Spectral analysis of Coronal Mass Ejection under the condition of Active Sun at Pakistan atmospheric regions

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Abstract: In this communication, we use observations of solar flare duration for calculation of intensity of solar particles emitted at Pakistan atmospheric region over a period of 1979-2006, to predict local behavior with proper degree of accuracy. Actually short records not fully describe the diurnal cycle but different spectral technique like Periodogram and spectral density are helpful in disclosing the true picture behind any physical phenomena. We find hidden periodicities and pin-point the peak frequencies in the time series during active sun by applying confidence limits to the peaks of these spectral estimates. The Fourier coefficients and spectral energy for different portion of the time series have also been calculated.

*Index Terms***:** Coronal mass ejection (CME), Solar proton event (SPE), Spectral analysis, Fast Fourier Transform (FFT)

I. INTRODUCTION

From observations of solar flare X-rays and radio bursts of highly accelerated particles within flares have been reported. Almost all solar activity depends on magnetic fields and it has been widely accepted that the energy associated with the active sun is derived from magnetic energy. This energy will be released when the twisted field becomes kink unstable. [1]

The solar particle emission is greatly increased following the appearance of some large flares. An interesting consequence of solar particle emission at the time of a large flare is the accompanying distortion of the sun's magnetic field

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Charged particles in plasma can cross the lines of force of magnetic field only as a result of collisions with other particles. Because of the very low pressure in the coronal region, such collisions are rare, and so the solar particles are unable to escape from a magnetic field. Consequently when they are expelled from the Sun at high velocities, they tend to carry the solar magnetic field with them. The interaction of this field with that of Earth is of considerable interest. [2]

It is now believed that coronal holes may be responsible for all geomagnetic disturbances and that flares and other active solar phenomena only intensify these effects. An especially energetic flare could subject astronauts outside of the earth's environment to a lethal amount of radiation within several days. A strong solar flare can cause the earth's thermosphere to increase in temperature and expand. When this occurs, the atmospheric density at a given latitude increases and a satellite orbiting near that height encounters more atmosphere than it otherwise. The increased resistance slow the satellite and it descends at a faster than anticipated rate. [3]

Solar activity has considerable effects on the earth. The normal solar wind produces small changes in the earth's magnetic field, but flares, CME and high velocity streams associated with coronal holes can produce a giant current system in the magnetosphere called geomagnetic storm. Coronal holes occur in the regions of open field lines where material can easily flow outward into the solar wind. Those flares identified with CME tend to be accompanied with mass ejections in the form of surges or sprays. There is a significant group of CME which is not connected with any optical solar phenomena. [4]

II. METHODOLOGY

Since general statistical quantities provide little insight into different types of signals that are blended together to make the recorded data. The methodologies like Fast Fourier Transform (FFT) help examine data series in terms of their frequency contents. Determination of the Fourier Components of a time series can be used to determine a Periodogram which can be used to define Spectral density of the time series.

A goal of time-series analysis in the frequency domain is to reliably separate periodic oscillations from the random and aperiodic fluctuations. Fourier analysis is one of the most commonly used methods for identifying periodic components in near-stationary time-series. [5]

Through the use of Fourier transform it is not only providing a better understanding of periodic signals through their frequency spectra, but the basic idea can be extended to a large class of aperiodic signals, as well. [6]

Mass spectrometers carried out by space vehicle calculate the number of particles emitted from solar disc. This information has been utilized to find the intensity of particles emitted during solar flare duration of our data series.

III. DATA ANALYSIS

A. Since each pair of Fourier coefficients are associated with a frequency, the amplitudes of the coefficients provide a measure of the relative importance of each frequency component to the overall signal variability. As spectral energy refers to the amplitudes squared of the Fourier coefficients which represent the variance and therefore the energy, for that portion of the time series. [5]

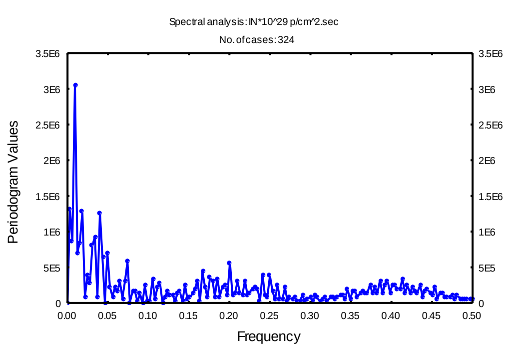

Fig.1 Periodogram versus frequency plot for intensity of particles emitted during solar flare duration.

From figure.1 the highest spectral energy exists at the frequency f = 0.0093 Hz.

Since, $f = \frac{1}{T}$ --------------- (1)

$T = \frac{1}{0.0093} = 108$ months

Corresponding to this period, "$14.29\text{X}10^{29}$" particles emitted per unit area in per unit time which is larger than the other ordinates and indicate the presence of cyclical component at this value.

