SOLAR NEUTRINOS, SOLAR FLARES, SOLAR ACTIVITY CYCLE AND THE PROTON DECAY

Probhas Raychaudhuri
Department of Applied Mathematics
Calcutta University, Calcutta-700009, INDIA

ABSTRACT

It is shown that there may be a correlation between the galactic cosmic rays and the solar neutrino data but it appears that the neutrino flux which may be generated during the large solar cosmic ray events cannot in any way effect the solar neutrino data in Davis experiment. Only initial stage of mixing between the solar core and solar outer layers after the sunspot maximum in the solar activity cycle can explain the higher (run number 27 and 71) of solar neutrino data in Davis experiment. But solar flare induced atmospheric neutrino flux may have effect in the nucleon decay detector on the underground. The neutrino flux from solar cosmic rays may be a useful guide to understand the background of nucleon decay, magnetic monopole search, and the detection of neutrino flux in sea water experiment.

Sheldon(1) indicated that the solar flares and solar active regions are energetic disturbances in the sun and may be associated with the production of neutrinos. The emission of particles from flares and active regions is well known phenomena. Thus any such relation between solar neutrino data and solar cosmic rays is important and may serve as an accurate long range predictor of solar cosmic ray activity properly. Recently Lanzerotti and Raghavan(2) and Raychaudhuri(3) suggested that the production of solar neutrinos by energetic particles involved in solar actvity is not a significant contributor to the solar neutrino flux recorded in the SN experiment(4). Again Raychaudhuri(5) pointed out that the neutrino flux which appears in the SN experiment can in no way connected with the solar surface nuclear reactions as the temperature and density are not suitable for such a rate of neutrino flux observed in the run numbers 27 and 71. We know that the energy release in solar particle flares where relativistic protons can be accelerated are seen typically in the energy range $10^{32}-10^{33}$ ergs or 10^{35} to 10^{39} Mev in about 5 minutes over an area of 10^{19} cm^2 projected on to the solar surface. Subramanian(6) and Bazilevskaya et al(7) suggested that the neutrino emission process underlying the flare mechanism may contribute to the higher SN flux as observed in Davis experiment. Recently Bazilevskaya et al(8) and Basu(9) have found that there is a significant relationship between SN data and solar particles. It is true that the geomagnetic index Ap is the index of solar particles but it may not have any connection with the SN flux. As mentioned earlier(3) that the surface nuclear reaction which may occur during large solar flare cannot account the flux observed in SN experiment. It is believed that the measurable fluxes of neutrinos could not be produced by solar flare particles interacting in the earth's atmosphere(10). The possible mechanism that may explain incresed ^{37}Ar production from flares and cosmic ray intensity is that the particles with energy mostly less than 1 Gev, produced spallation products in the earth atmosphere(^{15}O , ^{13}N , ^{8}B etc.). The expected yield from ^{15}O , ^{13}N , ^{8}B (which decays into neutrino with energy greater than 1 Mev) are less than 10^{-2} cm^{-2} sec^{-1}. Although ^{8}B decays into high energy neutrino upto 14 Mev but it cannot contribute an appreciable fraction in the SN data of Davis et al•(4)•Thus the question remains whether the cosmic ray muons,pions and kaons at the time of large solar flare can produce detectable flux of neutrinos in the Davis experiment•We know that (11)in the biggest solar flare which occurs in August 1972 produced proton flux $5\cdot5\times10^{8}\,cm^{-2}$ above 100 Mev in about 5 minutes and thus we cannot expect to have neutrino flux as high as $5\times10^{6}\,cm^{-2}\,sec^{-1}$ from pions,kaons and muons produced by relativistic protons through cascades in the earth's atmosphere• Thus from our present knowledge we cannot expect that the solar flare can effect the production of ^{37}Ar in the Davis experiment•We present below the solar cosmic ray event(12,13)which produces intense X-ray,γ-ray etc•)with the corresponding run in Davis experiment in Table I to see whether solar flare can contribute any detectable perturbation in the recorded SN flux•

