Solar eclipse and neutrinos

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It is pointed out that due to neutrino oscillations the observed solar neutrino rate in the terrestrial neutrino detectors may be enhanced during a partial or total solar eclipse. The enhancement is calculated as a function of the neutrino parameters.

It is generally true that during a solar eclipse there is a depletion of radiation arriving on the earth due to the intervention of the moon. Here we point out that there is one type of radiation, namely neutrinos, that may be augmented during the solar eclipse.

The neutrinos emitted in the sun in the thermonuclear reactions are the electron type of neutrinos, denoted as ν_e. The terrestrial neutrino detectors have detected these neutrinos; however the observed flux of these neutrinos in these detectors falls short of the flux theoretically calculated from models of the sun by a factor of 2 to 3. This is known as the solar neutrino puzzle and there exists an extensive literature on this topic (see, for instance, refs 1, 2).

The most widely believed resolution of this puzzle invokes the possibility of the so-called neutrino oscillation phenomenon, especially the matter-induced oscillation during the transit of the neutrinos from the solar interior to the solar surface. This phenomenon converts a part of the ν_e flux to other species of the neutrinos such as ν_μ and ν_τ, and since the terrestrial neutrino detectors are dominantly sensitive to ν_e only (although some of the detectors are sensitive to the other species also, but to a lesser extent), the explanation of the smaller observed flux is obvious.

If the moon now interposes itself in the path of the neutrinos between the sun and the earth, the same oscillation phenomenon will imply that a part of the ν_μ and ν_τ may be reconverted to ν_e and thus the detectable part of the neutrino radiation from the sun may be enhanced by the moon. This, in a nutshell, is the main point of this note.

We shall avoid technical details and also for simplicity restrict ourselves to oscillations between the two species ν_e and ν_μ only. Let P_s be the probability of conversion of ν_e to ν_μ by oscillation during its passage from the solar interior to the earth, and $(1-P_s)$ the probability of survival of ν_e. If ϕ is the original solar neutrino (ν_e) flux produced in the solar interior, the ν_e flux arriving on earth directly from the sun is

$$\phi_1 = \phi(1-P_s). \quad (1)$$

Taking the conversion and survival probabilities in the moon as P_m and $1-P_m$ respectively, the ν_e flux arriving on the earth during the solar eclipse will be

$$\phi_2 = \phi(1-P_s)(1-P_m) + \phi P_s P_m. \quad (2)$$

The difference in the fluxes is

$$\phi_2 - \phi_1 = \phi P_m (2P_s - 1). \quad (3)$$

We thus see that as long as the conversion probability of ν_e in the sun is larger than 0.5, *there will be an enhancement of ν_e flux during a solar eclipse.* For P_s equal to 0.5 or less than 0.5 respectively, the ν_e flux will be unchanged or reduced. Hence monitoring the neutrino flux during the eclipse provides us with another window on neutrino physics.

These fluxes ϕ_1 and ϕ_2 can be converted into the corresponding neutrino counting rates R_1 and R_2 in the detectors by multiplying by the cross-section σ for the neutrino to interact with the matter in the detector. All these quantities ϕ, P_s, P_m and σ are functions of the energy E of the neutrino and a final integration over any desired range of energies can be performed. As already mentioned, in some of the detectors the other species ν_μ also is detected, but with a smaller cross section and the addition of this detection rate does not change the above conclusion on the enhancement.

Actually, there exists another phenomenon that is similar to the eclipse effect discussed here—the so-called day–night effect. The reconversion of other species into ν_e can take place during the passage of the solar neutrinos through the earth and so the neutrino detectors will detect an enhanced flux in the night as compared to day. This effect has been looked for, but within the statistical errors no such variation has been observed[3]. However, the eclipse effect is independent and worth a separate investigation.

