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Exploration of the Solar Activity Indices Data with the Near Periodicities of its Synodical Rotation Period

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Abstract

Discrete Fourier transforms were conducted for the solar activity indices such as solar daily sunspot numbers and daily measurements of the integrated emission from the solar disc at 2800 MHz (10.7cm wavelength) at the rising phase of solar activity in deferent epochs. Spectral analyses were carried out at the periods near the periodicity associated with the solar synodic rotation period ≈27 days.

The solar activity data were filtered against low and high frequencies to reveal more clearly the real periodicities in the researching intervals.

The special approach was developed to estimate the reality of the revealed frequencies. In the power spectrum of the solar activity indices. The adjusted to the power of the solar data random numbers were used to estimate frequency peaks in the power spectrum for the validation of the real physical processes in the solar activities and 99% confidence level was calculated for these frequencies.

Introduction

Exploration of the solar activities has a great role for studying of Solar- terrestrial connections and for the processes occurring with the galactic cosmic rays due to the Solar physical influence on them. Many articles among them [1-4] were devoted to this phenomenon including those which are related to the effects on the Earth, caused by rotating of the sun.

Quantitatively Solar activity (SA) is characterized by several of physical indices among which are sunspot numbers (SN) on the Solar sphere and the integrated emission (IE) from the sun at 2800 MHz (10.7 cm wavelength). Generally, these indices undergo various variation among which basics are 11year cycle (pict.1) and 27 days periodicity. First of them is caused by so called Solar magnetic field dynamo and second due to the rotation of the sun with 27 days synodical period (respect to the Earth) about its axis.

On the pict.1 it is clearly seen 11year cycles of sunspot numbers (one of the indicators of the solar activity).

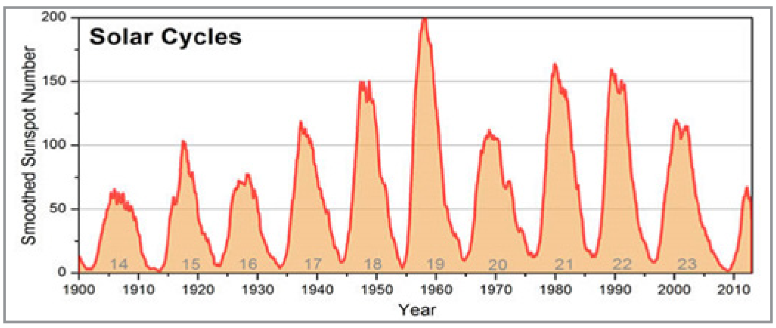


Figure 1: Solar 11 years cycles activity

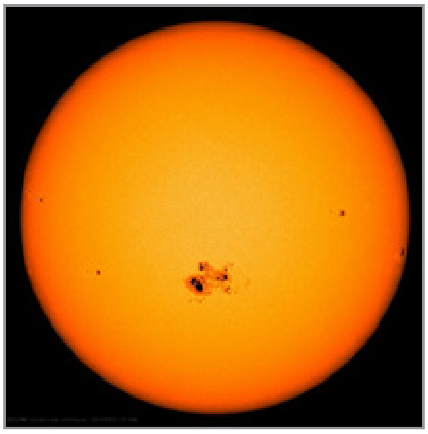


Figure 2: Sunspots

On the pict.2 one can see sunspots which reach its maximum at the 11-year solar cycle peaks. While the sun rotates about its axis, in the sun-spots numbers data, 27 days periodical curve is detected to the respect of the Earth. Sunspots can last from for a few days to several months, with smaller sunspots appearing and disappearing more quickly, while larger, more intense groups can persist for longer periods. The duration of a sunspot is influenced by its magnetic field and can vary significantly, with some lasting less than a day and others persisting for over 100 days. Hence, it is obvious that 27 days periodical signal of sunspot numbers, detected by Earth observer, is caused by rotating of the sun with synodical period of 27 days.

On the following pictures are shown discrete Fourier transform of SN and IE for the rising phase of the solar activity (3 years daily data). On the pict.3 it is seen how the program code filters the original signal.

