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The Solar Corona of July 20, 1963

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Abstract

The total solar eclipse of July 20, 1963 was observed at the AAVSO site near Wilton, Maine, U.S.A. where totality lasted for 58 seconds. Pictures of the corona were obtained with a camera of focal length 57 cm. on Kodak Plus X emulsion through a Wratton 15G filter. Photometric calibrations were impressed with a Hilger step wedge. Coronal isophotes have been derived by the Sabattier procedure and intensities assigned to the equidensity contours by conventional microphotometry. Tables given contain the brightness distribution for different position angles to r=4.2 solar radii. The coronal intensity gradients are presented over the range r=1.4 to 2.8. The Ludendorff index of the corona's photometric form is 0.24.

Introduction

At the total solar eclipse of July 20, 1963, the white light corona was photographed by one of us with the aim of coronal isophotometry to about four solar radii. The camera had a focal length of about 57 cm. providing a scale of 6 minutes of arc per mm. The corona was photographed on Kodak Plus-X 35 mm film through a Wratton 15G filter. The effective wavelength of our coronal pictures was, therefore, 5300Å. The exposure times were 0.5 seconds, 1.0 second and 2.0 seconds. The 2 second exposure was near mid-totality and forms the material for the present study. The equipment was located at the AAVSO site located 50 miles north-east of Wilton, Maine, U.S.A. and 12 miles from the central line. The duration of totality was 58 seconds.

The Isophotes of the Corona

We have carried out our programme of isophotometry by two methods. The first was the tedious procedure of microphotometer scans in an arbitrary rectangular co-ordinate system. The scans were made at closely spaced intervals and intensities read off subsequently from the calibration curve. Contours of equal intensity were then drawn through the appropriate points. To ensure adequate repeatability, we have also scanned the corona radially in 10 degree intervals. The agreement in contour representation between the two types of microphotometer scans was quite satisfactory. The success of this technique rests largely on the close spacing of the scans and subsequent intensity evaluation. The advantage of simplicity and accuracy must nevertheless be considered along with the tedious and exceedingly time consuming aspect of the technique.

Our second approach was to determine the isophotes by the technique of equidensitometry employing the Sabattier effect. This is an exceedingly simple and accurate procedure that has probably not received the attention in astronomy that it certainly merits. Schroter (1958) has shown how line profile distortions can be easily evaluated by the use of this technique. Richter and his collaborators have demonstrated its efficiency in the study of extended nebulosities and galaxies. At this observatory Bappu and Sivaraman (1968) have shown its efficiency in the evaluation of the location of the centre of gravity of a diffuse feature on a spectrogram. We feel convinced of its great utility because equi-density contours can be determined most conveniently and speedily. It only remains then to evaluate the intensity levels for each density contour, a process which can be done by the microphotometer.

Hogner and Richter (1966) have described in detail the procedure to be used for determining equidensity contours. We have used exclusively ORWO FU 5 emulsion with its very high gamma and find this most satisfactory. Figure 1 shows these contours on the single coronal frame of two seconds exposure.

