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Observation of Intensity Oscillations in Corona during the Total Solar Eclipse of October 24, 1995

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Abstract

An experiment to search for short-period oscillations in the solar corona was conducted during the total solar eclipse of 1995 October 24 at Kalpi, India. The intensity in the continuum, centred around 5500Å and with a passband having a half-width of 240Å, was recorded at a counting rate of 20Hz using a thermoelectric-liquid cooled photomultiplier. The power spectrum analysis of the data reveals that most of the power is contained in 6 frequencies below 0.2Hz. A least-square analysis gives the periods of the 6 frequency components to be 56.5, 19.5, 13.5, 8.0, 6.1 and 5.3 sec. These oscillations are found to be sinusoidal and their amplitudes are found to lie in the range 0.2 - 1.3% of the coronal brightness.

Key Words : Coronal intensity oscillations, High frequency photometry, Coronal heating.

Introduction

Evidence of periodic oscillations in the upper solar atmosphere especially in the corona is still an unresolved great problem to be pursued (Koutchmy *et al.* 1983). It is extremely important to confirm the existence and nature of coronal oscillations, since these could be responsible for the heating of solar corona. Chapman *et al.* (1972) found 300 sec. oscillations in the line intensities of Mg VIII and IX obtained from OSO-7 data while Vernazza *et al.* (1975) detected no oscillations in the transition region and the corona from the Skylab observations. During the 1973 eclipse, Liebenberg and Hoffman (1974) observed periodic intensity oscillations of 6 ± 1 minutes period in 5303 Å coronal line from Concorde SST. Analysing the white light observations made aboard the same aircraft, however, Koutchmy (1975) failed to detect periodic oscillations due to large amplitude intensity fluctuations (± 20 %) possibly caused by SST itself. From the analysis of time series observations of 5303 (FeXIV) emission-line spectra, Tsubaki *et al.* (1986) concluded that periodic intensity fluctuations of nearly the same phase existed over some 100,000 Km along the spectrograph slit, while no periodicity was detected both for the line width and line - of - sight Doppler velocity.

Soon after the acoustic wave heating models for the corona were discarded because of OSO-8 observations and several theoretical studies emphasizing the importance of looking at coronal waves in the short period range were reported, Pasachoff made observations during a number of eclipses starting with the Indian eclipse of 1980. Pasachoff and Landman (1984) and Pasachoff and Ladd (1987) detected excess power in the 0.5-2 Hz range at the level of 1% in the coronal green line. Pasachoff's observations were mostly confined to the green coronal line using apertures with 2.5 and 5 arcsec diameters, isolating small regions of the solar corona.

With the background of such observations, we decided to conduct an experiment complementary to that of Pasachoff during the total solar eclipse of 1995 October 24 using a larger aperture to isolate 1.5 arcmin region of the corona and with a broader bandpass filter in the coronal continuum radiation.

Instrumentation and observations

A stepper motor-driven coelostat of 30 cm aperture was used to collect the light from the Sun which in turn was reflected horizontally with the help of a second mirror of 15 cm aperture. The telescope objective was a 10 cm Zeiss achromatic doublet having a focal length of 100 cm. A conventional single channel photometer was mounted horizontally with its diaphragm in the focal plane of the telescope. The 0.5 mm diameter diaphragm used subtended an angle of 1.5 arcmin in the sky. With an interference filter of 25 mm diameter placed immediately behind the diaphragm, a spectral band of half-width ~240Å around 5500Å was isolated for the measurement of coronal intensity. (Singh *et al.* 1996). The HT supply to the PMT was kept on continuously for more than 15 hours for stabilizing the dark current and the cooling system was turned on about 4 hours before the event. The dark counts before and after the observations were found to be below 250 s^{-1}. A region of the corona at a position angle of 65° at $1.25R_{\odot}$ was selected so that an appreciable signal could be obtained during the total phase of the eclipse, and the diaphragm was centred visually around this region. The observations were begun at 3:06:19 UT and ended at 3:08:06 UT. The photon counts were recorded continuously with an integration time of 50ms. The tracking rate of the stepper motor was adjusted to ensure negligible drift of the image in the E-W direction. The drift in the solar image as a result of the changes in the declination of the sun and errors in the polar axis alignment was less than 1 arcsec per minute. Visually, the sky transparency appeared good and steady throughout the eclipse period. Here, we note that the skies were extremely clear at the site throughout 23-25 October. In order to check the performance of the instrumental setup we made several test runs on the sky brightness during the previous evening twilight.

