THE FINE SCALE STRUCTURE OF THE SOLAR LIMB IN A CORONAL HOLE

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Abstract

Using simultaneous multiwavelength observations made with the Extreme Ultraviolet Spectrometer of the Harvard experiment on Skylab, and an image enhancement algorithm we explore the fine scale structure of the solar limb in a coronal hole at temperatures ranging from 10^3 to 10^6 K.

1. Introduction

Simultaneous multiwavelength observations of the solar corona were carried out using the Harvard EUV spectroheliometer on Skylab, 1973-74. The data were recorded through the same instrumental slit thus removing any ambiguity regarding spatial correspondence between the different wavelengths. The instrumental resolution is 5"x 5" and the temporal resolution is 1 to 5.5 min. The data cover a wavelength range that spans the chromosphere into the corona. The Skylab data used in this study consist of solar limb observations of the quiet Sun in a coronal hole. A series of 21 images, spanning an interval of 40 minutes, was recorded at the north pole on 1973 December 11.

The Skylab images show many complex superposed structures at different spatial scales. Figure 1 shows Skylab images recorded at 23h 30m UT in three spectral lines: Mg X, O VI, and C III. The pixel size is 2.5" x 5". The choice of grey levels is such that the darkest corresponds to the most intense emission in any given spectral line. The region below the limb is overexposed in order to show the faint structures above the limb. The observations were made through the same instrumental slit, hence no ambiguity exists regarding the spatial correspondence between all three wavelengths. While the solar limb is not defined in the Mg X line, it appears as a jagged boundary in O VI and C III. The bright features seen in Mg X are bright points with extensions above the limb forming polar plumes. There is diffuse O VI emission associated with the plumes. The most noticeable large scale structures above the

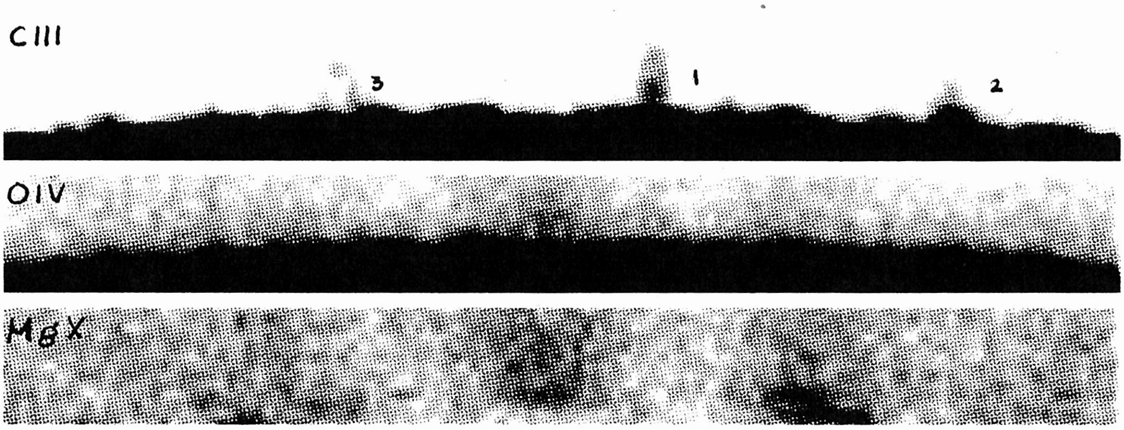

Fig. 1. EUV spectroheliograms of a 300" x 65" area of a coronal hole at North pole recorded on December 11, 1973 at 23:30 UT in C III, OVI, and Mg X.

limb in C III are the macrospicules, which do not coincide spatially with the polar plumes observed in Mg X or O VI.

The characteristics of the smallest spatial scale structures and their distribution cannot be readily determined from Skylab images, either because of the limited resolution, or because of the high dynamic range between small-scale and large-scale structures. Detailed study of the small spatial scale structures is extremely important for a better understanding of the characteristics of the small-scale magnetic field, and could provide new empirical constraints on coronal heating mechanisms.

To improve the resolution and/or to reduce the dynamic range, we applied our version of an image enhancement algorithm originally developed by Koutchmy et al (1988). This algorithm (IEA) detects the location where a significant change in grey level occurs in the image. It basically calculates the maximum of the differences of the second derivatives of the intensity in 8 directions. Several levels of block-average smoothing may be applied prior to the derivative, and the results may be blended to emphasize features at various scales.

In this article, we present the results obtained using IEA on a time series of multi-wavelength Skylab images of a section of the solar limb in a coronal hole.

