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A Proof of Chaotic Nature of the Sun through Neutrino Emission

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It is known that detection of neutrinos from the sun can lead to understand the nature of the nuclear energy generation inside the core of the sun and also the propagation properties of neutrinos in the high-density matter. Solar neutrino flux data have analysed for periodicities by different techniques. In this paper solar neutrino flux data from Homestake chlorine detector during the year from 1970 to 1995 is analyzed by Wavelet transform technique and found periods are around 22 years, 11years, 7.3 years, 5.5 years, 4.4 years and 3.7 years. We have also analysed the solar neutrino flux data that have been generated by the Monte-Carlo simulation with production rate and background parameter that are typical of those in the actual Homestake detectors. A statistical significance test is done to ensure the periodicities through red noise power spectrum method. It is found that the same types of periodicities are observed in solar surface activities (e.g. solar proton events data, sunspot data etc.). This indicates that there is a connection between solar core energy and solar surface activities and it can be suggested that solar core may be in chaotic nature.

Keywords: Solar core, Chaotic, Homestake, Wavelet, Solar neutrino flux, Periodicity.

1. Introduction

Standard solar model (SSM) are known to yield the stellar structure to a very good degree of precision but SSM cannot explain the solar activity cycle, the reason being that the SSM consider the sun as spherical symmetrical in nature. SSM does not include temperature and magnetic variability of the solar core. The temperature variability implied a variation of the nuclear energy source and from that source of energy magnetic field is generated which is also variable in nature [1]. The basic generation of magnetic field in the sun appears to involve the combined effects of the non-uniform rotation and the cyclonic convection, referred to as α-ω dynamo, but there is no understanding of rapid diffusion and dissipation of the strong magnetic field that is essential for the operation of the α-ω dynamo which is responsible for the solar activity cycle. Again SSM with α-ω dynamo cannot explain why the sunspot maximum to sunspot minimum takes about 6–6.4 years while for sunspot minimum to sunspot maximum it takes about 4-4.6 years, Raychaudhuri [1] suggested an internal dynamo due to the cyclic nuclear energy generation inside the core of the sun which is responsible for the solar activity cycle. It is shown by Raychaudhuri [2} that solar flares data and major solar proton events (E >10 MeV) data exhibit periods around 0.95, 2.5 and 5.0 years at >99% level of confidence (CL) and the periods are not being appreciably different from 0.88, 2.5 and 4.7 years found for the Chlorine solar neutrino data [3,4,] and periodicities found in the variation of solar diameter data. The common periodicity around 2.5 years suggested that they are inter-related and that pulsating solar core may be their origin. Raychaudhuri [7] has shown that in the stars like the sun a cyclic variation of nuclear energy generation occurs due to plasma neutrino emission process in theory of weak interaction of photons. Solar energy cycle according to Raychaudhuri [6] is characterized by concurrent changes in $\varepsilon_N \,\alpha\, T^4$ (nuclear energy generation from pp and CNO cycle) and $\varepsilon_{\nu\nu} \,\alpha\, T^3$ (rate of energy loss by neutrino emission) and around the near balance

$$\varepsilon_N - \varepsilon_{\nu\nu} - \varepsilon_{ph} = 0$$

where T is the solar core temperature and ε_{ph}(luminosity of the sun) α T^4 .When a slight contraction occurs from the equilibrium state the temperature in the solar core increases which lead to a pronounced increase in ε_N than in ε_{vv}. This is followed by the expansion phase at the end of which a close coupling is possible between the solar energy source and the solar outer layers (convective zone). This is characterized by the dominant surface activity in the sun (sunspot maximum phase) [6]. Solar neutrino flux variation with the solar activity cycle is supported the view that the solar activity cycle is due to the pulsating nuclear energy generation inside the core of the sun [1,5].

The observed solar neutrino flux data by various solar neutrino detectors suggest that the solar neutrino flux is about 1/3rd of that predicted by SSM. One of the long time detector of solar neutrino flux data is the Homestake Chlorine experiment. This experiment was a radiochemical experiment and the Homestake detectors observed solar neutrino flux data for about 25 years from 1970-1995. The observed event rate was 2.55 ± 0.25 SNU whereas the predicted event rate is $9.3^{+1.2}_{-1.4}$ SNU (SNU stands for Solar Neutrino Unit and 1 SNU = 10^{-36} interactions per target per atom per second) [7].

We have first analyzed the cubic splined filtered Homestake solar neutrino flux data during 1970-1995 by Wavelet transform technique with red noise power spectrum method. Wavelet transform technique can suggest the periodic behaviour of a data series and can produce frequency at different times.

2. Method of searching periodicity

We have chosen Morelet wavelet to analyse the solar neutrino flux data by Wavelet technique. Searching for periodicity using Wavelet transform technique needs the data series to be equally spaced and filtering is necessary to remove the aliasing peaks near the prominent peak in the plot which ensures the data to be periodic. Cubic spline method is being used for evenness of the uneven Homestake solar neutrino flux data from 1970-1995 and making the data as monthly, 1.5 monthly, 3monthly, 4monthly & 3.317monthly equally spaced data series. We have simply filtered the data by 5 point running average method to normalize the errors present in the original data. Moreover red noise power spectrum of 95% confidence line has been presented in the plot to search the actual periodicity in the data.