Results

During the total phase of the eclipse the observed counts showed a variability of ~ 1000 counts/50ms about a mean level of 17700 counts/50ms, i.e., at the 6% level. An inspection of Figure 1 clearly reveals the variation in the coronal brightness. In order to detect and isolate the periodic components, the data were Fourier analyzed using the technique of Discrete Fourier Transform (DFT), developed by Deeming (1975).

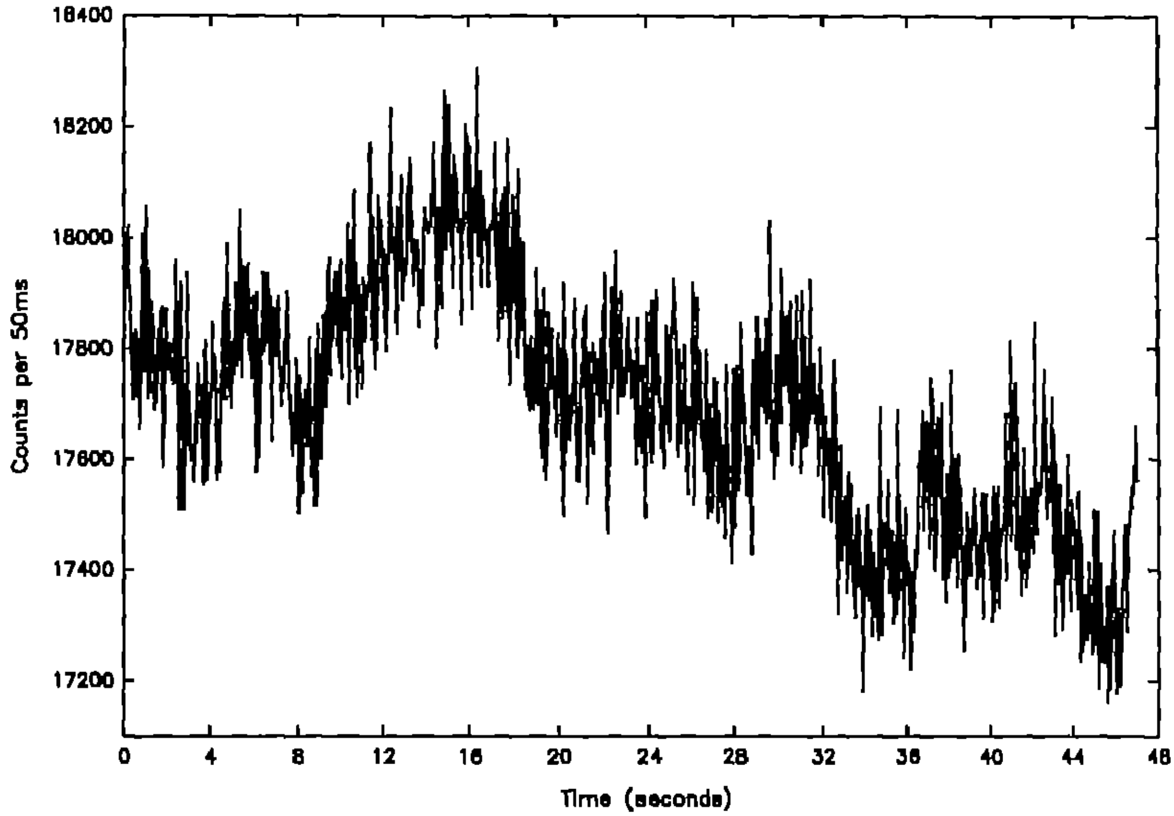

Figure 1 : The figure shows the measured coronal intensity with an aperture of 90 arcsec at 1.25 solar radii at a frequency of 20 Hz during the total phase of the eclipse. The time along the x-axis is reckoned from 03:06:31 UT.

