Total solar eclipse in Brazil (November 3, 1994)

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Abstract. The expedition to observe the total solar eclipse in Brazil on November 3, 1994 was arranged by the Slovak Central Observatory, Hurbanovo (Slovak Republic). The circumstances of the eclipse, planned experiments, instruments, scientific goals, observations and some preliminary results are described and discussed.

Key words: solar eclipse – solar corona – polarization – neutral matter – fast structural changes

1. Circumstances and geometry of the eclipse

We observed the total solar eclipse on November 3, 1994 near the town of Criciuma in Brazil ($\lambda = 49°\ 22'\ 02''$ W; $\phi = -28°\ 43'\ 11''$). The locality was situated directly on the central line of the eclipse path. The duration of the eclipse totality was 4 min and 6 sec in this region. The time of the 2nd contact was $12^h58^m43^s$ UT at position angle 89.6°. In the middle of totality the solar corona was covered by the Moon up to a height of 53". The geometrical scheme of the eclipse at the moment of the second contact is shown in Figure 1.

2. Experiments, instruments and scientific goals

The expedition gained observational data for three experiments designed to investigate the coronal density distribution, to search neutral matter in the corona, and to study the short-term dynamics of the solar corona.

2.1. Photometry and polarization of the white-light (K + F) solar corona

A telescope, 130 mm in diameter and 1950 mm in focal length, was used to realize this experiment. The solar corona in continuum was photographed on

ILFORD 400 sixty millimetre roll-film witha Pentacon-Six camera using different exposures (their list is given in Subsection 3.1). To record coronal polarization, additional sets of white-light corona images were taken through a polarizing filter fitted near the focus of the telescope. The pictures were taken in three positions of the polarizer, the angle between the individual positions of the polarization axis being 60°. To obtain the calibration curve, the sun was photographed prior to the eclipse through a neutral density filter using various diaphragmas differing by a factor of 2 in area. The diaphragmas were placed in front of the telescope lens. This experiment should be considered more or less

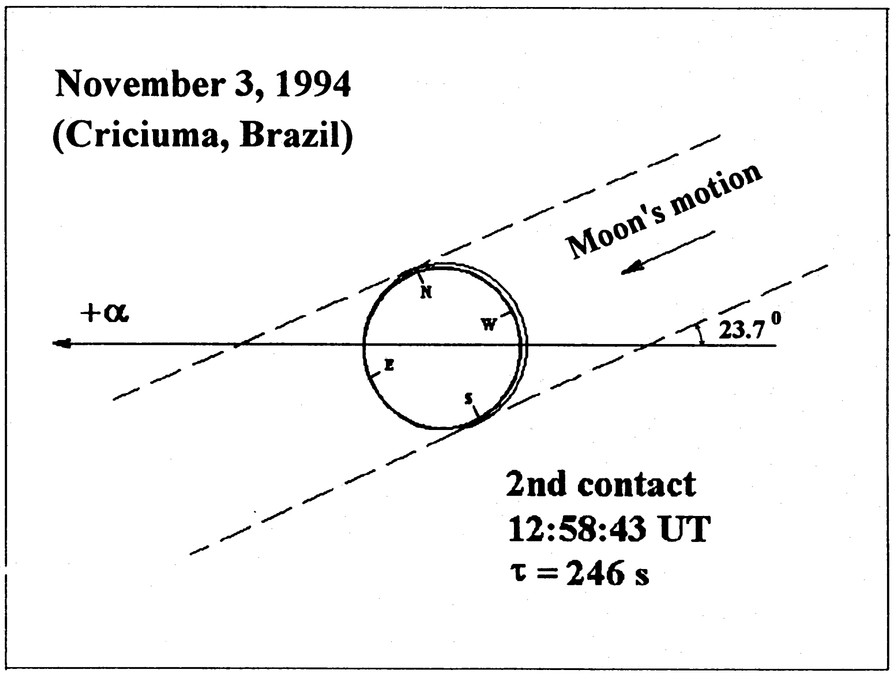

Figure 1. Geometrical scheme of the eclipse at the moment of the second contact (τ is duration of the eclipse in Criciuma, Brazil).

