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STRUCTURE AND DYNAMICS OF THE CORONA SURROUNDING AN ERUPTIVE PROMINENCE

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ABSTRACT

We report on the 1997 December 14 prominence eruption event that was accompanied by eruptive signatures in X-rays, EUV and white light: coronal dimming, X-ray arcade formation , X-ray brightenings, EUV eruption, and a white light CME. The data used were obtained by the Nobeyama Radioheliograph, Yohkoh Soft X-ray Telescope (SXT) and SOHO/LASCO and EIT. We identified various substructures of the eruption and their inter-relationships. We found that the pre-disruption swelling of the equatorial streamer was caused by the outward displacement of the coronal material around the prominence location. The dynamical behaviors of the CME and the accompanying eruptive prominence seem to be very different.

INTRODUCTION

After the advent of the Yohkoh and SOHO missions and the Nobeyama radioheliograph, we are able to image plasmas at widely different temperature regimes to obtain information on the near surface manifestations of CMEs (Gopalswamy et al, 1996; 1997a,b; Hudson and Webb, 1997; Gopalswamy and Hanaoka, 1998). In particular, microwave emission from prominences associated with CMEs can be imaged over long stretches of time to study the physical processes associated with the eruptive events (Hanaoka et al 1994; Gopalswamy et al 1997a). A study of the structure and evolution of prominences using radio, X-ray and EUV observations is also important to characterize the pre-eruption phase of CMEs. White light coronagraphic observations, taken alone, paint only a simplistic picture of CMEs; when coupled with data at other wavelengths, we can obtain detailed information on the origin and evolution of CMEs. The simple fact that a CME contains substructures with temperatures that can vary over three orders of magnitude demands a multi-wavelength study. The prominence core has chromospheric temperatures, while the X-ray arcade formation can be at several MK. In this paper, we report preliminary results of our investigation of the 1997 December 14 prominence eruption event.

OBSERVATIONAL RESULTS

The Prominence Eruption: The 1997 December 14 prominence eruption was observed by the Nobeyama Radioheliograph above the east limb starting at about 00:30 UT. In the pre-eruption state, the prominence was sitting at a radial height of 0.25 $R_\odot$, located at the southern base of the bright equatorial streamer. Yohkoh/SXT observations (see Figure 1) show an X-ray structure (December 13, 22:42 UT) overlying the prominence (December 14, 00:00 UT). Part of this structure can also be seen on the disk. This structure disrupted suddenly at about 00:38 UT on December 14 and the prominence erupted, moving radially outward. The prominence was accelerating at the rate of 5 m s^{-2} and reached a speed of about 44 km s^{-1} when it left the field of view of the Nobeyama radioheliograph.

Figure 1: Yohkoh/SXT image showing the pre-eruption X-ray structure (A) overlying the prominence (contour) observed at 17 GHz. The scale of the image is marked (5'). North is to the top and east is to the left.

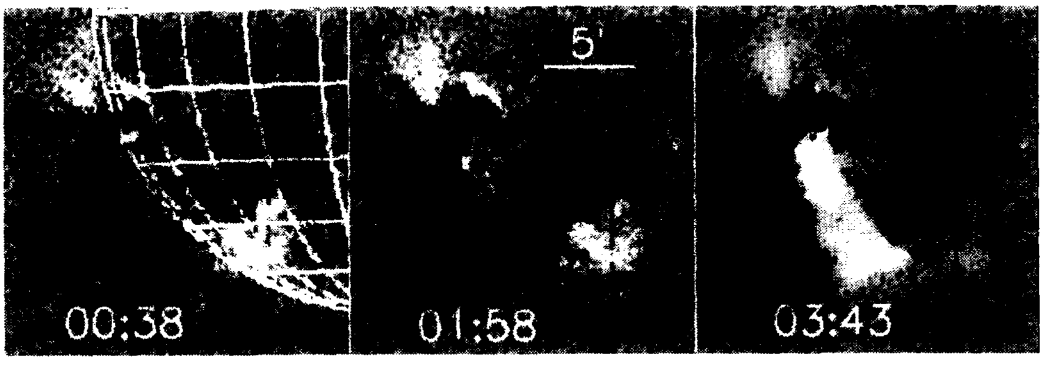

Figure 2: Yohkoh/SXT difference images showing coronal dimming and brightenings associated with the 1997 December 14 prominence eruption. The 03:43 image shows arcade formation. Heliographic grid (spacing 15°.) is superposed on the image at 00:38 UT. The image at December 13, 22:42 UT has been subtracted from all the images. The dark (bright) region corresponds to depletion (increase) of X-ray emitting material.

X-ray and EUV Structures: The disruption of structure A (Figure 1) around 00:38 UT on December 14 was also accompanied by significant changes in the plage regions B and C, including the fading of a nonradial structure pointing northward from above B. The disruption of the X-ray structures can be seen better in the difference images of Figure 2, which reveals the following: (i) coronal dimming on the disk and above the limb; (ii) X-ray brightenings at the outskirts of the dimming; and (iii) arcade formation at the bottom of the dimming region (see the 03:43 UT image). Note that the overall extent of the disturbance associated with the eruption is about 60° in position angle. Coronal dimming is thought to be one of the X-ray signatures of CMEs (Hudson et al, 1996). Gopalswamy and Hanaoka (1998) demonstrated that the X-ray dimming indeed takes place in a region overlying the eruptive prominence and consists of a comparable amount of coronal material typically estimated from white light CMEs. The location of the prominence (P) with respect to the dimming region (XD) is shown in Figure 3. It is worth noting that there was a very weak dimming signature (marked XD? in Figure 3) at the location corresponding to the northern base of the equatorial streamer. We need to do more work before confirming the possible activity at the latter location. When we analyzed the EUV data from SOHO/EIT at 195 Å we found excess emission overlying the X-ray dimming and the prominence. This suggests that the X-ray dimming indeed represents outward displacement of material from the initial location.

