THE CONJECTURE CONCERNING TIME VARIATIONS IN THE SOLAR NEUTRINO FLUX

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1. Introduction.

The most challenging problem in neutrino astronomy in the past two decades has been the solar neutrino problem, i.e., the discrepancy between the predicted rate of detection of neutrinos in the standard solar model of 6...8 SNU and the averaged value 2.1± 0.3 SNU actually observed (1SNU ≙ 10^{-36}captures/sec ^{37}Cl atom; cf. 1,2).

In this paper we shortly review the results of our Fourier transformation of the unequally-spaced time series of the recorded ^{37}Ar production rate of the solar neutrino experiment (runs 18-80, 1970-1983). We will determine significance criteria for every period discovered by the harmonic analysis (3,4). We will also perform a Fourier synthesis of certain discovered harmonics and it seems that the solar neutrino flux increases shock like with a period of approximately 8.3 years and after that breacks down. We point to possible connections between the periods found by the harmonic analysis and several observed phenomena on the solar surface.

2. Fourier Analysis of the ^{37}Ar Production Rate Measurements

For the harmonic analysis of the time series of 59 measurements of the ^{37}Ar production rate $f(t)$ (runs 18-80, cf. 1) we consider it as a stochastic process which we can split phenomenologically into two components : $f(t) = \mu(t) + \eta(t)$ where $\mu(t)$ denotes a non-stochastic function of time - the systematically varying component in $f(t)$ -, and $\eta(t)$ denotes the stationary stochastic process - the remainder in $f(t)$. The systematically varying component $\mu(t)$ can be split also into the trend ξ which we consider as time independent identified with the mean value over all n = 59 measurements ($\xi \approx 0.47$ ^{37}Ar atoms per day), and the non-stochastic periodic function $\nu_k(t)$: $\mu(t) = \xi + \sum_{1}^{n} \nu_k(t)$. Further we make the ansatz for $\nu_k(t)$ composed of sinusoidal and cosinusoidal terms : $\nu_k(t) = a_k \cos(2\pi \nu_k t) + b_k \sin(2\pi \nu_k t), k=1,\dots,n$. From the harmonic analysis of $f(t)$ by means of the finite Fourier transformation of unequally-spaced data described in (2,4) we obtain the power spectrum $N_1 = F(\nu) F^*(\nu)$ shown in Fig.1 by multiplying the Fourier transform $F(\nu)$ with its conjugate complex form $F^*(\nu)$. For a detailed discussion of the connection between the power spectrum $N_1(\nu)$ and the related spectral window see (4, 5). In Fig.1 are clearly recognizable the periods Π_i = 8.33, 5.26, 2.13, 1.56, 0.83, 0.64, 0.54, and 0.50 (all T's in years, i = 1,...,8). We consider the complementary power quotient, $1-Q = (\sigma^2 - \sigma^2(2\pi\nu_i))/\sigma^2$, shown in Fig.1 as a function of ν, as the significance criterion for every discovered harmonics of frequency ν_i (σ is the variance of the respective measurement). The higher the complementary power quotient the higher the significance of the considered harmonics. If we compare the power spectrum in Fig.1 obtained for runs 18-80 with earlier results of the Fourier analysis for runs 18-69 (2) and 18-74 (5) we find full consistency.

3. Fourier Synthesis of Certain Harmonics Discovered in the ^{37}Ar Production Rate

All variations in the power spectrum $N_1(\nu)$ shown in Fig.1 with power quotients $1-Q$ = 0.9500...1.0000 we consider as belonging to the stationary stochastic process $\eta(t)$ which has by definition no significant meaning for the search for periodics in $f(t)$. The periods $T_1 \ldots T_6$ in Fig.1 are characterized by nearly equidistant frequencies and could be attributed to a series of harmonic waves. Taking every frequency of those six periods into consideration we can synthesize it to sinusoidal oscillations of the ^{37}Ar production rate belonging to a fundamental wave with $T_1 = 8.33$ years. For the purpose of smoothing the stochasticly caused function $\eta(t)$ in $f(t)$ we perform a folding of $f(t)$ with Gauss' normal distribution function. If we multiply the Fourier transform of $f(t)$ by the Gauss function the high frequencies will be smoothed out symmetrically to the frequency zero. In the process of the reconstruction (Fourier synthesis) of the time series $f(t)$ all harmonics with low frequencies will have the main contribution and determine the smoothed form of $f(t)$. This procedure applied to the ^{37}Ar production rate $f(t)$ with the fundamental wave T_1 = 8.33 years as shown in Fig.1, and a smoothing constant σ = 3 years^{-1} led to Fig.2. In Fig.2 we see that there occur three shock like rising waves within the fundamental period T_1 = 8.33 years up to a maximum ^{37}Ar production rate and after that a breack down of the ^{37}Ar production rate can be observed. To prove the influence of a curve shown in Fig.2 on the power spectrum given in Fig.1 we performed the Fourier analysis of $x(t)$ in Fig.2 and obtained the power spectrum $N_2(\nu)$ (see Fig.3). The power spectrum $N_2(\nu)$ in Fig.3 reproduces nearly completely all periods found in the harmonic analysis of the ^{37}Ar production rate measured in the solar neutrino experiment (1), T_2 = 4.5, T_3 = 2.34, T_4 = 2.17, T_5 = 1.73, T_6 = 1.49 (all T's in years), and fits into the fundamental period T_1 = 8.33 years the new period T_0 = 11.1 years. We believe that the value of the period T_0 = 11.1 years is connected with the total running period of the experiment of Davis and associates (1).

