Magnetic field decay in pulsars. Population synthesis and other statistical methods.

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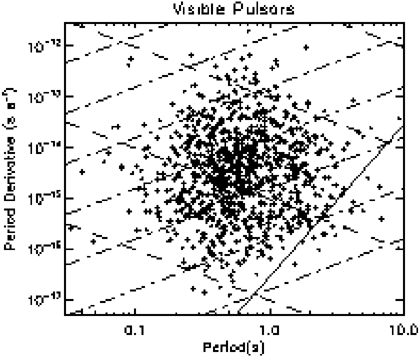
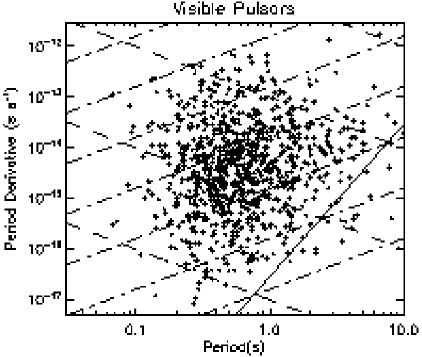
Population synthesis

Popov, Pons et al. (2010)

The authors reproduced the distribution of pulsars in $P - \dot{P}$ plane in the case of constant magnetic field (left figure; similar to Faucher-Giguere & Kaspi 2006) and decay of 'magnetar'-like fields (right figure).

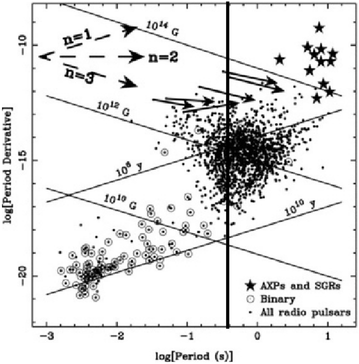




Pulsar current

Old approach

Phinney & Blandford (1981) and Vivekanand & Narayan (1981) supposed that motion of pulsars in $P - \dot{P}$ plane can be considered as a fluid flow. The density is $N_p(P, \dot{P}, t) dP d\dot{P}$. The rate of change of density with time is due to evolution and follows continuity equation with source term.

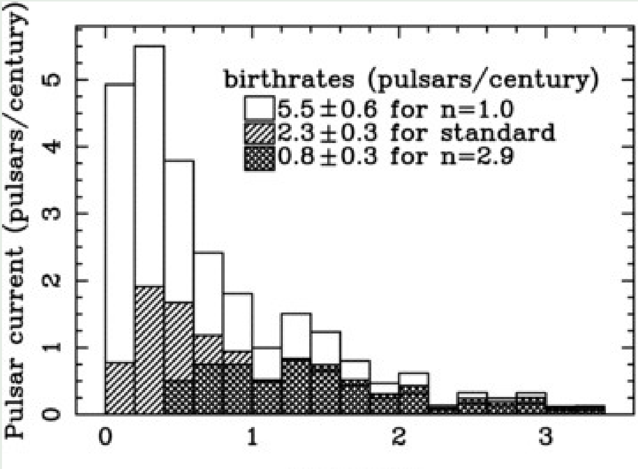


Current

The flow of pulsars through a vertical line in the $P - \dot{P}$ plane is called pulsar current.

Results with different braking indices. (Vranešević & Melrose (2011)

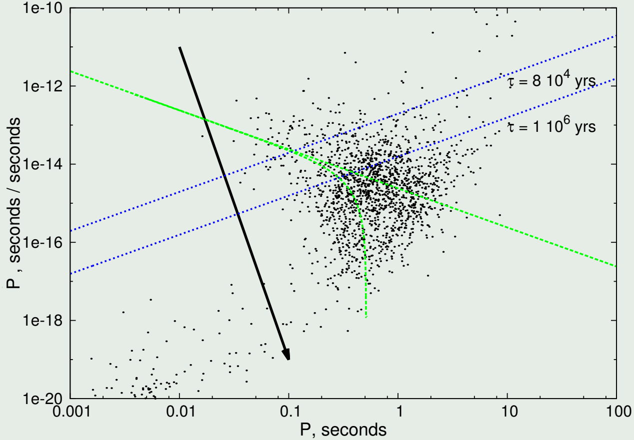
The method is designed to estimate the pulsar birthrate. However, this estimate appears to be strictly dependent on the assumed braking index. In the pulsar population a variety of braking indices values is observed and it is difficult to choose the proper one.



