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Determination of Linear Polarization of Solar Corona from Observations of the Eclipse of October 24, 1995

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Abstract

Photographs of the Solar Corona were taken using a refractor telescope and polarizer during the Solar Eclipse of October 24, 1995. Two sets of photographs with 0.5 second and 1.0 second exposure, for different polarizer orientations, were obtained. The maps for linear-polarization and for angle of the plane of polarization of the radiation from the solar corona were obtained from these photographs.

Key Words : Total Solar eclipse, K-Corona, Polarization, Electron density.

Introduction

The corona, which is the outermost region of the solar atmosphere, extends from about 20,000 km above the solar surface to many solar radii. Its temperature is of the order of a few million degrees (Hulst, 1953).

Its constituents are almost entirely plasmic, including ions like Fe XIV etc; and fast moving electrons existing at very low densities. On a normal day the scattered sky-background is many orders brighter than the intensity of the solar corona, but during a total solar eclipse the Moon blocks out the Sun's photospheric light and provides an ideal opportunity for visual observations of the corona (Singh, 1994). From previous eclipse studies, it has been found that the shape of the corona changes with solar activity; the corona becomes asymmetric and elongated at the Sun's equator near the solar minimum, but is quite symmetric during solar maximum. Coronal radiation in the visible region has contributions from three components called the K, E and F-Corona. The K-corona contributes nearly 98% of the coronal intensity. The light from this component is simply a small part of the photospheric emission scattered off by the electrons in the dilute plasma whose thermal emission in the visible wavelength region is itself negligible. The E-Corona contributes about 1% of the coronal optical radiation, due to the forbidden transitions in the highly ionized atoms. The rest of the coronal intensity is from the scattering of photospheric light by heavier particles including dust. These solid particles are not really part of the Sun's atmosphere; they exist between the Sun and the Earth, in the plane of the ecliptic. This component is labelled as the F-Corona.

We find that radiations from K- and F-coronas are polarized by the scattering mainly due to electrons. Polarization measurements of the coronal light help determine electron densities in the corona. In our experiment to study the polarisation of the corona, we obtained broad-band continuum images of the corona using a polariser and a filter.

Observations

We performed observations of the Total Solar Eclipse of October 24, 1995, from Lunkaransar, Rajasthan (28° N, 74° E). It happens to be the western-most point of the coordinated observations of this eclipse in India.

The choice of place of observation was based on information on cloud cover, duration of totality and observing program (Espenak and Anderson, 1994; Singh, 1995). The eclipse occurred between about 7:30 to 9:30 IST, with the totality lasting for about 40 seconds. Our equipment consisted of a 3-inch refractor telescope in front of whose objective were placed a broad-band red filter, an aperture stop and a polarizer. A Pentax 5000 SLR camera with Kodak 2415 film was used for recording images. For each of four polarizer orientations of a fiducial zero, 45, 90 and 135 degrees, we obtained two photographs with exposure times 0.5 and 1.0 second.

Data Processing and Analysis

The photographic negatives were developed at the Kodaikanal Observatory of the Indian Institute of Astrophysics. The films were scanned using a PDS microdensitometer at the Indian Institute of Astrophysics, Bangalore, using a 20 μm^2 aperture. Each image was thus digitized as a 701 x 801 matrix. Using step-wedge data, the emulsion density matrix thus obtained was converted into an intensity-matrix. Image processing was performed in IRAF environment.

The sets of 0.5- and 1.0-second images were carefully aligned in the following way. The original images have the same pixel scale (about 5"/pixel), and are shifted relative to each other by simple translation and no rotation. Since our images were of low-resolution, we could not find enough number of pointlike sources to obtain good registration. So we had to align the images using an indirect method. Dividing a given image by its median filtered image produced a quotient image that brought out the sharp features like the Moon's limb into relief. Then the limbs were satisfactorily aligned. In one case, coronal features on the limb, which were shared by the images, were used as markers to obtain alignment.

A preliminary examination showed that the 1-sec photographs were over exposed in some regions. Hence, only the 0.5 second exposures, which did not show a contamination to such a degree, were used for the analysis. We designate the images obtained at polarizer angles 0, 45, 90, 135 as I(0), I(45), I(90) and I(135), respectively. Then, the degree of polarization P can be computed using the standard formula as:

$$P = \sqrt{\left(\frac{I(0) - I(90)}{I(0) + I(90)}\right)^2 + \left(\frac{I(45) - I(135)}{I(45) + I(135)}\right)^2} \quad (1)$$

The orientation, θ, of the maximum intensity of linear polarization with respect to the angle 0 of the polarizer is:

$$\theta = \tan^{-1}\left(\frac{I(45) - I(135)}{I(0) - I(90)}\right) \quad (2)$$

Since the images do not extend to much over one solar radius from the solar limb, sky polarization has not been taken into consideration. But we believe this is lower than 1% (Sivaraman *et al.*, 1984).