classical. It was designed to determine some basic parameters of the solar corona during this particular eclipse. Among them the identification and description of the individual coronal structures, classification of the overall shape of the corona, coronal photometry, and the degree and direction of the white-light (K + F) corona polarization. Any contribution to the statistics of the above-mentioned parameters, measured during previous eclipses, is still very valuable, namely from the point of view of their behaviour throughout the solar cycles. In addition, we hope to compare the structures on our white-light images with those obtained at other points of the path of totality (see, for example, the paper on the observations in Chile, in this Volume) and to identify for possible changes of the coronal structures, or possible coronal transients. The described experiment was performed by T. P.

2.2. Intensity distribution in the spectrum of the K-corona (colour of the corona)

A prism spectrograph produced an image of the spectral region from 430 nm to 910 nm in the CCD ST-4 camera with dimensions 2.5x2.5 mm (192x165 pixels). The width of the entrance slit was 0.015 millimetre and the spectral resolution at 600 nm was about 1000, i.e. far better than the CCD camera can resolve. Scheduled exposures were from 0.1 sec to about 3.5 sec to be sure that the correct exposure of the spectrum was applied to different parts of the solar corona. The spectrograph was designed by M. R. and manufactured in the S.C.O. Hurbanovo by M. Mačanský and M. Vanya. Their perfect work is very much appreciated by the authors of this paper.

The image of the corona was formed on the entrance slit of the spectrograph by a "Zeiss Astrocamera" (D = 60 mm and f = 270 mm). The spectrum was recorded by using the digatization technique together with an on-line PC-486. A comparative spectrum of the photosphere was obtained with the same instrument immediately before the eclipse. The light intensity was reduced to the desired level by reducing the entrance aperture, thus avoiding the use of a neutral density filter.

The scientific goal of this experiment follows from the hypothesis assuming the presence of neutral matter in the solar corona medium. Scattering of photospheric radiation by neutral atoms (Rayleigh's scattering) would cause the solar corona to be more blue in comparison with the solar photosphere. Any positive result of the present experiment could lead to drastic changes of the magnetohydrodynamical theories connected with substantial reduction of the coronal plasma conductivity in comparison with an ideal plasma. Previous attempts to identify this effect led to controversial conclusions, owing to the limited accuracy of the photographic method of measurement. This experiment was performed by B. L.

2.3. Detection of fast changes in the inner corona structures

The instrument for this experiment was a telescope with D = 80 mm and f = 1200 mm. The photographic record of the image was obtained by using a mechanical "Krasnogorsk" 16 mm movie camera, recording 32 images per second. Negative black-and-white ORWO NP-7 400 ASA cine-film was used.

The aim of this experiment is based on our preliminary measurements of the so-called oscillations of the green-corona emission line intensity, observed outside the solar eclipse by the coronagraph. These observations indicate that detectable changes of the green-line intensity already exist at a split-second level. The camera used worked for about 30 seconds on one winding up and recorded about 900 images. It was wound up three times during the totality. It is hoped that the analysis of this observational material will help us to identify and describe the possible fast changes of the coronal structures in more detail. M. L. was responsible for the observation.

The experiment was successful. We have obtained about three thousand pictures of the chosen coronal region at the east limb. The images are being successively digitized and have not yet been analysed.

3. Preliminary results

Unfortunately, the time between the return of our solar eclipse expedition and the deadline of submitting manuscript of this paper according to the CAOSP Editorial Board schedule was very short. That is why we are only able to list the data obtained, and to present some very preliminary partial results.

