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SOLAR NEUTRINOS AND SOLAR OSCILLATION

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Davis[1] and his collaborators at BNL have conducted an experiment to detect solar neutrinos in the reaction $\nu_e + {}^{37}\mathrm{Cl} \to {}^{37}\mathrm{Ar} + e^-$ and have found that the upper limit of the neutrino flux and the cross-section for all sources of neutrinos is $(1.5\pm1.0)10^{-36}s^{-1}$ per ${}^{37}\mathrm{Cl}$ atom. The limit has since been converted to an actual limit. The flux of neutrinos produced by the Sun is an important quantity because it measures conditions deep in the solar interior.

The result has been discussed by many authors and although the reported limit is about one order of magnetude less than it had been anticipated (see Fowler[2]).

Recently the experimental measurement of the flux of neutrinos from the Sun has been reported in New Scientist[3] which are shown in the figure below.

From the figure we see Davis's most recent measurement in the latest successive runs is about three times larger than his previous mean value and only marginally below the theoretical predicted one.

Here we would like to point out that we believe the figure indicates variation of the solar neutrino rate with the 11 year solar cycle. The dashed curve line is our expectation.

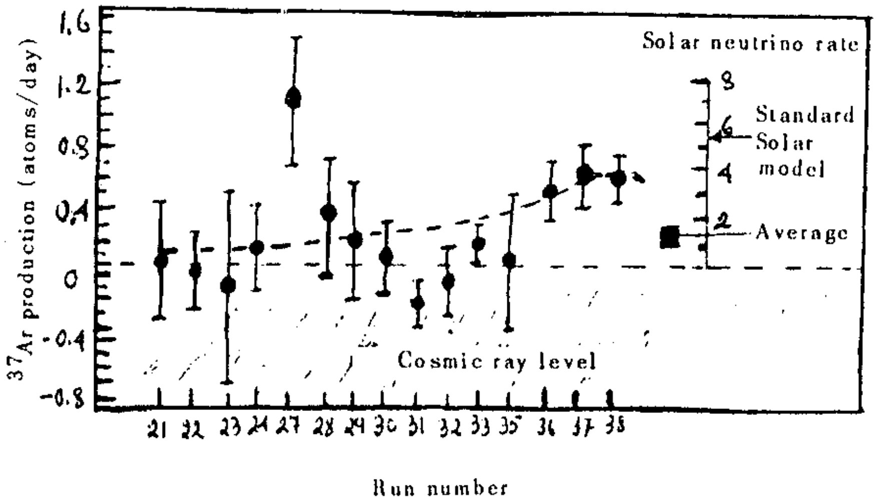

Fig.1. Solar neutrino rate with run number

The solar energy source has usually been considered as steady (i.e., constant). Raychaudhuri/4/ has shown that for the stars of mass in the range $1M_\odot - 4M_\odot$ in the main sequence energy loss due to neutrino emission according to the photon-neutrino weak coupling theory is more pronounced than due to the photon luminosity, and a cyclic variation of energy production arises. This oscillation is caused by the different ρ (density), T (temperature) dependences of ϵ_N (nuclear energy generation) and ϵ_ν (energy loss by neutrino emission). In the case of the Sun, 11 years of solar activity can be interpreted in this way. In this picture, the solar energy generation cycle is characterized by concurrent changes in ϵ_N and ϵ_ν around the near balance $\epsilon_N=\epsilon_\epsilon$. When a slight contraction occurs from the equilibrium state the temperature in the solar core increases which leads to a more pronounced increase in ϵ_N than in ϵ_ν . This is followed by the expansion of the core (just before this Sun reaches to a sunspot minimum) at the end of which a close coupling is possible between the solar energy source and solar surface layers. After maximum expansion (sunspot maximum) contraction starts thus increasing internal energy at the expense of gravitation energy and thermal energy and the equilibrium state $\epsilon_N=\epsilon_\nu$ is again reached and a new cycle starts. It is clear from the above that the temperature of the solar core at sunspot minimum is greater than the temperature of the core at sunspot maximum. So it is natural to expect that the solar neutrino rate at sunspot minimum must be greater than the solar neutrino rate at other time in the 11 year cycle. Davis's enlarged number of counts in 3 latest successive runs occurs at when the sunspot is very near to minimum. In this way we can explain the Davis's recent solar neutrino rate in the latest runs. It was suggested also (Raychaudhuri/5,6/) there must be variation of solar neutrino rate with the 11 year solar cycle. The dotted curve which we have drawn in the figure shows the expected variation of solar neutrino rate with the 11 year cycle.