Results and Discussion

The contour map for linear polarization of coronal emission is presented in Figure 1. Figure 2 is an array of numbers corresponding to the 5x5-pixel averaged values for angle of linear polarization at individual points. Radial profiles of the degree of polarization map are presented in Figures 3 and 4.

In Figures 3 and 4 we find that degree of polarization falls off radially, though not smoothly, suggesting that the electron density varies non-uniformly in the corona. Figure 1 also shows that the degree of polarization does not show complete radial symmetry. This is of course to be expected given the existence of magnetic activity in the corona.

In Figure 2, we find that the angles of polarization show a rough radial symmetry, which is expected in view of the nature of coronal polarization.

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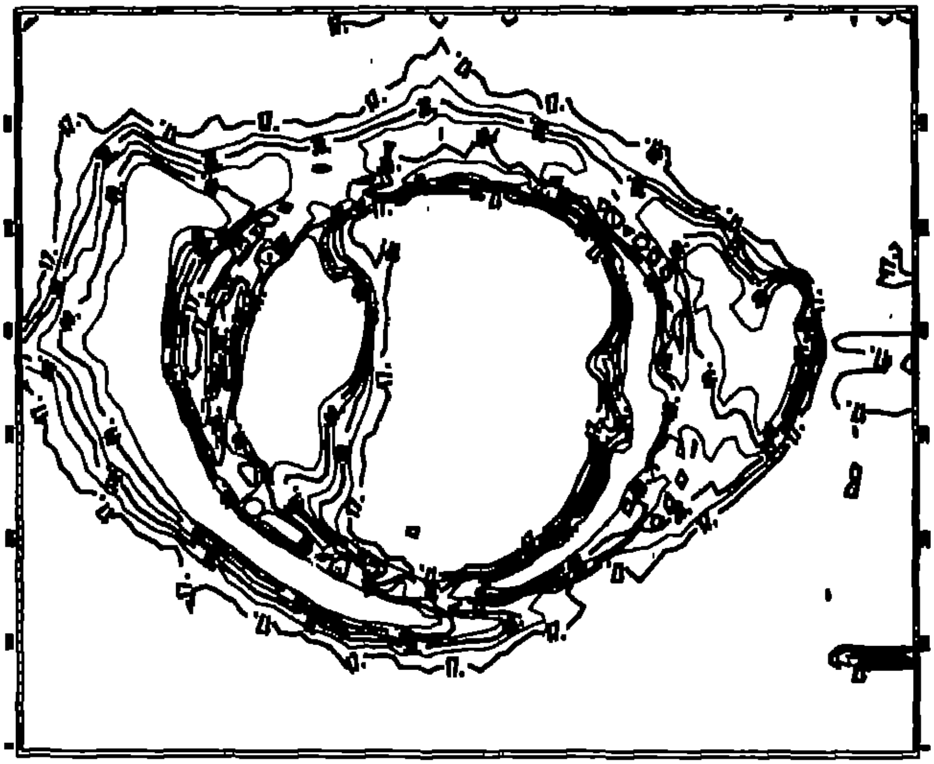

Figure 1 : Map of percentage linear polarization of the solar corona. Contours are from 17% to 57% at intervals of 8%.

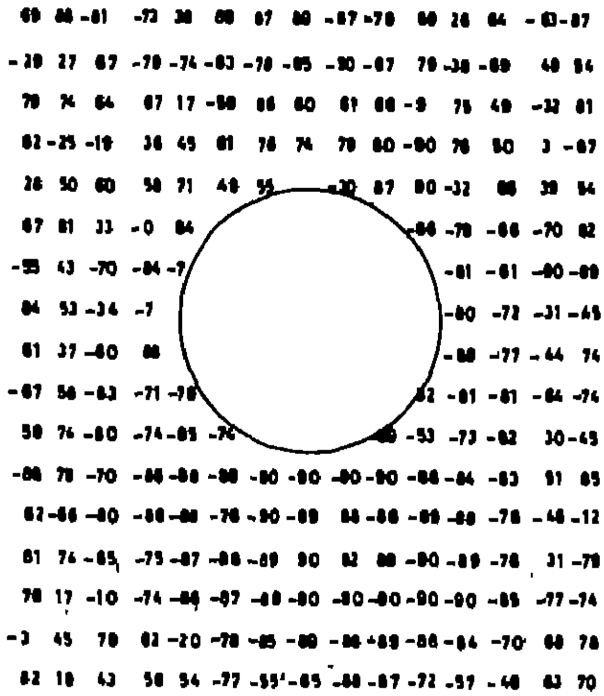

Figure 2 : Array of linear polarization angles with the outline of moon's limb shown.

