CORONAL IMAGES FROM THE 1984 SOLAR ECLIPSE

JAY M. PASACHOFF and KEVIN P. REARDON
Williams College--Hopkins Observatory, Williamstown, MA 01267, U.S.A.
and
JOHN W. MACKENTY
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, U.S.A.

(Received 3 February, 1992; in revised form 13 May, 1992)

Abstract. We present digitized photographs of the white-light solar corona taken during the total solar eclipse of 22-23 November, 1984, on both calibrated black-and-white film and on color film. Conditions on site in Hula, Papua New Guinea, were exceptionally clear. The color image was used to produce an isophotal map of the inner corona, from which a flattening coefficient of 0.23 was measured. The black-and-white image was enhanced through a digital radial filter. Our images are the best processed images available from the 1984 eclipse and so provide important data for synoptic observations.

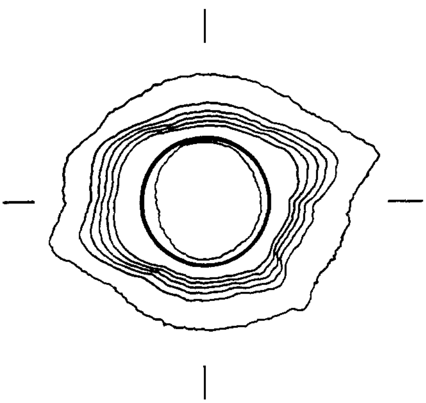
1. Introduction

Images taken at total solar eclipses are important for synoptic studies of the solar corona. These observations, especially the more recent ones, can be compiled to gauge the changes in the solar corona over time and the solar cycle (Loucif and Koutchmy, 1989). However, the weather forecasts along the path of the total solar eclipse of 22-23 November, 1984, were generally very poor. This problem – especially so soon after the major expeditions of the 1983 eclipse – and the very remote, mostly ocean-bound path of totality, made the 1984 eclipse seem in advance to be less attractive to observe than usual. These factors have resulted in very few observations of this eclipse, and even fewer calibrated and processed photographs. The 1984 eclipse took place near solar minimum when the sunspot number was the lowest during any observed total eclipse between 1976 and the present (Pasachoff, 1991). In order to maintain the continuity of eclipse observations, particularly coverage over the solar cycle, we present observations made at the 1984 eclipse.

2. Observations

Our observations were from a site in Hula, Papua New Guinea, on November 22-23, 1984 (Pasachoff, 1985; Pasachoff and Nelson, 1986). This eclipse occurred during the decline of solar cycle 21, two-thirds of the way from maximum to minimum of the cycle (phase = –0.35). The International Sunspot Number on the day of the eclipse was 41, and the monthly mean for that month was 22. In strong contrast to the weather predictions, the sky at the site during totality was particularly clear, the best eclipse observing conditions since the eclipse of 1970. The event was recorded on Kodachrome 64 color-reversal film and calibrated 35-mm Kodak black-and-white 5062 film using an unfiltered 500-mm Nikon camera lens that resulted in a plate scale of 6 arcmin/mm. The black-and-white film was calibrated using exposures of a step wedge that had been placed on it prior to the eclipse. A series of black-and-white images with different exposures was taken; the longest exposure,

Solar Physics **146**: 405–408, 1993.



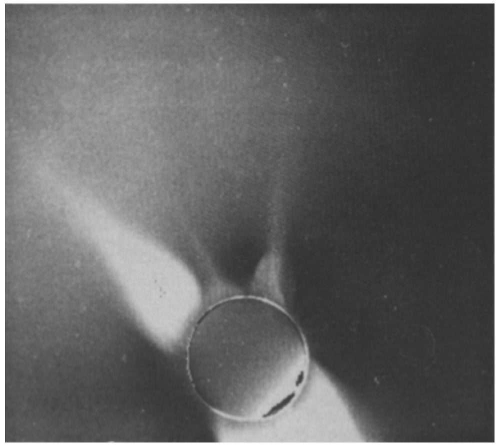


Fig. 1 (left). Coronal isophotes from our digitized color photograph.
Fig. 2 (right). Digitally radially filtered image of the solar corona showing details on east limb at 4 R_o.

on which most of the image processing was performed, had the solar disk slightly off-center.

3. Image Processing

The longest-exposure black-and-white photograph was scanned with the PDS-1010A microdensitometer at the Institute for Astronomy of the University of Hawaii. The film was sampled every 24 μm (~ 9 arc seconds) with a 24 μm-square scanning aperture. The densities were transformed to intensities from measurements of the step wedge. One of the color frames was similarly digitized because it showed more extensive streamers than any of our centered black-and-white images. The color film was digitized through a Kodak green acetate filter. While the isophotes do not correspond to a known level of coronal intensity because of the lack of calibration, they do accurately portray the shape of the coronal intensity contours (Figure 1).

