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CCD Observations of the Total Solar Eclipse of October 24, 1995

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Abstract

The observations of the solar corona during the Total Solar Eclipse of October 24, 1995 were attempted in white light and in narrow band filters with peak wavelengths centered at 5303Å (FeXIV) and at 6474Å [Fe X], the coronal emission lines. The site for the observations of the eclipse was the campus of Jawahar Navodaya Vidyalaya, Meja Khas, Allahabad (longitude : 82° 07' 32.5" E, latitude : 25° 07' 36.4" N, and altitude of about 134 meters above msl). The equipment used for the observations is briefly discussed. Nine coronal images in the red line were successfully obtained. The preliminary results of the observations are also presented.

Key Words : Total solar eclipse, Coronal emission lines, Electron density

Introduction

The electron density in the corona can be determined most suitably by measuring the K-component during an eclipse. More accurate values of electron density (Ne) at different heliographic latitudes and at different radial distances can be determined from the emission corona. The variation of the electron density has been derived from the intensity ratio of the green and the red coronal lines I_{5303} / I_{6374} (Waldmeier, 1954; Trellis, 1957). For any heliographic latitude the electron density is higher during the sunspot maxima than during the minima. This difference at the equator is small and is large at poles. In general a variation of a factor of 2 exists between maxima and minima. However, in coronal condensations the density may increase 10 fold.

The intensity of the emission lines depends not only on the electron density but also on the temperature. For the emission line 6374Å (FeX) an almost constant coronal intensity has been observed during the whole solar cycle, as the two effects nearly compensate each other. On the contrary, for the line 5303Å (Fe XIV), the two factors enhance the line intensity by 8 to 10 times during the maximum as compared to the minimum (Trellis, 1957; Waldmeier, 1960). From the intensities of the lines FeXIV and FeX the electron density as well as the kinetic

temperature can be determined simultaneously, since the intensity ratio I_{5303} / I_{6374} depends largely on the temperature.

The shape of the white corona is characterized by the Ludendorff index, a + b, which represents the ellipticity of the isophote at $2R_\odot$. This index was published by Waldmeier (1957). At solar maximum this index is least, and it reaches its largest during the solar minimum. The height of the green corona (5303Å) varies with solar cycle, increasing from 0.5 million kilometers during sunspot minimum to 3.4 million kilometers at the solar maximum. The variation occurs not only over the spot-zone but also at higher latitudes and even at the poles. The red corona (6374Å) shows a much smaller extension than the green. Its height amounts to about 0.6 million kilometers at the poles and increases towards lower latitudes, where it reaches a maximum of about 2 million kilometers. At latitudes larger than 35°, the height of the red corona shows almost no variation from sunspot minimum to maximum. The maximum height of the red corona occurs over the zones of spots and faculae, except during sunspot minimum when it is observed over the equator (Waldmeier, 1958). Observations of the solar corona in the above mentioned most prominent lines of Fe are regularly made in every eclipse, as the monochromatic corona shows structures like loops, rays, spikes etc., (Dollfus, 1971; Dunn 1971; Guetman *et al.*, 1994; Takeda *et al.*, 1994 and Pasachoff 1994).

Keeping all this in mind we have carried out the observations, with narrow band filters, during the total solar eclipse of October 24, 1995.

After inspecting many sites, falling on the central line of the belt of totality in the state of Uttar Pradesh we selected Jawahar Navodaya Vidyalaya (Longitude : 82° 07' 32.5" E, Latitude : 25° 07' 36.4" N and altitude of about 134 meters from msl) Meja Khas, Allahabad as the eclipse observation site.

The observational program consisted of the following experiments :

(1) Observations of solar corona in red line of Fe X (6374Å)

(2) Observations of corona in green line of Fe XIV (5303Å)

(3) Observations of corona in integrated white light

The Instrumentation

The observations of the total solar eclipse of October 24, 1995 from Meja Khas, Allahabad, India has been carried out with a 15 cm, f/15 Coude refractor. This telescope forms a 21 mm image of the sun's disk at the focal plane. The telescope has a field of view (FOV) of about 1.5 degrees (5.8 cm) free from optical aberrations. A manually rotating filter disk, equipped with red (6374Å) and the green (5303Å) narrow band Daystar coronal filters and also with a clear aperture to acquire white light images, was placed before the focal plane.

