Bull. Astr. Soc. India (1996) **24**, 143–146

Solar neutrino flux variation and its implications

Probhas Raychaudhuri

Department of applied mathematics, Calcutta University, Calcutta 700 009, India

Abstract. Considering the solar neutrino flux data during the period from June 1989 to April 1992 from four solar neutrino experiments (Cl Solar neutrino experiment, SAGE I & II, GALLEX, Kamiokande II & III) we suggest that the solar neutrino flux appears to be varying with the solar activity cycle. The above variation of solar neutrino flux data with the solar activity cycle and the common periodicity around 2.5 years of solar neutrino flux data, solar diameter data, sunspot number data, solar proton events data, Forbush decreases with solar flares data etc., suggests that the pulsating character of the nuclear energy generation inside the solar core may be their common origin.

Key words: Solar neutrinos

The solar neutrino flux is of fundamental importance towards the understanding of stellar evolution and the origin of stellar activity cycle, because it is a measure of the physical conditions within the core of the sun and other stars. The longest running detection experiment (Davis et al. 1976) and its result have shown that the observed solar neutrino flux production is about 1/3 of that anticipated from the standard solar model. Now there are three other experiments to observe solar neutrino flux and all the experiments (Kamiokande, SAGE and GALLEX) observed a deficit of neutrinos compared to the standard solar model predictions.

Many observations on luminosity, radius, neutrino flux from ^{37}Cl solar neutrino experiment and Kamiokande experiment (Hudson and Wilson 1991; Delache et al. 1985, Raychaudhuri 1976, 1981, 1984, 1986a), *p*-mode (Elsworth et al. 1990) exist at present and there is evidence that these quantities vary during the solar activity cycle (Raychaudhuri 1989). Neutrino flux from ^{37}Cl solar neutrino experiment have been analysed by many authors and have shown the solar neutrino data is anticorrelated with the sunspot numbers (Raychaudhuri 1986a and many others). According to Hirata et al. (1990) solar neutrino data from Kamiokande experiment is consistent statistically with a ^{8}B neutrino flux constant in time but possible time variation related to solar activity cannot be ruled out. However, Raychaudhuri (1991) showed that the solar neutrino flux data from

Kamiokande experiment is not constant throughout the solar activity cycle by both the parametric and nonparametric methods. Recently, Oakley et al. (1994) showed that anticorrelation of the neutrino capture rate with the solar surface magnetic flux is stronger than the anticorrelation with sunspot numbers when the surface magnetic flux is taken from near the centre of the solar disk. They have shown also that the Kamiokande solar neutrino flux data is also marginaly anticorrelated with solar surface magnetic flux within 10% of disk centre. Mcnutt (1995) claimed that he has found a connection between variations in the solar neutrino flux and variations in the solar wind. Massati et al. (1991) have shown that neutrino flux data from Homestake experiment have been correlated with several solar and interplanetary parameters. Raychaudhuri (1989, 1993) has shown that the solar neutrino flux in ^{37}Cl solar neutrino experiment from 1970-1989 is significantly different from the solar neutrino flux at the first sunspot maximum time (wolf numbers) than at the second sunspot maximum time (usually appears after 2 to 3 years from the first sunspot maximum).

Gnevyshev (1977) and Kangas and Raychaudhuri (1973) and many others have shown that solar activity cycle consists of two events, the first sunspot maximum and second sunspot maximum, having different features. Both maxima are seen in photosphere, chromosphere and corona with optical and radio observations. It is observed that during the first sunspot maximum the solar activity increases in all solar latitudes but it is maximum in latitude 25° in each hemisphere. The far UV radiation and number of small spots, flares and geomagnetic disturbances with sudden commencements and without 27 days recurrences appear. In the period of second sunspot maximum the activity is maximal in latitude ±10° and large spots, big solar flares, aurora and geomagnetic disturbances with gradual commencements and long series of 27 days recurrences appear.

In this paper, we will analyse the solar neutrino data from the four solar neutrino experiments from June 1989 to May 1992. These years corresponds to first sunspot maximum time and second sunspot maximum time. We present in Table 1, average solar neutrino production rate during the first sunspot maximum time and second sunspot maximum in the four existing solar neutrino experiments (see also Raychaudhuri 1993).

Table 1.

	Sunspot maximum	
	First	Second
	1969–1970	1971–1972
^{37}Cl solar neutrino expt.	1.30 SNU	2.84 SNU
	1980	1980–1981
	1.10 SNU	2.66 SNU
	June 1989 to April 1990	May 1991 to May 1992
	2.20 SNU	4.32 SNU
Kamiokande II & III	June 1989 to April 1990	Jan. 1991 to August 1991
	Exp/SSM $= 0.40 \pm 0.09$	Exp/SSM $= 0.60 \pm 0.15$
SAGE I & II	Jan. 1990 to July 1990	July 1991 to Dec. 1991
	40 SNU	109 SNU
GALLEX		May 1991 to April 1992
		92 SNU

(1 SNU $= 10^{-36}$ neutrino capture per second per target atom).

