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No signature of Circum-Solar Dust Ring up to $5R_\odot$ from Optical Polarization and Near IR Observations of 24 October 1995 Total Solar Eclipse

Debi Prasad C. and Ashok K. Ambastha
Udaipur Solar Observatory, Physical Research Laboratory
(Department of Space, Government of India)
Badi Road, Udaipur 313 001, India.

Abstract

A circum-solar dust ring, consisting of interplanetary particles, is believed to be situated at $4R_\odot$, and temporarily variable in anti-phase with the solar activity cycle. The signatures of such a ring should be observable through: (i) a highly polarized scattered solar radiation, and (ii) its thermal component in near IR. We designed an instrument for detecting these ring-signatures and conducted the experiment at Kalpi, UP during the October 24, 1995, total solar eclipse. The instrument consisted of a computer-controlled wide-field imaging polarimeter having three filters centered at 6500, 8100 and 9750 Å. The observed coronal polarization and surface brightness were found to be consistent with the overall expected in the Corona at the solar minimum phase. We report that no ring signature was observed by our experiment.

Key Words : Dust ring, Interplanetary dust, Solar eclipse.

Introduction

During the last 30 years, there have been several attempts to detect the circum-solar dust ring, believed to be located at $4R_\odot$, however, these reports have only provided contradictory results. The experiments were conducted both during total eclipse and non-eclipse periods as well as during solar maximum and minimum phases. On some occasions, positive detection of dust ring signatures was found to exist. From the general trend of these reports, it is inferred that the dust ring might be temporally variable in anti-phase, with the solar activity cycle. The experiments have generally aimed at detecting the scattered sunlight or the thermal radiation from the constituent particles of the ring. As the sunlight would get scattered perpendicularly by the ring particles, it is expected to be linearly polarized. The thermal equilibrium temperature of the interplanetary dust particles at $4R_\odot$ would be around 1000°K. Therefore, its thermal radiation would peak in the near infrared region of the electromagnetic radiation. The enhanced coronal electron density during the maximum phase could either destroy the dust particles (Debi Prasad, 1995), or modify their dynamics (Isobe and Kumar, 1994), such that detection of the ring has larger probability during the solar minimum phase. The total solar eclipse of October 24, 1995 was occuring in the solar minimum phase, therefore, an experiment to detect both these signatures of the dust ring was designed by Udaipur Solar Observatory (USO) in collaboration with the Space Applications Center, Ahmedabad (Debi Prasad *et al.*, 1996). The analysis of the data from this experiment showed that whereas the overall coronal structure was consistent with the solar minimum phase, no significant feature existed at these wavelengths, which could be attributed to the dust ring. Therefore, the solar cycle dependence of the ring appears to be unlikely.

Experimental Setup and Observations

The USO experiment was aimed at imaging the corona in the near infrared waveband 9750Å, and for measuring the linear polarization of the light from the circum-solar region at 6500, 8100Å. Accordingly, we designed and fabricated an imaging polarimeter. The instrumental parameters are listed in Table 1. The entire 4° x 6° field-of-view was imaged on a 576 x 384 pixel CCD (Thompson chip Th 7863), using an 80 mm f/2.8 Hasselblad objective lens. In order to record the solar images through the desired polaroids and interference filters in front of the objective lens, two stepper motors were driven by a specially designed electronic control unit. The entire sequence of operations of controlling the stepper motor rotation and image acquisition was performed by dedicated computer software and hardware. The polaroid filters were mounted on a wheel at polarizing axis orientations of 0°, 120°, and 240°, respectively. The data were recorded by a video recorder at a rate of 25 frames per second. The video data were digitized by the Imaging Data Acquisition System (IDAS) at USO.

Table 1. Instrumental Parameters

Parameter	Value
Field-of-View	4° x 6°
Image Scale	43 arcsec. per pixel
Filters for Polarization measurement	6500 and 8100Å
Filter for imaging	9750Å
Polarizing Filters:	
Mean polarization for unpolarized	
white light	33%
Total transmittance for two in parallel:	20%
Crossed :	0.002%
(i.e., extinction is 1:10,000 for a degree of polarization of 99.99%)	
Filter change-over time:	0.5 second

The experiment was successfully performed during the total solar eclipse of October 24, 1995 from Kalpi, UP. The Kalpi site was selected by the USO team for eclipse observation due to its marginally longer totality duration compared to the more popular site, Nim ka Thana, in Rajasthan. The entire totality period had perfect weather and clear sky conditions. The expected totality duration at Kalpi was reported around 61 seconds whereas at the actual camping site of our experiment, it was only about 55 seconds, which was still sufficient to complete all the steps of our observation.

