A SOHO/CDS OBSERVATION OF A MACROSPICULE IN THE SOUTH CORONAL HOLE

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ABSTRACT

We report preliminary results of an observation made in March 1998 using the Coronal Diagnostic Spectrometer (CDS) on SOHO. The data covers a region of 4 x 4 arcmin, extending from the limb southwards at the meridian, and includes a macrospicule. An estimate of the outflow velocity in this feature has been made. Densities, temperatures and abundances using both line-ratio and differential emission measure techniques, have been obtained.

Key words: Macrospicule; coronal hole

1. INTRODUCTION

EUV macrospicules are seen as columns of chromospheric material extending above the solar limb, into the corona. They are found in coronal holes, with typical dimensions of 5-15'' in diameter and 5-50'' in length, and lifetimes of about 4-45 min (Dere et al. 1989, Bohlin et al. 1975). Occasionally arch-like structures at their base have been observed, which evolve into the shape of a spike after the expulsion of material (Karovska & Habbal 1994, Georgalikis et al. 1999). This kind of evolution has also been observed in radio wavelengths (Habbal et al. 1991).

Dynamical studies have found outward velocities of 10-200 Km/s (Bohlin et al. 1975, Dere et al. 1989, Karovska & Habbal 1994). Doppler shift studies have revealed evidence of blue and red-shifted components, corresponding to flows of up to 100 km/s, either side of the brightest central part of the feature, suggesting the presence of rotating plasma (Pike & Harrison 1997, Pike & Mason 1998).

EUV macrospicules have also been found to have, in most cases, an Hα counterpart, while the converse is less common. Several authors have addressed this topic, finding similar behaviour in both the Hα and the EUV forms (Moore et al. 1977, Wang 1998, Georgalikas et al. 1999). However, the relationship between the two is still not clear.

Here preliminary results are presented of observations which show the evolution of a macrospicule seen by CDS in the south polar coronal hole. Velocity, plasma density, temperature and abundance are determined.

2. THE DATA

The observations, made in March 1998, were rasters of 120'' x 150'' centred just above the solar limb at the south pole. Three successive rasters were carried out in the same location (Figure 1, white square), each taking about 2 hours. The first of these shows (see Figure 2) a macrospicule that extends up to 70'' from the solar limb with a width of ~12'' (3 pixels in E-W direction). This feature is clearly visible in chromospheric and transition region lines. The following two rasters do not show any sign of the feature, so spectra from these were averaged to provide a 'background' which was subtracted from the pixels containing the macrospicule in the first observation. In Figure 2, monochromatic images of the raster show the range of temperature where the macrospicule is visible.

Each raster is made up of a sequence of 30 exposures, each of 160 sec, where the slit is scanned from West to East. A further time delay between exposures results in an interval of about 270 sec between successive positions of the slit. This means that there are both spatial and temporal variations between adjacent slit images.

The following analysis was done using data from the three exposures where the feature mainly is evident. These will be referred to as columns 4-6, corresponding to the three pixel positions, numbered from east to west, centered near solar X = -40''.

3. MACROSPICULE EVOLUTION AND VELOCITY

Figure 3 shows the profiles of fitted intensity vs. distance from the sun centre, along the ordinate (N-S direction), for OV (629.7 Å), Mg IX (368.1 Å) and Mg X (624.9 Å) lines, after subtraction of the background emission. The resulting emission is therefore due almost solely to the macrospicule material. Moving from column 6 (Figure 3c) to 4 (Figure 3a), in the O V profiles, we can see the evolution of the macrospicule. The feature moves outward, reaching maximum brightness in column 5 (Figure 3b). In column 4 (Fig. 3a) the line is brightest at around 1010'' from sun-centre. This behaviour is common to all the
chromospheric and transition region lines, suggesting the expulsion of cool material from the upper chromosphere/transition region which then travels away from the Sun. The effect is somewhat different in the coronal lines (Mg IX, Mg X). A possible explanation of this is that the coronal plasma is being propelled further out, in front of the lower temperature material.

The average radial velocity of the plasma has been estimated in two different ways. An uncertainty of 20 km/s, corresponding to two spatial pixels, has been assumed.

The points where the O V intensity drops close to zero are at the distances of 1030, 1061 and 1081 arcsec for the columns 5, 4 and 4 respectively. This suggests that the velocity is decreasing with time. The time delay between the observation of two successive columns is about 271 s, and assuming that the motion is uniform across the width of the feature, velocities of ≈ 80 and 50 km/s are obtained between columns 6/5 and columns 5/4, respectively.

The small peak observed in column 4 is interpreted as the "tail" of the ejected material. The fact that this is not seen in the previous exposure (column 5) suggests a lower velocity limit to the velocity of the latter part of the macrospicule material of about 50 km/s. This is derived considering that it has travelled, at least, for about 20 arcsec.

