Upper Limit on Neutrino Energy Associated with Weber Pulses

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An upper limit is established on the fraction of energy associated with the gravitational pulses reported by Weber that could be in the form of neutrinos with energies between 0.9 and 100 MeV.

We report an upper limit on the fraction of energy associated with Weber pulses[1-3] that could be in the neutrino energy band between 1 and 100 MeV. This limit can be established from previously published results[4,5] because the neutrino detector, a large tank of C_2Cl_4, can be regarded as an omnidirectional calorimeter.

An unsuccessful search for radio signals coincident with Weber pulses has been carried out by groups at five British institutions[6,7] using widely spaced radio receivers operated at 151 MHz (with bandwidths of 0.200 to 1.5 MHz). A search at microwave frequencies for coincidences with Weber pulses is being carried out by Partridge (Haverford College).[8] These results represent valuable constraints on the possible kinds of events that might be invoked to explain Weber pulses. Unfortunately the searches in progress are hampered by the necessity of observing coincidences between Weber pulses and electromagnetic signals with an unknown relative time delay (dispersion of the electromagnetic waves) and an unknown radio pulse shape. Moreover, the opacity to electromagnetic waves of the source of Weber pulses might be large and could prevent electromagnetic radiation from escaping before gravitational collapse quenched all energy loss.

The neutrino opacity[9,10] is sufficiently small that one might expect a significant fraction of any energy that is converted to neutrinos in the initial phases of the collapse to escape promptly. Weber[1] has estimated that he is detecting a gravitational energy flux of the order of 10^4 ergs $\mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$. If a similar energy flux were incident in the form of ~10-MeV neutrinos,[11] it would be ~10^3 times as large as the expected[12] flux of such relatively high-energy neutrinos from the sun and would have already been detected. We note that coincident measurements are unnecessary since the capacity of the C_2Cl_4 neutrino detector is ~10^{25} times the amount of energy that would be deposited by pulses whose average flux was 10^4 ergs $\mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$. There is therefore no problem, as is the case for the usual electromagnetic detectors, of saturating the detection system by a pulse of radiation.

From the calculated neutrino absorption cross sections[10,13,14] and the published upper limits on the neutrino detection rate,[5] we find that any energy flux of neutrinos incident upon Earth must be less than or of the order of $20(10\ \mathrm{MeV}/E)^{2.5}$ erg $\mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$, for $0.9\ \mathrm{MeV} \leq E \leq 100\ \mathrm{MeV}$. Here E is the energy of the neutrinos and the exponent 2.5 comes from a crude representation of the complicated energy dependence of the absorption cross section. The lower and upper limits on E in the above relation are due to the threshold of the reaction $\nu + {}^{37}\mathrm{Cl} \to e^- + {}^{37}\mathrm{Ar}$ (0.814 MeV) and the threshold for knocking out a proton from ${}^{37}\mathrm{Cl}$. The fraction of energy, F (= neutrino energy flux/gravitational energy flux), associated with Weber pulses that could be in the form of neutrinos satisfies

$$F < 2\times 10^{-3} \left(\frac{10\ \mathrm{MeV}}{E}\right)^{2.5} \boxed{\left(\frac{10^4\ \mathrm{ergs\ cm^{-2}\ sec^{-1}}}{\text{incident gravitational energy}}\right)}, \quad 0.9\ \mathrm{MeV} \leq E \leq 100\ \mathrm{MeV}. \tag{1}$$

We have included the boxed factor in Eq. (1) since, e.g., Gibbons and Hawking[15] have estimated that the incident gravitational energy corresponding to Weber pulses must be at least 10^5 ergs $\mathrm{cm}^2\ \mathrm{sec}^{-1}$, a factor of 10 larger than Weber's earlier estimate. Similar estimates have been made by Ruffini and Wheeler.[16]

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Interplanetary Deceleration of Solar Cosmic Rays*

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Observations of solar-flare proton fluxes of low energies (1-10 MeV) during the 7 June 1969 event have been used to study the effects of energy-change processes on particles propagating in interplanetary space. It is found that the proton energies are decreasing with time at a rate which is consistent with an exponential-decay time constant of 210 ± 10 h. Since adiabatic deceleration in a uniform solar wind would result in a faster decay (78 ± 4 h), additional processes such as Fermi acceleration or a more general deceleration process must be considered.

The propagation of charged particles through the interplanetary medium may be described by a Fokker-Planck transport equation including terms for diffusion, convection, and energy change in the expanding solar wind. The general formulation of particle propagation, as introduced by Parker[1] in 1965, included a term accounting for adiabatic deceleration in a uniformly expanding solar wind. Parker also considered for relativistic particles the effects of Fermi acceleration in the solar wind and concluded that this process was unimportant.

There has been only limited success in obtaining analytical solutions to the cosmic-ray transport equation with convection and adiabatic deceleration processes included. Fisk and Axford[2] obtained a solution for solar-flare propagation based on special forms for the diffusion coefficient and boundary conditions which are not generally applicable. More recently Forman[3] has obtained a solution based on the assumption that diffusive effects and density gradients are small and that convection and adiabatic deceleration processes dominate the decay phase of solar-flare proton events. However, there had been to date no direct experimental evidence for the existence of an energy-change process occurring in interplanetary space. In this paper we present data which provide strong evidence for energy-change processes.

It has been suggested[3] that the effects of an energy-change process can be observed experimentally during the decay phase of a solar-flare proton event provided that there is a distinct feature in the proton differential density spectrum. A variation with time of the characteristic energy associated with the feature would be evidence for an energy-change process.

It should be noted that in the absence of a distinct feature the effects of energy change could not be as easily separated from the effects of diffusion and convection. Similarly, if the feature is indistinct as a result of inadequate statistical accuracy or energy resolution, then an energy change of only 10 to 50% per day would not be detected. However, the measurements reported