The specifications of the filters are as follows :

	Red filter	Green filter
Aperture	7.0 cm	7.0 cm
Central wavelength	6374Å	5303Å
Passband	2.0Å	3.0Å
Transmission	37.39%	25.66%
Operating temperature	45° C	45° C

At the back of the filter disk a 6-cm diameter electro-mechanical shutter was placed. This shutter, through an interface card fabricated at the Observatory, operated at the desired time on the command signal generated by the DSPOS software and Sun computer i.e., the software and computer controlled the exposure time at the desired time intervals.

On the focal plane of the telescope, a Photometrics PXL High Speed Modular CCD Camera system was mounted. This CCD system includes the following components :

Thermoelectrically cooled FTS Cold Probe camera head (ambient temperature –42° C) with TK 1024 CCD class I chip (pixel size 24 x 24 m); fibre optics bonding (2.45 : 1) to the CCD in the Camera head (aperture 6.2 x 6.2 cm^2). The system acts as 58.8 μm sized pixels with a pixel resolution of about 5 arc sec.

12 'bit' digitizer (4096 grey levels).

Read out Rate : 920 K pixels/sec or 990 K pixels/sec.

Software : DSPOS

Computer : Sun Sparc Station 20, 50 MHz with 7.3 GB hard disk.

The schematic diagram of the telescope and the instruments used during total solar eclipse is shown in Figure 1.

The Sun computer with 7.3 GB hard disk and software helped us to record solar data at high speed read out rate. The read out rate of the PXL camera controller may be set from 500 K pixels/sec to 4 Mega pixels/sec but for TK 1024 (Tektronics) CCD the read out is designed for about 1 Mega pixel/sec. The read out rate of the camera controller during eclipse observations was set at 990 K pixels/sec as at this read out rate the CCD system's dark current was minimum. A GPS (Global Position System) clock was used to adjust and correct universal time in the computer clock.

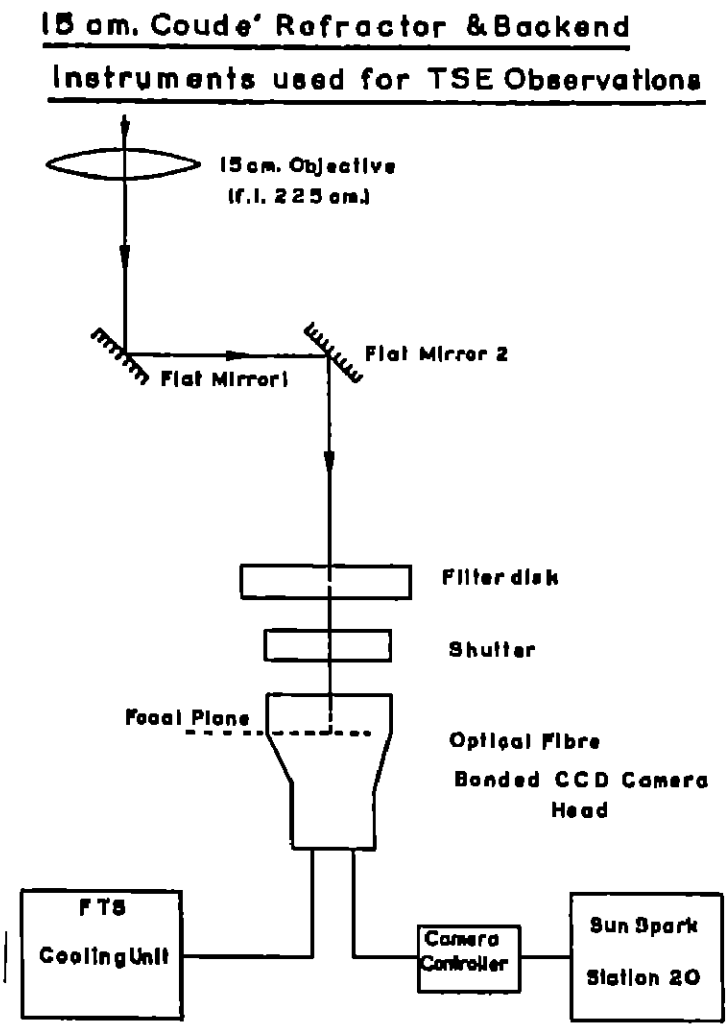


Figure 1 : The schematic diagram of the telescope and instruments used during eclipse observations.

