SOHO EIT OBSERVATIONS OF CORONAL HOLES

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1. ABSTRACT

We present a study of coronal holes (not including the polar holes) using observations from SOHO EIT during 1996 and 1997. EIT obtains daily full disk observations of the Sun at spectral emission lines from Fe IX,X (171 Å), Fe XII (195 Å), Fe XV (284 Å), and He II (304 Å). Previous studies (mainly He I 10830 Å and ground based magnetograms) have demonstrated the role that bipolar magnetic regions play in the evolution and rotation rates of recurrent coronal holes. We further the correlation between coronal holes and bipolar fields by presenting definitive symbiotic relationships between coronal holes and active regions. Comparisons of EUV observations and magnetograms plus potential field extrapolations are shown. We also investigate the nature of formation of coronal holes in the quiet sun, and find that there are distinct active longitudes that produce coronal holes.

2. INTRODUCTION

The Extreme Ultraviolet Imaging Telescope (EIT) has made daily full disk observations of the Sun at spectral emission lines from Fe IX,X (171 Å), Fe XII (195 Å), Fe XV (284 Å), and He II (304 Å). Coronal holes appear as dark features in these images. They are regions of low temperature and plasma density, and are known to be located at the foot-points of open field regions (Zhao and Hoeksema, 1995). They are also regions of weak chromospheric emission.

This study is focusing on low and mid latitude coronal holes in 1996 and 1997, i.e. near solar minimum. The quiet sun affords an opportunity to assess the connections between coronal holes and active regions, as well as the evolution and formation of the holes, in a relatively uncomplicated corona.

Previous studies have demonstrated the role that bipolar magnetic regions play in the evolution and rotation rates of recurrent coronal holes, however, there has typically been some ambiguity due to the use of chromospheric data. Using ground based magnetograms and He I 10830 Å spectroheliograms, Sheely et al. (1978), demonstrated that coronal holes are characterized by their surrounding bipolar magnetic regions. They concluded that the emergence and diffusion of bipolar magnetic regions controls the birth and evolution of coronal holes. Zhao et al. (1999) investigated the morphology of a coronal hole boundary using data from the Michelson Doppler Imaging telescope (MDI) on board SOHO, and ground based He I 10830 Å observations, and concluded that the changing magnetic field played a part in determining the shape and rotation of the coronal hole.

In this preliminary study, we focus on presenting the relationship between the emergence of disk coronal holes to the presence of active regions, and we explore the existence of active longitudes that result in coronal hole formation. In particular, we investigate whether all disk coronal holes are associated with active region complexes. The association is clearly seen in movies (although it is more difficult to demonstrate here), and future work using magnetic field extrapolations will be used to confirm the visual appearance.

3. Observations

First results from the Extreme-ultraviolet Imaging Telescope (EIT) are described by Moses et al. (1997). A complete description of instrument can be found in Delaboudinière et al. (1995). EIT's normal incidence and multilayer-coated optic mirrors provide a sensitive temperature diagnostic of regions that are dominated by EUV emission lines. Nice examples of full disk images for each bandpass would be from August 27, 1996 (figure 1). The "elephants trunk" coronal hole is quite apparent in all four bands.

We have selected daily images taken in Fe XII (195 Å) from the relatively quiet sun period of January 1996 to December 1997. Use of Fe XII (with a peak formation temperature of 1.5 MK) allows a better determination of the coronal hole boundaries than previous chromospheric studies. Coronal holes tend to be best observed using the Fe XII channel in EIT images due to its slightly higher temperature than Fe IX,X and...
the contamination of the Fe XV channel with cooler lines. We analyzed the daily images for the presence of disk coronal holes, and selected a sub-set of images that are most visible.

We have examined in detail images for three representative days. For each day the EIT Fe XII image is viewed along with the corresponding MDI magnetogram and Kitt Peak He I 10830 Å. A comparison of these figures clearly shows the difficulties in using the ground based data as well as the heightened clarity of the hole boundaries in the EIT images. The magnetograms clearly show active region complexes. A more detailed examination of these does reveal a dominant polarity within the coronal hole boundary.

We analyzed approximately 15 coronal holes as seen in the Fe XII EIT images and created solar time maps (figures 2a,b show examples for 6 coronal holes) to assess the development of these features, both with respect to active regions, and on their own. Solar time maps illustrate the time evolution of features across solar rotation. For the duration of a half solar rotation, the feature of interest is extracted from a daily image of the whole sun. These extracted images are compiled in a horizontal strip so that the development and variations of the feature can be assessed. In this study we created time maps of the coronal holes and active regions and stacked them vertically so that their individual fluctuations, as well as fluctuations with respect to each other could be analyzed.

4. DISCUSSION

Preliminary observations uphold the notion that coronal holes and active regions adhere to a symbiotic relationship. Analysis of the daily images for the period of 1996 to 1997 show that each coronal hole is flanked by an active region or filamentary brightening. Initial analysis suggests that active regions tend to be magnetically associated with disk coronal holes. In order to evaluate this relationship, we compare magnetograms taken with MDI with the selected EIT images. The magnetograms show that coronal holes and active regions emerge from unipolar magnetic regions that border bipolar magnetic regions. As mentioned above the active regions are easily distinguished as bipolar regions while the coronal holes can be seen as unipolar regions. Examining time sequences of the coronal and magnetic data, it is clear all the coronal holes that appear in the EIT selected data set are magnetically related to nearby active regions.

During the quiet sun period of 1996 we found that there is an active longitude that produced all coronal holes and active regions. We measured the location of all the coronal holes seen by EIT in 1996 at the time of central meridian crossing, and found that the coronal holes appeared in a longitudinal corridor that was less than 36 degrees wide. The holes recurrent with slightly erratic rotational rates, suggesting that we might be observing holes that have dissipated and reformed, rather than a single constant hole. The location of formation was consistently within the given longitudinal corridor. The famous elephant’s trunk coronal hole that appeared in August of 1996 spanned virtually the entire length of the sun, and joined several existing coronal holes along the same longitude. It persisted for several months and began to break up in November. The dissipation of the elephant’s trunk coronal hole resulted in several smaller holes scattered across various regions. This event presaged a more active sun when coronal holes are seen to appear at numerous longitudes.

Parameters that we considered in our analysis of the coronal hole morphology included the average lifetime vs. the maximum area, the rates of increase and decrease in area, the rate of change of shape, and the rate of migration, if any migration was present. The average lifetime of the coronal holes was generally found to increase linearly with the maximum area. On the whole, the active regions tend to grow and slowly migrate away from the coronal holes. These parameters are still undergoing final analysis. Difficulties include projection effects and shadowing of the coronal hole by nearby “quiet sun” loops.

5. FUTURE WORK

This study presents very preliminary work on the study of coronal holes. We have very suggestive data of a symbiotic relationship between the coronal holes and nearby active regions. However, we need to obtain better comparisons with the underlying magnetic field to definitively quantify this relationship. We hope to obtain force free magnetic field extrapolations on days of particular interest to overlay with the EIT observations. This should enable us to relate the coronal hole characteristics to the magnetic field structure and polarity.

We are also interested in the finding of an active longitude that is responsible for the coronal holes seen during solar minimum. We will follow up on this lead to try and understand what mechanism(s) could be responsible for this.

Lastly, as we have obtained a catalog of coronal holes we will compare this with solar wind data.

6. REFERENCES


**Figure 1:** EIT Full Disk images, August 27, 1996. Fe IX, X 171 Å, Fe XII 195 Å, Fe XV 284 Å, He II 304 Å.

**Figure 2a:** Solar time maps.

**Figure 2b:** Solar time maps.