Before subjecting the data to the technique of DFT, they were not modified in any way other than the subtraction of the arithmetic mean. We find from the amplitude spectrum that most of the power is contained in 6 frequencies, namely, 0.018, 0.050, 0.073, 0.125, 0.162 and 0.190 Hz. The presence of peaks in the power spectrum with amplitudes significantly larger than the noise level does not necessarily indicate the presence of coherent brightness modulation with the corresponding periodicities. Therefore, we used the method of least-squares to derive the frequencies, amplitudes and the times of maximum of the six significant components identified in the power spectrum. These constitute 18 unknowns which were solved simultaneously using the original data and their values thus obtained are given in Table 1 alongwith their probable errors; the mean brightness level was also treated as an unknown in the least-square solutions.

The strong point in favour of attributing the above six component frequencies to the coronal oscillations is their extremely sinusoidal nature and near-coherence over the entire period of observation. We could determine their periods, amplitudes and input phases which facilitated the exact reconstruction of the data only because of these characteristics of the components. Further, no harmonics of significant amplitudes were seen in the power spectrum. It is difficult to understand why any variation associated with either atmospheric transparency, or seeing effects, or image motion, or blurring should cause such coherent oscillations of constant amplitudes over a minute interval. All the above sources are expected to cause variations but of non-periodic and variable amplitudes. Here we stress that there is no reason to believe that the usual sources of error, most of which were taken care of, could produce such constant amplitude oscillations coherent over a minute interval; any variation caused by them should be either random or spiky in nature.

Table 1. Periodicities identified in the data

Mean of input data = 17677 ± 5 counts/50ms.

No.	Frequency (Hz)	Period (Sec)	Amplitude (Counts/50ms)	Amplitude % coronal brightness	Time of Maximum (Sec)
1	0.0177 ± 0.0004	56.48 ± 1.44	232 ± 4	1.31 ± 0.02	13.4 ± 1.4
2	0.0512 ± 0.0017	19.52 ± 0.66	48 ± 4	0.27 ± 0.02	15.3 ± 0.6
3	0.0738 ± 0.0009	13.54 ± 0.17	85 ± 4	0.48 ± 0.02	14.8 ± 0.2
4	0.1246 ± 0.0012	8.02 ± 0.08	47 ± 4	0.26 ± 0.02	7.2 ± 0.1
5	0.1629 ± 0.0013	6.14 ± 0.05	54 ± 4	0.30 ± 0.02	5.7 ± 0.1
6	0.1896 ± 0.0020	5.27 ± 0.06	36 ± 4	0.20 ± 0.02	5.5 ± 0.1

We conclude that the 6 dominant sinusoidal components identified and given in Table 1 are not produced by any extraneous agencies, but are the essential components of the coronal brightness variation. To look for the short period oscillations 1-2 seconds reported by Pasachoff and Landman (1984) further analysis of the data was done. We subtracted the contribution of the 6 components identified above by using period, amplitude and phase information of these components from the original data. The short period oscillations may last for shorter duration and may not be coherent through out the observing period of 49 seconds. The small amplitude of these oscillations may not show a clear peak in the power spectrum of the whole data. To enhance the chances of detection of this period, we splitted the residual of time series in 5 subsets and performed DFT on each subset. The 5 power spectra were added together in the frequency domain and the resultant power spectrum (Figure 2) indicates excess power at 1 Hz. The peak in the power spectrum at ~ 1 Hz is just at 3 sigma level. Therefore, more data are needed to confirm the existence of this period. The only drawback of this experiment is that the observations were made on a single location and in one wavelength. The observations on multi locations will help to indentify the nature of waves in the corona.