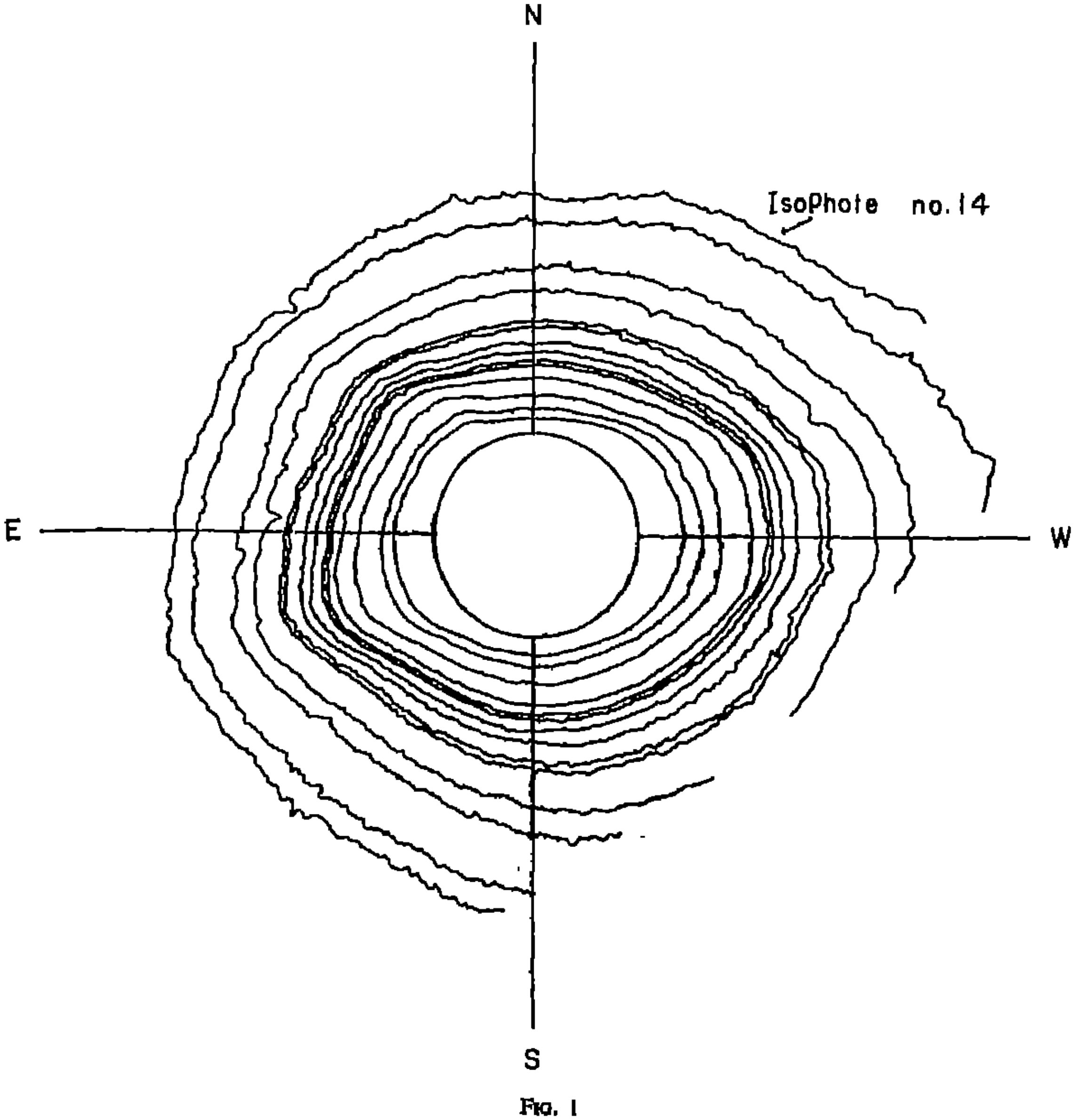

FIG. 1

The intensity marks utilized for deriving the calibration curves for conversion from density to intensity were impressed on the eclipse film a few hours after the event with the aid of a well calibrated Hilger step-wedge and a diffuse source of light of uniform intensity over the step-wedge. The intensity levels of these contours have been assigned from microphotometer scans along position angles 0°, 90°, 180° and 270°. The mean of these four values is chosen to indicate in Table 1, the value of intensity along each contour. We give here

TABLE 1

Isophote No.	Mean Log I
1	2.730
2	2.700
3	2.499
4	2.138
5	1.998
6	1.964
7	1.906
8	1.863
9	1.756
10	1.731
11	1.600
12	1.565
13	..
14	..

only those intensity levels for which the photometry can be considered to be secure. Such a consideration assigns a low weight to the intensity value of contour 1 and eliminates the use in subsequent discussion of contours 13 and 14, because of the inaccuracies in interpolation from the toe of the calibration curve. We, however, retain these equidensity contours in Figure 1 to show the general trend exhibited in the shape of the solar corona at these distances from the centre of the sun. It also shows up the efficacy of the Sabattier technique of equidensitometry in deriving a contour of equal density that has a level just detectable above that of the clear plate. Table 2 lists the values of r for the isophotes at different position angles.