Fig. 4 shows the position of the fitted O V line vs. distance for column 4 (top), 5 (middle) and 6 (bottom). Error bars are plotted only for the points where the signal is strong enough. Considering just these points, no significant transverse velocity is apparent. If the plasma is rotating, it is expected from the literature that the maximum components at the sides of the feature (Pike & Mason 1998). They have also reported that this velocity increases with distance. In the data presented here, the difference in the line

Figure 2. Series of images of the raster at different temperature showing the macrospicule position.

position between the two opposite columns (6 and 4) give a maximum relative velocity of ≈ 30 km/s.

A study of the FWHM variation on the same line has also been carried out, but again this has not revealed any double velocity component which might indicate a Doppler shift.

4. SPECTROSCOPIC DIAGNOSTIC

In order to work out average plasma properties of the macrospicule, the spectra from the 5 successive brightest pixels in column 5, apart from the first one, have been averaged. The first has been discarded because it is close to the limb where it is more prone to temporal plasma variations.

The average density and temperature in the macrospicule have been calculated using the line ratio technique.

4.1. Density

The ratio of lines of the same ion, and therefore emitted by the same plasma volume, is a function of the density only, under the conditions in the low corona. The ratio of the transition region lines O IV (625.8)/O IV (608.4) was used, giving a value of
$N_e = 5 \times 10^{10}$ cm$^{-3}$.

4.2. Relative abundances

Abundances were derived using the Differential Emission Measure (DEM) technique (Monsignori Fossi et al. 1994). The DEM is defined by

$$DEM = N_e N_H \frac{dh}{dT}$$

where $N_e$, $N_H$ are the electron and hydrogen densities, $h$ is the distance along the line of sight and $T$ is the temperature. The DEM was determined from the intensities using atomic physics data from the CHIANTI database (Dere et al. 1997), the density value obtained above, and assuming the ionization equilibrium of Arnaud and Raymond. Fig. 5 shows the DEM curve obtained for the macroscopic. The curve is well-defined at lower temperatures, where the lines are brightest, while at higher temperatures, the weak emission leads to a higher uncertainty. The maximum of the macroscopic emission can be found in the first peak at log $T = 5.4$ (2.5 × 10$^6$ K), while the others may be due to a remnant of the background emission. In particular, the peak at around log $T = 5.9$ is characteristic of plume emission (Del Zanna and Bromage 1999).

Relative abundances have been derived with respect to the photospheric value for oxygen (Grevesse et al. 1992).

Table 1 shows logarithmic values for the photospheric abundances together with those obtained for the macroscopic. As expected, these values are mostly close to photospheric. However, a significant depletion is found for magnesium (about 30%), and an increase for calcium (50%) and neon (20%) is also obtained.

<table>
<thead>
<tr>
<th>Element</th>
<th>Photosphere</th>
<th>Macroscopic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>8.87</td>
<td>8.87</td>
</tr>
<tr>
<td>Neon</td>
<td>8.08</td>
<td>8.16</td>
</tr>
<tr>
<td>Magnesium</td>
<td>7.58</td>
<td>7.40</td>
</tr>
<tr>
<td>Aluminium</td>
<td>6.47</td>
<td>6.47</td>
</tr>
<tr>
<td>Silicon</td>
<td>7.55</td>
<td>7.50</td>
</tr>
<tr>
<td>Calcium</td>
<td>6.36</td>
<td>6.70</td>
</tr>
<tr>
<td>Iron</td>
<td>7.51</td>
<td>7.50</td>
</tr>
</tbody>
</table>

4.3. Temperature

An average temperature was also obtained from the ratio of two lines from the same element but at different (close) stage of ionization, which is a function of temperature only. If the lines are not density-dependent and it is assumed that the two lines are emitted from the same, isothermal, plasma. The ratio O V 629.7 / O IV 608.4 was chosen, giving a value of $T = 2.25 \times 10^5$ K, similar to that obtained using the DEM.

5. CONCLUSION

Using off-limb SOHO/CDS data obtained in the south polar coronal hole, a study of a macroscopic has been carried out. Preliminary results indicate that the feature is composed of cool material that moves radially outward from the sun, with a velocity between about 50 and 100 km/s. No significant evidence of transverse motion has been found. An average density of $5 \times 10^{10}$ cm$^{-3}$ and a temperature of $2.25 \times 10^5$ K, have been determined for the macroscopic material using the line ratio technique. Temperature has also been determined using the DEM technique, giving a result which is consistent with this.

Relative element abundances have also been derived using the DEM technique. The values found are close to photospheric, although a departure for magnesium, neon and calcium indicate the need for further investigation.

REFERENCES

Del Zanna, G. and Bromage, B.J.I., Ibid.

Figure 3. Variation of the fitted line intensity (phot/cm²/s/str) with distance from the Sun, for Mg IX, Mg X, O V (see text). a. in column 4; b. in column 5; c in column 6.
Figure 4. Variation of the O V position as function of distance. Top: column 4; middle: column 5; bottom: column 6. Error bars are plotted for the points where the signal is significant.

Figure 5. Log DEM curve vs. log T. The first peak (log T = 5.4) corresponds to the macroscopic temperature.