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The formation of an equatorial coronal hole

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Abstract. The formation of an equatorial coronal hole (CH) from 2006 January 9 to 12 was simultaneously observed by *GOES-12*/SXI, *SOHO*/EIT and *SOHO*/MDI instruments. The varieties of soft X-ray and EUV brightness, coronal temperature, and total magnetic flux in the CH were examined and compared with that of a quiet-sun (QS) region nearby. The following results are obtained. (1) A preexisting dark lane appeared on the location of the followed CH and was reinforced by three enhanced networks. (2) The CH gradually formed in about 81 hours and was predominated by positive magnetic flux. (3) During the formation, the soft X-ray and EUV brightness, coronal temperature, and total magnetic flux obviously decreased in the CH, but were almost no change in the QS region. The decrease of the total magnetic flux may be the result of magnetic reconnection between the open and closed magnetic lines, probably indicating the physical mechanism for the birth of the CH.

Keywords. Sun: corona, Sun:evolution, Sun: magnetic fields

1. Introduction

Coronal holes (CHs) are large-scale regions of considerably low density and temperature in the solar corona (Krieger *et al.* 1973). In soft X-ray (SXR) and EUV observations, they are identified as dark areas, and their magnetic fields are usually weak, unipolar and open (Joshi 2001). CHs are considered to have a strong association with the fast solar wind, which may induce geomagnetic storms on the Earth (Krieger *et al.* 1973). However, the concrete explanation of their formation and subsequent evolution is still ambiguous.

Until now, only a few works investigated the birth of a single CH. Solodyna *et al.* (1977) showed that a small equatorial CH was formed in less than 9.5 hours and accompanied by a 40% decrease of X-ray emission. However, no obvious change was detected in the photospheric magnetic field. Harvey & Sheeley (1979) then found that a CH rapidly formed in 1 day also without associated change in the photospheric magnetic field.

To unclose the nature of the CH formation, we analyze both the morphological and quantitative varieties of a single equatorial CH in its formation and compare with that of a nearby quiet sun (QS) region.

2. Observations

For the present work, the following data are used:

1. Full-disk longitudinal magnetograms from *SOHO*/MDI (Scherrer *et al.* 1995) with a 96-minute cadence and a pixel size of about 2″.

2. Full-disk EUV images from *SOHO*/EIT (Delaboudiniére *et al.* 1995). We primarily examined the data from Fe XII 195 Å and Fe IX/X 171 Å filters, whose ratio can obtain the temperature maps. The EIT obtained 195 Å images roughly every 12 minutes with a scale of 2.6″, but 171 Å images only once in 6 hours.

3. Full-disk CH SXR images from the *GOES-12*/SXI (Hill *et al.* 2005). The images cover a wavelength range of 6-65Å (0.9-2.4 MK), with a 6-hr cadence and a 5″ pixel size.

3. Results

The CH was formed from 2006 January 9 to 12 and centered at E47N02 (E05N02) on January 9 (12). Figure 1a and 1b show its appearance in full-disk MDI magnetogram and EIT 195 Å image when it was fully developed. It is clear that the CH (marked by curves) was a dark, extended region in 195 Å image and lay within a predominantly unipolar magnetic region with positive polarity. Noted that three enhanced networks (marked as R1, R2 and R3, respectively) were around the CH. Figure 1c and 1d display the formation process of the CH in EUV and SXR wavelengths, respectively. Before its formation, a dark lane (marked by the oblique white arrows) was identified on the location of the followed CH. Similar structure, also observed and called as separatrix by Solodyna *et al.* (1977), is thought to be the location of the footprints of open magnetic field lines and pre-existing structure to produce a CH. Then the CH gradually formed around the dark lane and reached its maximum area at about 18:47 UT on January 12.