TABLE 2

Isophote No.	Position Angle 0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°
1	1.14	1.15	1.18	1.25	1.28	1.31	1.32	1.32	1.35	1.37	1.38	1.39	1.38	1.33	1.24	1.19	1.17	1.15
2	1.22	1.23	1.27	1.36	1.39	1.39	1.41	1.41	1.45	1.48	1.51	1.53	1.51	1.44	1.33	1.31	1.26	1.26
3	1.35	1.37	1.41	1.52	1.61	1.62	1.60	1.62	1.67	1.71	1.77	1.81	1.74	1.61	1.51	1.45	1.43	1.45
4	1.52	1.54	1.57	1.68	1.78	1.81	1.74	1.78	1.82	1.87	1.96	2.00	1.91	1.75	1.68	1.63	1.61	1.63
5	1.65	1.65	1.67	1.75	1.88	1.91	1.88	1.87	1.93	1.97	2.04	2.10	2.00	1.84	1.75	1.71	1.71	1.74
6	1.70	1.69	1.71	1.78	1.91	1.95	1.92	1.91	1.97	2.01	2.07	2.13	2.04	1.88	1.78	1.75	1.74	1.78
7	1.77	1.78	1.79	1.85	1.98	2.04	1.98	1.98	2.07	2.11	2.18	2.26	2.13	1.96	1.89	1.85	1.86	1.87
8	1.84	1.88	1.87	1.94	2.05	2.11	2.11	2.10	2.16	2.21	2.27	2.36	2.23	2.06	1.98	1.95	1.97	1.98
9	2.03	2.01	2.01	2.08	2.18	2.24	2.12	2.20	2.33	2.37	2.43	2.48	2.33	2.17	2.14	2.12	2.13	2.17
10	2.08	2.07	2.07	2.14	2.22	2.30	2.26	2.27	2.36	2.41	2.49	2.55	2.39	2.24	2.20	2.17	2.18	2.23
11	2.37	2.36	2.38	2.41	2.50	2.57	2.54	2.50	2.56	2.63	2.74	2.83	2.69	2.55	2.49	2.50	2.53	2.55
12	2.57	2.57	2.60	2.62	2.67	2.76	2.76	2.72	2.73	2.87	2.93	3.03	2.90	2.74	2.71	2.70	2.71	2.78
13	3.06	3.03	3.09	3.09	3.10	3.15	3.17	3.11	3.19	3.26	3.33	3.39	3.32	3.24	3.21	3.29	3.23	3.39
14	3.31	3.28	3.28	3.32	3.30	3.32	3.38	3.33	3.42	3.46	3.59	3.65	3.54	3.49	3.49	3.43	3.52	3.65

