The possibility of nuclear ferromagnetism at Supernovae II explosions

A.I. Sery

Brest State A.S. Pushkin University,
Kosmonavtov Boulevard 21, 224016 Brest, Belarus
E-mail: alexey_sery@mail.ru

The research is done according to the suggestion of V.G. Baryshevsky and V.V. Tikhomirov. Considering the energy of free nucleons and their nuclear energy Coulomb exchange and correlation energies for protons, we find expressions for Stoner criterion and energy density at finite degrees of nucleon spin polarization in degenerate (D) and non-degenerate (ND) neutron-proton system.

Table 1 - Regions of ferromagnetism of np-system.

system	region		influence of energy	
	I ($n_n^{(min)} = 0$)	II ($n_n^{(min)} \neq 0$)	exchange	correlation
D	$n_p \leq 6.9 \cdot 10^{31}$ cm^{-3}	$n_p, n_n \geq 10^{35}$ cm^{-3}	positive	negative
ND	$n_p \leq 8.9 \cdot 10^{30}$ cm^{-3}, $T \leq 2.7 \cdot 10^8$ K	the results are not reliable	positive	negative

Stoner criterion for non-degenerate np-system ($i = n, p; l = n, p; j = n, p, t, s$):

$$\nu_{0p}^T \nu_{0n}^T ((g_{np}^{T\uparrow\downarrow} - g_{np}^{T\uparrow\uparrow})^2 - \tilde{g}_{pp}^T \tilde{g}_{nn}^T) + \tilde{g}_{pp}^T \nu_{0p}^T + \tilde{g}_{nn}^T \nu_{0n}^T > 1, \nu_{0i} = \frac{2m_i^{3/2}\sqrt{kT}}{3\hbar^3\pi^{3/2}},$$

$$g_{np}^{T\uparrow\downarrow} = -\frac{\pi\hbar^2}{m_{np}^*}(f_s(q_{np}) + f_t(q_{np})), g_{np}^{T\uparrow\uparrow} = -\frac{2\pi\hbar^2}{m_{np}^*} f_t(q_{np}), g_{ii}^T = -\frac{2\pi\hbar^2}{m_i} f_i(q_{ii}),$$

$$\tilde{g}_{nn}^T = g_{nn}^T, \tilde{g}_{pp}^T = g_{pp}^T + \frac{2\alpha\pi(\hbar c)^3}{m_p c^2 kT} - \frac{3\pi^2\alpha^{3/2}(\hbar c)^{9/2} n_p^{1/2}}{(m_p c^2)^{3/2}(kT)^2},$$

$$f_j^{-1}(q_{il}) = -\frac{1}{a_j} + \frac{1}{2} r_{0j} \left(\frac{q_{il}}{\hbar}\right)^2, q_{il} = \sqrt{3(m_i + m_l)kT}$$

Here $\alpha = e^2/(\hbar c)$; n_i and m_i are nucleon densities and masses, respectively. The values of effective radii and scattering lengths are (in fm): $r_{0p} = r_{0n} = 2.79$, $r_{0t} = 1.76$, $r_{0s} = 2.7$, a_t=5.42, a_s=-23.71, a_n=a_p=-17.2 (at the presence of electrons).

The main possible mechanisms for magnetic fields of Supernovae II are rotation, jets, asymmetric collapse with different hydromagnetic instabilities, magnetic flux conservation during the contraction. Here the version of ferromagnetism of nucleons is considered. If $p_{0p} \approx -p_{0n} \approx 1$ then $B \approx 4\pi\mu_N(\sigma_p n_p p_{0p} + \sigma_n n_n p_{0n}) \sim 10^9$ Gs at $n_p \sim n_n \sim 10^{31}\text{cm}^{-3}$; $\sigma_p \approx 2.793, \sigma_n \approx -1.913, \mu_N$ is nuclear magneton.