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BROAD BAND PHOTOMETRY OF THE SOLAR CORONA OF 1983, JUNE 11

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Abstract

The solar corona was photographed at an effective wavelength of 6300A during the total eclipse of 1983, June 11 at Indonesia. From the isophotes of the corona, the intensity distributions along the equator, poles, streamers and gaps have been derived. The intensity along the equatorial and polar directions can be represented well by a 19° polynomial. The brightness distribution and the Ludendorff parameters of this corona are typical of the intermediate phase of the solar cycle.

Key words: Solar Corona, Solar Eclipse, Coronal Photometry

1. Introduction

After the eclipse of 1980, February 16 in India, the next eclipse with sufficiently long duration of totality was the one on 1983 June 11 at Indonesia. The camp was established at Tanjung Kodok (Long: 112° 21' 28"E; Lat: 6° 51' 54"S) on a spit of elevated rocky land protruding into the Java sea. This site in the neighbourhood of the village Paciran, on the north west of Surabaya was very close (~3km) to the central line of totality. The duration of totality at this site was 309 seconds and the second contact was predicted to occur at $04^h32^m44^s$ U.T. which corresponded to approximately 1135 hours local time. There were heavy rains for two days prior to the day of the eclipse which stopped in the afternoon of June 10. The day of the eclipse started off with skies with broken clouds which thinned out with the progress of the day and at the time of totality the coronal light shined through a thin veil of cirrus clouds. In this paper we present the results from the photographs of the corona obtained through a broad band filter during the time of totality.

2. The Observations

The experimental set up consisted of an f/15, 2.25 m focal length Zeiss lens objective into which sunlight was fed from a coelostat of 30 cm aperture. On the focal plane end individual plate holders carrying plates of size 3¼" x 4¼" of IIIa-F emulsion could be introduced. The shutter of the camera fixed in front of the objective was operated from the focal plane end by the observer who exposed the plates to the solar corona through the broad-band filter Wratten 25 which has a peak transmission around 6300A.

The duration of the exposures were 2, 3, 5, 8 and 10 seconds, the first one being exposed 10 seconds after the announcement of the second contact in the camp The photo metric standards were impressed on plates belonging to the same box of IIIa F emulsion in the laboratory with a Hilger step wedge of six steps and this established the relative photometric scale We also obtained, exposures of the disc on the next day of the eclipse with the Sun at the same hour angle as during the eclipse through a kodak neutral density filter of density 3 0 and a 10 mm diaphragm over the objective Each photograph of the corona was developed along with its step wedge calibration and absolute calibration plates The first two plates were developed in D 19 developer for 5 minutes while the remaining three plates were developed in promicrol for 12 minutes

3 Photometric Analysis

Of the five photographs, the 2 sec exposure plate is very well exposed and shows the coronal features well and we chose this for the analysis We scanned this plate with the microdensitometer at every 5° interval in position angle along the solar radius starting from the centre of the disc This gave 72 density profiles corresponding to 5° position angle We selected 33 density levels distributed over the density profile and then marked off the locations of these levels on each of these 72 profiles We then measured on the tracings the radial distances of these locations from the centre of the solar disc and expressed them in terms of the radius $R_\odot$ of the solar image These points were now plotted and the equal density contours were constructed which span a radial distance $r/R_\odot$ 1 06 to 1 8 These contours are too close to each other and we therefore picked out 12 of them well representative of the system discarding the rest to avoid overcrowding These isophotes are presented in Fig 1 The relative intensities corresponding to these contours are now obtained via the step wedge calibration curve One main source of error in coronal photometry at eclipses is the scattered light Our estimates of the brightness level of the sky contributions from traces made at $5R_\odot$ from the centre of the moon show that this is negligibly low and if at all existing it is definitely less than two percent The longer exposures begin to show the presence of sky fog on them

