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ORIGINAL ARTICLE

Accretion, ablation and propeller evolution in close millisecond pulsar binary systems

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Abstract A model for the formation and evolution of binary millisecond radio pulsars in systems with low mass companions (< 0.1 $M_\odot$) is investigated using a binary population synthesis technique. Taking into account the non conservative evolution of the system due to mass loss from an accretion disk as a result of propeller action and from the companion via ablation by the pulsar, the transition from the accretion powered to rotation powered phase is investigated. It is shown that the operation of the propeller and ablation mechanisms can be responsible for the formation and evolution of black widow millisecond pulsar systems from the low mass X-ray binary phase at an orbital period of $\sim$0.1 day. For a range of population synthesis input parameters, the results reveal that a population of black widow millisecond pulsars characterized by orbital periods as long as $\sim$0.4 days and companion masses as low as $\sim$0.005 $M_\odot$ can be produced. The orbital periods and minimum companion mass of this radio millisecond pulsar population critically depend on the thermal bloating of the semi-degenerate hydrogen mass losing component, with longer orbital periods for a greater degree of bloating. Provided that the radius of the companion is increased by about a factor of 2 relative to a fully degenerate, zero temperature configuration, an approximate agreement between observed long orbital periods and theoretical modeling of hydrogen rich donors can be achieved. We find no discrepancy between the estimated birth rates for LMXBs and black widow systems, which on average are $\sim 1.3 \times 10^{-5}$ yr^{-1} and 1.3×10^{-7} yr^{-1} respectively.

Keywords Binaries: close · Magnetic fields · Pulsars: general · Pulsars: individual (PSR J1023+0038) · Stars: neutron

1 Introduction

The discovery of a radio pulsar with a 1.69 ms spin period in J102347.67+003841.2 (Archibald et al. 2009), a system characterized by a 4.75 hr binary orbital period (Woudt et al. 2004), has provided observational confirmation of the link between rotation powered radio millisecond pulsars (MSPs) and the low mass X-ray binary (LMXB) phase. This source is of special interest since it appears to have undergone a transformation from a LMXB to a recycled MSP (see Bond et al. 2002; Thorstensen and Armstrong 2005; Wang et al. 2009). Takata et al. (2010) suggested that the emission of γ-rays from the pulsar magnetosphere was important in facilitating the transformation of a MSP from the accretion powered to the rotation powered phase.

Among the binary MSPs, there is a class of systems characterized by short orbital periods (< 1 day), of which J102347.67+003841.2 is a member, from which we define two distinct populations. In one population, known as ultra compact binary X-ray MSPs (UCXBs), systems consist of MSP-white dwarf (WD) components with orbital periods

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