Kodaikanal Obs. Bull. (1997) 13, 25–28

Ultra-low Spatial Resolution Photometry in Near-Infrared to Detect the Solar Dust Ring

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Abstract

There are conflicting reports about the existence of the dust ring around the Sun. An experiment to detect the solar dust ring was performed by IIA group during the total solar eclipse of Oct. 24, 1995. A near-infrared extended coronal image was obtained with a 12 inch coelostat, 210 mm telephoto objective and a liquid nitrogen cooled CCD Camera. The data were analysed in a Sparc workstation using the IRAF image processing package. A contour map of the image shows lot of irregularities in the infrared emission. The intensity scans in the solar equatorial regions do not show evidence for a solar dust ring at 4 solar radii at 1 μm. The coronal flattening index upto 7 solar radii was obtained from the data.

Key Words : Total Solar Eclipse, Solar corona, Solar dust ring

Introduction

The existence of a solar dust ring at 4 solar radii has been predicted by various authors. There are differences of opinion regarding the constitution of the ring material, one in favour of fine dust particles, and the other, in favour of large boulders (Peterson 1963, Kaiser 1970, Brecher *et al.* 1979). The temperature of the ring material is proposed to be in the range 1000-2000 K and hence the peak of emission is expected at 1.5-3 μm. One expects, therefore, both enhanced polarization and emission in the infrared wavelengths due to the ring material.

The observational evidences, however, remain inconclusive. While many observations showed signatures of dust ring at about 4 solar radii (Peterson 1967 and 1969, Mizutani *et al.* 1984), some other observations failed to detect any evidence (Mankine, MacQueen and Lee 1974, Rao *et al.* 1981). Variability of the solar dust ring with respect to the solar cycle has been suggested with the possibility of a prominent dust ring at the solar minimum periods (Isobe and Kumar 1993, Debiprasad 1995).

During the total solar eclipse of Oct. 24, 1995, IIA group has conducted an experiment to detect the dust ring, through near-infrared imaging. As the year 1995 belongs to the solar minimum periods, the chances of encountering the solar dust ring were also thought to be better. In the following sections, we describe the experimental setup, observation, analysis and the results.

Experiment

In the experimental setup, a telephoto objective of 210 mm focus collected the sun light through a 12 inch coelostat and formed the solar image of 1.9 mm diameter. A near-infrared filter at 1 μm with a passband 1000 Å was kept near the focal plane. A liquid nitrogen cooled photometrics CCD camera having 1024 x 1024 chip with pixel size of 24 μm served as the detector. The high dynamic range and low dark noise of the CCD could be made use of, in the detection of weak signals from large radial distances from the solar limb. The experimental set up provided us a pixel resolution of 48 arcsec.

A series of test images were taken with the Sun at the centre of the CCD frame, to calibrate the instrument. Some images of the partial phases of the eclipse, both before and after the totality, were also obtained and they served as the direction indicators. During the totality, one frame was taken with an exposure time of 40 sec. The frames were later transferred to the Sparc workstation in IIA for further analysis.

Results and Discussion

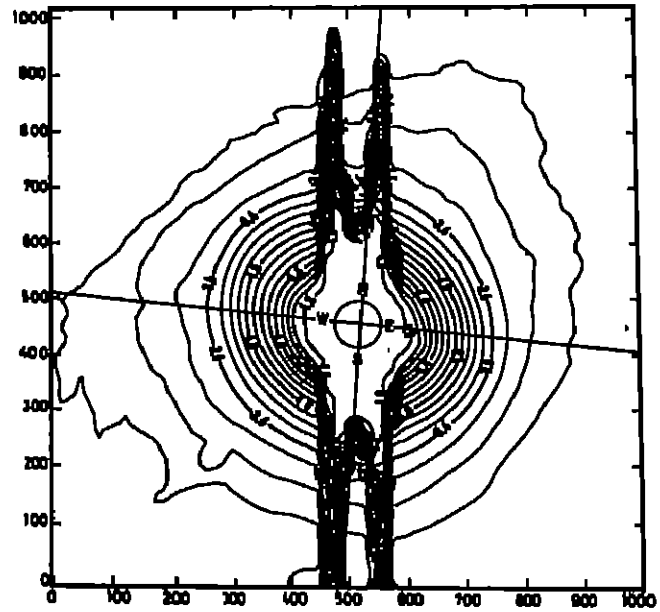

Figure 1 : The contour map of the near-infrared image at 1 μm. The N-S and E-W directions are marked in the Figure. The central circle represents the solar image. The contour levels are from 4.8 to 3.3 with an interval of 0.1 on the logarithmic scale.

A contour map of the image, obtained using the IRAF image processing package, is shown in Figure 1. The infrared emission was found highly irregular and extended upto 10 solar radii in the equatorial regions. The innermost regions of corona and the central portion of the image are saturated in the CCD frame due to the long exposure. The ellipticity of the contours may be clearly seen in the inner contours. In the outer contours this is somewhat smoothened out because of the low spatial resolution of the instrument.

