SOLAR NEUTRINO FLUX DATA ANALYSIS BY WAVELET TRANSFORM TECHNIQUE

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Abstract:

We have used Wavelet transform technique to find periodicities in the solar neutrino flux data from 1970-1995 in the Homestake detector for the solar neutrino detection. Cubic Spline method has been used for the evenness of the data from Homestake detector and the data is transformed as monthly, 1.5 monthly, and 3 monthly and 3.317 monthly data. By using the Wavelet tansform (WT) technique for the higher periodicities, we have found periodicities around 22 years, 11 year, 7.3 year, 5.5 year, 4.4 year and 3.7 years with high confidence level and these type of periodicities are observed in solar surface activiies indicating that there is a connection between the solar core energy and the solar surface activities and that solar core energy source is pulsating in nature.

Keywords :

Wavelet, Homestake, Solar neutrino flux , Periodicity.

Introduction:

Wavelet analysis offers an alternative to Fast Fourier transform based data series analysis, which is useful when the spectral features are time dependent. The Wavelet transform is a relatively new concept in the field of astrophysics, geophysics, and meteorology etc. The Wavelet transform can suggest the periodic behavior of a data series. This technique can produce frequency at different times rather than Fourier transform technique.Again the running variance contains no information on the frequency of a given data series, but only it's amplitude. Through the Wavelet analysis we get information on both the amplitude of any periodic data within the data and how this amplitude varies with time. Also Fast Fourier transform gives a fixed resolution at all times, whereas wavelet transform gives a variable resolution. Higher frequencies are better resolved in times and the lower frequencies are better resolved in frequencies.

Our aim is to study the properties of the solar core through the calculation of variation in the solar neutrino flux data. It is well known that solar neutrino flux can reveal the characteristics of the sun properly and can describe the inner behaviour of the sun. According to the standard solar model (SSM) core of the sun is steady and also the model predicted the steady solar neutrino flux. But the observed quantities of solar neutrino flux by various detectors like Homestake, Sage, Gallex, and Kamiokande etc. are about 1/3 of that predicted by SSM [1]. In this paper we have analyzed the solar neutrino flux data from Homestake experiment and obtained variations which are supported by [2], [3], [4] etc.

The first solar neutrino experiment to be performed was the chlorine radio-chemical experiment, which detects solar neutrinos more energetic than 0.81 Mev. After more than 25 years of the operation of this experiment, the measured event rate is 2.55 +/- 0.25 SNU whereas the predicted value is 9.3/+1.2/-1.4 SNU [1] (1 SNU =10^{-36} interactions per target per atom per second).

Since significant variations is obtained through the calculation of periodicities in the Homestake solar neutrino flux data by wavelet transform technique, we can demand that the inner core of the sun in the SSM must be perturbed in nature and one of the author (PR) suggested a perturbed nature of the solar model to explain the variation of solar neutrino flux with the solar activity cycle [5].

Method :

The solar neutrino flux data is analyzed by the wavelet transform (WT) technique containing non-stationary power at many different frequencies. Let the data series be x_l. l=0,1…….,N-1, where N is the total number of sample points with equal time spacing δt.

The continuous wavelet transform of a discrete sequence x_l is defined as a convolution of the sequence with a scaled and translated version of a wavelet function $\psi_0(\eta)$,

$$W_n(s) = \sum_{l=0}^{N-1} x_l \, \psi^*[(l-n)\delta t/s],$$

where (*) indicates the complex conjugate.

Again by convolution theorem, the wavelet transform is the inverse Fourier transform of the product, i.e.

$$W_n(s) = \sum_{k=0}^{N-1} \hat{x}_k \, \hat{\psi}^*(s w_k)\exp(i w_k n \delta t)$$

where the angular frequency is defined as

$$W_k = \begin{cases} 2\pi k/N\delta t & ,\text{when } k \le N/2 \\ -2\pi k/N\delta t & ,\text{when } k > N/2 \end{cases}$$

and (^) denotes the Fourier transform.

The Wavelet function at each scale 's' is normalized to have unit energy by

$$\psi\hat{}(sw_k) = \left(2\pi s/\delta t\right)^{1/2} \psi\hat{}_0(sw_k).$$

This type of normalization ensures that the wavelet transform at each scale are directly comparable to each other and to the transforms of the other data series.

The wavelet function $\psi_0(\eta)$ may be the Haar wavelet, Daubichies wavelet,Morlet wavelet,Mexican hat wavelet etc.The Haar wavelet and Daubichie wavelets are used for orthogonal Wavelet transform. When smooth continuous variations in wavelet Amplititudes are expected, the non-orthogonal transform is useful one. Morlet wavelet contains both complex and contains more oscillations than the Mexican hat wavelet and hence the wavelet power combines both positive and negative peaks into a single broad peak. That is why we have chosen the Morlet wavelet to analyze the solar neutrino flux data by Wavelet transform technique.