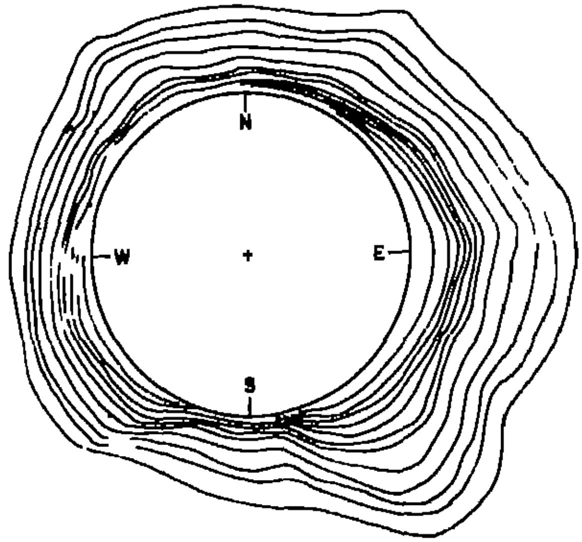

Fig 1 Isophotes of the solar corona The outer most isophote is 1 and the numbers increase towards the solar limb (see Table 1)

4 Equatorial and Polar Intensity Gradients

We found our solar disc exposures meant for use as the absolute calibration were too dark We have therefore used the calibration of Koutchmy and Nitschelm (1984) who observed the same eclipse from a site near Cepu in Central Java. These authors have given the brightness of the isophotes of the corona in units of the mean solar disc radiance ($B_{\odot}$) for the red region. We constructed the curve of brightness along the equator (mean of east and west) in units of $B_{\bar{\odot}}$ versus radial distance $r/R_{\odot}$ using their data. Our intensities match well with their data for the region around $r/R_{\odot} = 1.3$. Adopting the value of $40 \times 10^{-8} B_{\bar{\odot}}$ for the coronal brightness at $r = 1.3\ R_{\odot}$ in the equatorial direction from their curve, we derived the absolute brightness of our isophote system in terms of $B_{\bar{\odot}}$. These are presented in Table I. The brightness of the corona along the N,S,E,W are represented in Fig.2 and those along

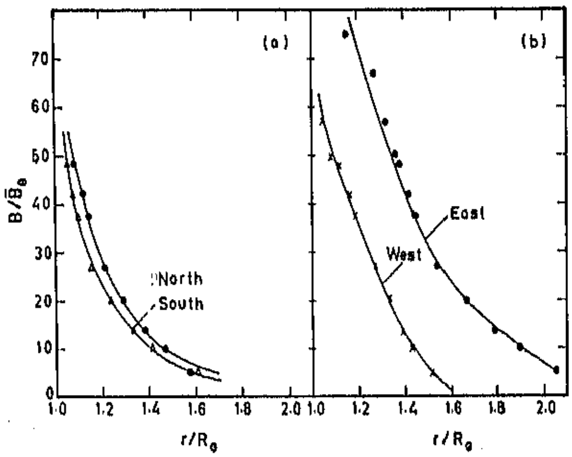

Fig. 2. Brightness of the corona (K+F) expressed in units of 10^{-8} of the mean brightness of the solar disc ($B_{\bar{\odot}}$). (a) along the North (filled circles) and South (open triangles) directions; (b) along the East (filled circles) and West (crosses) directions. The continuous curves represent the 19 degree polynomial fit to the observed points.

the equatorial and polar diameters in Fig.3. The coronal brightness along the same directions derived by Saito & Hasta (1964) for the eclipse of 1962, February 5 are also shown in Fig.3 for comparison. This eclipse observed at New Guinea occurred at a similar