We now present some numerical results. The mixing angle θ and the difference of squared masses $\delta \equiv (m_2^2 - m_1^2)$ are the two fundamental parameters that determine the neutrino oscillation phenomenon and the detailed theory has been already worked out (see, for instance, ref. 4). The probabilities P_s and P_m can be calculated in terms of these neutrino parameters using the astrophysical information on the solar and lunar densities and diameters, and the earth–sun distance. We have assumed a constant lunar density of 3.32 gm/cc and we have considered the solar eclipse to be total so that the path length within the moon is the lunar diameter. We have integrated over all energies above 5 MeV. This is because the effect under discussion can be observed only in (real-time) Cerenkov detectors which have such high thresholds typically. We calculate the ratio $(R_2 - R_1)/R_1$ for a range of θ and δ and Figure 1 gives the result in terms of contours in the $\delta - \theta$ plane for different values of this ratio. We see that

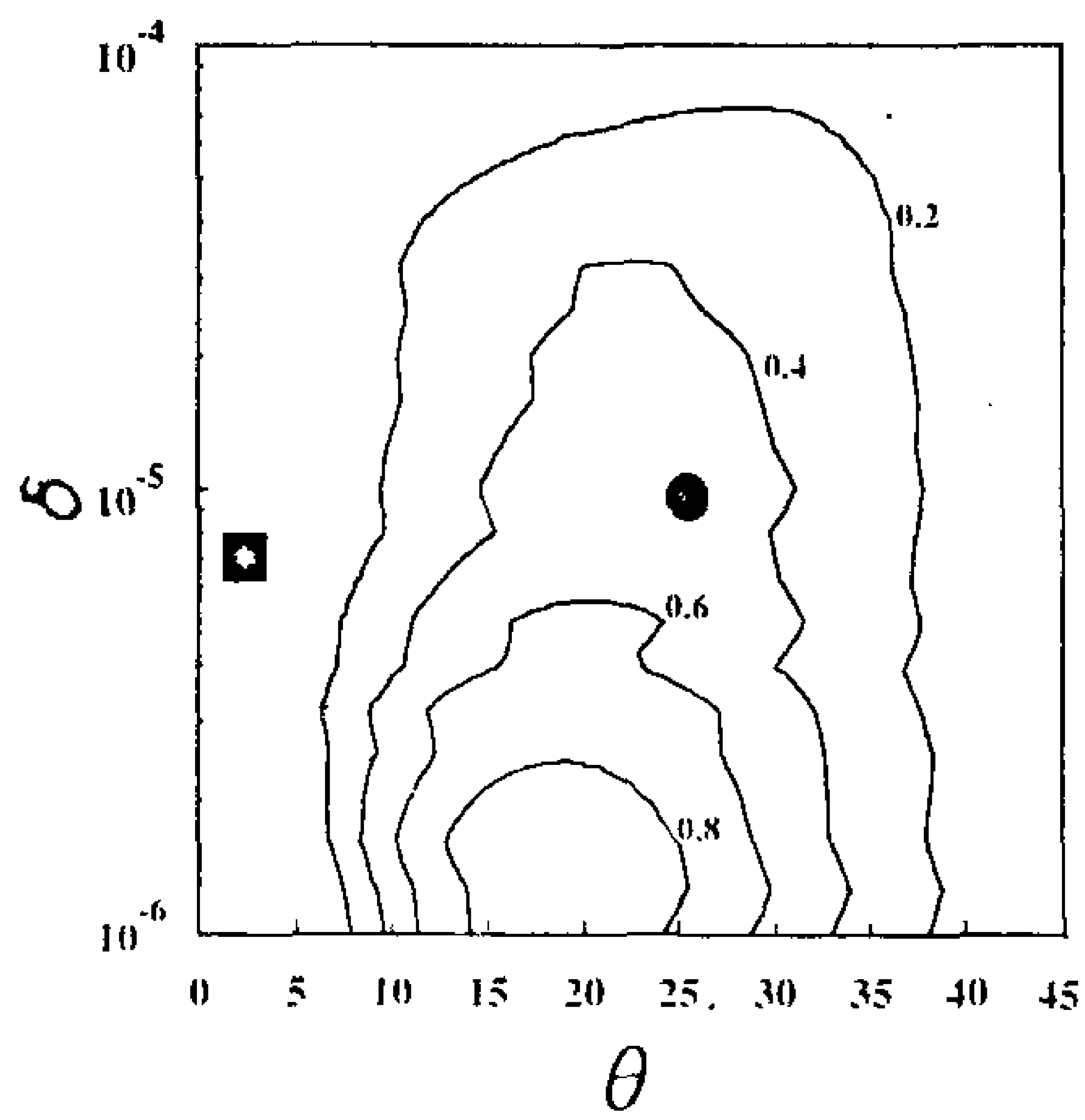

Figure 1. The contour plot of the enhancement in the neutrino detection rate $(R_2 - R_1)/R_1$ during a solar eclipse as a function of the neutrino mixing angle θ (in degrees) and the neutrino mass-difference parameter δ (in eV^2). The numbers 0.2–0.8 labelling the various curves are the values of $(R_2 - R_1)/R_1$. The dark square and circle correspond respectively to the central values of the 'small-angle' and 'large-angle' solutions of the solar neutrino problem.

there could be a sizeable increase in the flux of ν_e reaching the earth during the solar eclipse for some range of θ and δ. In particular for $\theta \approx 25°$ and $\delta \approx 10^{-5}\,eV^2$ which provides a solution[5] (the large angle solution) for the original solar neutrino puzzle, the increase is about 50% although for the small angle solution, the increase is only about 10%.

But the bad news is that the counting rate in the neutrino detectors is so small because of the notoriously tiny cross section σ for the interaction of the neutrinos with matter, that the enhancement in the counting rate during the few hours of the solar eclipse cannot be observed in any of the existing neutrino detectors which have a counting rate of utmost a few hundred per year and there is only a marginal possibility of its being seen even in the next generation of neutrino detectors[6] which will be ready soon, where the counting rate is expected to