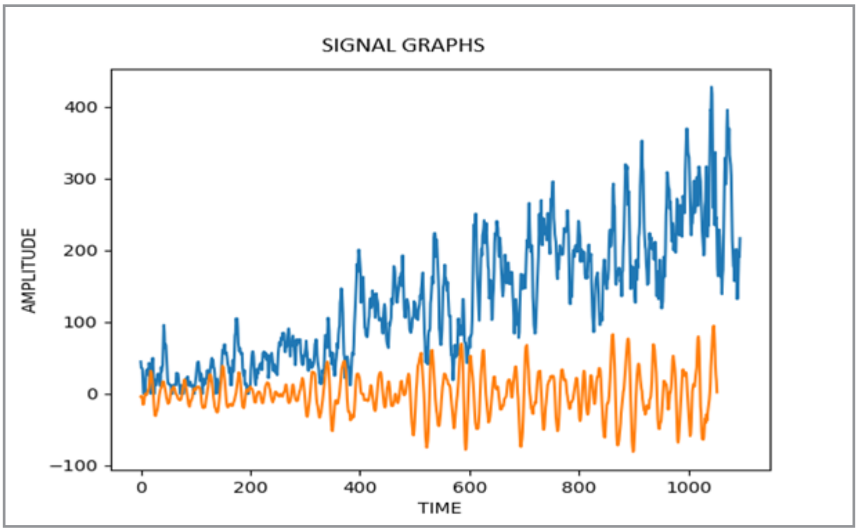
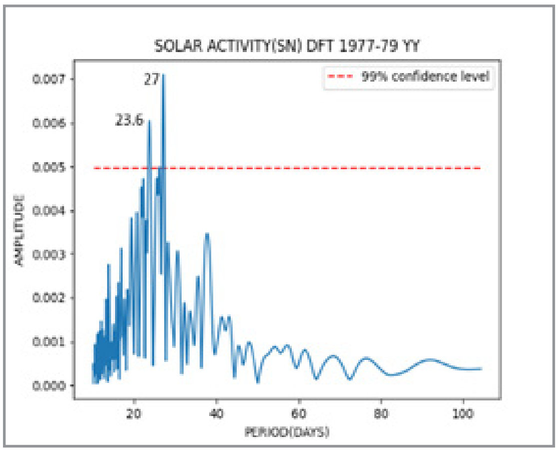


Figure 3: The blue color curve corresponds to the original signal and the orange color one to the filtered signal

On the picture 4-9 are seen DFT of sunspot numbers and IE in different epoch with different periodicities but 27 days period peak is most prominent.

It clearly indicates the rotational effect of the sun observed on the Earth. distinguished periods, other than 27 days periodicity, are called as quasi periodic variations and they correspond to the different complex physical mechanism of the sun activity which explanation is not the aim of this paper. Red dashed line corresponds to the 99% confidence level of these peaks. The following pictures illustrate DFT of filtered SN and IE data for the low and high frequences relative to the 27 days periodic signal, for different epoch of the SA.

Now, our goal is to estimate the reality of the peaks in DFT analyses, whether they really correspond to the physical processes occurred on the sun or not. As we mentioned above the red dashed lines express 99% confidence level of the peaks of data's DFT. It means that above it, these peaks are real (not random) with 99% confidence.



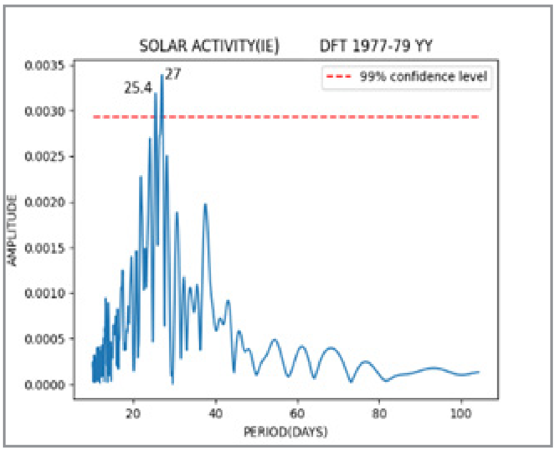
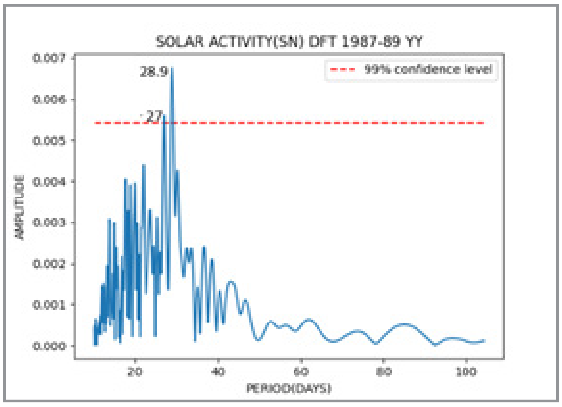


Figure 4: Filtered SN DFT (1977-79 y)

Figure 5: Filtered IE DFT (1977-79 y.)



