HOT CORES IN CORONAL FILAMENT CAVITIES

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ABSTRACT

Filaments represent cold intrusions in the corona, embedded in magnetic configurations termed "filament cavities." Such cavities may occur without actually containing prominence material. A cavity then may erupt, leading to a coronal mass ejection (CME). Studies of *Yohkoh* soft X-ray images have previously shown that such eruptions may contain elongated high-temperature regions closely aligned with the Hα filament material. We report in this paper multi-wavelength observations of an extremely stable filament cavity, observed by *Yohkoh* and SOHO during July-September 1997. Hot multi-thermal structures persistently occupied the core of this large-scale polar-crown cavity.

INTRODUCTION

The existence of an Hα prominence in the corona poses interesting theoretical problems: how can cool plasma survive in the hot corona? And what keeps it from falling back down to the chromosphere? We conventionally solve these problems by appealing to the anisotropy of heat conduction in magnetized medium, and by postulating "dipped" field lines that can support the cool material against gravity.

Filaments occur in coronal filament cavities (*e.g.* Engvold, 1989), detectable both in chromospheric and coronal structures. A prominence tends to form along the axis of one of these elongated structures. The term "cavity" refers to the relative vacuum within these structures, as inferred from the reduced signal seen in Thomson-scattered light (K-corona) as seen in a corongraph.

This paper reports novel observations of filament cavities that reveal the presence of hot cores (Hudson *et al.*, 1998). The inference of temperature from the broad-band SXT measurements is difficult, and the present paper notes that the SOHO EIT images formed at lower temperatures support the conclusion that the core sources are hot, rather than merely denser than their surroundings. We note that both SXT and EIT images frequently show high-temperature structures associated with filaments (*e.g.* Solberg, 1997), but often these features accompany eruptions, when one would expect transient heating, and none reported to date have had the obvious quiescence of the structure reported in this paper.

SXT AND EIT IMAGE MORPHOLOGY

The best example of the "hot core" phenomenon to date, that reported by Hudson *et al.* (1998), appeared at several limb passages centered on July 3, 1996 (W limb). Figure 1 shows the structure seen then in the two SXT "thin" filters, which are sensitive primarily to plasma near 2×10^6 K. The cavity appears on the limb as a void, surrounded by hot walls and containing a core brighter than its surrounding cavity volume. This pattern strongly resembles that of a normal streamer base seen by coronagraphic white-light images. We write the excess brightness S approximately as $\Delta \mathrm{S} \sim n^2 V f(T) \times L$, with L the integration path length, n the density, and T the temperature. At these temperatures the detector response $f(T)$ rises steeply (Tsuneta *et al.*, 1991), so that a brighter source suggests a higher temperature. But excess emission could also come from higher density and/or longer integration path length. Because we do not know the geometry, we cannot

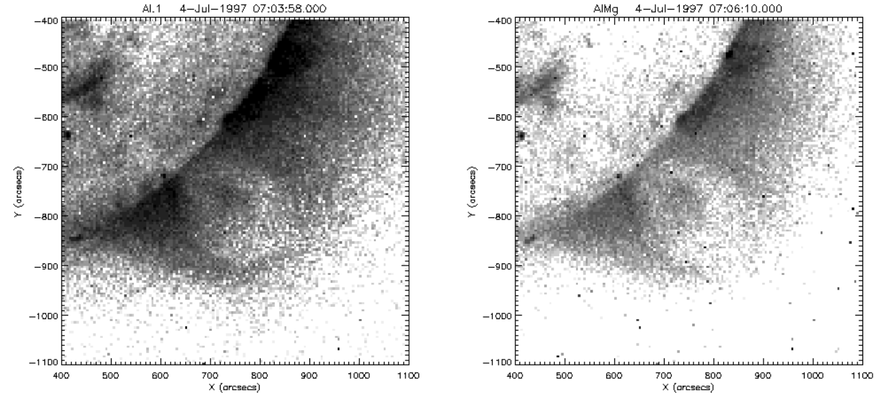

Figure 1. Observation at the SW solar limb on July 3, 1996, from the soft X-ray telescope SXT aboard *Yohkoh*. Left: Al.1 filter; right: AlMg filter. These (negative) images show a filament cavity seen end-on, revealing the presence of a relatively bright X-ray source on the axis of the cavity and above the filament itself.

be sure about these factors, especially for a newly-discovered coronal feature. Accordingly the confirmation of an elevated temperature in the "bright" core becomes important, and the SOHO EIT data provide an excellent means for doing this.

In Figure 2 we show individual images from the four EIT channels: He II 304 Å, Fe IX/X 171 Å; Fe XII 195 Å; and Fe XIV 284 Å, covering a temperature range extending from near SXT's down to the chromosphere/low transition region.