We should mention here that on the basis of certain lepton-hadron relation and the dynamical origin of charge, Bandyopadhyay/7/ has computed the cross section for the scattering process $\nu_e + {}^{37}\mathrm{Cl} \to {}^{37}\mathrm{Ar} + e^-$ and predicted

$$\Sigma\phi\sigma = 0.82 \times 10^{-36}\,\mathrm{s}^{-1} \text{ per } {}^{37}\mathrm{Cl} \text{ atom for CNO cycle}$$

$$= 0.20 \times 10^{-36}\,\mathrm{s}^{-1} \text{ per } {}^{37}\mathrm{Cl} \text{ atom for pp cycle.}$$

So the theoretically predicted $\Sigma\phi\sigma$ according to this model of weak interactions is well within the experimental limit.

In connection with the recent enlarged solar neutrino rate we would like to comment on solar oscillations which are recently measured by Severny et al.[8], Brookes et al.[9] and Hill et al.[10] Hill and his collaborators have seen 20 modes in the 6-70 minute range of solar oscillation when they were observing solar oblateness. They claim that the large amplitudes they see are primarily from brightness fluctuations caused by the temperature variations. Severny et al. found that the Sun's surface oscillated with a period of 2 h 40 min, with a peak velocity about 2 metres per second. This period was also found by Brookes et al. in their measurements. All they have seen, however, is the outer 0.1% only. According to our picture which we have pointed out above the formation and development of magnetic fields are byproducts of the stellar evolution (Raychaudhuri[13], Kangas and Raychaudhuri[11]) and all aspects of solar activity are only secondary effects stimulated by interactions of hydromagnetic nature between the energy source and outer solar layers. Changes in all aspects of solar activity are associated with the changing interaction between the solar core and solar outer layers. Again we have pointed out above that at the time of maximum sunspots within the solar cycle a close coupling may exist between the core and solar surface layers. It is evident due to the impulse from solar core solar surface should also oscillate. Due to this temperature of the surface should also vary (i.e., oscillate). This may be a possible explanation of the observed oscillation of the Sun. According to our picture this oscillation should vary with the 11 year solar cycle. Although it will be difficult to detect such a small variation of the solar oscillation. According to Kotov (after the author's suggestion) the dependence of solar cycle seems to be possible and thus it is interesting to observe this phenomena for years to come.

Due to the changes in the radius of the solar energy source during the solar cycle changes in the rotation period should appear in order to conserve the angular momentum. Thus a longer rotation period of the core should be expected at the sunspot maximum than at the sunspot minimum, similarly also for the solar surface layers (Kagas and Raychaudhuri[12]). The spectroscopic data from Mount Wilson have shown also a general tendency for the rotation rate to increase (i.e., shorter period) as solar activity has declined from the most recent maximum of the 11 year solar cycle 1969 (Howard[14]).

We have pointed out (Raychaudhuri[4,13], Kangas and Raychaudhuri[11,12]), that many of the observed activities of the Sun are varying with the 11 year sunspot cycle, but the variation should not be drastic. It should be noted that Sheldon[15] assumed more drastic changes in solar energy source but he did not explain why the core energy source should be pulsating. The data on the variability of the solar constants with the solar cycle are conflicting and inconclusive (Thekaekara[16]). We believe that all the activities of the Sun should vary with the solar energy generation cycle of 11 years.

We conclude that the variation of the solar neutrino rate, solar oscillation, solar rotation and solar constant, etc., with the 11 year solar cycle will lead to a better understanding of stellar evolution.

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