XXVIII General Assembly of the International Astronomical Union, Beijing, China, 20-31 August 2012

BIRTH ACCELERATIONS OF NEUTRON STARS

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THE BIRTH-ULTRAFAST-MAGNETIC-FIELD-DECAY MODEL

R. Heras, "The birth-ultrafast-magnetic-field decay applied to isolated millisecond pulsars" presented in X-Ray Binaries conference, Boston Massachusetts USA , 10-12 July 2012

R. Heras, "Pulsars are born as magnetars" presented in Conference on Electromagnetic Radiation from Pulsars and Magnetars, Zielona Gora, Poland, 24-27 April 2012

Basic assumptions of this model: The birth neutron stars experience three related physical processes:

1. An increase of its period from the initial value P_0 to the current value Ps (a change of rotational energy)
2. An increase of its space velocity from the initial value V_0 to the current value V (a change of kinetic energy)
3. An exponential decay of its magnetic field from the initial value B_0 to the current value B_s (a change of radiative energy)
4. These energy changes occur during the time $\tau_s = (R/c)\ln(B_0/B_s)$ and are connected by the formula

$$\frac{B_0^2 R^3 \ln(B_0/B_s)}{6} + \frac{Mv^2}{2} = \frac{4\pi^2 MR^2}{5}\left(\frac{1}{P_0^2} - \frac{1}{P_s^2}\right)$$

ΔE_{rad} ΔE_{kin} ΔE_{rot}

where M and R are the radius and mass of the neutron star; c the speed of light and the initial velocity is taken to be zero. According to the above formula, the radiation loss and increase of kinetic energy are both at the expense of rotational energy. [A similar equation but with a different radiative term is the basis of the "Rocket Model" proposed by Harrison ad Tademaru, ApJ , 201, 447 (1975), See Eq. (12)]. For field decays from one to eight orders of magnitude one has $2.3 \leqslant \ln(B_0/B_s) \leqslant 4.4$ and then the time decaying is very small $\tau_s \sim 10^{-4}$ s indicating an ultrafast process! **According to this model: (i) all neutron stars are born with magnetic fields in the range of 10^{15}–10^{16}G and initial periods in range 1–20 ms. Then neutron stars are born with magnetic fields of magnetars and periods of millisecond pulsars; (ii) very tiny fractions of second after their formation, neutron stars display their current periods and magnetic fields.**

Taking into account that the process is ultrafast the speed v can be approximated by $v = a\tau_s$ which can be used together with the green ad reed formulas to obtain the birth acceleration

$$a = \sqrt{\frac{8\pi^2 c^2 (P_0^{-2} - P_s^{-2})}{5\ln(B_0/B_s)^2} - \frac{B_0^2 Rc^2}{3M\ln(B_0/B_s)}} \quad \star$$

The birth acceleration is determined by the initial period and magnetic field: P_0 and B_0 and the current period and magnetic field: P_s and B_s

Interval: 2 s $< P_s \leqslant 8.5$ s. There are 9 neutron stars in this interval. The average values of this set are $\widetilde{P_s} = 4.82$ s, $\widetilde{B_s} = 3.14\times10^{13}$G and $\widetilde{v_1} = 226.55$ km/s. If $\widetilde{P_0} = .02$ s and $B_0 = 7\times10^{15}$G then $\star$ predicts $a = 5.0\times10^8$g.

Interval: 1 s$\leqslant P_s \leqslant 2$ s. There are 29 pulsars in this set of neutron stars. The average values are $\widetilde{P_s} = 1.32$ s, $\widetilde{B_s} = 4.17\times10^{12}$ G. If $\widetilde{P_0} = .02$ s and $B_0 = 5\times10^{15}$G then $\star$ predicts $a = 5.8\times10^8$g.

Interval: .02 s$\leqslant P_s < 1$ s. There are 130 neutron stars with periods in this interval. The average values are $\widetilde{P_s} = 0.41$ s, $\widetilde{B_s} = 1.28\times10^{12}$G. If $\widetilde{P_0} = .02$ s and $B_0 = 5\times10^{15}$G then $\star$ predicts $a = 4.5\times10^8$g.

Isolated millisecond pulsars in the interval: .0015 s $\leqslant P_s < .009$ s. There are 9 pulsars in this set of neutron stars. The average values are $\widetilde{P_s} = 0.005$ s and $\widetilde{B_s} = 2.59\times10^8$G. If $\widetilde{P_0} = .0049$ s and $B_0 = 10^{15}$G $\star$ predicts $a = 3.1\times10^8$g.

RESULTS

The birth accelerations of neutron stars are in the range: $10^8 - 10^9$g

Neutron stars possessing similar surface magnetic fields have different velocities because they had distinct initial magnetic fields and thereby they experienced different initial accelerations during the birth process. Similar explanation works for neutron stars with similar velocities and distinct surface magnetic fields.