Asymmetric Neutrino Emission Process and Rapid Spin-Deceleration of Magnetized Proto-Neutron Stars

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We calculate the neutrino scattering and absorption cross sections in the magnetized proto-neutron-star (PNS) matter in fully relativistic mean field (RMF) theory [1]. The calculation results showed that the magnetic contribution increases the neutrino momentum emitted along the south magnetic pole and decrease it along the north magnetic pole. Furthermore, we applied this asymmetry to the calculation of the pulsar kick, and estimated PNS kick velocities of ~ 600 km s^{-1} [1] for a neutron star of mass $M_{NS} = 1.68 M_\odot$, a uniform dipole magnetic fields of $B = 2 \times 10^{17}$ G, temperature of $T = 20$ MeV, and a total emitted neutrino energy of $E_T \approx 3\times 10^{53}$erg.

There is accumulating evidence that magnetars spin down faster than expected [2]. Recent super-novae simulations [3,4] suggested the toroidal magnetic field configurations of the magnetic field in PNSs. In this work, then, we consider the asymmetric neutrino emissions caused by this toroidal magnetic field as a new source for the spin deceleration.

For this purpose we use the magnetic field distribution shown in Fig. 1, Then, we solve the neutrino transport and obtain the ratio of total rate of angular momentum loss to the total power $(cdLz/dt)/(ET/dt)$. From its result we can estimate $\dot P/P$ as

$$\frac{P}{P} = \frac{P}{2\pi c I_{NS}}\left(\frac{cdL_z/dt}{dE_T/dt}\right)\mathcal{L}_\nu$$

where $\mathcal{L}_\nu$ is the neutrino luminosity, and INS is the moment of inertia of the neutron star.

In actual calculation we use $\mathcal{L}_\nu \approx 3 \times 10^{52}$erg·$s^{-1}$, P =10s, and $B_0 = 10^{16}$G which has been given in Ref. [4].

Then, we can get a result of $\dot P/P \approx 3.4 \times 10^{-6}$ and 6.39×10^{-6} s^{-1} in PNS without and with Λ, respectively.

On the other hand, the magnetic dipole radiation gives $\dot P/P$~$10^{-9}s^{-1}$ in the poloidal magnetic field with 10^{14}G, which has been also given in [4]. Thus, we can conclude that the asymmetric neutrino emission in a toroidal magnetic field makes large effects in the PNS spin deceleration.

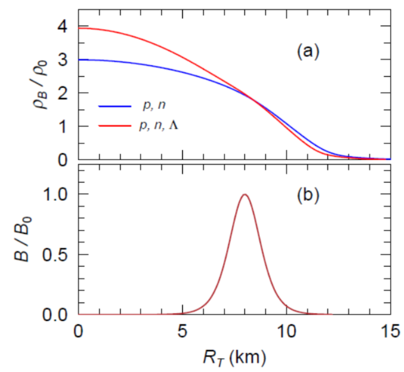

Figure 1: (a) The baryon density distribution for a PNS with $T = 20$ MeV and $Y_L = 0.4$. (b). Distribution of toroidal type of the magnetic fields at z = 0.

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