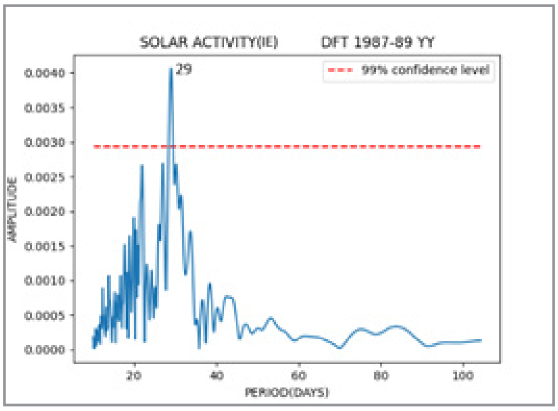
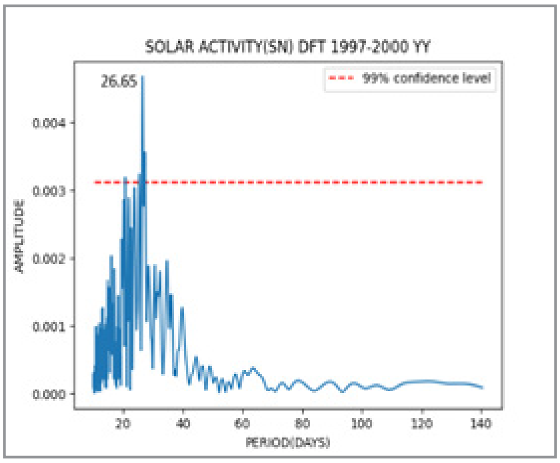


Figure 6: Filtered SN DFT (1987-89 y).

Figure 7: Filtered IE DFT (1987-89 y).



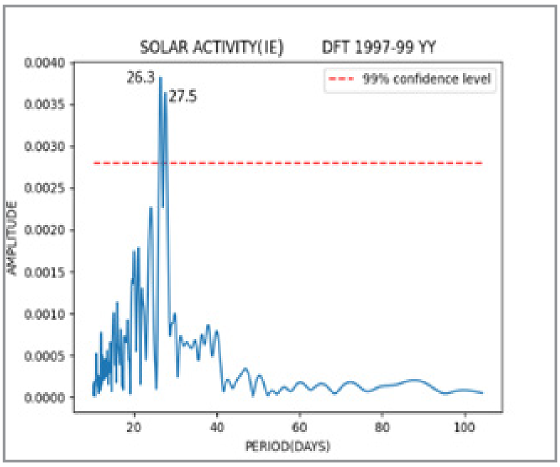


Figure 8: Filtered SN DFT (1997-200 0 y).

Figure 9: Filtered IE DFT (1997-2000 y)

These results were achieved with the help of random numbers. Because the fact that we have to make only one DFT realization for the SA data for the given epoch, we used random numbers with the same power (the same minimum and maximum boundaries of the numbers) and the length as SA data have and carried out a DFT for them 200 times in order to raise a statistical confidence of the results. From those 200 times realization of the DFT of the random numbers we calculated the mean of the values of the peaks from each DFT ones and added it 3 times deviation and assigned it 99% level of confidence above which every peak of DFT of SA data must be considered as real. It can be expressed by the formula: L = μ + 3*σ where μ is the mean value of the abovementioned obtained data and σ is its deviation. Since the data we treat can be considered as random numbers their distribution is similar to the Gaussian distribution function which is described by the probability one: $F(X) = \frac{1}{\sqrt{2\pi\sigma}} * e^{-(x-\mu)^2/2*\sigma^2}$.

On the pict.10 it is depicted Gaussian function where L = μ + 3*σ value (as maximum) covers nearly (99% <value <100%) all possible random numbers.

