Comment on "A Solution of the Solar-Neutrino Problem"

A recent Letter of Bahcall and Bethe[1] makes the assertion, "The best-estimate rate for the gallium experiments that are just getting started is 5 SNU [solar-neutrino units], much smaller than the standard-model prediction of 132 SNU." We counter that a direct calculation with the Mikheyev-Smirnov-Wolfenstein (MSW) mechanism yields a range of possible rates from a minimum of about 8 SNU up to a maximum of about 90 SNU.

The nonadiabatic MSW solution is advocated[1] as the only one consistent with both the Cl experiment and the Kamiokande II experiment if one drops the large-mixing-angle "third solution." We accept this premise here. Then, the solution in the Δm^2 vs $\sin^2 2\theta$ parameter space that is consistent with both Cl and Kamiokande II extends along a narrow diagonal band from $\Delta m^2 = 10^{-5}$ eV^2, $\sin^2 2\theta = 0.005$ to $\Delta m^2 = 10^{-7}$ eV^2, $\sin^2 2\theta = 0.5$, with the product of the two approximately a constant (see shaded area in Fig. 1).

Within the allowed band, the minimum rate that we calculate[2] for the Ga experiments without the effect of the Earth (see Fig. 1) is 6.8 SNU at $\Delta m^2 = 5\times10^{-7}$ eV^2, $\sin^2 2\theta = 0.1$; the maximum rate is about 90 SNU at $\Delta m^2 = 10^{-5}$ eV^2. At $\Delta m^2 = 10^{-7}$ eV^2 the rate is about 25 SNU. The low solution is at one extreme of a continuum. The region of high rates for ^{71}Ga corresponds to neutrino energies below the physical cutoff of the MSW transformation at $E/\Delta m^2 \simeq 10^5$. (^{71}Ga is sensitive to neutrinos of $\sim \frac{1}{20}$ the energy of ^{37}Cl and Kamiokande neutrinos.) This is very different from carrying their exponential approximation to low energies.

In addition to the above general conclusions we make an additional detailed technical observation. The Earth-Sun transit effects are excluded by Bahcall and Bethe; these raise the minimum rate (averaged over 1 yr) within the allowed band to 8.6 SNU at $\Delta m^2 = 10^{-6}$ eV^2, $\sin^2 2\theta = 0.04$. Whether or not the day-night effect can ever be reliably measured, the effect of the Earth will affect the rate in an average way by increasing the minimum. Even if we take the unconstrained minimum given by MSW calculations appropriate to the Ga experiments, which happen to lie just outside the allowed Cl and Kamiokande II band, then the minimum value with (without) the Earth effect is 7.6 (6.3) SNU.

In summary, Bahcall and Bethe have arbitrarily chosen the *minimum* MSW prediction for Ga consistent with the Cl nonadiabatic solution as most likely. This choice ignores the equal possibility of a Ga result not reduced from the standard-solar-model prediction by more than about 30%. The difference between an observation of 90 SNU and one of 8 SNU is the difference between a relatively small reduction from the expected 132 SNU, which might be explained away in terms of solar-model difficulties, and a result that is reduced enough to be an unambiguous proof of neutrino transformations on the basis of the Ga experiments alone. The question of the Ga rate is still open; data from the SAGE and GALLEX experiments promise to fix the choice of Δm^2 and $\sin 2\theta$ within the two-component MSW model.

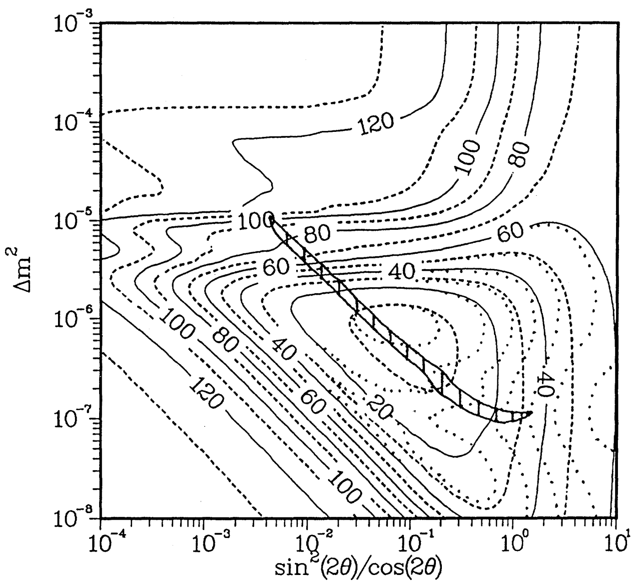

FIG. 1. Predictions for the Ga experiments in SNU from the standard solar model and the MSW effect in the Sun. The shaded area is the overlap region of MSW solutions for the Cl experiment and the Kamiokande II experiment (Refs. 2 and 3). The boundary of the shaded area at the largest mixing angle has been estimated from Ref. 3. The effect of the Earth is included in determining the outline of the shaded area, although it only slightly affects the location of the outline on the lower right. On the other hand, the effect of the Earth on the Ga experiments (averaged over 1 yr) causes a distortion in the contours seen in the lightly dotted lines.

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