From these isophotes, the flattening index of the white light corona can be computed. We first find the radial distance to each isophote averaged over 23° on either side of the polar and equatorial radial directions. From this we compute the flattening, $\varepsilon(r^i_{equ}) = (r^i_{equ} / r^i_{pol}) - 1$, where r^i is the distance to the i^{th} isophote. The flattening for all values of r_{equ} can be plotted and approximated by a straight line with the formula $\varepsilon(r_{equ}) = a + b(r_{equ} - 1)$. The value of (a+b) is used as the flattening index. The correlation between phase of the solar cycle and flattening index has been investigated by Loucif and Koutchmy (1989). For this eclipse, we compute an index of 0.23, which is considerably lower than their value of 0.35. While the flattening index is only a simple tracer of the cyclic variation of the corona with solar activity cycle, this value of 0.23 better fits with their measurements from other eclipses.

It is best to compensate for the radial gradient of the coronal intensity at the time of the eclipse by using a radial-gradient filter, which has a varying neutral density in the radial direction. Radial-filter images (Lilliequist, 1973) have been made most recently at the eclipses of 1980 (HAO and Southwestern at Memphis, 1980), 1981 (Fisher, *et al.*, 1983), 1983 (Sime, *et al.*, 1984), 1988, and 1991. A group led by Serge Koutchmy also made a radially-filtered image at the 1984 eclipse; they used a 400-mm lens and color film (Koutchmy and Nitschelm, 1984a, b).

From our (unfiltered) 1984 data, we digitially synthesized the effects of a radial filter using the digitized black-and-white image. This was done by computing the radial distance from the center of the solar disk to each pixel and then computing (with suitable interpolation) the average intensity at each radius. This intensity profile was then normalized, which gives the ratio of the average intensity at each radial distance to the maximum intensity. This profile was rotated around the central point to construct a smoothed image symmetric in azimuth, by which the original image was divided. The resulting image, shown in Figure 2, with coronal streamers visible 4 solar radii from the limb, clearly shows the benefits of this technique. While such filtering can bring out otherwise hidden details, it cannot improve the inherent signal-to-noise limitations in a unfiltered coronal photograph or overcome the problems of saturation and non-linearity to extend the dynamic range.

4. Discussion

Our work with the images obtained at this eclipse shows the possibility of improving unfiltered eclipse images with digital image processing after the eclipse. We also have available on request radial traces of coronal intensity in various directions, though they are only relatively calibrated. Our photographs are important because they are some of the few calibrated photographs available from this eclipse, and the only calibrated image displayed with radial filtering. The electron corona's large-scale morphological changes with the phase of the solar cycle are dramatic. It is important to maintain as completely as possible synoptic coverage of the white-light corona during the solar cycle in order to determine the corona's dependence on that cycle.

Acknowledgements

We thank Alfred Kruikshoop, then of the University of Papua New Guinea, with his help on site and for arranging the site. We thank the Director and the staff of the Institute for Astronomy of the University of Hawaii and of the Sacramento Peak Observatory for their hospitality. We thank Brant Nelson for the information he collected in his thesis. We are grateful to Serge Koutchmy for providing information about his observations. We thank the Photographic Division of the National Geographic Society and Mary G. Smith for calibrating and developing the film. The expedition and data reduction benefited from NSF grants RII-8304403 and National Geographic grant 2547-82 for the 1983 eclipse; and NSF grants ATM-9005194, USE-9050643, and AST-9014889, and National Geographic grant 4433-90 for the 1991 eclipse. We have also benefited from grants from the Bronfman Science Center at Williams College.

References

Fisher, R.R., Lacey, L., Rock, K., Yasukawa, E., Sheeley, Jr., N., Michels, D. Howard, R., Koomen, M., and Bagrov, A.: 1983, *Solar Phys.* **83**, 233.

High Altitude Observatory and Southwestern at Memphis: 1980, *Solar Phys.* **68**, 216.

Koutchmy, S., and Loucif, M.: 1984, *Proceedings of the Fourth European Meeting on Solar Physics - The Hydrodynamics of the Sun*.

Koutchmy, S., and Nitschelm, C.: 1984a, *l'Astronomie* **138**, 161.

Koutchmy, S., and Nitschelm, C.: 1984b, *Internal Institute d'Astrophysique Report* **84**.

Lilliequist, C.: 1973, *National Center for Atmospheric Research Technical Note* TN128+STR.

Loucif, M.L., and Koutchmy, S.: 1989, *Astron. Astrophys. Sup. Ser.* **77**, 45.

Nelson, B.O.: 1986, Williams College Senior Thesis.

Newkirk, Jr., G., Dupree, R.G., and Schmahl, E.J.: 1970, *Solar Phys.* **15**, 15.

Nitschelm, C., and Koutchmy, S.: 1984, *l'Astronomie* **138**, 393.

Pasachoff, J.M.: 1985, *Sky and Tel.* **69**, pp. 97, 99, and 183.

Pasachoff, J.M., and Nelson, B.O.: 1986, *Solar Phys.* **108**, 191.

Pasachoff, J.M.: 1991, in *Flare Physics in Solar Activity Maximum 22, Solar-A Science Meeting in Memory of Katsuo Tanaka*, Y. Uchida, R.C. Canfield, T. Watanabe, and E. Hiei, eds., Springer-Verlag, p. 283.

Sime, D.G., Fisher, R.R., McCabe, M.K., and Mickey, D.L.: 1984, *Astrophys. J.* L123.