be of the order 10^4 per year. One must also add that the neutrino detectors are all huge and immovable, so in order to see the effect the detector must lie in the path of the eclipse. However, there are some positive factors. First the eclipse need not be a total one. Further, the effect can also be observed on the other side of the earth since the straightline connecting the sun and the moon during the eclipse cuts the surface of the earth at two points. In fact, on the far side of the earth the effect may be an enhanced one.

In any case, the aim of this communication is not to propose any experimental test of immediate relevance, but rather to focus general attention on the novelty of the phenomenon: the sun seen through ν_e radiation may shine brighter during the eclipse.

Finally one cannot avoid the temptation of speculating on the futuristic role of neutrino radiation since it is the most penetrating radiation known to man (except for gravitational radiation). The neutrino oscillation phenomenon is sensitively dependent on the density of matter traversed by the neutrinos, especially on its variation. Because of this, the possibility of using neutrino radiation from astrophysical sources for the tomography of the earth has already been speculated upon[7]. Similarly, monitoring of the solar neutrino radiation during the solar eclipse can lead to the tomography of the moon. Of course this has to wait until neutrino technology is mastered.

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A large conductance Ca^{2+}-activated K^+ channel in αT3-1 pituitary gonadotrophs

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The Ca^{2+}-activated K^+ channel in endocrine cells is responsible for membrane hyperpolarization and rhythmic firing of action potentials. The probability of opening of this channel is sensitive to intracellular-free Ca^{2+} concentration. In this study we have identified one such large conductance Ca^{2+}-activated K^+ channel in αT3-1 pituitary gonadotroph cell. This channel is ohmic with a unit conductance of 170 pS in symmetrical KCl (135 mM) and its current reverses near zero millivolts. When more than one channel is present in the patch membrane they open and close independent of each other, exhibiting no cooperativity between them as expected of a binomial distribution. The regulatory mechanism of this channel in modulating hormone secretion from αT3-1 gonadotroph cells is indicated.

BRAIN anterior pituitary gonadotrophs secrete luteinizing