3.1. Large-scale structure of the observed corona and a qualitative estimation of its degree of polarization

Altogether nine images of the polarized (K + F) corona and four images of the unpolarized white-light corona were taken during totality. The exposures and positions of the polarizer are listed in Table 1. The first column gives the sequence number of exposure, the moment of the exposurę in U.T. is given in the second column, the third column shows the exposure time, the interval after the 2nd contact of the eclipse is tabulated in the fourth column and, finally, the position of the polarizer axis is given in the last column of the table.

Table 1. The list of the white-light corona polarized (P) and unpolarized (WL) images.

Sequence number	Exposure at U.T.	Duration of exposure	Time interval after the 2nd contact	Position of the polarizer axis
1	$12^h\ 58^m\ 55^s$	1/15sec	12sec	P1
2	12 59 07	1/4	24	P1
3	12 59 16	1	33	P1
4	12 59 25	1	42	P2
5	12 59 39	1/4	56	P2
6	12 59 50	1/15	67	P2
7	13 00 01	1/15	78	P3
8	13 00 25	1/4	102	P3
9	13 00 36	1	113	P3
10	13 01 39	1/15	176	WL
11	13 01 48	1/4	185	WL
12	13 01 59	1	196	WL
13	13 02 10	1/30	207	WL

The global structure of the solar corona on November 3, 1994 at about 13.00 U.T. is shown in Figure 2. This sketch was obtained by processing the white-light images by a well-known technique, i.e. by combining the negatives and positives of the same pictures and rotating them through a very small angle. This produces much more contrast in the structures than it is seen on the single original images. It is evident that the global shape of the corona is almost of the

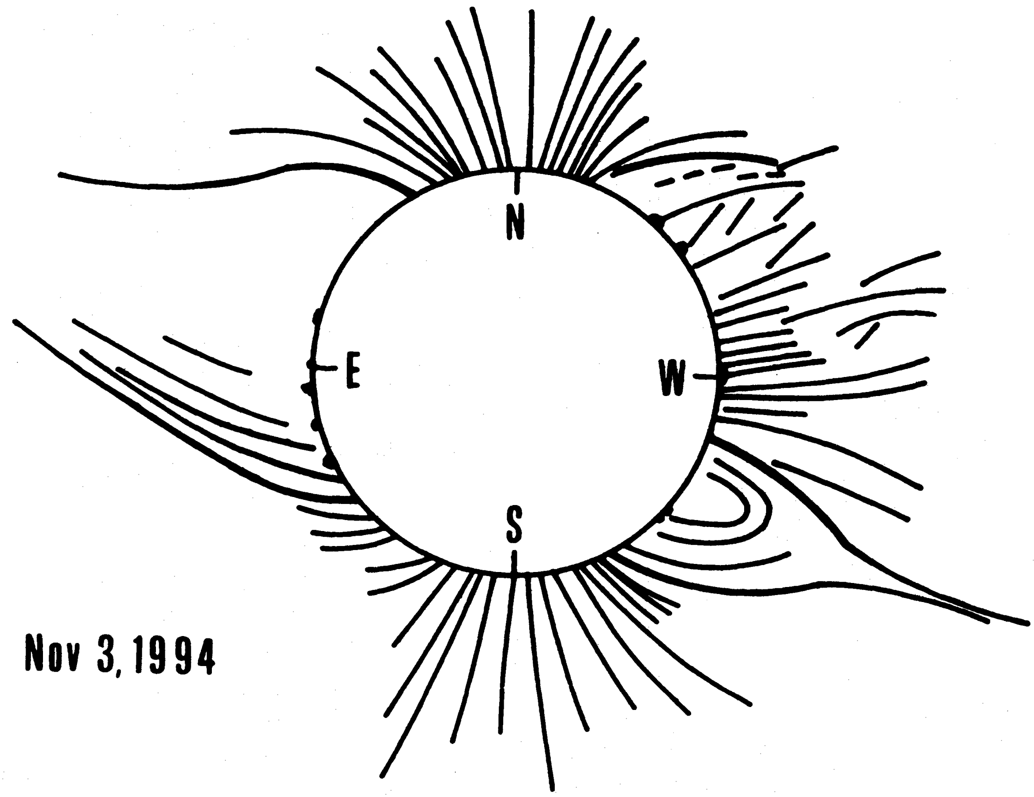

Figure 2. Structure of the total solar eclipse on November 3, 1994 (13.00 U.T.).

