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# Results of 1995 eclipse observation and observing program for 1998 and 1999 eclipses

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**Abstract.** We, at the Institute of Astrophysics, conducted ten experiments from two places namely Neem Ka Thana in Rajasthan and Kalpi in Uttar Pradesh. The experiments involved high spatial and spectral resolution spectroscopy to determine the temperature and velocity structure in the corona; high temporal resolution photometry to detect intensity oscillations in the corona; narrow-band photometry in three emission lines to determine the differences in 'closed' and 'open' field structures in terms of density, temperature and turbulence, if any; photometry at near infrared (1 micron) wavelength to detect dust ring, if any; around the sun. Broad-band photometry and polarisation measurements and photometry in H-alpha line to detect cool regions in the hot ambient coronal plasma. It was for the first time successful efforts were made to photograph the solar corona using IAF planes, and students and amateur astronomers coordinated to photograph the solar corona from many different places along the length of totality path to study the gross dynamics of coronal structures. Efforts were also made to measure the solar diameter by IUCAA scientists. Many foreign teams conducted their own experiments from Neem Ka Thana, Mukandgarh Fort, Dundload Castle and a place near Agra to study the dynamics and heating mechanism in the corona and detect long term or quasi-periodic variations in the solar diameter. The analysis of high frequency photometry data shows the existence of intensity oscillations in the corona. To confirm the existence of these oscillations, delineate the size of the oscillating region and to determine the changes in these oscillations with radii, we plan to develop a multi-channel photometer during the total solar eclipses of 1998 and 1999.

*Key words*: sun, solar corona, Total solar eclipse, temperature and velocity structure, intensity oscillations, coronal heating

## 1. Introduction

The advancement of the solar coronagraph and observations of the sun from space in X-ray by number of instruments onboard various satellites and recently YOHKOH and SOHO have provided a large body of data and new insight in the solar corona. A number of discoveries, e.g. coronal holes, coronal jets covering a large surface of the sun, coronal mass ejection, lines indicating extremely high temperature in the range of 10-20 million degrees etc., have been made. We have learnt about the existence of hot plasma overlying sunspots, possible circumstances leading to triggering of solar flares and possible processes responsible for heating of solar corona.

Notwithstanding these great discoveries, the occurrence of a total solar eclipse still provides an opportunity to plan and conduct experiments to find answers to a number of open questions regarding the physics of the solar corona. The existence of microturbulence and its role in heating the solar corona are still not fully known (Singh et al. 1985). Attempts have been made to detect velocity and intensity oscillations in the solar corona but without a definite answer because of small amplitude of these oscillations and requirement of excellent sky conditions (c.f. Singh et al. 1997). The differences in 'open' and 'closed' magnetic field structures in terms of density, temperature and microturbulence need to be investigated. There are controversies about the existence of dust ring around the sun and its relation with the solar cycle phase. We need to know the detailed temperature and velocity structure of the solar corona. Are there systematic mass motions in the solar corona? (c.f. Raju et al. 1993; Singh et al. 1982; Livingston and Harvey 1982). The answer to these questions will help in understanding the dynamics of solar corona and making the realistic modelling of coronal structures. In view of this background a number of experiments, e.g., high spatial and spectral resolution multislit spectroscopy of solar corona, high temporal resolution (20 Hz) photometry at a fixed location, narrow band (5 Å pass-band) photometry in three emission lines, photometry at near infrared (1 micron) wavelength, broad-band photometry and polarisation measurements, Fabry-Perot interference fringes to map two dimensional temperature structure in the green line and photometry in H-alpha line were conducted during the 1995 eclipse. Keeping in view the results of these experiments we have planned to modify two experiments and perform these during the total solar eclipses of 1998 and 1999.

## 2. Observations

The weather parameters for the past 60 years were studied along the length of totality. Looking at the cloud cover, rainfall, wind, duration of totality at different locations and logistic support to establish a big camp, and also to support the foreign scientists visiting India, it was decided to develop two observing sites, one at Neem Ka Thana (27°44'*N*, 75°48'*E*) in Rajasthan and other at Kalpi (26°08'*N*, 70°45'*E*) in Uttar Pradesh.

The details of the experiments conducted during this eclipse have already been published (Singh et al. 1997). Here we look at some of the important results obtained.

