Neutrino magnetic moment and the shock wave revival in a supernova explosion

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Could sterile $\nu_R$’s stimulate the supernova explosion?

In a modelling of the supernova explosion, two main problems arise.

- The mechanism of the damped shock wave stimulation has not been developed completely yet.
- Even in the case of the “successful” theoretical supernova explosion, the energy release turns out to be essentially less than the observed kinetic energy of the envelope $\sim 10^{51}$ erg (FOE problem).
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It is necessary for the self-consistent description of the explosion dynamics, that the neutrino flux, outgoing from the supernova core, could transfer by some mechanism the energy $\sim 10^{51}$ erg to the supernova envelope.
Could sterile $\nu_R$’s stimulate the supernova explosion?

The mechanism first proposed by A. Dar, 1987, with the neutrino magnetic moment being not too small.

A part of left-handed electron neutrinos $\nu_e$ produced in the collapsing supernova core could convert into right-handed neutrinos due to the interaction of the neutrino magnetic moment with plasma electrons and protons.

It was shown earlier (A.K., N.M., JCAP, 2007) that the obtained $\nu_R$ luminosity was large enough to influence essentially on the supernova explosion dynamics.

These $\nu_{eR}$’s (sterile to the weak interaction), freely escape from the central part of the supernova, if the neutrino magnetic moment is not too large, $\mu_\nu < 10^{-11} \mu_B$. 

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In the supernova envelope, a part of these neutrinos can **flip back to $\nu_{eL}$’s** due to the interaction of the neutrino magnetic moment with a **magnetic field**, which could achieve the critical value

$$B_e = m_e^2/e \simeq 4.41 \times 10^{13} \text{ G}.$$ 

These $\nu_{eL}$’s being absorbed in **beta-processes**, $\nu_e n \rightarrow e^- p$, can transfer an **additional energy** to the supernova envelope.
We have analysed quantitatively the two-step conversion of the neutrino helicity, $\nu_L \rightarrow \nu_R \rightarrow \nu_L$, under the supernova conditions. This process could provide an additional energy $\sim 10^{51}$ erg to be injected into the region between the neutrinosphere and the shock-wave stagnation area, $R_\nu < R < R_s$, during the typical stagnation time of the order of some tenths of a second.

This energy could be sufficient for stimulation of the damped shock wave.

The conditions for the realization of this scenario appear to be not very rigid. The Dirac neutrino magnetic moment should belong to the interval $10^{-13} \mu_B < \mu_\nu < 10^{-12} \mu_B$, and the magnetic field $\sim 10^{13} \text{ G}$ should exist in the region $R_\nu < R < R_s$. 