Fourier spectrum analysis of the new solar neutrino capture rate data for the Homestake experiment

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The paper provides results of the Fourier spectrum analysis of the new Ar-37 production rate data of the Homestake solar neutrino experiment and compares them with results for earlier data, revealing the harmonic content in the Ar-37 production in the Homestake experiment.

1. THE SOLAR NEUTRINO PROBLEM

All four solar neutrino experiments (Homestake, Kamiokande, GALLEX, SAGE) observe a deficit of solar neutrinos compared to the predictions of the Standard Solar Model. Additionally, any two of the three classes of solar neutrino experiments indicate that the largest suppression is in the middle of the solar neutrino spectrum (the Be-7 line and the lower part of the B-8 spectrum) [1]. Among these four experiments the Homestake experiment is taking data for almost 25 years [2,3]. The reliability of the radiochemical method for detecting solar neutrinos has been tested recently by the GALLEX experiment [1].

2. IS THE SOLAR NEUTRINO FLUX CONSTANT?

All efforts to resolve the solar neutrino problem by improving solar, nuclear, and neutrino physics have not proven successful so far [4]. This may also mean that the average solar neutrino flux extracted from the four experiments may not be the proper quantity to explain the production of neutrinos in the gravitationally stabilized solar fusion reactor [5,6].

This conjecture is supported by the fact that the pattern of the detected solar neutrino flux in the four solar neutrino experiments hints at possible variation of the solar neutrino flux over time, which has been generated interest to look at time dependent phenomena [7–10] related to solar physics and neutrino physics.

3. FOURIER SPECTRUM OF THE HOMESTAKE DATA

Figs. 1 and 2 show the Ar-37 production rate data which Davis and collaborators have acquired and analyzed in more than 25 years. For the analysis of the radioactive decay of argon with a small number of counts the method of maximum likelihood was employed which brings in a wide range of error. These error bars are omitted in Figs. 1 and 2 and will not be taken into account in the following analysis. Thus, Figs. 1 and 2 show
only the mean values for the Ar-37 production rate for the various individual experiments. The data are unevenly spaced and the two data sets contain only low numbers of data. Recently, the Ar-37 production rate data, shown in Fig.1, have been reviewed, taking into account counter efficiencies, chemical yields, and background effects [3]. The new analysis has yielded an overall rate approximately ten percent higher than the earlier analysis. The time distribution of the data in Figs. 1 and 2 is essentially unchanged. The combined maximum likelihood rate for the 99 experiments in Fig. 2 is 0.480±0.032 Ar-37 atoms per day in 615 tons of perchlorethylene or 2.55 SNU ($1SNU = 10^{-36}$ captures/target atom/sec). This experimental result, compared with the theoretical predictions of 8 SNU for the Standard Solar Model, has become known as the solar neutrino problem [4]. The following provides the Fourier spectrum analysis of the earlier Ar-37 production data [9] and, for comparison, of the new data. The analysis shows that the review of the earlier data did not change essentially the resulting power spectral density that reveals a strong harmonic content in the data.

To remove some of the high frequency noise from the data in Figs. 1 and 2, the five-point moving average is calculated, which adjusts each point to be the average value of the five points around it. The results in Figs. 3 and 4 are longer than original by one point. This causes a slight phase shift in the display.

The fast Fourier transform of a real series results in a complex series where the second half of the result is the mirror image of the first half. The power spectral density is the magnitude squared of the first half of the fast Fourier transform and factors out the length of the original series. The power spectral density in Figs. 5 and 6 is useful for comparing the frequency spectrum of different series and can be thought of as the power of a series at a particular frequency [9].

4. CONCLUSION

The investigation of the variation of the Ar-37 production rate over time in the Homestake solar neutrino experiment reveals several periodicities shorter than or almost equal to 11 years. A number of harmonics contained in the Ar-37 data set may have a non-random origin. It is a striking fact that the power spectrum density did not change significantly in the various analysis undertaken over the years while gradually accumulating data in the Homestake experiment. It can not be excluded at this point of time that the discovered harmonic content of the data reflects solar activity through a not yet known physical phenomena, seated in the deep interior of the sun. Attention is drawn to the existence of distinct peaks in the power spectrum density of the Ar-37 production rate. Extending and improving of the data could be achieved through taking into account the results of the other three solar neutrino experiments (Kamiokande, GALLEX, SAGE) if they continue operating over a sufficient period of time. In conclusion, the present results confirm the existence of periodicities in the new set of Homestake data, previously reported for the earlier data.
Figure 1. The observed Ar-37 production rate in the Homestake experiment ("earlier" data) for runs 18(1970.78)-109 (1990.04)[abscissa: time (years), ordinate: Ar-37 production rate (atoms/day)].

Figure 2. The observed Ar-37 production rate in the Homestake experiment ("new data") for runs 18(1970.78)-124 (1992.38)[abscissa: time (years), ordinate: Ar-37 production rate (atoms/day)].

Figure 3. Five-point moving average of the Ar-37 production rate shown in Fig.1.

Figure 4. Five-point moving average of the Ar-37 production rate shown in Fig.2.
Fig. 5 and 2 exhibit periods of high and low Ar-37 production rates indicating that there is an apparent change in the signal. In Figs. 3 and 4 one notes that the five-point moving average in the periods 1977 to 1980 and 1987 to 1990 shows a strongly suppressed signal. The highest peaks in Figs. 5 and 6 appear at about 10.0 yr and 0.5 yr periodicities. Shorter periods of 1.66 yr and 0.71 yr can also be observed.

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