Streamer Swelling and CME: The prominence eruption was associated with a CME observed by the LASCO C2 and C3 coronagraphs on board SOHO. The overall scenario of the eruption is similar to the one reported by Gopalswamy and Hanaoka (1998), but the present event had additional information from

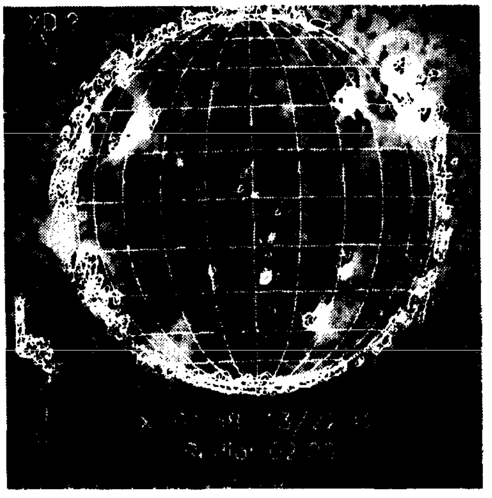

Figure 3: Overlay of the SXT difference image and the 17 GHz prominence contours for 02:00 UT. XD is the X-ray dimming. There may be also slight dimming in the northern hemisphere (XD?) at the expected location of the northern end of the equatorial streamer base. The streamer swelling already started at a much larger height than where the prominence (P) height.

SOHO mission in white light and EUV wavelengths. During the disruption of the low-lying X-ray structures and the prominence eruption, the C2 coronagraph showed widening of the streamer base at its southern end starting 00:30 UT. The "swelling of the streamer" can be clearly seen in Figure 4. There was a data gap during 02:26 to 06:23 UT during which time the streamer disrupted and the leading edge of the CME moved to a height of $\sim$ 10 $R_{\odot}$. Based on the available images, the CME speed in the sky plane was estimated as 575 km s^{-1} (St Cyr, 1998 - private communication). The prominence speed, when extrapolated to the time of the CME observation (06:23 UT), was only 110 km s^{-1} (assuming constant acceleration) and therefore is expected to lag far behind (Gopalswamy et al, 1998) the CME.

DISCUSSION AND CONCLUSIONS

We were able to show that the streamer-swelling observed prior to its disruption is caused by the eruption of low-lying coronal structures observed in X-rays and EUV. In the present event, the streamer swelling was asymmetrical, located near the southern base of the equatorial streamer. By combining radio, X-ray and EUV data we showed that the mass addition to the streamer takes place from dynamical phenomena close to the solar surface. Once the CME is formed, it appears that the entire equatorial streamer disrupted and participated in the CME. The LASCO CME was essentially moving eastward (position angle (PA) $\sim$ 90°). The direction of prominence motion was at a PA of $\sim$ 130°. The prominence occupied a position angle range of 30°. while the overall activity observed in X-rays extended to a range of $\sim$ 60°. The equatorial streamer that disrupted had an extension almost twice that of the X-ray activity. The streamer swelling was observed as early as 02:03 UT at a height of $\sim$ 2 $R_{\odot}$ when the prominence was still at a height less than 1.5 $R_{\odot}$. This suggests that an extended corona participated in the eruption even in the radial direction. The identification of mass addition to the streamer has important implications to model calculations on CMEs. For instance, we can determine the amount of mass added to the streamer from the X-ray and EUV observations which can serve as an important input to the stability analysis of streamers (see e.g., Wolfson and Gold, 1985). Another related question is whether the field lines overlying the prominence erupted or not. Although it is difficult to tell what exactly is happening from the 2-d data, there are some indications that the field lines indeed open up. This is clear from the expansion of the dimming region in the southeast direction (see the image at 02:03 UT in Figure 4). How these field lines relate to the streamer field lines is not clear. Opening of the X-ray structures would be consistent with the classical CSHKP model. A detailed investigation including extreme ultraviolet data is underway.

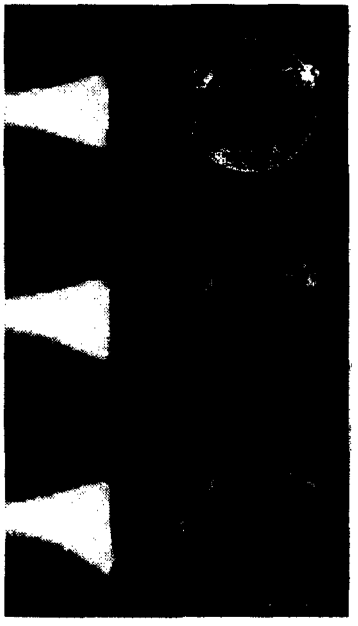

Figure 4: Overlay of LASCO/C2 images of the equatorial streamer and the Yohkoh/SXT difference images showing coronal dimming. The arrow points to the streamer swelling towards the southern end. The broader end of the streamer corresponds to the C2 occulting disk. Note that the streamer widening takes place radially above the X-ray dimming. Some apparent excess/deficit regions on the disk result from solar rotation. North is to the top and east is to the left.

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