Observational Data, Analysis and Results

The backend instrument used for narrow band imaging could be tested on the telescope only on October 20, 1995 because of various reasons. The progress of the solar eclipse i.e. CCD imaging of the partial eclipse phase was observed in the 6374Å red filter. During the totality 9 images in the red coronal lines could be recorded successfully with exposure time of 2 seconds and 1 second (Table 1). The corona could not be observed in the green line because of a mechanical problem in the filter disk. We recorded number of images for dark current and bias with various exposure times. The flatfield images with various exposure times were also recorded before sunset. These flat field images were later used in correcting the eclipse images. The weather on the eclipse day was cloudless and good for observations. At the Vidyalaya, which was almost on the central line, the duration of totality was observed to be 57.8 seconds.

Table 1. Eclipse images in red coronal filter

Frame No.	Exposure Time	Time UT
1	2 Seconds	03:09 : 31.934
2	2 "	03:09 : 44.282
3	2 "	03:09 : 49.184
4	2 "	03.09 : 54.066
5	2 "	03.09 : 58.911
6	2 "	03:10 : 04.049
7	2 "	03:10 : 16.004
8	1 Second	03:10 : 19.993
9	1 "	03:10 : 23.885

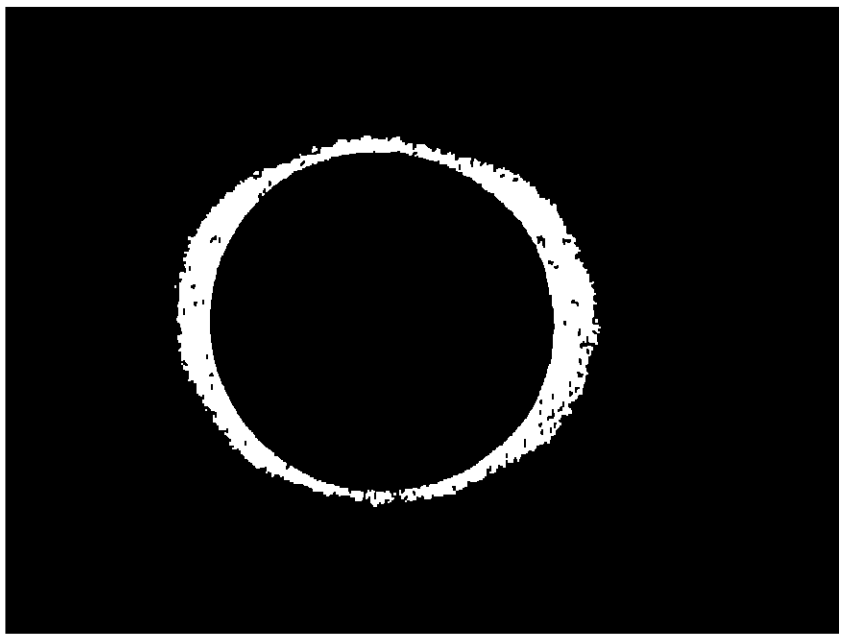
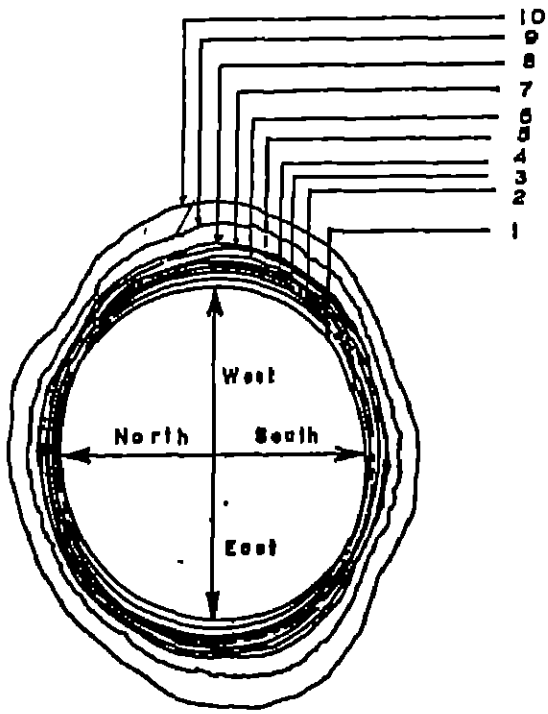


Figure 2 : Total solar eclipse image recorded in 6374Å filter (exposure time 1 sec) at time 03:10:19.993 UT.

