NEUTRINO MAGNETIC MOMENT INDUCED BY TORSION AND CONSEQUENCES FOR SUPERNOVA NEUTRINOS

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Abstract

If neutrinos couple to torsion in the framework of the Einstein-Cartan theory, with a strength about that of the weak interaction, then the spin-torsion interaction can induce an effective neutrino magnetic moment. We explore the emission and propagation of neutrinos in a hot dense medium of neutron matter in the presence of large magnetic fields. These effects could be significant for neutrino production in dense collapsing cores.

<u>Introduction</u> As is well known [Sivaram 1975], [de Sabbata 1979], the torsionic contact interaction lagrangian between two spin-half particles of vanishing mass is formally identical to the weak interaction lagrangian and may be written in the (V - A) form, suggesting that the spin-torsion coupling constant should be also of the same magnitude as the weak Fermi interaction constant [de Sabbata 1978], [Sivaram 1979]. Detailed justification for this interaction strength of neutrinos with torsion is given by de Sabbata [de Sabbata 1989a] and in fact has been applied to consider its effect on supernova neutrinos [de Sabbata 1989b] i.e. torsion can induce flavour oscillations even for zero mass neutrinos [de Sabbata 1981], the torsion interaction inducing an energy splitting ΔE_T giving rise to an oscillation length

$$l_T = 2\pi/\Delta E_T = c^3/2G_T\hbar\,\rho\,\delta^2 \qquad (1)$$

which is greatly increased by a factor $(l_M/l_T)^2$, where $l_M \sim 4\pi E_\nu/\Delta m^2$, for neutrinos with rest mass. Moreover the formal analogy of the interaction energy between spin S and torsion Q is given by [de Sabbata 1980]:

$$E = -\bar{S}\cdot\bar{Q} \qquad (\bar{Q} = 4\pi G_T/c^2)\bar{S}n \qquad (2)$$

(n is the number density of aligned spins), with the interaction energy of a magnetic dipole μ in an external magnetic field $\bar{B}$, i.e. $E = -\bar{\mu}\cdot\bar{B}$, was used by de Sabbata [de Sabbata 1988] to estimate the effective magnetic moment induced by torsion for zero mass neutrinos (by their mutual spin-torsion interaction) in the early universe. Using for the field B, at the weak interaction dominated stage, the expression obtained by Sivaram [Sivaram 1989], the expression obtained for the induced neutrino magnetic moment due to torsion was [de Sabbata 1989c]:

$$\mu_\nu \approx \frac{64\ (2)^{1/2}}{11} \frac{\pi^{3/2} c^2 \hbar^0 G_T\ G^{1/2}\ a}{K_B G_F^2 T^2} \qquad (3)$$

which for the corresponding temperature $T \approx 10^{100}K$ in the early universe gives:

$$\mu_\nu \approx 10^{-21} \mu_B$$

where μ_B is the Bohr magneton.

This is of the same magnitude as that obtained in the Salam-Weinberg electroweak theory, i.e.

$$\mu_\nu \approx (3eG_F m_\nu)(8\pi c 2^{1/2}) \simeq 3 \cdot 10^{-19} \mu_B (m_\nu / 1ev) \qquad (4)$$

The above neutrino magnetic moment would imply an oscillation (or 'spin-flip') length in the primordial magnetic field corresponding to that of $(\Delta m^2) \approx 10^{-6} ev^2$ consistent with other independent limits.

<u>Effect of neutrino magnetic moment in supernovae</u> Now relativistic neutrinos ($v \approx c$) with a small magnetic moment can flip helicity in a magnetic field (i.e. left handed neutrinos precess into right handed components) at a rate.

$$\Gamma_{LR} \approx \frac{2}{\pi} \frac{\mu_\nu Bc}{\hbar}, \qquad (5)$$

where B is the magnetic field normal to the neutrino path. For neutrino propagation in intergalactic (10^{-7}G) and galactic (10^{-6}G) magnetic fields, the requirement that they do not flip helicity on the way [Sivaram 1989], (i.e. $\Gamma_{LR} \simeq 1/t_{LMC} \simeq 2 \cdot 10^{-13} s^{-1}$) constrains $\mu_\nu < 10^{-12} \mu_B$.

In the unlikely situation that the magnetic moment of the neutrino is $> 10^{-10} \mu_B$ (as required by the VVO mechanism) then the SN 1987A neutrinos would have flipped helicities several times, so that they reach the earth as an equal mixture of left and right handed helicities.

However if at the neutrino source, (i.e. the protoneutron star) the collapsing star traps a large amount of magnetic flux, the magnetic field during the collapse can rise to values > 10^8G, then for a neutrino diffusion time scale of ~ 10s (i.e. time scale of neutrino emission and propagation by coherent scattering in the stellar core) the above eq.(5) implies that the neutrinos can flip helicity even for a neutrino magnetic moment as small as $10^{-24}\mu_B$ much smaller than implied by eq.(3). So even for a magnetic moment $<<10^{-21}\mu_B$, for neutrinos of N_f flavours, only $(1/2)N_f$ of detectable neutrinos would emerge out of the collapsing core [Sivaram 1989], which is quite a significant effect.

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