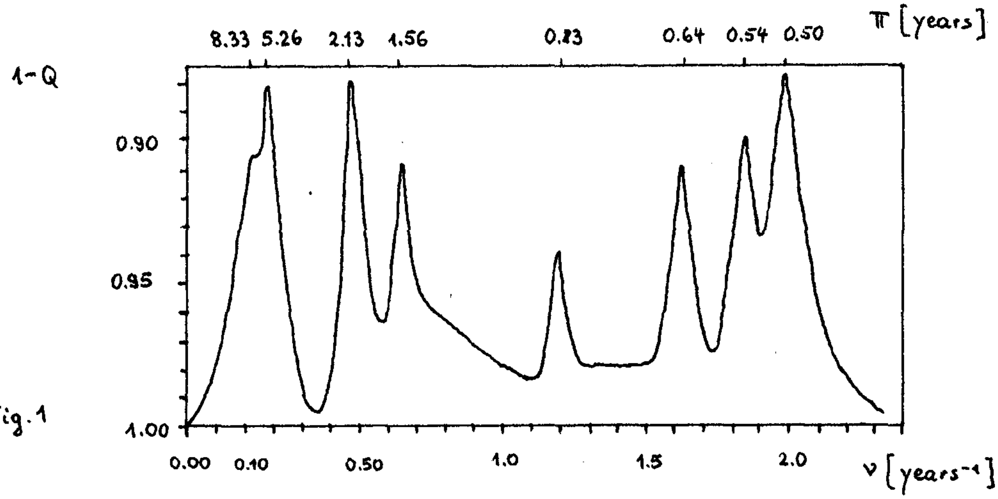

Fig.1

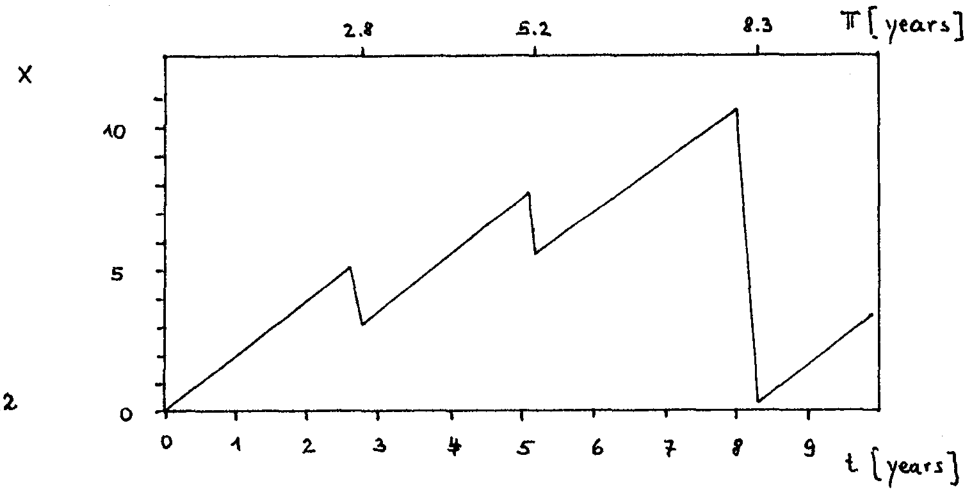

Fig.2

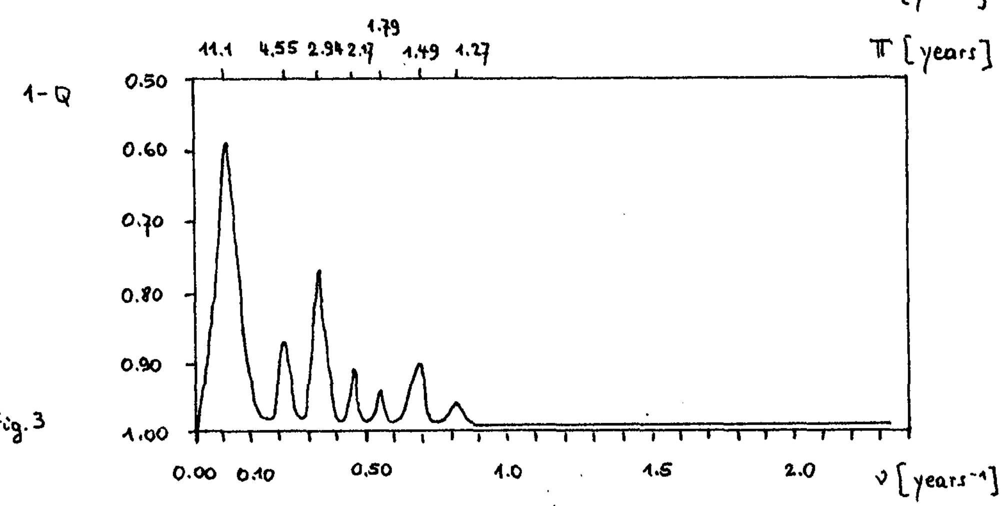

Fig.3

4. Remarks

- One of the eight periods discovered by harmonic analysis, $\pi_3 = 2.13$ years, is identical with the quasi-biennial period obtained by Sakurai (6).
- It is interesting to note that Rieger et al. (7) recently published results concerning a 154 day periodicity in the occurence of hard x-ray flares of the Sun. Approximately the same periodicity observed Wolff (8) which he attributes to g-mode oscillations of the Sun. Both periods are rather close to our periods π_7 and π_8.
- In the present understanding of the solar interior only very few is known about physical processes which could lead to variations of the solar neutrino flux with periods in the order of years. However, non standard solar models are still under consideration where gravity mode oscillations are excited (9) and specific stratification of the solar interior exists (10). Such non standard solar models can explain, in principle, short time variations of the solar neutrino flux.

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