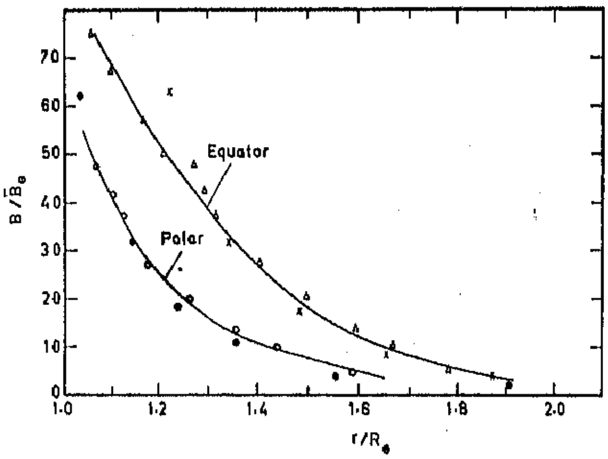

Fig. 3. Brightness of the corona (K+F) along the equatorial (open triangles) and polar (open circles) diameters. The curves represent the 19 degree polynomial fit to the observed points. Saito and Hata's results (crosses and filled circles) for the corona of February 5, 1965 eclipse are also plotted for comparison.

phase of the solar cycle as the present one. It is interesting to note the close agreement between our values and those of Saito and Hata as both these eclipses occurred at similar epochs of the solar cycle. For an earlier eclipse (Sivaraman et al. 1984) we have shown that a 19° polynomial represents the brightness distribution along the equatorial and polar directions better than the three term representation of Baumbach (1937). Following this, we have computed the polynomial fit both for the equatorial and polar directions in the present case utilizing all the 33 observed values of intensity. We find that only the following coefficients are significant to give a best fit.

Equatorial:

$$\frac{B_{eq}}{B_0} = -\frac{0.398\times10^5}{r^3} + \frac{0.484\times10^6}{r^5} - \frac{0.206\times10^7}{r^7} + \frac{0.189\times10^7}{r^9} + \frac{0.133\times10^8}{r^{11}} - \frac{0.528\times10^8}{r^{13}}$$

$$+\frac{0.863\times10^8}{r^{15}} - \frac{0.690\times10^8}{r^{17}} + \frac{0.222\times10^8}{r^{19}}$$

Polar:

$$\frac{B_{polar}}{B_0} = -\frac{0.113\times10^6}{r^3} + \frac{0.144\times10^7}{r^5} - \frac{0.794\times10^7}{r^7}$$

$$+\frac{0.247\times10^8}{r^9} - \frac{0.473\times10^8}{r^{11}} + \frac{0.574\times10^8}{r^{13}}$$

$$-\frac{0.432\times10^8}{r^{15}} + \frac{0.184\times10^8}{r^{17}} - \frac{0.340\times10^7}{r^{19}}$$

These polynomial curves are also shown in Fig.3.

5. Intensity Gradients in the Streamers and the Gaps

The corona of this eclipse has many streamers which can be identified individually and traced upto 2.0 $R_\odot$ in our photographs. Also, there are regions in between the streamers where the brightness is strikingly low. We have chosen six directions representative of thick bright, thin bright, and weak streamers and gaps in between the streamers and have evaluated the brightness gradients in the radial directions along these features. These are presented in Fig.4. We have marked off these features in a hand drawn schematic sketch for easy identification (Fig. 5).

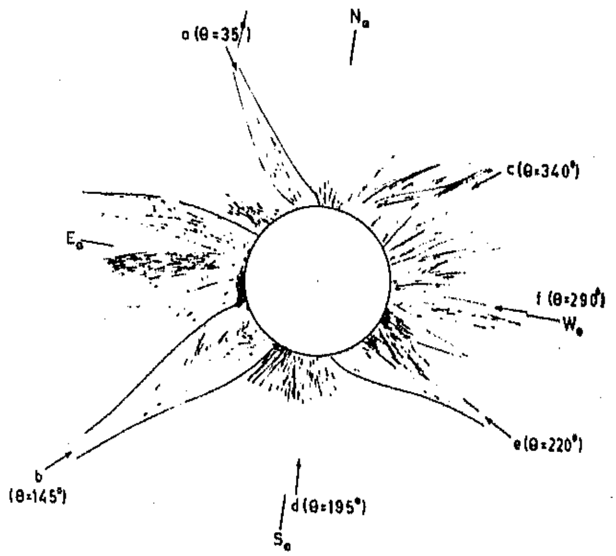

Fig. 5. Schematic hand sketch of corona showing the locations of prominent streamers and gaps in between them referred to in Figure 4. The position angles of the features a, b, c, d, e and f are indicated in brackets. The arrow indicates the exact direction along which the brightnesses have been measured for each of these features.

