SIGNATURES OF CORONAL HOLE SPECTRA BETWEEN 660 Å AND 1460 Å MEASURED WITH SUMER ON SOHO

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Abstract. Spectra of the northern polar coronal hole measured with the SUMER spectrometer on SOHO on 25 October 1996 are analyzed. We present spectra taken at locations on the solar disk where part of the spectrometer slit intersects a polar coronal hole region and an area of brighter emission from outside of the coronal hole area. By comparing the line intensities between the parts of the spectrum taken inside the "dark" area of the coronal holes and the brighter regions, we work out the signatures of the specific coronal hole in the chromosphere, transition region and lower corona. We find that emissions of neutral atom lines, of which there are many in the spectrum of SUMER, show no difference between the coronal hole and the bright boundary areas, whereas all ionized species show strong intensity enhancements, including the continuum emissions of carbon and hydrogen. These enhancements are larger than in normal quiet Sun areas.

1. Introduction

With the SUMER spectrometer on SOHO a spectral atlas of the full spectral range of the instrument is performed regularly in quiet Sun areas on the solar disk. More rarely such an atlas has been measured at coronal hole locations. While coronal holes observed on the solar disk show very clear intensity deficiencies in coronal emission lines, the signatures in the transition region and chromosphere are less significant and less well known. The SUMER spectrometer covers the spectral range of most chromospheric and transition region lines, as well as the lines from the lower corona. In search of signatures in the spectral emission from the base of the coronal holes, we have analyzed SUMER spectra in the spectral range from 660 Å to 1460 Å at locations on the solar disk where the spectrometer slit intersects areas with a clear deficiency of coronal emission, identified as coronal holes in the SUMER spectra in the emission of the Ne VIII lines at 770 Å and 780 Å and by comparison with images of the Fe XII window at 195 Å of the Extreme Ultraviolet Imaging Telescope (EIT) on SOHO. On 25 October 1996 the northern polar coronal hole was inclined towards the Earth. Bright emission at 195 Å extended across the coronal hole from its boundaries and was probably caused by the polar crown filament present in the field-of-view at that time. A SUMER spectral atlas was acquired with the spectrometer slit extending across the coronal hole and part of it outside the hole.

2. Data Acquisition and Reduction

The SUMER spectral atlas was acquired with the $1'' \times 300''$ slit crossing the northern polar coronal hole from the limb to the hole boundary. The data consist of

Space Science Reviews **87**: 299–302, 1999.

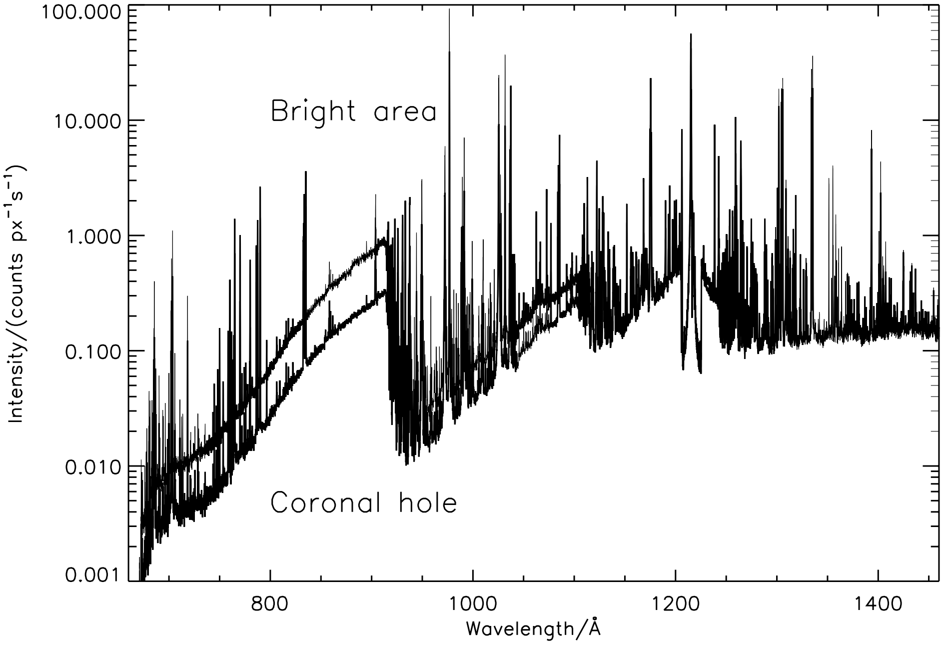

Figure 1. SUMER spectra of the polar coronal hole and the brighter boundary on 25 October 1996. Note the effect of the attenuator at the Lyman-α line.

60 exposures of 5 minutes each with overlapping wavelength ranges to cover the whole spectral range from 660 Å to 1460 Å in first order using the B-Detector. Thus, the time required to record the whole spectrum was 5 hours. The position of the slit was selected in such a way as to include some brighter emission from the coronal hole boundary. The EIT images of this day show that the coronal emission from the polar crown was brighter than “normal” quiet Sun emission. The SUMER data arrays were treated with standard routines for decompression, flat field correction, and geometrical distortion correction, before the entire spectrum was built up by concatenating appropriate sections from the KBr part of each exposure (see Wilhelm *et al.* 1997 for details). Then the part of the slit intersecting the coronal hole was selected by identifying the typical deficiency in the intensity of the Ne VIII lines at 770 Å and 780 Å. Next the intensity was averaged over 50″. For comparison, a similar section was selected from the part of the image outside the coronal hole. An overview of the full spectrum is given in Figure 1. By comparing the emission from two sections not far apart along the slit, we minimize the influence of the center-to-limb differences. Line identification and wavelength calibration could be done automatically by reference to a comprehensive line list determined previously (Curdt *et al.* 1997).