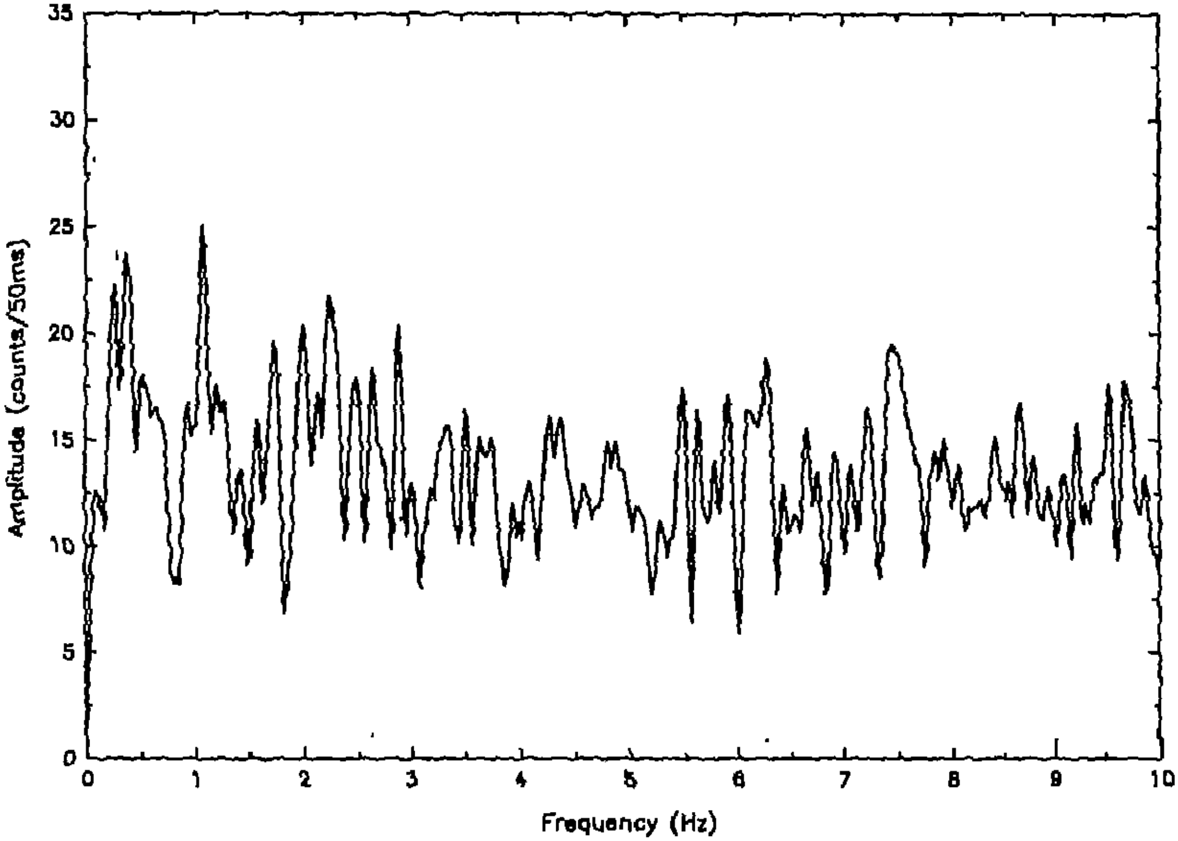

Figure 2 : The resultant power spectrum obtained after adding 5 power spectra of 5 subsets of residual data. The computed contributions of six identified oscillation components were subtracted from the original data to yield residual data. The power spectrum shows a peak at ~1Hz just at 3 sigma level.

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