Table I

No• of runs in SN experiment	Solar cosmic ray event connected with flare etc)	No of runs in SN experiment	Solar Cosmic ray event connected with flare etc•
19	24•1•71	67	25•11•80 24•12•80
21	1•9•71	68	1•4•81 4•4•81 10•4•81 27•4•81
27	4•8•72 7•8•72	69	30•4•81 10•5•81 6•5•81
30	29•4•73	71	7•10•81 12•10•81
32	7•7•74	75	12•7•82
36	23•9•74	76	26•11•82 7•12•82 18•12•82
42	30•4•76		16•2•84
51	19•9•77 24•9•77		25•4•84
52	22•11•77		
53	29•4•78		
55	23•9•78		
60	20•8•79 21•8•79		
63	7•6•80		
66	6•11•80		

It is interesting to analyze the possible temporal fluctuation of SN flux with solar cosmic ray variation• If we see the data of fig•1(14) we see that the run numbers 21,27,29,31,36,39,42,47,49,51,52,54,56,58, 64,71 gives the higher ^{37}Ar production than the average ^{37}Ar production rate• The run numbers 36-58 belong to the sunspot minimum range(5)• According to Bazilevskaya et al (15)only solar cosmic ray events connected with the run numbers 21,27,51,71 can increase the production rate of ^{37}Ar in the SN experiment• But 2 solar cosmic ray events(connected with run numbers 21 and 51) took place on invisible side of the sun and therefore the increases of ^{37}Ar production will be absent• Raychaudhuri(16,17,5)showed that the SN data varies with 11 year solar cycle• He also explained why the SN flux is increased from 1975 to 1978• It is clear from the data(8,15) that there is a correlation between the galactic cosmic rays and the SN data and all of them vary with the 11 year solar cycle• Raychaudhuri(5,16)already explained the incrase of SN data(in run numbers 27 and 71) due to large amount of ^{3}He is mixed periodically in the core after the sunspot maximum. Thus the largest solar flare and highest SN flux occurs synchronously and the solar flare has no direct connection with the SN flux. If the solar cosmic ray event has some effect on the SN flux we could have observed it from other solar flare events e.g. run number 55, since the proton fluence greater than 10 Mev and 30 Mev in run numbers 55,71 are almost the same(18), but it did not happen. The solar flare event cannot explain the higher counts in run numbers 27 and 71 in Davis experiment but it may have effect in the nucleon decay detector and also on the neutrino experiment in the accelerator etc. Thus the solar flare has no direct connection with the SN flux(5).

