

# Deriving fundamental parameters of millisecond pulsars via AIC in white dwarfs

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**Abstract.** We present a study of the observational properties of Millisecond Pulsars (MSPs) by way of their magnetic fields, spin periods and masses. These measurements are derived through the scenario of Accretion Induced Collapse (AIC) of white dwarfs (WDs) in stellar binary systems, in order to provide a greater understanding of the characteristics of MSP populations. In addition, we demonstrate a strong evolutionary connection between neutron stars and WDs with binary companions from a stellar binary evolution perspective via the AIC process.

**Keywords.** Neutron stars, white dwarfs, cataclysmic variables, fundamental parameters.

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## 1. Introduction

Observable parameters of binary Millisecond Pulsars (MSPs), e.g. mass of the pulsar, mass of the companion, spin period, orbital period, eccentricity, etc., are used to probe the past accretion history of the MSPs. The purpose of this proceeding is to demonstrate how to infer some of the observable quantities (spin period, magnetic field and mass) during the Accretion Induced Collapse (AIC) of a white dwarf (WD) on its way to become a member of the MSP family.

## 2. Evolution of spin period

We are able to determine the spin period of MSPs originating from WDs. The process begins with simple Keplerian frequency. We assume that the angular velocity of the NS is equal to the Keplerian angular velocity,  $v_K$ , of the magnetosphere, at roughly the Alfvén surface,

$$v_K \propto R_{NS}^{-3/2} \rightarrow P_{MSP} \sim R_{NS}^{3/2} \quad (2.1)$$

from which we obtain the spin of the MSP,  $P_{MSP}$ , as a function of the WD spin,  $P_{WD}$ .

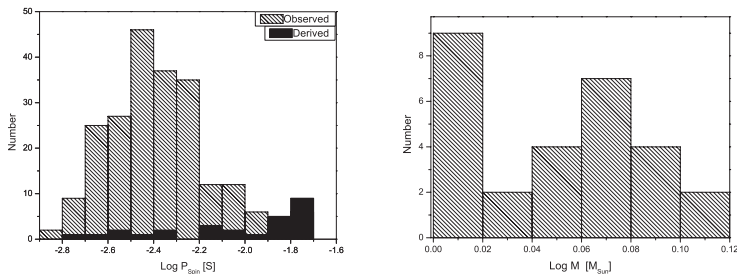
$$P_{MSP} \sim P_{WD,min} \left( \frac{R_{NS}}{R_{WD}} \right)^{3/2} \quad (2.2)$$

where  $P_{WD,min}$  is the minimum spin period of the standard WD (Warner 1995). Assuming  $P_{WD,min} \sim 30$  s,  $R_{NS} = 10$  km and  $R_{WD} = 1000$  km, we thus obtain,

$P_{MSP} \sim 1$  ms. Fig. 1 (left) shows the observed and derived spin period distributions of MSPs. As for the observed MSPs, they show a relatively Gaussian distribution. According to these distributions, the ratio of MSPs originating from CVs is about  $\sim 10\%$ . This result agrees with some theoretical predictions such as those by Warner (1995) and Warner & Woudt (2002).

## 3. Magnetic field

To investigate the correlation between the magnetic fields of MSPs with bottom fields of CVs (where the field is partially restructured due to accretion), we follow the model



**Figure 1. Left:** The distribution of MSPs in terms of spin-period (observed data from Manchester *et al.*(2005). **Right:** Mass distribution of massive CVs (Ritter & Kolb 2011).

of Zhang *et al.* (2009). The magnetic flux is assumed to be conserved. This corresponds to the magnetic fields produced by AIC.

$$B_{NS} = B_{f,WD} \times \left( \frac{R_{WD}}{R_{NS}} \right)^2 \quad (3.1)$$

If we adopt  $R_{NS} = 15 \times 10^5$  cm and  $B_{f,WD} \sim 10^3$  G in CVs, the minimum value,  $B_{NS} \sim 10^{8.5-9}$  G.

#### 4. Mass

The sample of CVs whose masses we have considered is the set of binary systems collected by Ritter & Kolb (2011). Among them we have 26 massive CVs in the range  $1.0 - 1.3M_{\odot}$ . Fig. 1 (right) shows the relatively Gaussian distribution, with mean at  $M_{CV} \sim 1.1M_{\odot}$ . A summary of the known properties of these systems is given in Table 1 of Taani *et al.* (2012). Note that the AIC process leads to a MSP with mass less than Chandrasekhar limit Zhang *et al.* (2011). This provides evidence for the AIC in massive CVs and evolutionary hypotheses of MSP birthrate.

#### 5. Summary and Conclusions

(a) CVs would be invoked via the capability of producing a significant portion of the MSPs via the AIC process, a regime which may be unattainable by normal channels.

(b) We find that the quantitative implications of our calculations are that we estimate the expected  $P$  in the observed of MSPs which could have originated from CVs to be  $\sim 10\%$ .

(c) We further find that the predictions of some parameters after AIC process for the average levels are consistent with the observed MSP population. Future work will consider other quantities e.g. orbital period, eccentricity, and mass ratio ( $q$ ) using more data sets from SDSS.

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