"minimum type", typical for the periods around solar cycle minima. This shape is, of course, the indisputable consequence of the global development of the large-scale solar magnetic field topology, as freuently described by Hoeksema (e.g., 1993). Namely, in the periods around solar cycle minima, the field exihibits a distinct dipole character, the heliographic axis and the solar magnetic axis being almost identical. This situation is reflected in the solar corona by the presence of well-defined polar rays and conspicuous streamer structures near the solar equator. All this produces a considerably flattened shape of the global corona (we will discuss the real changes of the coronal shape with the solar cycle elsewhere). In fact, the streamers delineate the presence and position of the neutral sheet of the magnetic field, extending far into the heliosphere. In short, the above description seems to be very near to what we see in Figure 2.

In our pictures we have recorded at least nine very small prominences both at the east and west solar limbs. Though all of them are related to the streamer or streamer-like structures, only two of them are covered by the dome formed below the most pronounced SW-streamer. The orientation of the solar polar and equatorial axes is defined by comparing the positions of the eclipse prominences and prominences observed by the Lomnický Štít coronagraph at 13.17 U.T.

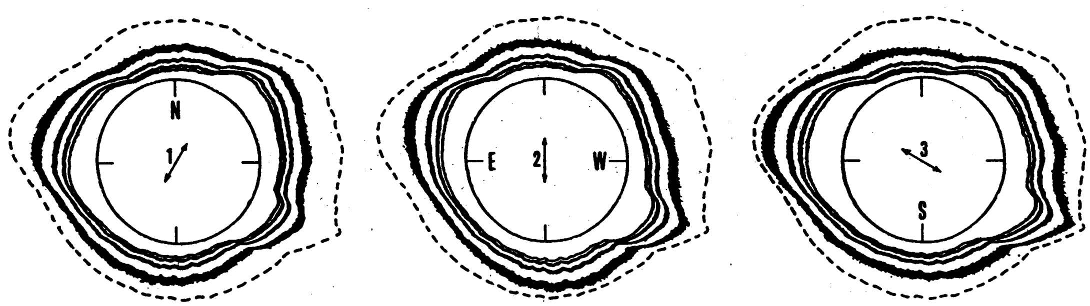

Figure 3. Equidensities, as derived from the images of the solar corona taken with 1/4 sec exposure through the polarizer differing by 60° in orientation of its axis. For comparison, one equidensity of the unpolarized corona is drawn by the dashed line.

A qualitative estimation of the degree of polarization can be obtained from Figure 3, where the equidensities of three images (1/4 sec exposure) taken through the polarizing filter differing by 60° in position of its axis (see the arrows), are presented. For comparison, the dashed equidensity indicates the shape of the unpolarized white-light corona. As expected, the highest degree of polarization (up to about 45%) seems to be present in the most pronounced streamers in the vicinity of the east equator and in the SW-quadrant. The lowest polarization (15-20%) is typical for the polar regions.

3.2. Determination of the solar corona colour

The slit of the spectrograph was oriented radially to the sun's surface at position angle 24°. During the eclipse we were able to take six exposures. The data necessary for the further processing of the pictures are given in Table 2.

Table 2. The list of the solar corona colour observations

Sequence number	Exposure at U.T.	Duration of exposure	Time interval after the 2nd contact	Height covered by the Moon
1	$12^h\ 58^m\ 43^s$	0.1 sec	0 sec	0"
2	12 59 16	0.2	33	14"
3	12 59 47	0.4	64	27"
4	13 00 20	0.7	97	40"
5	13 01 36	1.5	173	72"
6	13 02 29	3.4	226	94"

Successively the sequence number of exposure, the moment of the exposure in U.T., the exposure time, the time interval after the 2nd contact and the height (in the seconds of arc) to which the Moon overlaps the solar corona at the above position angle are given in the different columns of this table.