2. Results

The lower panel in Figure 2 shows the C III image from Figure 1 after the application of the IEA. When compared to the unprocessed data (upper pannel), the processed image uncovers a fine structure at the limb, consisting of low-lying arch-like features, and filamentary structures extending from the solar limb into the corona. The filamentary structures are often twisted. Structures with similar characteristics have been detected in solar eclipse images (see Koutchmy, 1988 and the references therein). The thin (5" diameter or smaller) structures observed at the limb in the processed images, reminiscent of spicules, were lost in the jagged limb in the unprocessed images. The lower portion of these structures (up to 15000-20000 Km above the limb) is brighter than their upper portion, and is often cospatial at lower

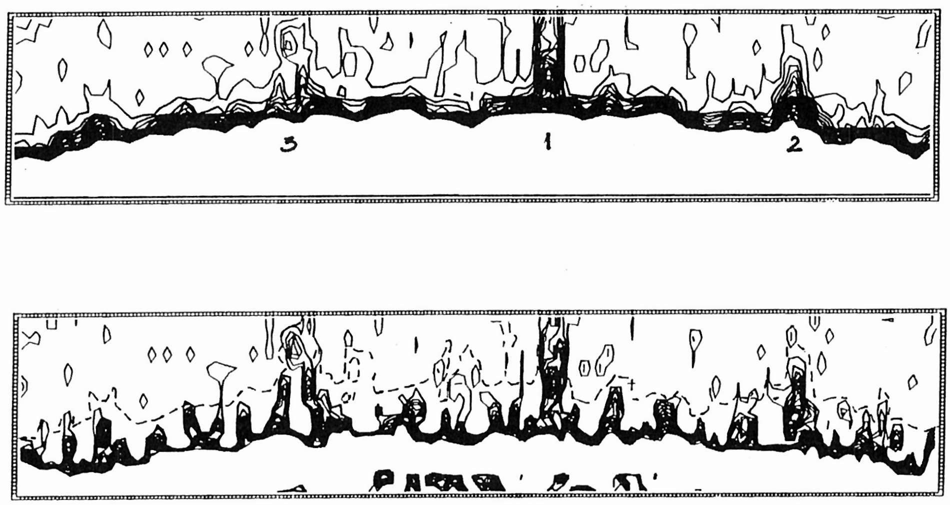

Fig. 2. Observations of the solar limb at North pole recorded on December 11, 1973 at 23:30 UT in C III. Upper panel - unprocessed image. Lower panel - same image after being processed using IEA.

temperatures, in Ly α, C II, C III, and O IV. In some regions, the brightness of several spicules is enhanced and they form macrospicules.

We find similar fine structures in the images recorded in all other spectral lines. Using Fourier analysis, we estimated the characteristic spatial separation of the filamentary structures of about 10"-15". The characteristic spatial scale is similar at all wavelengths. However, we find that O VI and Mg X emission is not cospatial with the emission at lower temperatures, clearly indicating the presence of different temperature plasmas in the field of view.

A series of images recorded on 1973 December 11 approximately every 2 minutes from 22:56 to 23:35 UT shows continuous interaction between the filamentary structures. The time sequence of images recorded simultaneously at six wavelengths show the different temperature plasmas coexist in the field of view, although the dynamic behavior of each seems to be quite different. The movie made of these images shows that the spicule-like structures are rising and falling like fountain jets in a way similar to the H α spicules (Suematsu at al 1993). The mean lifetime of individual spicule-like structures is several minutes. Often, the spicule-like structures connect and form short-lived small arches. Occasionally arch-like structure formation is followed by expulsion of material. The most dynamic events occur at the location of the macrospicules. Such events could be a reflection of the dynamic nature of the coronal magnetic field.

Spectroheliograms recorded from 22:56 to 23:16 UT show the evolution of a dynamic event in the macrospicule located in the central region of the Figure 1 (macrospicule 1). Initially, several bright spicule-like structures connect and the plasma is ejected at the top of the arch. The ejected matter extends rapidly and its brightest portion reaches a height of at least 30000 Km above the limb. At 23:07 UT, a pinching off occurs in the lower portion of the structure (Figure 3 a), and at 23:08 UT the structure completely detaches itself from the limb (Figure 3 b). A few minutes later, the matter descends. Because of the limited field of view we could not determine if any plasma actually escaped in this case. However, the movie does show that on several occasions blobs of plasma actually separate from the macrospicules and escape. For example, in the dynamic event occurring in the macrospicule 2, the plasma is

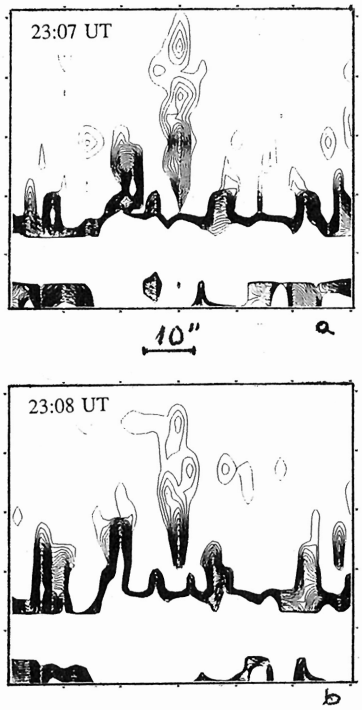

Fig. 3. Two IEA images in C III showing a dynamic event occurring in the macrospicule located in the central region of Figure 1.

ejected at an angle to the radial direction and actually returns few minutes later in a location several arcseconds further from its origin.

The time resolution in this series of images is not sufficient for a detailed study of these transient phenomena. Further studies using images with better spatial and temporal resolution could provide essential information on the energy input to the solar corona resulting from this dynamic behavior, its relationship to the coronal magnetic field, and its contribution to the heating and acceleration of the solar wind.

References

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