TABLE 2 — *Contd.*

Iso-phote No.	Position Angle																	
	180°	190°	200°	210°	220°	230°	240°	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°
1	1.16	1.17	1.17	1.19	1.25	1.29	1.34	1.36	1.39	1.42	1.41	1.39	1.39	1.35	1.32	1.25	1.19	1.15
2	1.28	1.28	1.28	1.30	1.35	1.42	1.48	1.55	1.58	1.59	1.58	1.55	1.55	1.51	1.42	1.35	1.28	1.25
3	1.44	1.46	1.45	1.48	1.52	1.56	1.65	1.74	1.78	1.75	1.75	1.74	1.72	1.61	1.52	1.43	1.42	1.36
4	1.65	1.67	1.68	1.71	1.75	1.80	1.88	1.98	2.05	2.05	2.03	2.01	1.96	1.81	1.68	1.60	1.56	1.53
5	1.75	1.75	1.78	1.80	1.85	1.90	1.96	2.06	2.20	2.22	2.18	2.18	2.07	1.92	1.81	1.74	1.69	1.66
6	1.78	1.81	1.82	1.85	1.89	1.94	2.01	2.11	2.24	2.28	2.24	2.22	2.11	1.98	1.87	1.79	1.74	1.71
7	1.89	1.91	1.94	1.97	2.02	2.04	2.12	2.17	2.31	2.37	2.37	2.33	2.18	2.03	1.94	1.87	1.81	1.79
8	1.98	2.07	2.09	2.13	2.15	2.21	2.27	2.37	2.47	2.50	2.50	2.44	2.29	2.15	2.04	1.96	1.94	1.90
9	2.19	2.24	2.27	2.34	2.40	2.46	2.50	2.58	2.70	2.75	2.74	2.63	2.47	2.34	2.24	2.16	2.10	2.04
10	2.26	2.31	2.36	2.43	2.48	2.53	2.59	2.67	2.76	2.83	2.86	2.70	2.56	2.40	2.31	2.20	2.15	2.10
11	2.64	2.73	2.76	2.80	..	..	3.02	3.06	3.17	3.29	3.26	3.08	2.83	2.70	2.59	2.52	2.46	2.40
12	2.92	2.97	..	..	..	..	..	..	..	3.59	3.59	3.42	3.14	3.02	2.90	2.76	2.70	2.62
13	3.46	..	..	..	..	..	..	..	..	4.24	4.46	4.18	3.78	3.60	3.43	3.33	3.22	3.09
14	3.69	..	..	..	..	..	..	..	..	..	..	..	4.29	3.89	3.72	3.61	3.54	3.33

The Radial Intensity Gradients

Several studies of coronal intensities have shown that over a restricted range of distances from the solar limb the distribution law of intensity can be represented by:

$$I = \frac{c}{d^n}$$

whence

$$n = -\frac{\Delta \log I}{\Delta \log d}$$

where d is the distance from the solar limb. We have determined values of n over the range in intensity covered by isophotes 3 to 10 for every ten degree interval of position angle. These are given in Table 3.

TABLE 3

Dependance of radial intensity gradients on position angle

Position Angle	n	Position Angle	n
0	1.50	180	1.63
10	1.60	190	1.60
20	1.89	200	1.63
30	2.25	210	1.55
40	2.62	220	1.61
50	2.35	230	1.66
60	2.05	240	1.86
70	2.22	250	2.05
80	2.13	260	2.10
90	2.40	270	1.97
100	2.51	280	1.92
110	2.72	290	2.08
120	2.79	300	2.26
130	2.42	310	2.08
140	1.82	320	1.77
150	1.74	330	1.64
160	1.60	340	1.61
170	1.65	350	1.62

The isophotes cover the range in r from 1.4 to 2.8 solar radii. Figure 2 contains a plot of log (d + 1) for the eight isophotes for different position angles. The