Revision

Illustration

We propose a method in which the pulsar current along the spin down ages axis is studied in a limited range of ages ($\sim 10^5 - 10^6$ yrs)



Restoration of magnetic field decay

Method

1. We select isolated non-millisecond pulsars from the ATNF catalogue inside 10 kpc distance from the Sun.
2. We assume a unique law of magnetic field decay for all NSs in the form $B(t) = B_0 f(t)$. This allows us to sort all the pulsars by their spin-down ages.
3. We introduce an estimate of the true age according to the equation $t(\tau) = \frac{N(\tau)}{n_{\mathrm{birthrate}}}$.
4. As a result we obtain relation between spin-down ages and true ages.
5. We fit this dependence by a sixth order polynomial.
6. Finally, we use this polynomial to restore $f(t)$, i.e. the magnetic field decay.

Restoration of magnetic field decay

Main equations

The spin-down age of a radio pulsar

$$\tau = \frac{P}{2\dot{P}}$$

Braking of the pulsar

$$P\dot{P} = \alpha B^2(t)$$

The integral expression for $f(t)$ function:

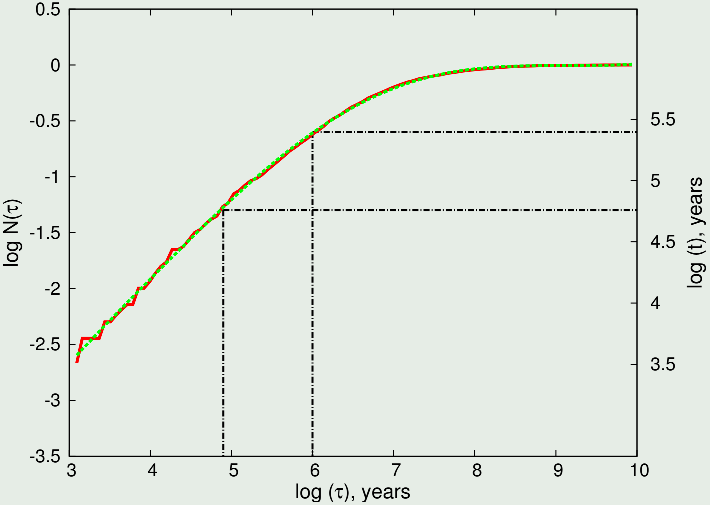
$$f(t) = \frac{\exp(\int_0^t \frac{dt'}{2\tau(t')})}{\sqrt{\tau(t)}}$$

SDA-code

http://www.pulsars.info/decay.html

Stages of the Method

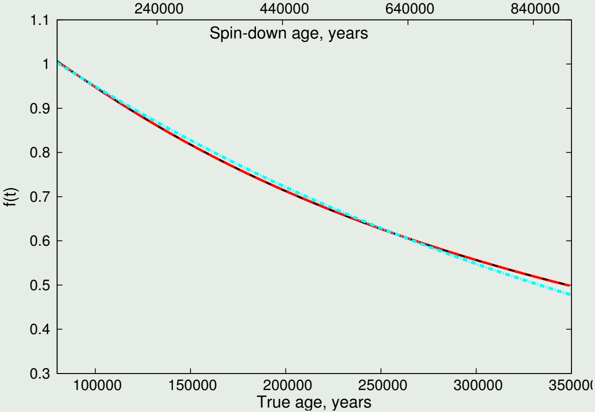
Fit to the cumulative distribution



Stages of the Method

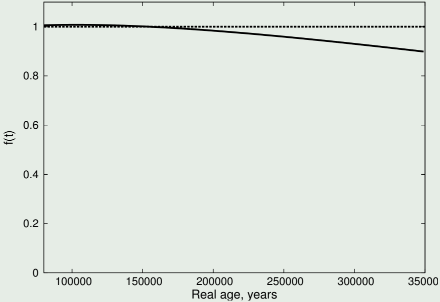
Restoration of magnetic field decay

The restored magnetic field decay law may be fitted by an exponential with timescale $3.6\,10^5$ years (in the interval of true ages from $8\,10^4 - 3.5\,10^5$ years).



Test of the method

We restore magnetic field decay for samples which are analogous to those from the article by Popov, Pons et al. (2010).



Method

Estimate of the birthrate

Our method (as well as the standard pulsar current method) also provides an estimate of the birthrate. We assume the absence of the magnetic field decay for $\tau < 8\,10^4$ years. Therefore, near this age the spin-down ages and true ages of pulsars should be similar. This gives an estimate 2.3 pulsars per century.

Method

Results

1. We propose a new method to uncover magnetic field decay in normal radio pulsars. The approach is analogous to the classical pulsar current method.
2. We demonstrate the existence of magnetic field decay for the time range $10^5 - 10^{5.5}$ years.
3. The method was tested using synthetic samples of pulsars.