## 3. Results

Analysis of the photometry at near infrared (1 micron) data has not shown the existence of dust ring around the sun at 4 solar radii. The corona in infrared could be recorded more than 10 solar radii with pixel resolution of 23 arcsec.

High resolution multislit spectra in two emission lines namely green and red lines could be recorded simultaneously for the first time. The preliminary analysis has indicated the differences in the 'open' and 'closed' field structures. The detailed analysis is being done to estimate these differences in terms of temperature, density and turbulence.

The excellent sky conditions during the eclipse permitted the detection of intensity oscillations in the solar corona. These oscillations have been observed for the first time. Earlier attempts by Pasachoff and Landman (1984) have only showed excess power in the frequency range of 0.5 - 2.0 Hz in the power spectrum of data obtained in 5303 line during the 1980 and 1983 eclipses. A detailed analysis of the high frequency (20 Hz) data in continuum radiations obtained during this eclipse has shown existence of intensity oscillations in the solar corona with 6 periods of 5.3, 6.1, 8.0, 13.5, 19.5, and 56.5 seconds (Singh et al. 1997). The amplitude of these oscillations lies in the range of 0.2 - 1.3% of the coronal brightness. We have shown that these intensity oscillations are of coronal origin and the data have not been modulated by experimental set up or by atmospheric conditions (Singh et al. 1997). 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 throughout the observing period of 49 seconds. To enhance the chances of detection of this period, we splitted the residuals 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 (Fig. 1) indicates excess power at ~1 Hz. 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 identify the nature of waves in the corona.

An imaging Fabry-Perot interferometer was designed and used for coronal observations in the green line [FeXIV] 5303 Å at Neem Ka Thana, Rajasthan. A dielectric coated Fabry-Perot etalon with 92% reflectivity and spacing 350 $\mu$m was used to obtain the interference fringes. A liquid nitrogen cooled Photometrics CCD served as the detector. The green line emission was found to be extremely weak and restricted to the eastern and western limbs of the sun. Emission line profiles were obtained at a few coronal locations. The average width was found to be 1.6Å indicative of the presence of large turbulent velocities (49 $kms^{-1}$). One of the line profiles, showed line splitting, possibly due to mass motion in the corona.

## Total solar eclipses of 1998 and 1999

Three total solar eclipses will take place in the remaining part of this century. The total solar eclipse of 1997 will be visible from parts of China, Mongolia, Russia, etc. The extreme cold weather, short duration of totality, low altitude of the Sun at the time of eclipse and poor chances of having clear sky during this period are not very favourable conditions for making serious observing programme during this eclipse. On the other hand, it will be an exciting event and would provide a rare opportunity for the amateur and adventurous astronomers to watch the corona and comet Hale-Bopp at its brighter phase at the same time.