Data Analysis

The images were corrected for different transmission levels of the optical components and the detector efficiency. The Stoke's parameters were determined as following :

If I_1, I_2 and I_3 are three images obtained through the polaroid filters, positioned at the orientations of 0°, 120° and 240° respectively, it can be shown that the Stoke's parameters of the transmitted light are,

$I = 2/3\,(I_1 + I_2 + I_3)$ = Total light intensity

$Q = 2/3\,(2I_1 - I_2 - I_3)$ = Twice the intensity transmitted by a linear polaroid at 0° minus I

$U = -2\sqrt{3}\,(I_2 - I_3)$ = Twice the intensity transmitted by a linear polaroid at 45° minus I

Then the degree of polarization P and θ angle in equatorial coordinate system are given by

$P = \sqrt{Q^2 + U^2}\,/\,I$, $\theta = 1/2\,\tan^{-1}(U/Q)$ respectively

Discussion and Conclusions

Figure 1a shows isophotes of the image taken at 6500Å. As may be noticed, the shape of the corona is consistent with a typical minimum phase corona - flattened along the poles, while extended in the equatorial direction. We were able to detect the coronal light up to a region beyond $5R_\odot$. The inner corona was saturated and the southern side of the images suffered from instrumental scattered light. Radial profiles of average intensity along the polar and equatorial directions were obtained by averaging the intensities over 50 pixels lying in the respective perpendicular directions (Figure 1b). It is seen that the average flux in the equatorial direction is larger than that in the polar direction at any given distance from the center of sun's disc. Furthermore, it is observed that there is an asymmetry in coronal flux along the east-west direction. No significant enhancement over the general coronal intensity was observed near $4R_\odot$, which could be attributable to the circumsolar dust ring. Similarly, the intensity profiles obtained from the image taken through filter at 9750Å are shown in Figure 2.

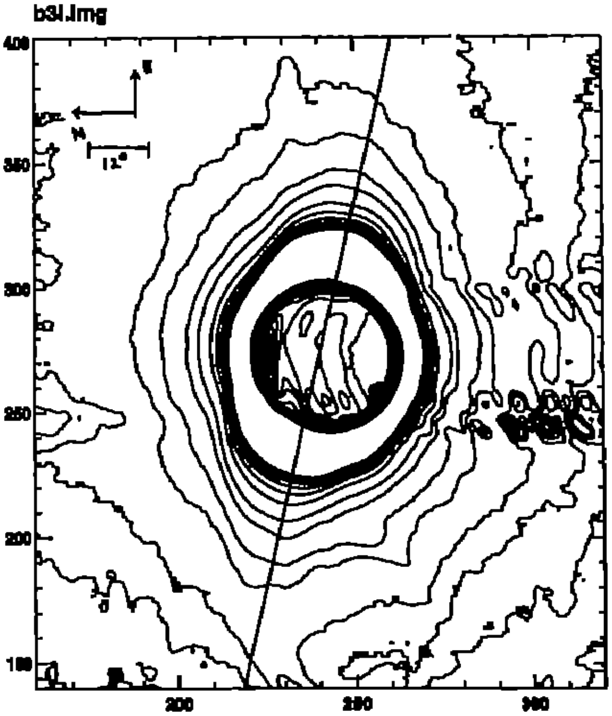

Figure 1a : Isophotes of the image of the solar corona taken through the filter centered at 6500Å on 24 October, 1995. The contour unit is 5%. The ecliptic plane is shown by a thick line. The ordinate and abscissa are in original pixel numbers of the CCD image.