The images were processed with the help of dark and flatfield images recorded on October 24, 1995. The image observed at 03:10:19.993 UT with exposure time 1 sec was analysed and processed image is shown in Figure 2. Further, we have also drawn iso-intensity contours as shown in Figure 3. The plotted contours comprise of normalised counts. The study of distribution of maximum intensity with latitudes for northern and southern hemispheres at west and east limbs in corona is also carried out. The plot of maximum intensity counts in corona

towards the west and east limbs versus heliographic latitudes is shown in Figure 4. In this Figure the maximum intensity of the corona is determined at latitudinal intervals of 5°. The distribution of maximum intensity in polar region as a function of heliographic latitude is also determined as this distribution will be related to various polar plumes existing in the polar region. The plot of polar intensity versus heliographic latitudes in northern and southern hemispheres is shown in Figure 5. Further, we have studied also the shape and ellipticity of the corona from the recorded eclipse images. The ellipticity or eccentricity (e) of the coronal images is found to be e = 0.544 at solar radii R_O 0.53 from the solar limb in the equatorial direction.



Contour No.	Normalised Intensity
1	1
2	0.63
3	0.53
4	0.59
5	0.49
6	0.46
7	0.41
8	0.39
9	0.27
10	0.23

Figure 3 : Isointensity contours drawn on coronal image shown in Figure 2.

Discussions

The shape and extension of the monochromatic corona have been observed by many groups (Waldmeier, 1961). According to Waldmeier (1963) the red corona (6374) shows a much smaller extension than the green (5303). Its height amounts to about 0.04 $R_\odot$ at the poles, thus increasing toward lower latitudes, where it reaches a maximum of about 0.133 $R_\odot$ during sunspot minimum. It increases upto 0.33 $R_\odot$ during sunspot maximum, over the sunspot zones. As mentioned earlier in our analysis based on Figure 2, the red corona shows an extension over the poles to about 0.32 $R_\odot$ and along the equator to about 0.53 $R_\odot$. These values are much higher than the earlier reported results. The eccentricity or ellipticity of the corona, as per our observations was e = 0.544 while Waldmeier (1957) reported a range of values of e from 0.07 to 0.17, based on white light observations.

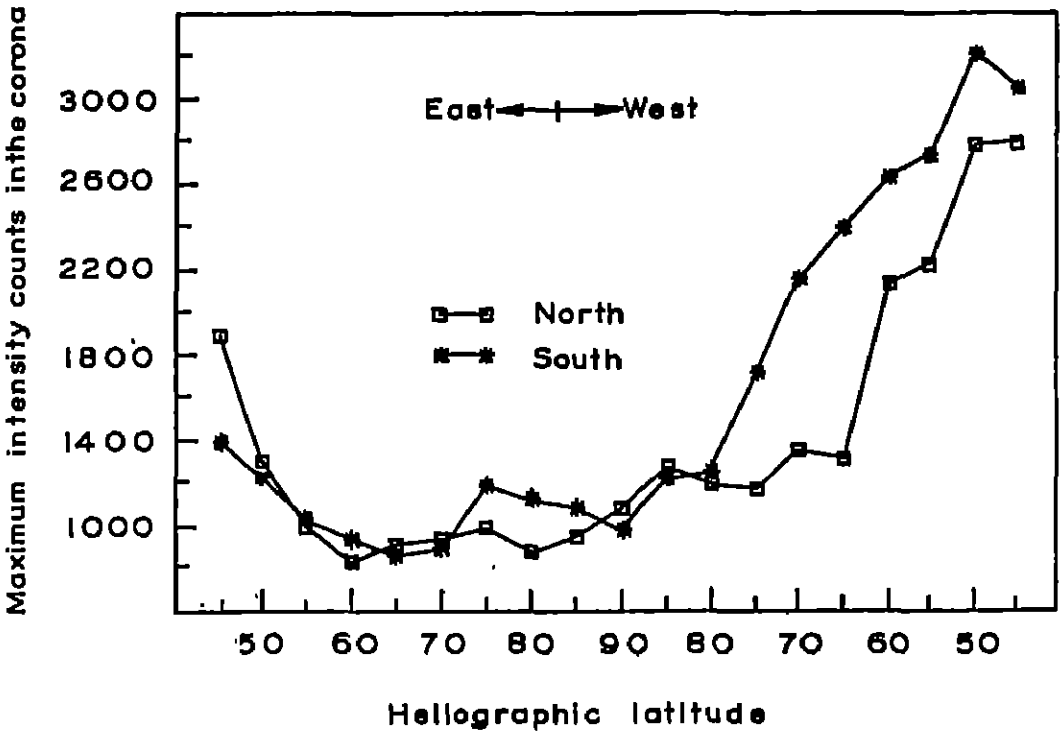


Figure 4 : The plot of maximum intensity counts in the East/West corona versus hellographic latitudes.