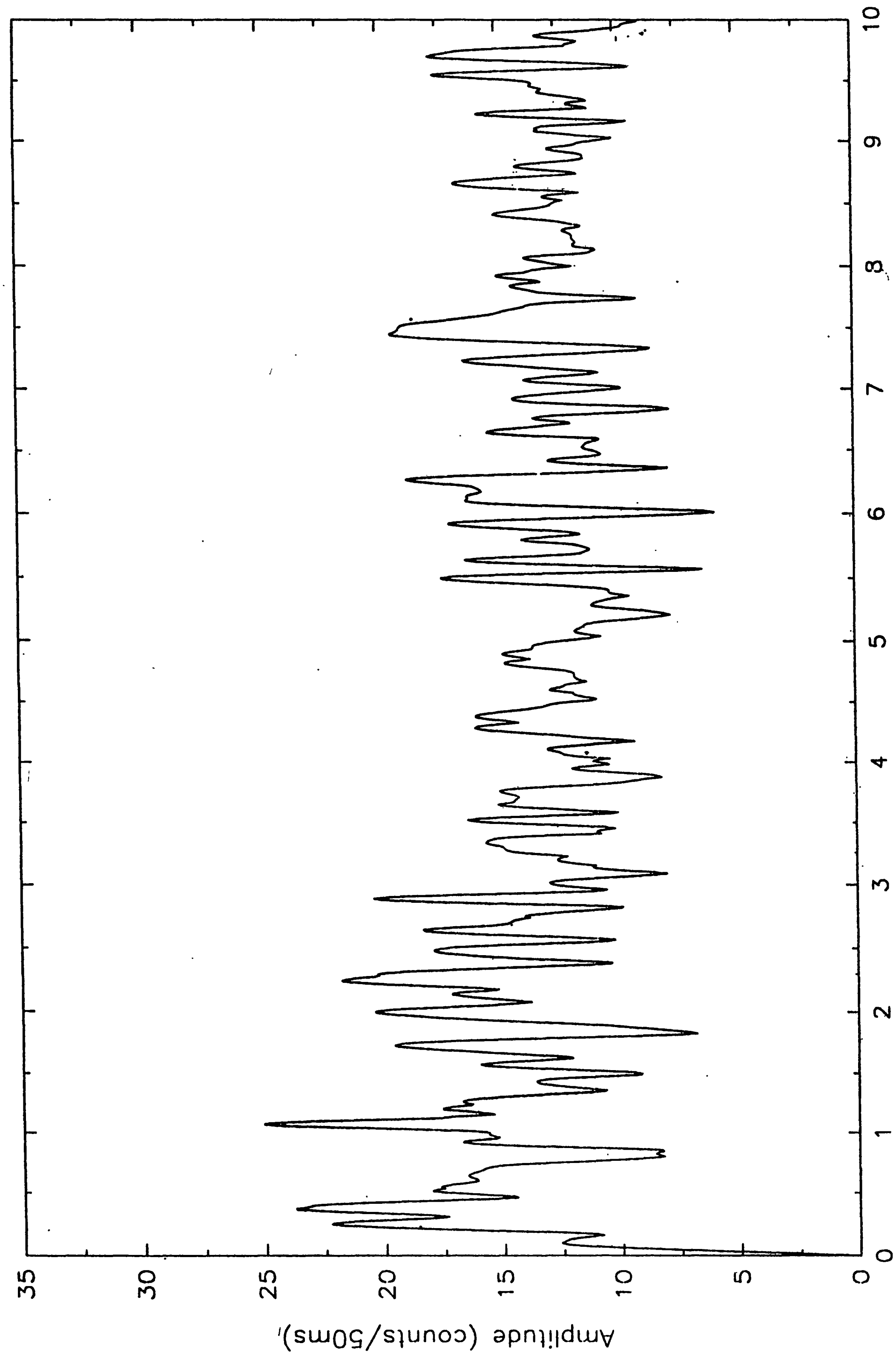


**Figure 1.** The resultant power spectrum obtained after adding 5 power spectra of 5 subsets of residual data. The computed contributions of six identified oscillation components were subtracted from the original data to yield residual data. The power spectrum shows a peak at ~ 1 Hz just at 3-sigma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

Most of the totality of the total solar eclipse of 1998 February 26 lies over the sea. Fortunately it passes over a small land portion of the earth at its near greatest phase. The totality will be visible from parts of Columbia, Venezuela, some of the Caribbean islands etc. The duration of totality will be about 4 minutes at the central line in this part of the totality path and the weather prospects for clear sky are good. This eclipse appears to be favourable for making elaborate plans for observations.

The total solar eclipse of 1999 August 11 will be visible from parts of Europe and India. The maximum duration of totality will be about 2 min. 23 sec. in Europe. In India totality path passes through Rann of Kachchh, Gujarat, Maharashtra, Madhya Pradesh, Orissa and Andhra Pradesh. The eclipse will take place late in the evening and totality will last about a minute. The monsoon is generally very active in India during this period. Rann of Kachchh offers better chances to watch this eclipse. The professional astronomers in India, planning sophisticated experiments may think of the possibility of observing this eclipse from Europe where the chances to view the corona will be fairer.

We plan to conduct two experiments during these total solar eclipses to confirm the existence of intensity oscillations, distinguish between standing and propagating waves, nature of turbulence and estimate differences in 'open' and 'closed' field structures in terms of temperature, density and turbulence. The experiments proposed are (i) Multi-location high frequency photometry of solar corona in emission line and continuum radiations (ii) High spectral and spatial resolution multislit spectroscopy in two emission lines using CCD detectors.