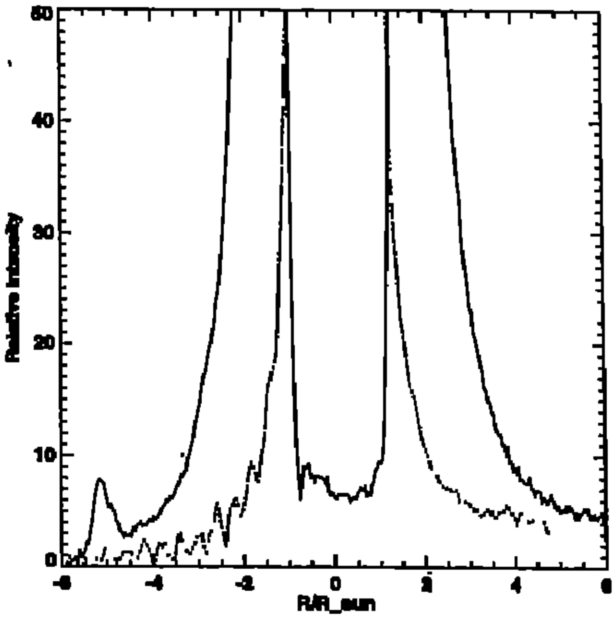

Figure 1b : Radial profiles of the image in 6500Å. The average intensity along the polar (dashed) and equatorial (solid) directions are obtained by averaging the intensities over 50 pixels lying in the respective perpendicular directions.

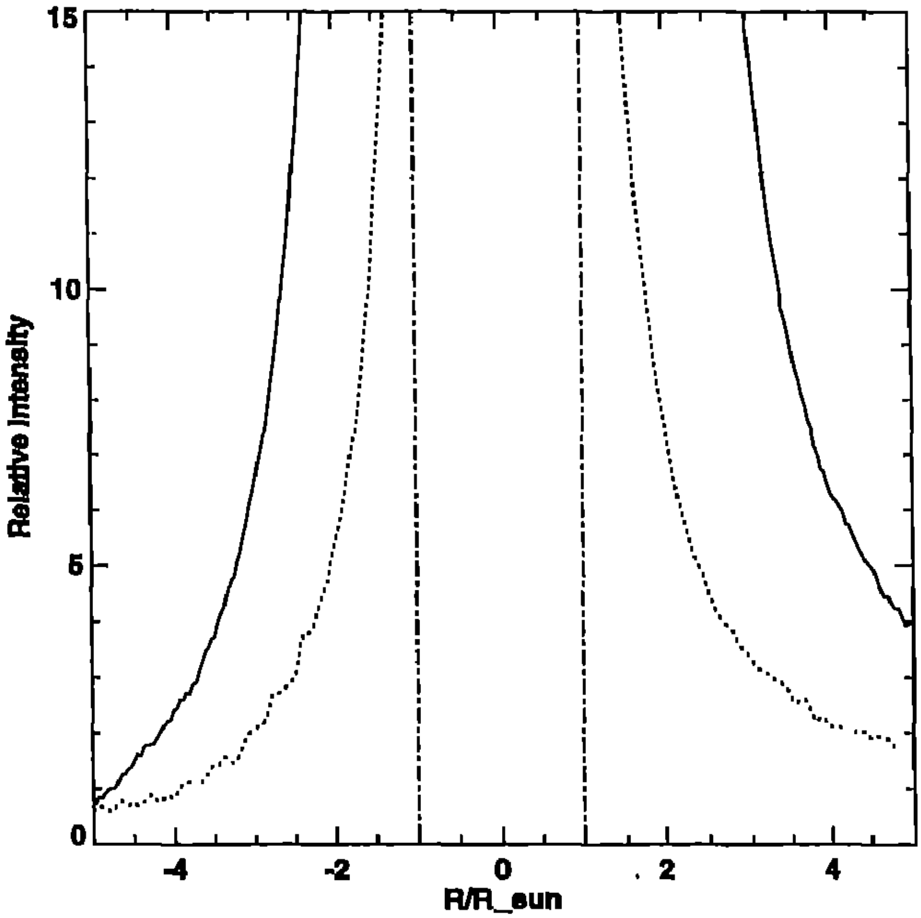

Figure 2 : Radial profiles of the image in 9750Å. The average intensity along the polar (dashed) and equatorial (solid) directions are obtained by averaging the intensities over 50 pixels lying in the respective perpendicular directions.

This wavelength (9750Å) is closer to the wavelength at which the peak corresponding to the ring was reported earlier (Mizutani, *et al.*, 1984). However, in our experiment, the ring signature was not found at this wavelength also. Figure 3 shows the polarization map of the corona. The detailed discussion of this map will be presented in a more comprehensive publication elsewhere. However, it may be noticed that the polarization along the equatorial direction is more than in the polar direction. There are some areas of large polarization away from the regions enclosed by contours. It is to note that the signal at these locations was considerably lower, therefore, the measurements were affected by larger errors. In the inner region the typical error is about 1%. Our intention at this point is to illustrate that the polarization map also does not show enhanced polarization corresponding to the dust ring at the expected locations, marked by the circles.