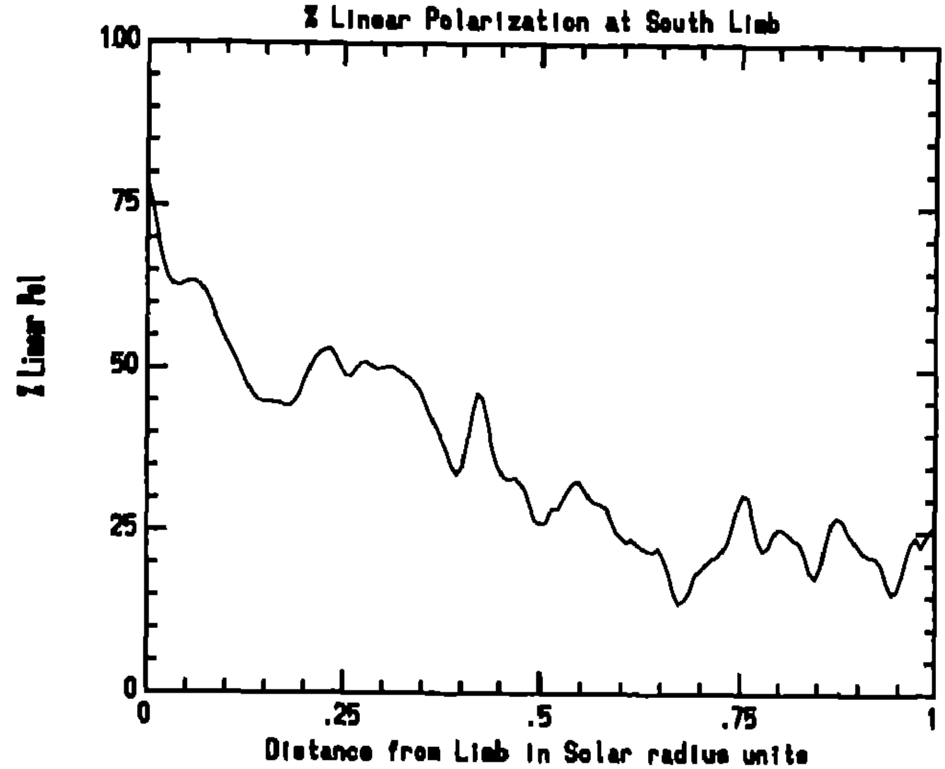

Figure 3 : Radial profile of percentage linear polarization of corona at the south limb.

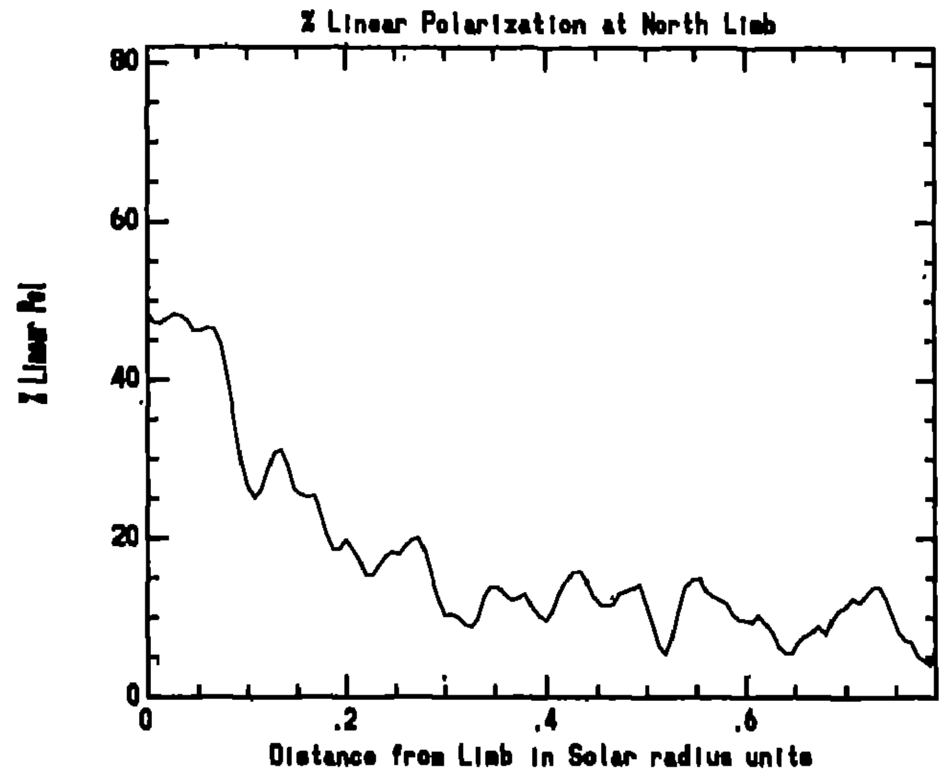

Figure 4 : Same as Fig. 3, but at the north limb.

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