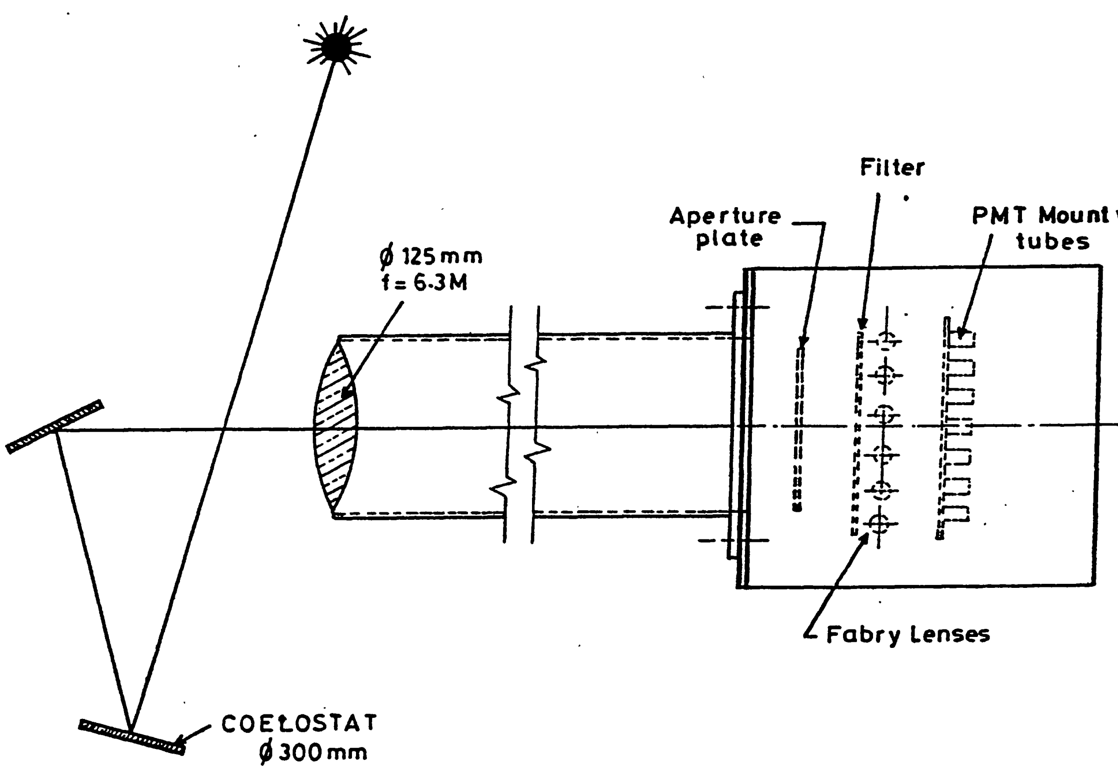


**Figure 2.** Optical layout of multichannel solar coronal photometer.

To perform multi-location high frequency photometry one can choose CCD camera or a number of photomultiplier tubes (PMT) located at different positions in the solar corona. The CCD has the advantage of providing data over the whole of the solar corona whereas use of PMT will yield data only at a few fixed locations in the solar corona. On the other hand, PMT has the advantage of providing data at a much faster rate in comparison with CCD and with a larger dynamic range. In spite of the advancement in technology, it is still very difficult to record and store the quantity of data from CCD at a rate which will be required during the totality phase. Therefore, we have preferred to conduct the experiment with PMT. The optical layout of the experiment is shown in Fig. 2. Stepper motor driven, a 30 cm coelostat mirror will feed the sun/coronal light to an objective of 6.3 M focus. Spatial resolution in the range of 3-30 arcsec will be obtained using circular aperture of various sizes. The large size image of the sun will permit us to directly mount the R647 Hamamatsu PMT at the various locations in the solar corona. We plan to mount two PMT on eastern corona, two on western and two on northern part of the corona. More details of the experiment will be published later.

We have recorded spectra in two coronal emission lines 5303 Å and 6374 Å on Kodak 4415 film using multislit spectrograph and Hamamatsu image intensifiers. The film has a limited dynamic range of about 100 and yields photometric accuracy of about 1-2 percent. Also image intensifier distorts the spectrum due to the pin-cushion effect. In addition, green line radiations may be emitted from different parts of the solar corona than those of red line along the line-of-sight due to large difference in ionisation temperature of these two ions. To avoid these effects, we plan to use CCD camera for recording the spectra and use 7892 Å (Fe XI) line instead of 5303z Å (Fe XIV) line. During the 1995 eclipse, we preferred 5303 line over 7892 line because of low altitude of the sun during the eclipse and atmospheric water vapour line close to 7982 Å.

The data obtained from these experiments will help in understanding the physical processes involved in heating of the solar corona and making realistic modelling of coronal structures.

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