From nine Monte- Carlo simulated data [8] we have used only three Monte-Carlo simulated data for illustration. The three Monte-Carlo simulated data were made equally spaced (3.317 monthly) to analyze these by Wavelet transform technique and we have noticed that at 9.9 month (0.825 year) & 19.8 month (1.65 year) high amplitudes were occurred. After this we have calculated the confidence level of these two periodicities, which shows a very low level of confidence.

The solar neutrino flux data from Homestake experiment is analyzed by the Wavelet transform technique containing non-stationary power at many different frequencies and red noise power spectrum method is used for the significance level of the periodicities.[9]

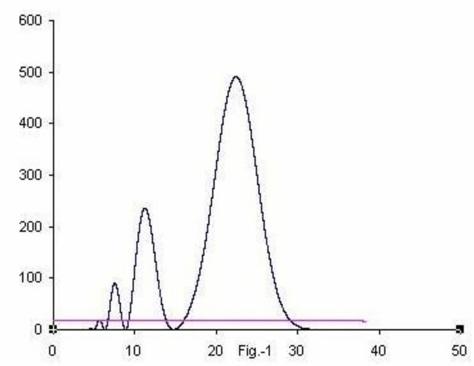
3. Results

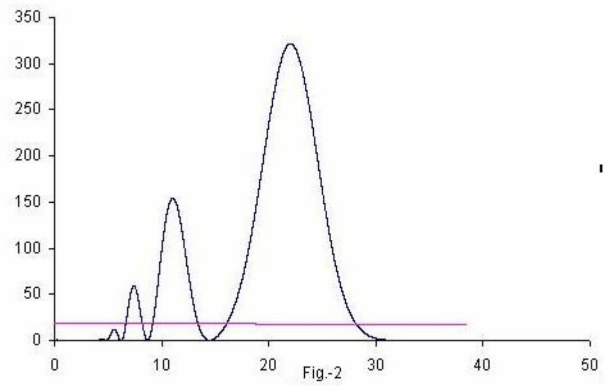
It is known that Homestake solar neutrino flux data are uneven. We have used the cubic spline method for evenness of the data and then applied 5 points running average method to monthly, 1.5 monthly, 3 monthly and 4 monthly data derived from the cubic spline method. On these data we have applied Wavelet transform technique and noted at what periodicities the wavelet amplitudes are maximum i.e. where the peak arises. The results are shown in table below. (see also in figures 1, 2, 3, 4)

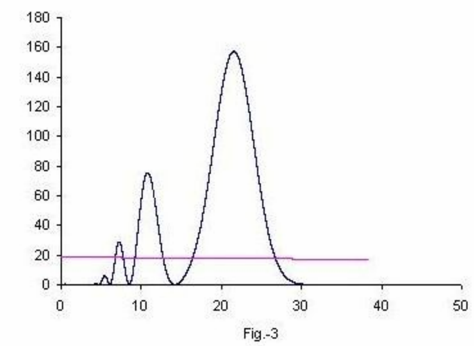
Homestake data	Periodicities in years
Monthly	22.44, 11.25, 7.54, 5.66, 4.54, 3.77
1.5- monthly	22.19, 11.03, 7.40, 5.56, 4.46, 3.70
3- monthly	21.53, 10.78, 7.23, 5.44, 4.34, 3.63
4 - monthly	21.29, 10.67, 7.09, 5.39, 4.32, 3.62

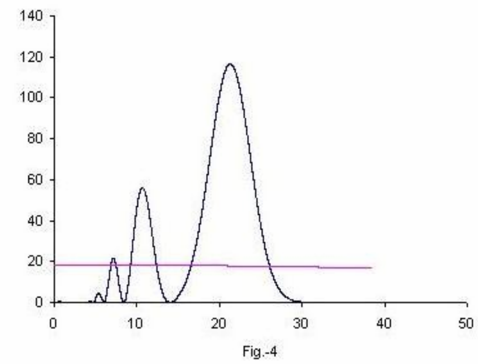
Discussion

We see that the periodicities around 22., 11, 7.3, 5.5, 4.4 and 3.7 years are present in the Homestake solar neutrino flux data. The same type of periodicities is observed in Mandal et al. [10]. Some of these are almost similar to the periodicities extracted from the sunspot data, solar proton data, solar flare data etc. Among these the most possible periodicities are 22,11 and 7.3 years since at these periodicities the Wavelet power spectrum are very much above the 95 % confidence level.









Figures 1, 2, 3, 4 corresponds to Wavelet power versus periodicity (in years) with more than 95% C.L. of the monthly, 1.5 monthly, 3 monthly, 4 monthly averaged cubic splined Homestake solar neutrino flux data by Wavelet transform technique respectively. From figures we are observing that the peaks are at around 22,11,7.3,5.5,4.4 and 3.7 years.

Ikhsanov & Miletsky [11] and Liritzis [12] have obtained periodicities 5 ± 0.5 and 11 years in the Homestake solar neutrino flux data between 1970-1995. The periodicity near 11 year was also found by Chang et al [13]. No such periodicity is obtained when Homestake Monte Carlo simulated solar neutrino flux data were analyzed. Hence it may be the concluded that the solar core is in periodic nature i.e., solar ore is in the state of pulsating nuclear energy generation implying chaotic nature of the solar interior.

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