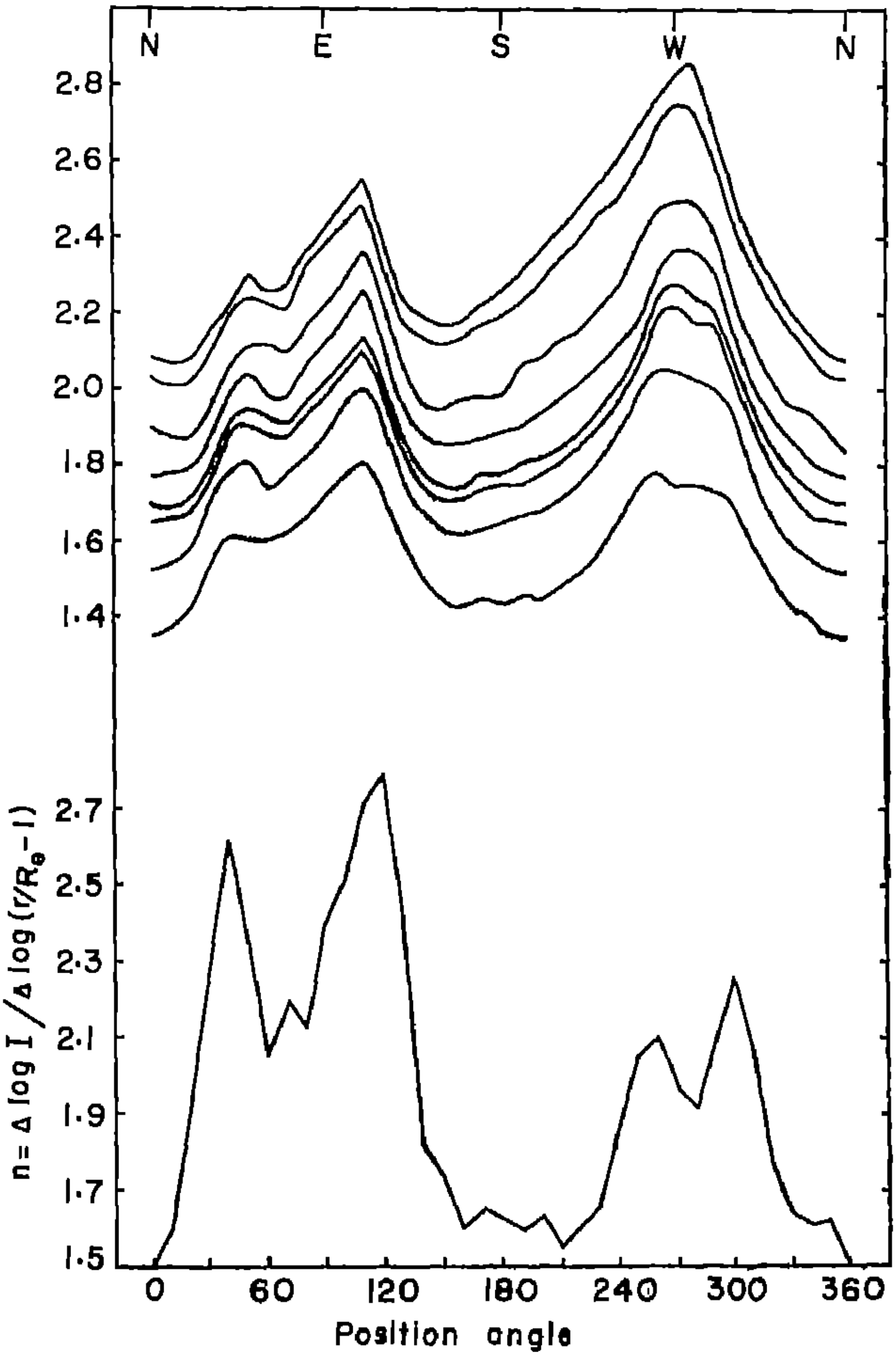

FIG. 2

lower portion of the diagram represents the variation in index n calculated by least squares from the eight intensity contours.

Ellipticity of the Corona

A measure of this parameter following Ludendorff (1928, 1934) needs measures of polar and equatorial diameters together with diameters inclined at 22.5° to each one of them. Hence ε, the ellipticity is

$$\varepsilon = \frac{3R}{D} - 1$$

where R is the mean of the equatorial diameter and those at position angles 67.5° and 112.5°, and D represents the sum of the three diameters at position angles 337.5°, 360° and 22.5°. Table 4 gives the Ludendorff ellipticity parameter for

TABLE 4

Ludendorff ellipticity parameter ε for the different isophotes

Isophote No.	R	ε	Isophote No.	R	ε
1	1.379	0.170	8	2.318	0.189
2	1.516	0.186	9	2 493	0.169
3	1.731	0.211	10	2.554	0.164
4	1.942	0.206	11	2.855	0.129
5	2.058	0.199	12	3.133	..
6	2.104	0.195	13	..	..
7	2.199	0.187	14	..	..