We see that all the four solar neutrino experiments mentioned above suggest that average solar neutrino production rate at the first sunspot maximum is significantly different from the average solar neutrino production rate at the second sunspot maximum. In the ^{37}Cl solar neutrino experiment we have seen that the average solar neutrino flux at the second sunspot maximum time is much higher than the average (which starts from one year before the first sunspot maximum and after three years from the first sunspot maximum time, except the second sunspot maximum time). We expect that the same behaviour will be observed in all the other three experiments and for that all the four experiments existing now should be continued up to the year 1998–2000.

Variations of solar neutrino flux data must be related to some other phenomena, because such periodic variations may produce some phenomena not only in the solar photosphere (e.g. sunspots and solar flares etc.) but also in the cosmic ray intensity and solar terrestrial relationships which are causally connected with those taking place in the Sun. Other quantities such as solar magnetic fields, sunspot areas, atmospheric variables and geomagnetic activity show variations on the same time scale.

We have studied also the Forbush (FD) data and its associated solar flare data, major solar proton data ($E > 10$ MeV) from 1976–1986 along with sunspot data and solar neutrino data. We have found that FD and solar flare data exhibit periods around 0.95, 2.4 and 4.75 years with more than 99% confidence level while the solar proton data exhibits period around 2.6 and 5.0 years with more than 95% confidence level and these periods not being significantly different from 0.88, 2.5 and 4.7 years in the ^{37}Cl solar neutrino data (Raychaudhuri 1986b; Filippone & Vogel 1990). It is also observed that occurrence of FDs in the solar cycle shows two maxima i.e., the occurrence of FDs in the second sunspot maximum period is higher than the occurrence of FDs in the first sunspot maximum. The common periodicity around 2.5 years and the similar behaviour in the solar neutrino flux data, sunspot data, solar diameter data, FDs with solar flare data and solar proton data etc. suggests that pulsating character of the nuclear energy generation inside the solar core may be their common origin.

The solar neutrino flux variation with the solar activity cycle indicates that our knowledge of what goes on below the standard solar model convection zone may need drastic revision. Raychaudhuri (1971, 1989) suggested that the variation of the solar neutrino flux with the solar activity cycle is due to the pulsating character of the nuclear energy generation inside the core of the Sun. To explain the pulsating character of nuclear energy generation, we need a mechanism inside the core of the Sun that generates almost the same energy (say $E_{\nu'}$ neutrino emission) as nuclear energy E_N with different ρ and T dependence. The temperature dependence will be as follows: if the nuclear energy generation E_N decreases (or increases), then neutrino energy generation E_ν increases (decreases) that is if $E_N \propto T^4$, then $E_\nu \propto T^3$, where T is the core temperature of the Sun. By studying neutrino processes in the weak interaction theories, Raychaudhuri (1971, 1989) found that the plasma neutrino process ($\Gamma \rightarrow \nu + \bar{\nu}$) in the weak interaction of photon theory (Raychaudhuri 1989) is needed to destabilize the solar core. The rate of energy loss by neutrino emission ($\rho < 10^5$ gm/cm^3) can be written in the form $E_\nu = 5(1+x)T^3$ erg/(gm sec), where x is the hydrogen abundance. The above suggestion is similar to the suggestion by Eddington. The above perturbed solar model may have profound implications in understanding the origin of the solar system and evolution of stars etc.

The variation of the low order acoustic solar oscillation over the solar cycle is also appeared to be due to the changes in the solar inner core temperature.

References

Davis, R. Jr. 1976, 7th Workshop on Grand Unification, Toyama, Japan.
Delache, P., Laclare, F. & Sadsaud, F. 1985, Nature 317, 426.
Elsworth, Y., Howe, R., Isaak, G. McLeod, G. R. & New, R. 1990, Nature 345, 322.
Filippone, B. W. & Vogel, P. 1990, Phys. letters B246, 546.
Gnevyshev, M. N. 1977, Solar Phys. 51, 175.
Hirata, K. S. et al. 1990, Phys. Rev. letters 66, 129.
Hudson, H. S. & Wilson, R. C. 1991, Nature 351, 42
Kangas, J. & Raychaudhuri, P. 1973, Astrophys. Sp. Sci. 21, 3
Mossat, S, Iucci, N. & Storini, M. 1991, Report CNR/IFSI-91-27
Mcnutt, R. L. 1995, Science (submitted)
Oakley, D. S., Snodgrass, H. B., Ulrich, R. K. & Van de kop, T. L. 1994, ApJ 437, L63
Raychaudhuri, P. 1971, Astrophys. Sp. Sci. 13, 231
Raychaudhuri, P. 1976, JINR Communications E2-10019, USSR
Raychaudhuri, P. 1981, Spec. Sci & Tech. 4, 271
Raychaudhuri, P. 1984, Solar Phys. 93, 397
Raychaudhuri, P. 1986a, Solar Phys. 104, 415
Raychaudhuri, P. 1986b, Solar Phys. 106, 421
Raychaudhuri, P. 1989, Phys. Essays 2, 118
Raychaudhuri, P. 1991, Mod. Phys. Lett. 6A, 2003
Raychaudhuri, P. 1993, Mod. Phys. Lett. 8A, 1961