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Multi-Observation Identification for Studying the Evolution of Spin-up line

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ABSTRACT

The measured characteristics of binary pulsars provide valuable insights into the evolution of these systems. We study the aspects of binary evolution particularly relevant to binary Millisecond Pulsars (MSPs), and the formation of close binaries involving degenerate stars. For this task, we use a wide variety of binaries, including ones with compact components, which we analyse through a spin-evolution diagram. We discuss their formation and evolution over timescales of binary evolution models.

INTRODUCTION

The last decade has seen a dramatic growth in our understanding of compact object populations, almost all driven by new facilities such as the Hubble Space Telescope, ATNF pulsar catalogue and LAT data (Large Area Telescope) observatories. Pulsars are classified on the basis of their observed properties. Their spin period (*P*) and magnetic field strength (*B*) together provide formation and evolution mechanisms of binary & Millisecond Pulsars (MSPs). Subsequent to the pulsar discoveries, we searched for archival X-ray, Gamma-ray and radio observations covering the new pulsars' sky locations. Binary MSPs represent the end point of stellar evolution, and their observed orbital and stellar properties are fossil records of their evolutionary history. Thus one can use binary pulsar systems as key probes of stellar astrophysics (Stairs 2004).

NSs accreting materials from their low-mass binary companions are spun up by the angular momentum carried by the accreted materials while the magnetic field decays. The X-ray binaries are the evolutionary progenitors to these `recycled' MSPs (Alpar et al. 1982, Taani et al. 2012, Taani et al. 2013). It is evident that the B and P of X-ray pulsars and recycled pulsars are correlated with the duration of both the accretion phase and the total amount of matter accreted.

We are mainly focusing on the formation and evolution of MSPs and binary pulsars, and then during the phases of accretion till the spin-up. We provide an updated distribution to the wide variety and natures of binaries with a compact component. In addition, we performed a statistical study of these binary populations including normal pulsars, MSPs, Fermi pulsars, Supernova Remnants (SNRs) and magnetars that are observed in different energy bands, which we plot together in the so-called P-B diagram (Ghosh & Lamb 1977 ; Bhattacharya & van den Heuvel 1991).

In the B-P diagram, the connection between high-B pulsars and magnetars (top-right corner) is strengthened by the discovery of a low-B SGR (PSR B1509- 58) which shows magnetar-like activity despite its canonical magnetic field.

Young pulsars associated with SNRs appear to be born with reasonable small periods, P ~0.1 s, and strong B ~ 10^{12}G, which can provide independent distance and age estimates for both objects and, with a statistically significant sample of associations, constraints on the birth properties of neutron stars, including initial period, and magnetic field, can be found.

The first double pulsar system PSR J0737-3039AB was discovered by Lyne et al 2004.

A: MSP, B~10^9 G, P=23 ms; B: PSR, B~10^{12} G, P=2.8 s

FORMATION AND EVOLUTION OF ACCRETING NSs

Pulsars are born in the upper left part of the diagram with high B ~ 10^{12} G) and extreme rapid spin ~ 30 ms. As such, they will within a few million years spin-down and move along a horizontal track eventually crossing the `death-line'. No radio pulsars can exist to the right of this line as the polar cap electric field has become too weak to create pairs During their stay in the graveyard the system further spins down as the weak winds of the companion star may make the magnetic dipole moment decay via mass transfer, causing it to move downwards in the B-P diagram (see schematic in Fig. 2). Then, the accretion of matter provides angular momentum to the NSs causing them to spin-up with shorter spin periods meaning they move towards the left in the B-P diagram until they reach the spin-up line. Later after the companions have themselves become compact stars (white dwarfs or NSs) or have disappeared, eventually the spun-up NSs become observable as MSPs.

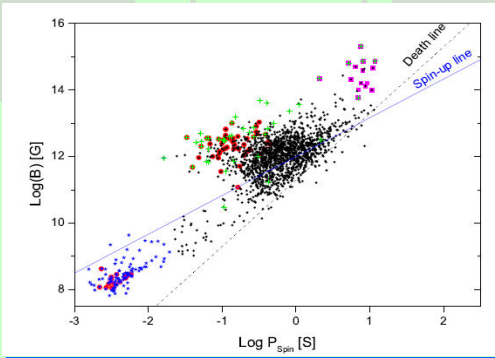

Figure 1. This is a scatter plot of magnetic field and spin period for pulsars in the current ATNF catalogue (Manchester et al. 2005). MSPs (together with binaries) are marked with blue stars, Fermi pulsars (red circle), SNRs (pink stars) and magnetars (green triangle). The solid line indicates the spin-up line which denotes the terminal period for objects moving to the left in the diagram owing to accretion that become the recycled pulsars once accretion ceases. The death line (shaded

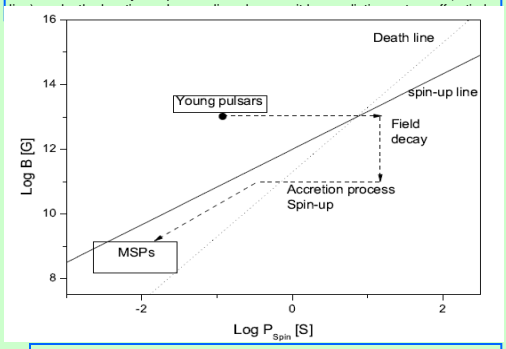

Figure 2. Evolutionary track of MSPs on the P-B diagram.

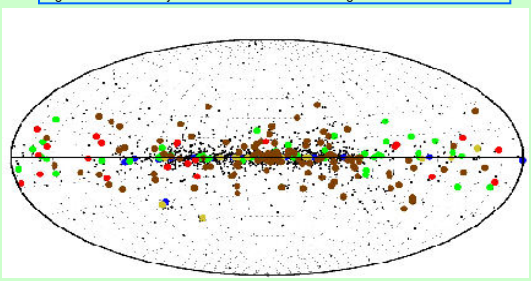

Figure 3. The full-sky distribution of all known pulsars in different nature, shown in Galactic oordinates in which the plane of the Galaxy is at the equator, and the Galactic center is at the origin (Black are the normal pulsars, green are the Fermi pulsars, red are SNRs, brown are MSPs, yellow are magnetars).

From the sky distribution in Galactic coordinates shown in Fig. 3, pulsars are mainly concentrated on the galactic plane. The youngest pulsars known to be associated with supernova remnants. The Fermi pulsars are also distributed closely on the galactic plane.

Such recycled pulsars would be close to the spin up line, and distinctly below the normal pulsars. Couple of pulsars (PSR 1541-52 and PSR 1804-08) were tentatively identified as recycled pulsars (Radhakrishnan and Srinivasan 1982).

Main Conclusions:

The spin-up line diagram represents the minimum spin period to which such a spin up may proceed in an Eddington-limited accretion scenario. The observed properties of binary pulsars reveal much information about the evolution any history of different types of binaries (including their spin period, magnetic field, component mass, and supernova process) due to the conversion of angular momentum and mass transfer. The current and futures surveys will ultimately provide a far more complete census of the Galactic pulsar population.

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