor's entropy and composition. In particular, for Roche Lobe (RL) filling systems at a given $P_{\rm orb}$, there are multiple combinations of T_c and composition for which a RL-filling donor can be found. The binary's configuration and evolutionary path varies with these parameters.

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2. IMPLICATIONS OF MULTI-VALUED M-R RELATIONS FOR ULTRACOMPACT BINARIES

For example, in the ultracompact accreting millisecond pulsar systems, where we know mass function, we can correlate the orbital inclination with the donor's T_c and composition. In particular, the system XTE J1751-305 (Markwardt et al. 2002), does not admit a fully degenerate donor. Also, the probability of finding a He donor in the systems XTE J0929-314 and XTE J1807-294 (Galloway et al. 2002; Markwardt et al. 2003a,b), from inclination constraints due to the $T_c = 0$ solution, is 35% and 15%, respectively. In general, though, for any given orbital inclination, a combination of donor T_c and composition can be found that produces a RL-filling donor.

The evolution of UCBs also depends on the donor's T_c and composition. For example, the relation between the mass transfer rate, $\dot{M}$, and $P_{\rm orb}$ in UCBs is multiply-valued (Figure 2) along with the M-R relations. At longer $P_{\rm orb}$, the variation in $\dot{M}$ from T_c variations can be 2-3 orders of magnitude, if the donors can be arbitrarily hot. However, a donor evolving adiabatically from short $P_{\rm orb}$ cannot be arbitrarily hot at longer $P_{\rm orb}$ (dashed line in Figure 2). Thus some regimes of the $\dot{M}$-$P_{\rm orb}$ can only be

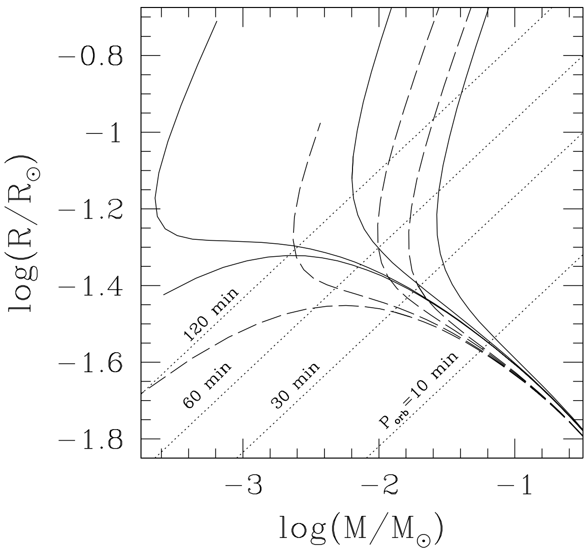

Fig. 1. The M-R relations along lines of constant T_c for He ($T_c = 10^4\,, 10^5\,, 10^6\,, \& \, 5\times10^6$ K) and C ($T_c = 10^4\,, 10^6\,, 3\times10^6\,, \& \, 5\times10^6$ K) donors.

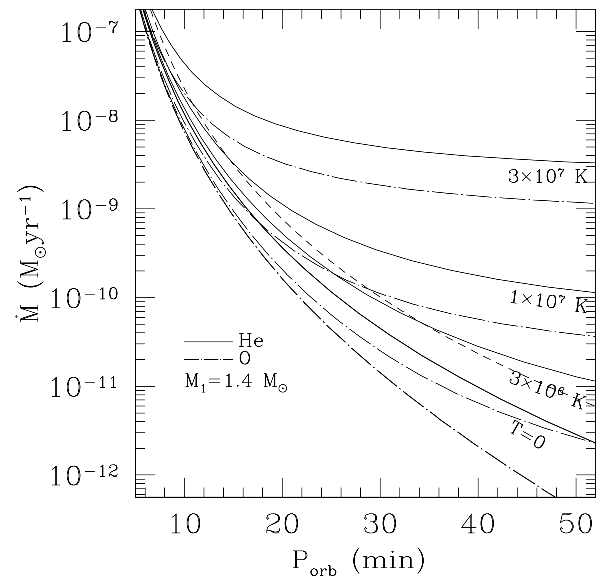

Fig. 2. How the $\dot{M}$-$P_{mathrmorb}$ relation is affected by the donor's T_c and composition. The dashed line shows an adiabatic evolutionary track, highlighting that finding arbitrarily hot donors at longer P_{orb} requires heating of the donor if the system evolved from contact at $P_{orb} < 10$ min.

reached if donors are either heated during their evolution (via tidal mechanisms?) or if they start mass transfer as hot objects at longer $P_{\rm orb}$ (Nelson & Rappaport 2003).

Differences in composition and T_c make a donor more or less compact, altering the $P_{\rm orb}$ at which the donor fills its RL and the resulting $\dot{M}$. In addition, these variation also affect the rate at which the donor's radius, R_2, changes with mass loss, affecting the rate the system evolves through $P_{\rm orb}$. The net effect is that C/O donors evolve faster in M_2, but slower in $P_{\rm orb}$ than He donors; hotter donors evolve faster in $P_{\rm orb}$ than colder ones. Integrated over the population of UCBs, these effects will alter our expectation for such things as the number distribution of UCBs with $P_{\rm orb}$ (Deloye & Bildsten 2003).

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