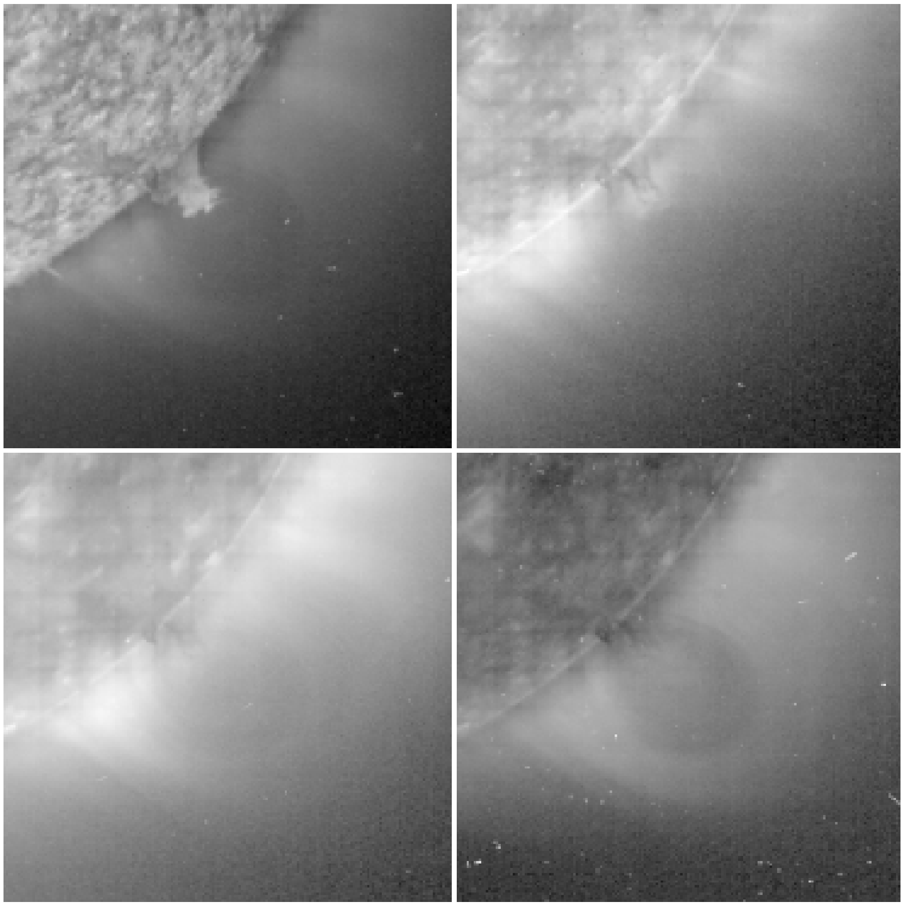

Figure 2. Contemporaneous SOHO EIT observations in the four EIT passbands: upper left, He II 304 Å; upper right, Fe IX/X 171 Å; lower left, Fe XII 195 Å; and lower right, Fe XIV 284 Å. The high-temperature bands confirm the presence of the bright core, and the He II 304 Å band shows that the core tends to envelop the cold material of the prominence embedded in the cavity.

The Fe XIV and Fe XII channels, emitted from 1-2 $\times 10^6$ K, show the feature. The He II channel, on the other hand, shows emission from below the X-ray source; we identify this with cold prominence material. The overall impression from this set of snapshots is that of cold material embedded in, and below, a hotter coronal source.

Because of the long life of this structure (more than one solar rotation), we have abundant data on its time variability. This snapshot mainly serves to confirm the *Yohkoh* SXT view of the structure of the features.

INTERPRETATION

We envision a bundle of intertwined magnetic elements supporting the filament material; the branches of these magnetic elements rising to higher altitudes contains a sufficiently higher pressure to become visible in soft X-rays (*cf.* Antiochos and Klimchuk, 1991).. The mainly EW orientation helps to make the hot core feature visible in projection at the limb, but the observation at the limb makes it difficult for us to draw quantitative conclusions about the spatial relationship between the faint hot features and the prominence, except for the general impression that the hotter parts of the structure appear at higher altitudes and with more latitudinal spread.

The cavity itself, according to our interpretation, consists of an elongated magnetic flux domain separated from the overlying hot corona. Because the corona must be largely force-free in this region, the magnetic pressure inside the cavity must be at least comparable to that outside. But the darkness of the cavity in soft X-rays strongly suggests that the internal gas pressure is lower. We suggest that this implies a lower volumetric heating rate for this coronal magnetic domain, apparently dependent more upon the structure of the magnetic field rather than the magnitude of **B** itself.

The magnetic separator surface between these two domains, based upon these observations, can persist stably for long periods of time without catastrophic reconnection processes. Because CMEs frequently appear to come from destabilized helmet streamers (*e.g.* Hundhausen, 1998), we speculate that the restructuring that must occur during a CME launch may disrupt this separator surface.

CONCLUSIONS

The comparison of SXT and EIT data confirms the presence of material with higher temperatures in the cores of filament cavities. The images are consistent with the presence of similar temperatures in the hot cores and in the normal corona surrounding the filament cavity itself; the enhanced X-ray surface brightness results from temperature, not only density and/or line-of-sight length. We suggest that in the material in the cavity in fact has a lower gas pressure resulting from lower temperature AND density, but this is a much more difficult point observationally, since it requires accurate knowledge of the 3D structure under observation.

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