Figure 2a presents the ratios of EUV brightness in the CH to that in the QS region. Since the formation was slow, the start and end times of the CH formation were difficult to determine only by vision. We thus set the time corresponding to the maximum value of the ratio, 10:00 UT on January 9, as the start time, and the time corresponding to the minimum value, 18:47 UT on January 12, as the end time. Based on the definitions, the formation experienced about 81 hours. Figure 2 also displays the time profiles of the SXR and EUV brightness, coronal temperature, and total magnetic flux in the CH and QS regions. During the whole CH formation, its mean SXR brightness had a relative decrease of 40%, the EUV brightness decreased from 480 to 80 counts pixel $^{-1}$, the temperature decreased about 0.14 MK, and the total magnetic flux decreased from 2.1×10^{21} MX to 1.4×10^{21} MX. By contrast, the SXR and EUV brightness were nearly stable in the QS region, the coronal temperature had a mean value, 1.15MK, and the total magnetic flux was stable at a level of 5.2×10^{21} MX. The decrease of the magnetic flux in the CH probably indicated that magnetic reconnection between open and closed magnetic fields may occur within the CH and represented a potential physical mechanism of the CH formation.

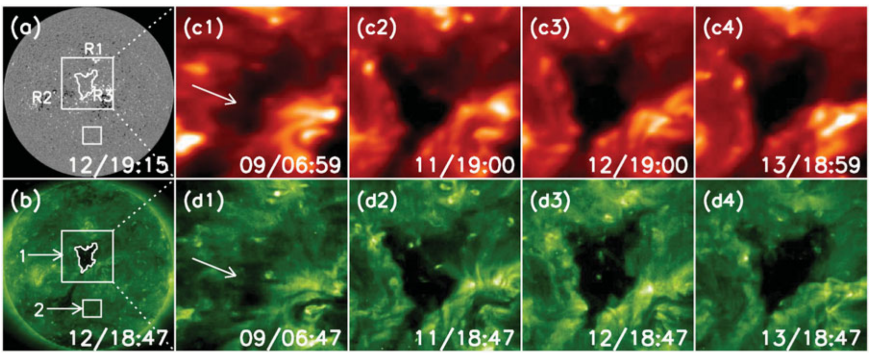

Figure 1. Full-disk magnetogram (a) and EIT 195 Å image (b) showing the CH as it completely formed. EIT 195 Å (c1-c4) and SXI SXR (d1-d4) images showing its formation. The field of view (FOV), outlined by window 1, is 600″×600″. The CH region is encircled by curves. Window 2 denotes the QS region, with a FOV of 218″×203″. Three enhanced networks are marked by R1, R2 and R3.

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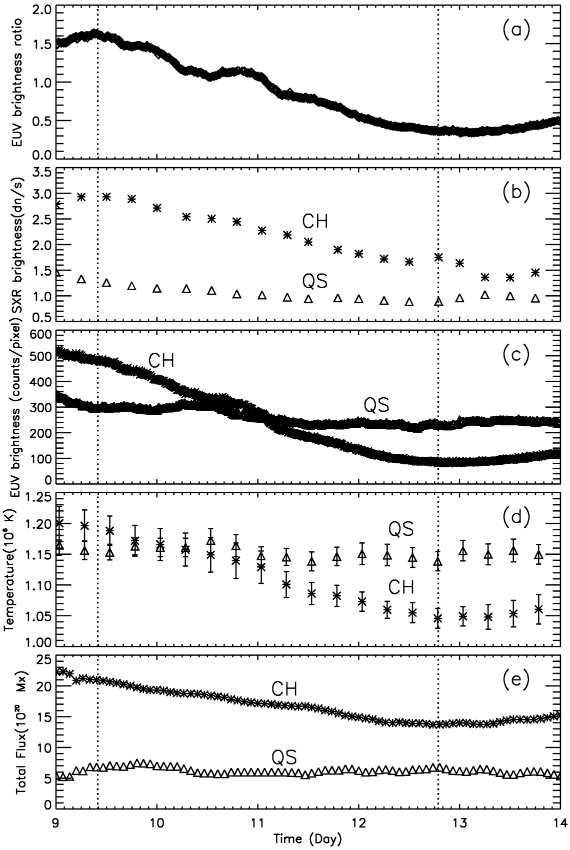

Figure 2. (a) The ratios of EIT 195 Å brightness in the CH (enclosed by curves in Fig. 1) to that in the QS (marked by window 2 in Fig. 1) region as a function of time. Time profiles of SXI SXR brightness (b), EIT 195 Å brightness (c), coronal temperature (d), and total magnetic flux (e) in the CH and QS region. The dashed lines indicate the start and end times of the CH formation, respectively.

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