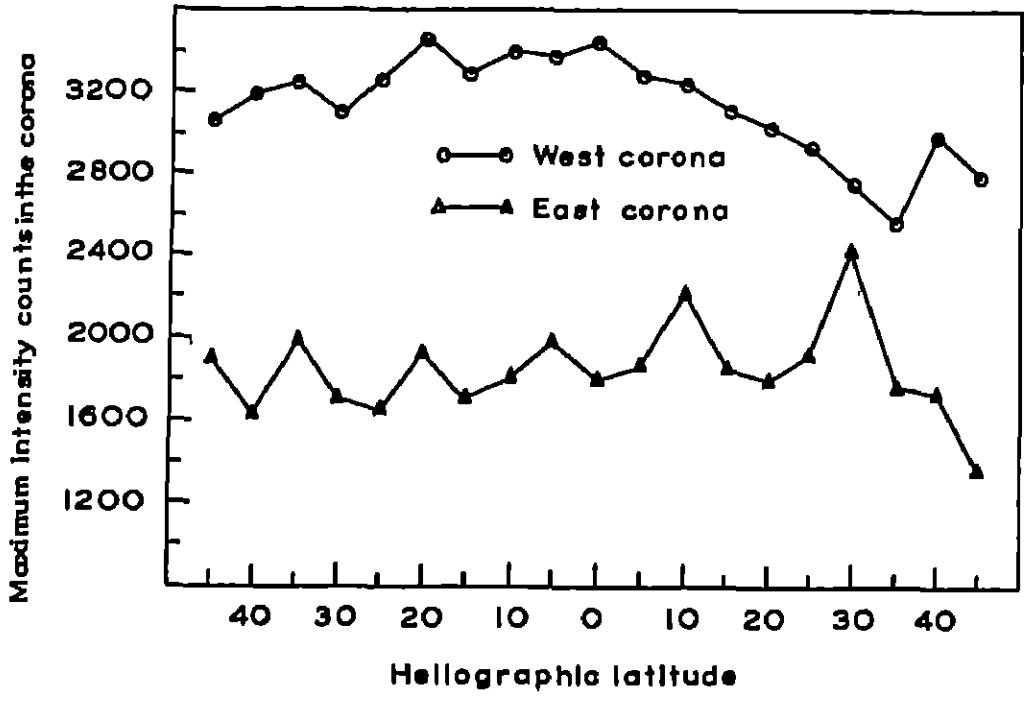


Figure 5 : The plot of maximum intensity counts in North/South pole regions versus latitudes.

From Figure 4, it is clear that west corona shows higher intensity counts as compared to east, although one expects similar intensity counts in west and east corona during solar minimum period. The higher intensity counts at west limb suggest the presence of sunspot groups and prominences close to this limb. During the image analysis we noted that some prominence like structure was present on the west limb. Figure 5 is a plot of maximum intensity counts in the direction of north and south poles. It is obvious from Figure 5 that the intensity counts increase towards lower latitudes. This figure also shows that west limb intensity counts are larger than those of the east limb. Thus one notices an asymmetry in the east and west corona. From Figure 3, it is clear that the corona attains a maximum intensity near the east and west limbs. The intensity counts decrease to 20% at about 0.5 R_O away from the limb. The above results are based on a single processed image. The processing of the remaining coronal images is in progress.

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References

Dollfus A. : 1971, In Physics of the Solar Corona (ed. C.J.Macris) D.Reidel, Dordrecht p.97.

Dunn R.B. : 1971 In Physics of the Solar Corona (ed. C.J.Macris) D.Reidel, Dordrecht p.114.

Guetman F.I. *et al.*, : 1994 IAU Colloquium 144, p.575.

Pasachoff J.M. : 1994 IAU Colloquium 144, p.523.

Takeda A., Kurokawa R., Kitai and Ishiura K. : 1994, In Proc. of Kofu Symposium (eds. S. Enome & T.Hirayama) Publ. NRO, Nat. Astr. Obs. Japan.

Trellis M. : 1957, Ann. Astrophys. Suppl No.5

Waldmeier M. : 1954, Z. Astrophys., 35, 95.

Waldmeier M. : 1957, Z. Astrophys., 42, 205.

Waldmeier M. : 1958, Z. Astrophys., 45, 155.

Waldmeier M. : 1960, Z. Astrophys., 50, 35.

Waldmeier M. : 1961, Z. Astrophys., 53, 81.

Waldmeier M. : 1963, The Solar Corona (Ed. J.W.Evans), Academic Press, New York, p.120.