The coronal flattening index is calculated from the contours in the range 3.3 to 7 solar radii. It is defined as

$$\epsilon = \frac{R_{eq}}{R_{pol}} - 1 \qquad (1)$$

for the same isophote. The values are given in Table 1. These may be compared with those values given by Newkirk (1967). The values are higher upto 5 solar radii and then become smaller outwards. It may be noted that our values are for the infrared wavelengths while those of Newkirk's are for the visible wavelengths and the behaviour in the two wavelength regimes could be different.

Table 1. The measured values of coronal flattening index at 1 μm. The columns denote the coronal radial distance in units of solar radii, measured flattening index and Newkirk's values, respectively.

r	ϵ	ϵ (Newkirk)
3.36	1.20	1.16
3.57	1.19	1.15
3.92	1.20	1.14
4.14	1.18	1.14
4.50	1.19	1.14
4.78	1.16	1.14
5.14	1.14	1.14
5.50	1.12	1.14
6.07	1.09	1.15
6.93	1.08	1.17

After the careful calibration of the image, intensity scans were obtained in the solar equatorial regions. Two intensity scans across the frame in the equatorial region are shown in Fig. 2. The intensity scans were examined for the enhancement of signals, as one may expect from the dust ring. However, no significant enhancement of the signal was seen in the equatorial regions near 4 solar radii. This rules out the possibility of the dust ring that would emit at about 1 μm.

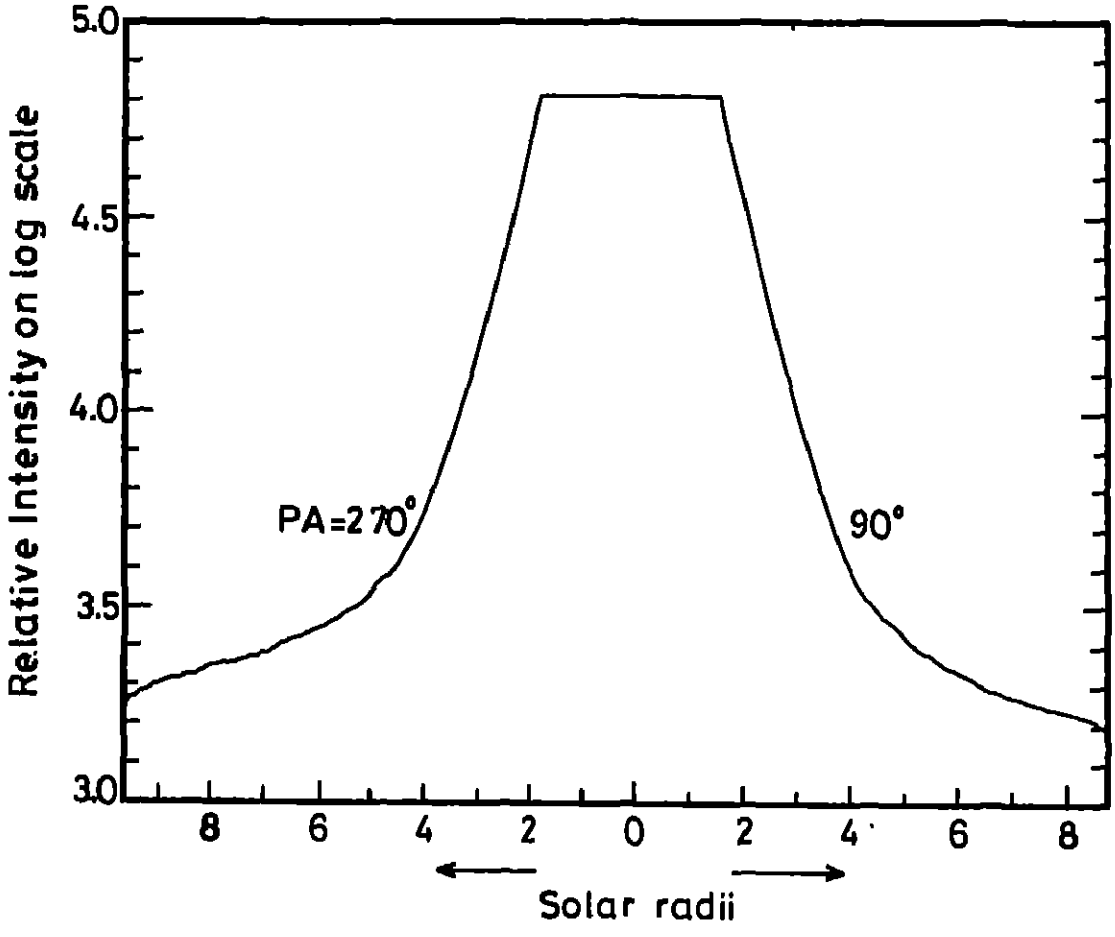

Figure 2 : The relative intensity (logarithmic units) as a function of the coronal radial distance in units of solar radii in the equatorial directions. The coronal image is saturated upto about 3 solar radii. The scan represents the position angles 90 and 270 degree.

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