Comments

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Comment on "Constraints on the Majoron interactions from the supernova SN1987A"

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(Received 18 July 1988)

We comment on a recently published analysis which places bounds on a particular combination of triplet Majoron-neutrino couplings from the neutrino signal of SN 1987A.

In a recent paper, Choi, Kim, Kim, and Lam[1] address the "Constraints on Majoron interactions from the supernova SN 1987A." Among several interesting results they suggested that Yukawa couplings of the Majorons in the range

$$2\times10^{-5}<h\equiv\left[\sum_{j=\text{neutrino species}}(h_j)^4\right]^{1/4}<3\times10^{-4} \qquad (1)$$

are excluded by the fact that Majoron emission does not lead to prompt cooling of the supernova, depleting the ν signal, and shortening the duration of the observed pulse. This intriguing bound cannot be obtained via terrestrial experiments, such as neutrinoless double-β decay with Majoron emission which depends on $h_1\equiv h(\phi\nu_e\nu_e)$ only.

Our analysis[2] based on different starting assumptions, did not produce such a strong bound. We would like to clarify the source of the difference. It lies in the different assumptions made in the two analyses regarding the interactions of the Majorons. Choi, Kim, Kim, and Lam[1] assumed a ϕ-transport subject "only to the elastic scattering process $\phi+\nu\rightarrow\phi+\nu$ as the source of the blocking of Majoron emission," once the quantity $\sum_i\sigma(\phi\nu_i\rightarrow\phi\nu_i)$, which is proportional to $\sum h_1^4$ is sufficiently small, the corresponding mean free path exceeds $R\simeq10^6-10^7$ cm, the size of the neutrino sphere.

The Majoron production reaction, $\nu+\bar\nu\rightarrow\phi+\bar\phi$ has (roughly) the same mean free path λ_ϕ, which could still be much shorter than the total path length $c\tau_\nu\simeq c(1-10)$ sec$\simeq3\times10^{10}-3\times10^{11}$ cm where τ_ν is the trapping time of the neutrinos. In such a case, Majorons will be amply produced and instantly escape leading to excessive quick cooling and to the quenching of the ν signal for $\sum h_1^4$ in the large ($\sim$5 orders of magnitude) excluded range in Eq. (1). We completely agree with this analysis as applied to particles which interact only with neutrinos.

The Majorons considered in our paper were specifically triplets of the weak interactions, $\phi^0,\bar\phi^0$, and carry the quantum numbers of $\nu\nu$, $\bar\nu\bar\nu$, respectively. Consequently, the cross sections for elastic scattering of Majorons on nucleons, $\sigma(\phi^0N)$ or $\sigma(\bar\phi^0N)$, are four times larger than $\sigma(\nu_\mu N)$ or $\sigma(\nu_\tau N)$, and the Majorons will be trapped directly by the nucleons for at least as long as ν_μ and ν_τ are trapped. Since, as pointed out in both Refs. 1 and 2, lepton-number symmetry is restored in the hot core, we should indeed consider the scattering of the states $\phi^0(\bar\phi^0)$ with definite lepton number.

It is worth mentioning, however, that the results are the same if we use the $M^0,\rho_0=(\phi^0\mp\bar\phi^0)/\sqrt{2}$ states instead. Because the $\phi_0N\rightarrow\phi_0N$ and $\bar\phi_0N\rightarrow\bar\phi_0N$, Z^0 exchange elastic amplitude have opposite signs we will have the same cross section but for the reactions $\rho^0N\overset{Z^0}{\leftrightarrow}M^0N$ (just like $K_1^0N\overset{\omega}{\rightarrow}K_2^0N$ or the crossed reactions $\phi^0\rightarrow K_1^0K_2^0$, $Z^0\rightarrow M^0\rho^0$ also involve the two vacuum mass eigenstate).

Since all of the above holds regardless of the Yukawa couplings, one cannot deduce the above bound of Ref. 1, in the triplet Majoron model, from the available information on SN 1987A.

[1]Kiwoon Choi, C. W. Kim, Jewan Kim, and W. P. Lam, Phys. Rev. D **37**, 3225 (1988).

[2]Y. Aharonov, F. T. Avignone III, and S. Nussinov, Phys. Rev. D **37**, 1360 (1988).

