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

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The neutrino chirality-flip process in a supernova core is investigated in detail; the plasma polarization effects in the photon propagator are taken into account [1] in a more consistent way than in earlier publications [2, 3]. In particular, it is shown that the contribution of the proton fraction of plasma dominates. The supernova core luminosity Q_{ν_R} for ν_R emission is calculated.

Assuming that the right-handed neutrino luminosity is less than the left-handed neutrino luminosity in ~ 0.1 sec after the collapse, $Q_{\nu_R} < 10^{53}$ ergs/s, we obtain a new upper bound on the Dirac neutrino magnetic moment, $\mu_\nu < (0.7 - 1.5) \times 10^{-12}\,\mu_{\rm B}$. This limit is rather robust with respect to variations of the supernova core parameters, when the product of the average value of the electron fraction Y_e on the core mass is fixed.

In this way, the best upper bound on the neutrino magnetic moment from SN 1987A is improved by a factor of 2.

Using this new approach to the neutrino chirality-flip process in the supernova core, the process of two-step conversion of the neutrino helicity, $\nu_L \to \nu_R \to \nu_L$ [4], is reanalyzed for supernova conditions. The first stage, $\nu_L \to \nu_R$, is realized due to the interaction of the neutrino magnetic moment with the plasma electrons and protons in the supernova core. The second stage, $\nu_R \to \nu_L$, is caused by the neutrino resonant spin-flip in a magnetic field of the supernova envelope. Given the neutrino magnetic moment within the interval $10^{-13}\,\mu_{\rm B} < \mu_\nu < 10^{-12}\,\mu_{\rm B}$, and assuming the existence of the magnetic field $\sim 10^{13}$ G between the neutrinosphere and the shock-wave stagnation region, we obtain an additional energy of the order of 10^{51} erg that can be injected into this region during the time of the shock-wave stagnation. This energy could be sufficient for triggering a damped shock wave.

References

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