the different isophotes. Also shown in Fig.3 is the ellipticity ε′ as defined by van de Hulst (1953) to be

$$\varepsilon' = \frac{r_{equator}}{r_{pole}} - 1$$

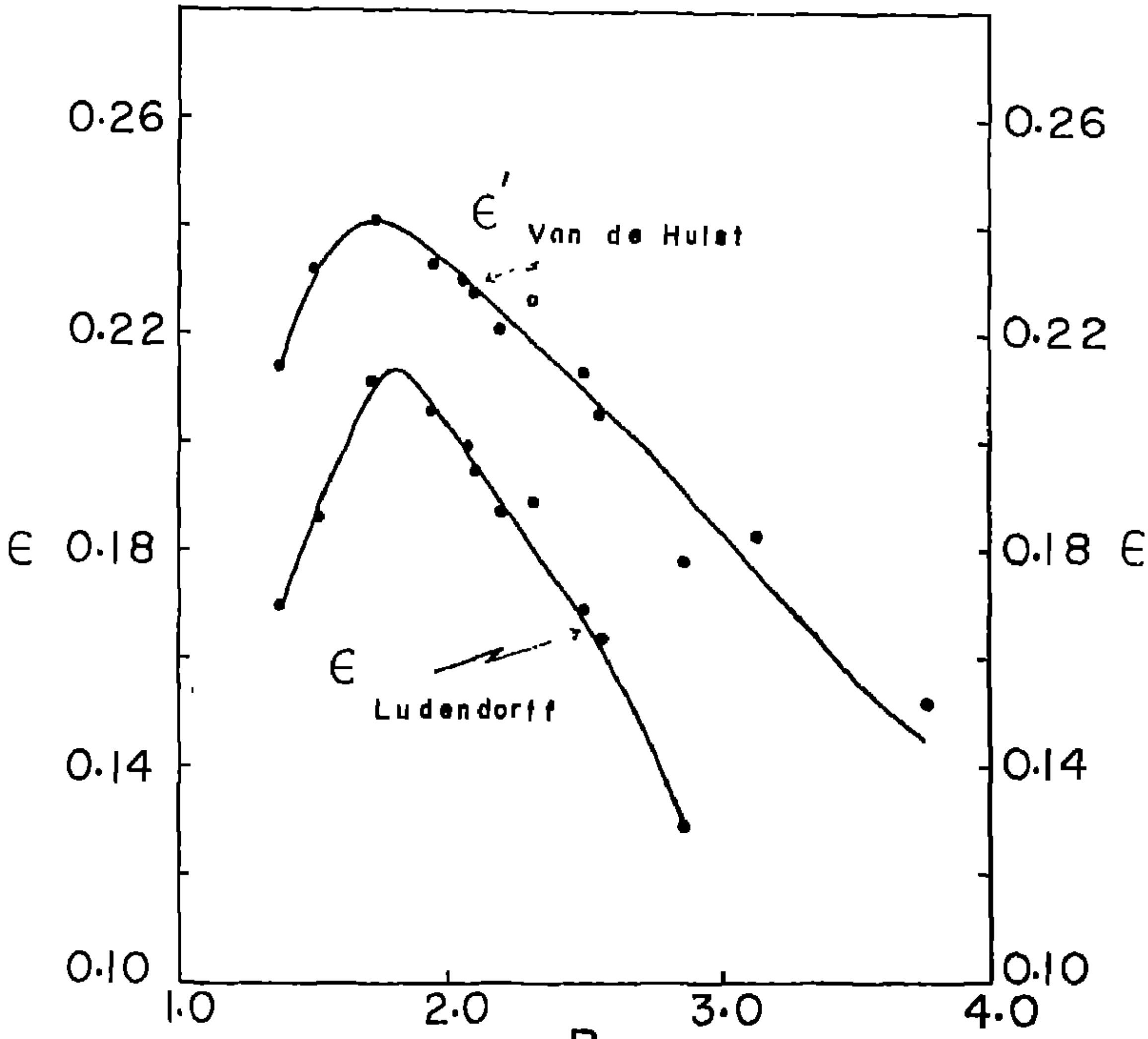

FIG. 3

In agreement with ellipticity values ε as derived for previous eclipses near the minimum phase of the solar cycle we find that a maximum value of the Ludendorff parameter is at 1.8 solar radii. The solar eclipses of 1936, 1954 and 1955 all have maximum ellipticities near this value.

Acknowledgement

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KODAIKANAL OBSERVATORY
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