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Low–Mass HeWDs and Millisecond Pulsars Age Determination

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1. Introduction

It is accepted that the formation of a millisecond binary pulsar (MBP) with a low–mass companion may be explained as the end–point of close binary evolution in which an old pulsar is spun–up by accretion from the red giant (Bhattacharaya & van den Heuvel 1991). In this paper we shall discuss the cooling properties of the helium white dwarfs (WD) in short orbital period MBP systems PSR J0437–4715, PSR J0751+1807 and PSR J1012+5307, without referring to the rotational history of neutron stars (NS).

2. Applications to Individual Systems

Below we discuss observational data for several system for which the results of our calculations (Sarna, Antipova, & Muslimov 1998; Sarna, Ergma, & Antipova 1999) may be applied, by taking into account the orbital parameters of the system, the pulsar spin–down time, and the WD cooling time–scale.

2.1. PSR J0437–4715

Timing information for this millisecond binary system: P_p=5.757 ms, P_{orb}=5.741 days, τ (intrinsic characteristic age of pulsar) = 4.4–4.91 Gyrs (Bell et al. 1995). Hansen & Phinney (1998 – HP98) have discussed the evolutionary stage of this system using their own cooling models. They found a solution for the secondary mass in the range 0.15–0.375 $M_\odot$ with thick hydrogen envelope (3×10^{-4} $M_\odot$). Our calculations also allow us to produce the orbital parameters and secondary mass for the PSR J0437–4715 system and fit its cooling age (2.5–5.3 Gyrs, HP98). From our cooling tracks for the binary orbital period is 5.741 days, the mass of the companion is 0.21±0.01 $M_\odot$ and its cooling age is 1.26–2.25 Gyrs (for Z=0.02).

2.2. PSR J0751+1807

This system consists of a 3.5 ms pulsar in a 6 h orbit with a $\sim$ 0.15 $M_\odot$ companion (Lundgren, Zepka, & Cordes 1995). For the observed P and $\dot{P}$ we have a spin–down age of the NS, of $\sim$ 8 Gyr. For PSR J0751+1807, the impinging pulsar flux allows for an efficient irradiation driven mass loss from the secondary. This decreases the mass of the hydrogen rich envelope and decreases the cooling time (Ergma, Sarna, & Antipova 1999).

2.3. PSR J1012+5307

Lorimer et al. (1995) determined the characteristic age of the radio pulsar to be 7 Gyr, or even larger if the pulsar has a significant transverse velocity (HP98). HP98 models yield the following results for this system; the companion mass lies in the range 0.13–0.21 $M_{\odot}$, NS mass in the range 1.3–2.1 $M_{\odot}$, and the age is < 0.6 Gyr. Alberts et al. (1996) were the first to show that the cooling time-scale of a low–mass WD can be substantially larger. Our and Driebe et al. (1998) calculations confirmed their results that for low–mass helium WDs ($< 0.2\ M_{\odot}$), indeed stationary hydrogen burning plays important role, and increases by one order of magnitude the cooling time–scale.

3. Conclusion

We have performed state–of–the–art evolutionary calculations to produce a close binary system consisting of a NS and a low–mass helium WD. We argue that thick hydrogen layers may change dramatically the cooling time–scale of the helium WD (< 0.25 M$_{\odot}$), compared to previous calculations (HP98, Benvenuto & Althaus 1998) where the mass of the hydrogen envelope was usually one order of magintude less than that obtained from real binary evolution computations. Also, we have demonstrated that using new cooling tracks we can consistently explain the evolutionary status of the binary pulsars PSR J0437-4715, PSR J0751+1807 and PSR J1012+5307.

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