POLAR PLUMES AND STREAMERS FROM 1994 AND 1998 ECLIPSES

B.H. Foin1, K. Muglach1, J.E. Wiik1, T. Beaufort1, S. Orlando1, L. Duvet, C. Desteve

1ESA Space Science Department, SCI-SO, ESTEC, 2200AG Noordwijk, NL

ABSTRACT

We report results of observations of a total solar eclipse on 3 November 1994 from the North Chile alteplano. We obtained images from the inner to the outer corona, as well as low-resolution spectra of prominences and of the inner corona. We present the analysis of images in the Thomson scattered continuum. The variations of density and equivalent temperature were derived in coronal holes (plumes and interplumes) and in equatorial streamers. In addition, we show first images from the eclipse on 26 February 1998 observed at Guadeloupe together with eclipse support images from the SOHO spacecraft.

Key words: Sun, corona, eclipses

1. INTRODUCTION

The total solar eclipse of 3 November 1994 was observed with ESA SSD experiments from Putre military base which was situated on the central line of totality. The aim of our observing campaign was to obtain images of the inner corona and to measure spectra of the inner corona and prominences on the observed limb.

The CCD experiment developed at the ESA Solar System Division consisted of a transportable automatic 25 cm aperture Meade LX200 telescope, a focal reducer from f/10 to f/6.3 in order to image a full solar diameter onto the area of our detector and a Peltier cooled Photometrics scientific CCD camera. The detector has 1384x1024 pixels of 16 μm, with Multi Pinned Phase technology allowing a very low dark current noise. The data were read through a controller at high rate of up to 2 Mb/s and transferred to a Macintosh memory. Automatic scripts were developed and tested before the eclipse to be started 20 s before 2nd contact totality, in order to optimally measure different phases of the eclipse, from last limb photospheric emission to chromospheric flash variations and deep exposures of the inner and middle corona.

We used a transmission objective grating with 200 grooves/mm blazed at 10 deg for 476 nm. It allows to measure simultaneously an image in zero order and a low resolution spectrum of the inner corona. The spectral dispersion was determined consistently using the constructor parameters and the distance from the spectro-imager to the detector resulting in a dispersion of 0.95 nm/pixel.

For the intensity calibration of the image we estimated the areas free of overlapping of the spectral orders, we corrected for the opening of the mechanical shutter at very fast exposures, we corrected the flat field response, and we estimated a straylight correction. A bias correction from a median of several biases (in order to avoid cosmic rays) was done. The flat field variations due to the vignetting of the optical system and the grating support was corrected. As the exposures were short compared to the opening of the mechanical shutter the corresponding inhomogeneity in the exposures was calibrated in the laboratory and applied to the data.

We determined the full light field of the telescope using both the CCD detector. The limits and calibra-

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tion of the first order spectrum could be estimated from the responsibility of the system or from the spectra of stars measured in the same configuration. We find a measurable contribution for a solar type star above 330. Otherwise the image until 0.7 radii is unaffected by spectral overlap. We showed that the contribution from the -1 order is limited to the lunar disk and does not affect the coronal image. As usual in eclipse observation, the straylight constitutes still a measurable contribution to the background, in particular in areas where the signal is weak such as the solar disk and beyond one radius away from the limb. The moon-reflected earthshine is typically 100 to 1000 times fainter than the coronal intensity between 1 and 2 solar radii. From the lunar disk signal we determined an estimate of the straylight and its variations in different positions of interest in the image.

2. LARGE SCALE STRUCTURES

![Graph showing logarithm of intensity vs. angle in degrees](image)

Figure 2. Spatial variations of the Thomson scattered intensity along circles at different distances above the solar limb (respectively at 0.05, 0.1 and 0.15 radii). One notices at the north pole (angle 35 degrees compared to the long axis of the CCD image in Fig.1) the lower emission in the coronal hole, as well as density variations associated to plumes/interplumes regions. The enhanced emission of the equatorial streamer allows also to diagnose the spatial variations of integrated electron densities. From the radial gradient of the emission we derived equivalent hydrostatic temperatures at different positions in the coronal holes and streamers and as a function of distance from the limb.

An immediate analysis of the CCD images shows several coronal characteristics. First, the respective centers and cardinal axes of the moon and the sun were determined. From the larger apparent diameter of the moon and limb contour we determined exactly the moon center.

Structures at larger scale are also visible on the image (Figure 1). At the pole one notices almost radial lines (polar plumes). A comparison with an image taken by the Yohkoh satellite shows their link with polar coronal holes. At the east one notices a streamer well visible in the low corona. Large field photographic images show at the moment of the eclipse a typical configuration of solar minimum, with polar coronal holes and two nearly equatorial streamers.

3. DENSITY AND TEMPERATURE VARIATIONS IN THE INNER CORONA

One of the eclipse campaign objectives was to derive a map of the coronal temperature, benefitting from the CCD sensitivity, linearity and dynamic range. Cuts of the calibrated coronal emission at constant altitude were derived above the solar limb at altitudes of 10 Mm, 44 Mm, 70 and 90 Mm (Figure 2). These cuts map the electron heterogeneity at a given altitude. In the 10 Mm cut the sharp emission due to prominences is well recognized, with an increase of a factor of 5-10 compared to the neighbouring emission. At the other altitudes, one confirms from these cuts the medium scale variations such as the polar plumes and the equatorial streamers.

The hydrostatic equivalent temperature can be derived from the logarithmic spatial gradient of the calibrated intensity. Errorbars on the measure of the gradient have been estimated, including the photon and read-out noise, and the systematic noise in gradient estimates (as derived from simulations, Duvet 1996). The temperature profiles are more variable (and also noisier than the density profiles). At low altitude one can obtain an inverse correlation between structures in density and equivalent temperature, but this correlation disappears at higher altitude. For $z=44$ Mm it appears that a local maximum of temperature corresponds to a local density minimum (and vice-versa). This is even clearer at the poles for plumes. The obtained temperatures are between 1 and 2 million Kelvin. The derived average equivalent temperature is 1.0 MK at 44 Mm, and 1.2 MK at 70 Mm height, with plumes/interplume differences of 0.1 MK. The streamer temperatures are on average 0.35 MK higher than the coronal hole (1.35 and 1.55 MK at 44 and 70 Mm height), but with a larger temperature dispersion (dispersion from 0.4 MK at 44 Mm decreasing to 0.2 MK at 70 Mm). The data allow to safely estimate the temperature up to 0.5 solar radii.

4. ECLIPSE 1998 AND SOHO OBSERVATIONS

Total solar eclipse observations were conducted from Guadeloupe (F) on 26 February 1998, by a team of ESAs Solar System Division in coordination with the SOHO observatory. Ground instrumentation included a set-up similar to the one of 1994 in addition to H α CCD observations and a white-light video and camera system.

Figure 3 shows a composite of three images of the sun during totality of the eclipse: the outermost part is a 02 image of LASCO, showing the corona beyond 2 solar radii, in the middle is a digitized white-light image of our SSD experiment and in the center an
EIT 195 Å image of the solar disk is shown. One can clearly recognize the typical coronal structures like streamers and plumes and follow them to their origins on the solar disk.

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REFERENCES