B. Confidence Intervals for the Spectrum: We can find the confidence interval for the spectrum at different frequencies.

The 100(1–α) % confidence interval for f (ω) is given by,

$$\frac{\nu\hat{f}(\omega)}{\chi^2_{\nu,\alpha/2}} \; to \; \frac{\nu\hat{f}(\omega)}{\chi^2_{\nu,1-\alpha/2}} \quad \text{---------------} \; (2)$$

The degree of freedom for the Hamming window is 2.5164 (N / M) = 23. A useful rough guide is to choose M to be about $2\sqrt{N}$ [7]

From equation (2) the confidence interval for the highest peak of '0.0093' is 0.00561 to 0.01830.

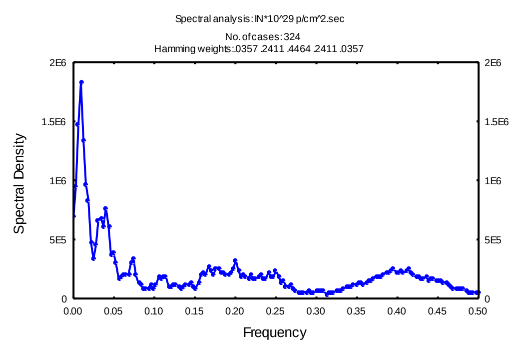

Fig.2 Spectral Density versus frequency plot for intensity of particles emitted during solar flare duration.

The spectrum for a stochastic process can be defined in terms of Power density (Spectral density) which is actually a variance per unit frequency. [5]

In this case spectral density decreases with increasing frequency so we recognized it as red spectrum, by analogy to visible light where red corresponds to longer wavelengths (lower frequencies).

C. Smoothing spectral estimates: The need for statistical reliability of spectral estimates brings us to the topic of spectral averaging or smoothing. For a data sequence of N values, the Periodogram estimates of the spectrum can have maximum N/2 Fourier components. If we use all N/2 components to generate the Periodogram there are only two degrees of freedom per spectral estimate, corresponding to the coefficients A_n, B_n of the Sine and Cosine functions for each Fourier components. Based on the assumption that data are drawn from a normally distributed random sample, we can define the confidence limits for the spectrum in terms of chi-squared distribution, χ_n^2 for n degrees of freedom,

$$E\,[\,\chi_n^2\,] = \mu^2 = n \text{ ------------- } (3)$$

$$E\,[(\chi_n^2 - \mu^2)] = \sigma^2 = 2n. \text{ -------------- } (4)$$

Substituting n=2, into these expressions, we find that the standard deviation, σ is equal to the mean, 'μ' of the estimate, indicating that results based on two degrees of freedom are not statistically reliable. It is for this reason that some sort of ensemble averaging or smoothing of spectral estimate is required. The more smoothing we do, the narrower the confidence limits and the greater the reliability of any observed spectral peaks. [5]

One of the approaches is to smooth the periodogram by simply grouping the periodogram ordinates in sets of size 'm' and finding their average value. The larger the value of 'm' the smaller will be the variance of the resulting estimate but the larger will be the bias, and if 'm' is too large then interesting features of f(ω), such as peaks may be smoothed out. There is little advice in literature on the choice of 'm'. It seems advisable to try several values in the region of N/40. [7]

According to our data series, m = 8. Therefore, we averaged the periodogram ordinates in group of '6' and resultant smoothed periodogram given as follows. Hence we get an increase in degree of freedom and our new degree of freedom is '12' instead of '2'.

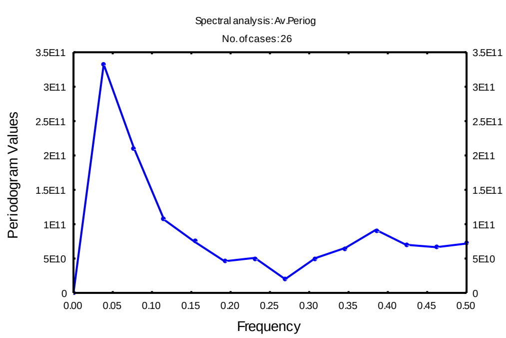

Fig.3 Periodogram versus frequency plot for intensity of particles emitted during solar flare duration.

From figure. 3 the peak value exists at the frequency "0.0385".

Now $T = \dfrac{1}{0.0385} = 26$ months

Now the corresponding value with respect to this period is "$11.08X10^{29}$" particles per unit area per unit time.

IV. CONCLUSION

In this paper we proposed an idea to find out the hidden periodicities in different parameters of solar flare. The more precise result obtained from fig.3 as compared with fig.1. On the basis of our analysis, we can utilize our study of active sun to predict future changes in our atmospheric regions like radio black-out, ozone disruption and influences in our orbital satellite.

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