Proton decay:- Accurate calculation of low energy neutrino fluxes ($E_\nu \simeq$ 1 Gev)is necessary for the evaluation of the nucleon decay background. Gaisser et al(19)calculated the atmospheric neutrino flux by taking into account the effects of solar modulation that they did not consider the atmospheric neutrino flux from solar cosmic ray events. They consider only that the cosmic ray flux is higher at solar minimum and lower at solar maximum. But it was indicated by Kodama(20)that the unusual increases in cosmic rays and fast type PCA events occur only during the ascending(for about 2 years before sunspot maximum year) and descending phases(for about 2-4 years after sunspot maximum year)of the solar cycle avoiding the sunspot maximum year. The neutrinos are generated in the earth atmosphere by solar protons but because of the diffusion mechanism of protons moving between the sun and earth the whole process is very prolonged in time and difficult to identify against the background of an ordinary atmospheric flux. We have gathered from table I of King(11) that in August 1972 biggest solar flare events produces flux of protons above 200 Mev constitute 83% of the fluxes obtained by integrating over the entire solar cycle. The biggest solar flare which occured in October 1981 is almost the same as powerful as the August 1972 flare. The fluence of proton of 100 Mev—1 Gev constitute above 6.6×10^{8} cm^{-2}. We know fluxes of neutrinos around 1 Gev are 3.93×10^{-2} cm^{-2} sec^{-1} $sterad^{-1}$ in vertical direction and 6.20×10^{-2} cm^{-2} sec^{-1} $sterad^{-1}$ in horizontal direction at ground level from galactic cosmic rays. Again we know that the fluxes of protons around 1 Gev are 10^{-1} cm^{-2} sec^{-1} $sterad^{-1}$ from the best estimates of galactic cosmic rays as we have taken the fluxes of protons at the time of low solar activity. Thus we can expect the ratio between the neutrino flux and proton flux is within 2/5 and 3/5 around 1 Gev. From October 1981 to July 1982 the average fluence of proton greater than 100 Mev constitutes 5×10^{7} cm^{-2} (roughly). Let us take that the solar flares lasted in such a way which produces significant fluxes of neutrinos. We get the neutrino flux is about 1.8 cm^{-2} sec^{-1} $sterad^{-1}$ and which is about 30 to 35 times higher than the cosmic ray neutrino flux around 300 Mev to 500 Mev. This supports also that the 100 Mev to 1 Gev solar proton flux is atleast an order of magnitude higher than the galactic proton fluxes. Here although neutrino energy is lower than 1 Gev but the fluences are higher so it is possible that the atmospheric neutrinos from solar cosmic ray affect the underground experiment on nucleon decay. Similarly muon fluxes from solar cosmic rays will also be an order higher than the muon fluxes from galactic cosmic rays in the region from 100 Mev to 1 Gev. As the experiments of KGF, Mont Blanc, IBM, Kamiokande, Soudan I were operated within the range of bigger solar cosmic ray event we suspect that all the nucleon decay events observed by them are due to atmospheric neutrinos from solar cosmic ray in the large scale experiments conducted at great depths underground since 1965 KGF group(21)recorded several anomalous events some of which are suggestive of decay of new particles or some of nucleon decay. From the above preliminary analysis we suggest that previous events was also perhaps due to theatmospheric neutrinos produced from solar cosmic ray events. So to decide about the nucleon decay properly we need better estimate of neutrino flux from solar cosmic ray events. At present we do not have better estimate of solar cosmic ray proton flux from the 21st solar cycle. So it is necessary to know the better knowledge of solar proton fluxes around Gev. We hope to calculate the neutrino flux from solar cosmic ray event when the full data of solar proton fluxes will be available upto 1984 for the 21st solar cycle from space missions. The solar cosmic ray neutrino flux will be an important step and guide(i)to understand the background for nucleon decay research from atmospheric neutrinos and also (ii)to the neutrino experiment which is operated on the underground, sea water and accelerator.

References:-

1)W.R.Sheldon(1969)Nature 221,650
2)L.J.Lanzerotti and R.S.Raghavan(1981)Nature 293,122.
3)P.Raychaudhuri(1983)Ind.J.Theo.Phys.31, (in press).
4)R.Davis,Jr., B.Cleveland and J.K.Rowley(1982)AIP conference proceedings 96,1.
5)P.Raychaudhuri(1984)Solar phys.93,397.
6)A.Subramanian(1983)Current sci.52,342.
7)G.A.Bazilevskaya et al(1982)JETP lett 35,343.
8)G.A.Bazilevskaya et al.(1983)Proc 18th.ICRC 4,218.
9)D.Basu(1982)Solar Phys.81,363.
10)K.O'Brien and A.dela Zerda(1984)Am.Nucl.Soc.46,64.
11)J.H.King(1974)J.Space Craft and Rockets 11,401.
12)M.Pomerantz and S.P.Duggal(1974)Rev.Geophys.&Space Phys.12,343.
13)S.I.Avdyushin et al.(1982)Bull.Acad.Sci.USSR(phys.Ser)46,107.
14)P.Raychaudhuri(1985)Proc.19th.ICRC SH 8.1-7.,San Diego,USA.
15)G.A.Bazilevskaya et al(1983)J.Nucl.Phys(submitted).
16)P.Raychaudhuri(1983)Proc.18th.ICRC, 7,108.
17)P.Raychaudhuri(1984)Proc.3rd.Asian Pacific regional meeting held at Kyoto,Japan,30th.Sept-6 Oct.(to be published in Astrophys.Sp.Science.
18)R.E.Mcguire et al(1983)Proc.18th.ICRC 2,66.
19)T.K.Gaisser et al(1983)Phys.Rev.Lett 51,223.
20)M.Kodama(1962)J.Phys.Soc.Japan 17,Suppl.II-A,594.
21)M.R.Krisnaswami et al.(1981)Phys.lett 106B,339.