- Roughly 68.3% of the data is within 1 standard deviation of the average (from μ-1σ to μ+1σ)
- Roughly 95.5% of the data is within 2 standard deviations of the average (from μ-2σ to μ+2σ)
- Roughly 99.7% of the data is within 3 standard deviations of the average (from μ-3σ to μ+3σ)

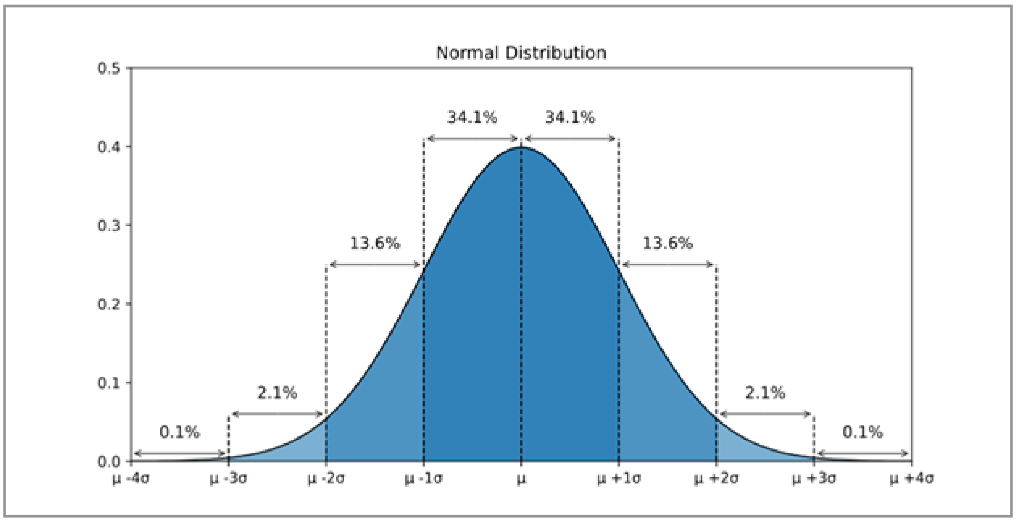


Figure 10: Gaussian(normal) distribution

According to this, on the pict.11 we see the distribution of the values(histogram), obtained from our program code, of 200 times DFT realization (maximum peaks chosen from each DFT) of random numbers which is almost similar to the Gaussian distribution.

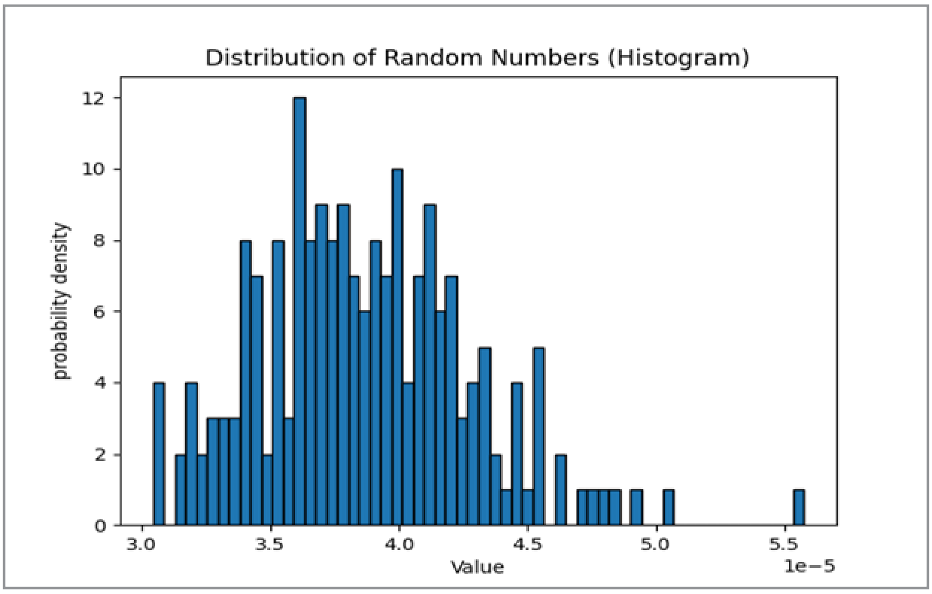


Figure 11: Distribution of values Related to the peaks Obtained from multiple DFT of random number

In this case μ=3.864250992924513e-05, σ=4.16638635430446e-06 and L=5.114166899215851e-05. It means that the value of L is big enough to think that every maximum values of DFT peaks gets into 99% confidence interval. Pict.12 shows how this math. Method(for estimating of 99% confidence level) works (for the sake of the tests) when we have 27 days periodic sine function with noise of equal power(respect to the main signal) and pict.13 shows when the noise is 6 times greater in power than the sine signal.