Prior to, as well as after the eclipse the dark radiation (dark current) and spectrum of the photosphere were recorded by using the same exposures and applying a reduced entrance aperture. Beside, prior to the eclipse, a neon lamp spectrum was used to calibrate the scale of wavelengths. After its analysis, we found the following relation between the pixels' sequence number *n(i)* and the wavelength:

$$n(i) = \sum_{k=0}^{4} a_{ki}\lambda^k \qquad (1)$$

Since the spectral lines are folded and the CCD-camera lines are not guaranteed to be precisely parallel with the direction of the spectrograph slit, it is necessary to determine the approximative relation for each of the analysed lines *(i)*.

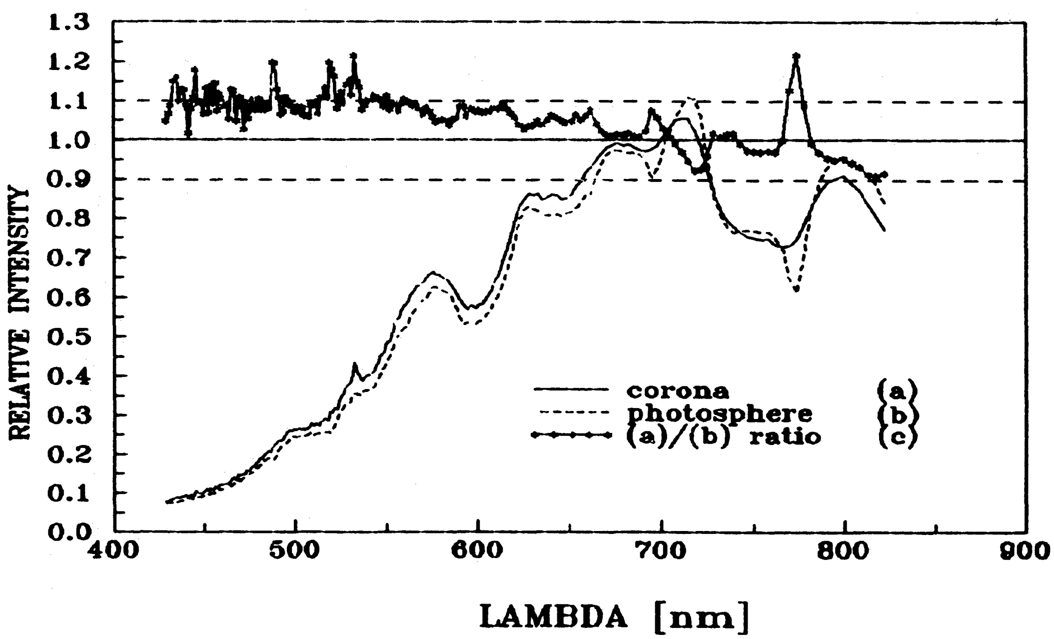

Figure 4. The spectral intensities averaged from 10 tracings of the spectrum: (a) of the corona at heights from 14 to 66 seconds of arc (full line); (b) of the photosphere (dashed line); and (c) the corona/photosphere ratio (asterisks line).

The record from the first picture (sequence No. 1 of Table 2) mostly shows chromospheric lines, while the other records exihibit a pure spectrum of the solar corona. Examples of the coronal spectrum and of the photospheric spectrum records, together with their ratio normalized to 1.0 at 700 nm, is demonstrated in Figure 4. Preliminary examination of all the records indicates that the solar corona is more blue than the solar photosphere; the ratio of the corona/photosphere intensities being about 5% higher at 430 nm than at 700 nm wavelength. Careful analysis of all the details in the spectral records and reduction of the measurements is necessary and will, of course, take a longer time.

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