Morlet wavelet: $$\psi_0(\eta) = \pi^{-1/4} \exp.(iw_0\eta) \exp.\left(-\eta^2/2\right)$$

where w_0 is the non-dimensional frequency here taken to be 6 so as to satisfy the admissibility condition. [7]

Since the wavelet function $\psi_0(\eta)$ is complex, the Wavelet transform $W_n(s)$ is also complex. The wavelet power spectrum or wavelet amplitude (WA) can be defined as $|W_n(s)|^2$ at each scale 's' and time 'n'.

We have used red noise power spectrum for computing significance levels of the peaks obtained through the calculation of Wavelet power spectrum. [7].

Results :

It is known that Homestake solar neutrino flux data are uneven. We have used cubic spline method for evenness of the data and then applied 5-points running average method to the monthly, 1.5 monthly, 3 monthly and 3.317 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 peaks arises.The results are shown in the tabular form.

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, 7.4, 5.56, 4.46, 3.7
3 monthly	21.53, 10.78, 7.23, 5.44, 4.34, 3.63
3.317 monthly	21.67, 10.86, 7.29, 5.47, 4.37, 3.66

Discussion :

We have analyzed 1970-1995 Homestake solar neutrino flux data by Wavelet transform technique to obtain periodicities in the data. Wavelet amplitude versus periodicities graphs have been presented and it is observed that clear peaks are arising around the 22 years, 11 years, 7.3 years, 5.5 years, 4.4 years & 3.7 years periodicities. Among the height of the peaks shows that the periodicities of 5.5 years, 7.3 years, 11 years, 22 years are above the 95% confidence level, which strongly favours the existence of periodicities in the Homestake solar neutrino flux data. These type of periodicities are observed in the other forms of solar activities (i.e. sunspot number data , solar flare data etc.).

Our calculated periodicities around 5 +/- 0.2 and 11 years are also supported by Liritjis [3]and Ikhsanov & Miletsky [2]. Solar neutrinos are emitted from the inner core of the sun and the periodicities in the solar neutrino flux indicating the periodic nature of the solar core. This may imply that the solar activity cycle is related to the pulsating character of the nuclear energy generation inside the core of the sun. It is also suggested in [2] that solar neutrino flux variation may be connected with the magnetic field of the sun but the magnetic field can not explain the occasional high count in the Homestake solar neutrino flux data e.g. in 1972, 1977, 1981, 1984 etc. Thus we suggest that the solar neutrino flux variation can be explained if it is related to the pulsating character of nuclear energy generation inside the core of the sun [4,5,6].

References:

[1] Bahcall, J. N., Neutrino Astrophysics (Cambridge University Press) (1989).
[2] Ikhsanov, R.N and Miletsky, E.V, arXiv: astro-ph / **0312581VI**, 22nd Dec, (2003).
[3] Liritzis, I., Solar Physics, **161,** 29(1995).
[4] Raychaudhuri, P., Solar Phys., **93**, 397 (1984).
[5] Raychaudhuri, P., Ap.Sp.& Sci, **13,**231 (1971).
[6] Raychaudhuri, P., Int. J. Mod. Phy, **A14**, 1205 (1999).
[7] Torrence, C and Compo, G. P, BullAmerMeteor. Soc.**79(1**),61(1998).

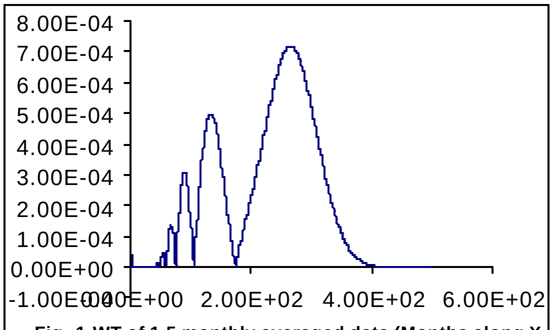

Fig.-1:WT of 1.5 monthly averaged data (Months along X-axis & WAs along Y-axis)

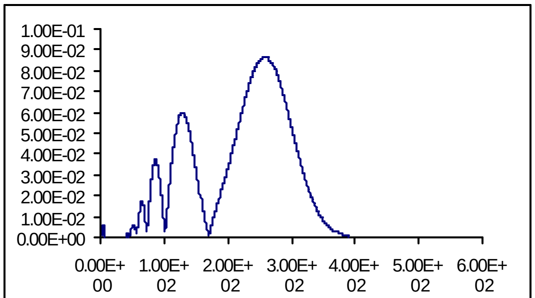

Fig-3: WT of 3 monthly averaged data (WAs along the X-axis & Months along the Y-axis)