In summary, it is to conclude that we did not observe, in λ = 6500, 8100 and 9750Å., any signature of the circum-solar dust ring during the October 24, 1995, total solar eclipse. It would imply that at least during this period, the enhancement of dust particles at $4R_\odot$ was not as significant as one would have expected from an observable ring.

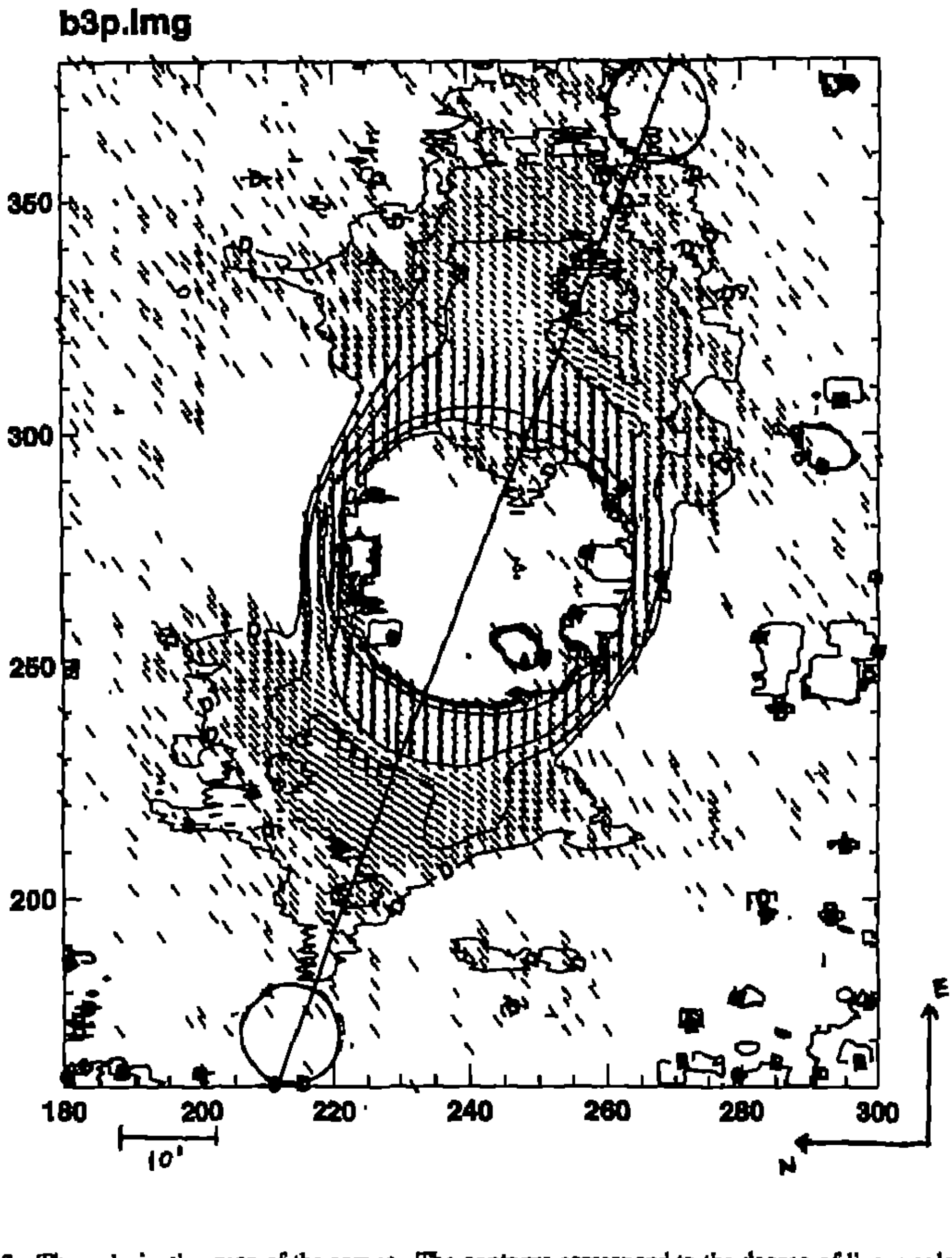

Figure 3 : The polarization map of the corona. The contours correspond to the degree of linear polarization and the line-segments represent the magnitude and direction. The hatched region is saturated inner corona. The two small circles along the equatorial plane are the expected positions of the dust ring. The contours A, B, C and D are the degree of linear polarization in the descending order. The bars represent the magnitude and direction of the polarization. The value of the polarization at the longest bar is 10%. The ordinate and abscissa are the original pixel numbers of the CCD image.

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