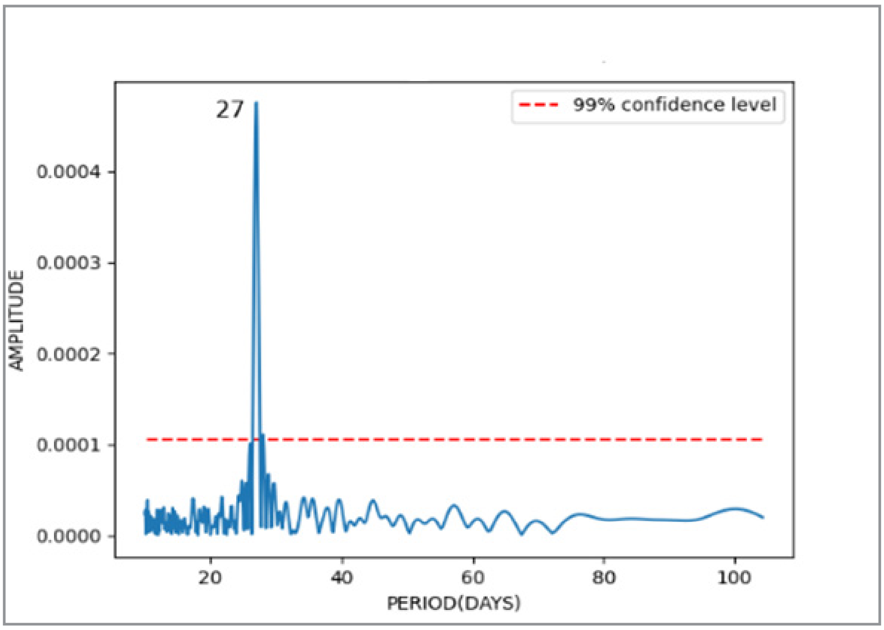


Figure 12: Sine wave (with equal noise in power than the signal) DFT

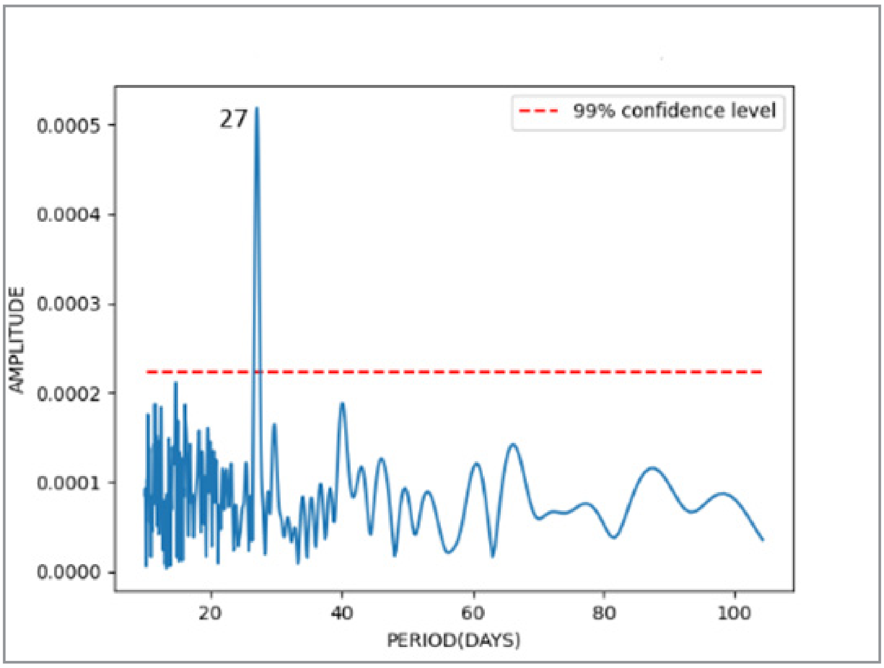


Figure 13: Sine wave (with 6 times greater noise in power than the signal) DFT

These simulations show pretty good results for determining the reality the DFT frequency peaks of signals in terms of defining 99% confidence thresholds of these peaks and it has an important role in the spectral analyses for one time given signals.

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