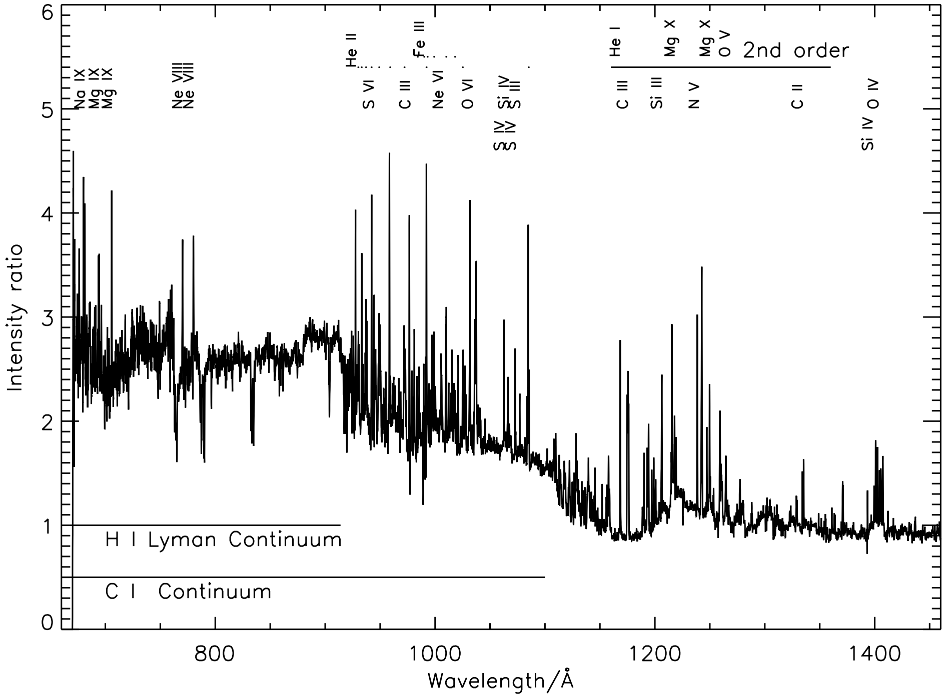

Figure 2. Ratio of the bright emission divided by the coronal hole spectra shown in Figure 1.

3. Results and Discussion

In Figure 1 we show the spectra of the bright area and the polar coronal hole superimposed, not converted to radiometric units for this purpose. At first sight, there are only small differences between both spectra except for the generally lower emission in the coronal hole. This distinction seems to be more pronounced in the Lyman continuum emission below 912 Å than in the longer wavelength range. To work out more clearly the signatures of the coronal hole spectrum, we simply took the ratio of both spectra. Since both spectra have been produced in exactly the same way, we have no shifts (other than of solar origin) between the two which could reduce the correlation and, thus, adversely affect their ratio.

In Figure 2 we show the ratio of the bright emission divided by the coronal hole spectrum. This simple treatment gives some striking results. First, many of the several hundred lines of the SUMER spectrum disappear in this ratio spectrum. Upon closer inspection, we see that almost all of the neutral lines give a ratio close to unity. Second, the ratio of the spectra shows a step at the edge of the H I Lyman continuum and another step at the edge of the C I continuum. At longer wavelengths, the ratio of the continuum is close to unity. Third, pronounced intensity enhancements in the bright areas are found in almost every line of ionized species with ratios ranging from 1.7 up to 5. Pronounced differences between the coronal hole and the bright area spectra are seen in the lines of the He II Balmer series. The lines showing enhancements in the coronal hole boundary area are, together with the measured ratios: He I λ584: 3.0; Mg X λ609, 624: 2.4; O V λ629: 2.2; Mg IX λ694, 706: 4.7; Ne VIII λ770, 780: 3.5; He II λ928, 930, 933, 937, 942, 949, 959, 972, 992, 1025, 1085: 2 - 5; S VI λ933, 944: 4.0; C III λ977: 4.5; Fe III λ981, 984, 986, 990, 991, 993, 997, 999, 1010, 1017, 1018: 3.5; N III λ990: 3.5; Ne VI λ1006, 1010: 3.0; O VI 1032, 1037: 4.0; S IV λ1063, 1073: 3.3; Si IV λ1067: 3.0; S III λ1077: 2.8; N II λ1084: 3.0; C III λ1175: 2.5; Si III λ1206: 2.5; N V λ1238, 1242: 3.5; C II λ1334, 1335: 1.8; O IV λ1401, 1404: 1.8; Si IV λ1393, 1402: 1.7. Since the compensation for the solar rotation was not invoked during this measurement, a change of solar conditions during the five hour period cannot be excluded. But the ratios we derive are measured strictly simultaneously, and the smooth ratio of the continuum and the ratio of all of the neutral lines above 1200 Å being precisely unity provides evidence that no dramatic changes occurred. The intensity ratios found here are larger than those of normal quiet Sun and coronal hole ratios as reported by Stucki *et al.* (1999), Lemaire *et al.* (1999), and Dammasch *et al.* (1999). Thus we conclude that the bright emission related to the coronal hole boundary is not identical with the normal quiet Sun spectrum but rather influenced by the polar crown filament. Further studies are necessary to characterize these differences.

Acknowledgements

The SUMER project is financially supported by DLR, CNES, NASA, and the PRODEX program (Swiss contribution).

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