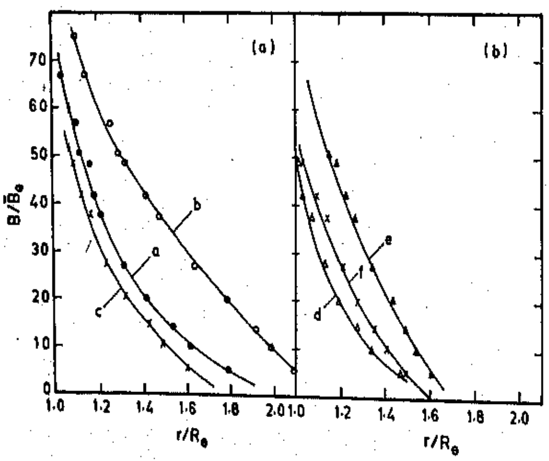

Fig. 4. (a) & (b) Radial intensity distribution along streamers and the gaps. The location of the streamers a, b, e, f, of the gap c and the region d close to the south pole can be seen in Fig.5.

The big streamer at position angle 145° shows an intensity much higher than the equatorial intensity, whereas the big streamer at position angle 220° has an intensity marginally lower than the equatorial value. The weak streamers at position angles 35° and 290° have brightness intermediate between the equatorial and polar values. Although the brightness of the corona along the gap at position angle 340° is quite low, it is still higher than the polar values, while the dark region at position angle 195° close to the south pole is much weaker than the mean polar brightness. This region appears quite dark in the broad band photograph obtained by L.Lacey and M. Mc Grath of the High Altitude Observatory with a radially graded filter from a site adjacent to our camp. This region most probably is a coronal hole and can be confirmed from electron density measurements by any other team.

6. The Ellipticity of the Corona

The ellipticity or the flattening of the isophotes of a corona is represented by the Ludendorff parameter (ε) defined by

$$\varepsilon = \frac{d_{equator}}{d_{pole}} - 1$$

where $d_{equator}$ is the mean value of the diameters of an isophote along the equator and in two directions making an angle of 22.5° with it. Similarly d_{pole} is the mean diameter along the polar direction and 22.5° on either side. Table II gives the values of this parameter (ε) for the different isophotes. The Ludendorff parameter shows exactly the same kind of variation as for the eclipse of 1962 February 5, (Saito and Hata; 1964) for the ranges of $r/R_\odot$ values for which we have observations.

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Table 1. Intensities in the equatorial direction (mean of East and West) of the corona of June 11, 1983.

Isophote No	$r/R_\odot$ *	$B/\bar{B}_\odot$ **
1	1.777	5.60
2	1.665	10.30
3	1.593	13.97
4	1.497	20.77
5	1.405	27.34
6	1.317	37.73
7	1.291	42.40
8	1.273	48.83
9	1.213	50.40
10	1.173	57.10
11	-	67.10
12	-	75.34

* Equatorial radius in units of the solar radius $R_\odot$

** Intensities are in units of 10^{-8} times the mean brightness of the solar disc.

Table 2: Ludendorff Parameter ε for the isophotes

Isophote No	$\frac{r_{eq}}{R_\odot}$ *	ε
1	1 7620	0 0949
2	1 6140	0 1143
3	1 5360	0 1146
4	1 4560	0 1215
5	1 3730	0 1224
6	1 3250	0 1120
7	1 2670	0 1070
8	1 2150	0 0980

* Equatorial radius in units of the solar radius $R_\odot$

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