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Evolution of Coronal Bright Points in Coronal Holes and a possible source of Solar Wind

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Abstract. On EIT and MDI data for 2007 coronal bright points (CBP) and magnetic bipoles (BP) output of coronal hole are studied. CBP and BP identification method developed by authors is used. Temporal variations of CBPs and BPs flux maximums are found, they took place before a fast solar wind maximum. On the base of similarity of longitudinal distribution frequency of coronal mass ejection and velocity of fast solar wind it is supposed that fast forced CBPs are source of fast solar wind.

Key words: Sun, corona, coronal bright points, solar wind

1 Introduction

The apparent contradiction between the fact that there is a high correlation between a high speed stream and a coronal hole and the fact that the thermal structure of the coronal hole, based on X-ray, EUV and radio observations, does not support the thermally driven solar wind models may be solved by considering that dynamo process around X-ray bright points in a coronal hole is partly responsible in accelerating coronal plasma to flow away from the sun (Akasofu, 1980). Non-thermal mechanism that drives coronal hole (CH) mass loss could be X-ray (commonly, coronal) bright points (XBP), as at their base there are sites of matter flow sufficient to account for the total solar mass flux (Ahmed and Webb, 1978), solar wind densities positively correlate with number of XBP (Davis, 1980) and XBP associated with newly emerged magnetic flux (Golub et al., 1977).

Wang et al. (1998) identified white-light jets in 2−6 $R_☼$ range of LASCO images with EUV jets observed on EIT. They were rooted in bright points. High-resolution X-ray images from Hinode revealed many bright points with complicated structure and evolving dramatically with time and all of dramatic jet like eruptions connected with the bright points (Kotoku et al., 2007). Recently Kamio et al. (2007) and Fillipov et al. (2007) studied evolution of XBP inside the CH of polar regions and found evidences that the jet like eruption is followed XBP flaring.

In this paper we study temporal variation of coronal bright points (CBP) and magnetic bipoles (BP) number and flux of low latitude CH and identification maximums of the CBP and BP number and flux with solar wind data. There were used SOHO/EIT full Sun in 195 pass band (Delaboudinnière et al., 1995) and SOHO/MDI data. There were used also Coronal Hole vs Solar Wind Calendar (http://spot2.mtk.nao.ac.jp/pub5/ch_rep/calendar2007.html) and coronal mass ejection watch data from SOHO/LASCO (Solar Eruptive Events Detection System, SEEDS, http://spaceweather.gmu.edu /seeds/index.php).

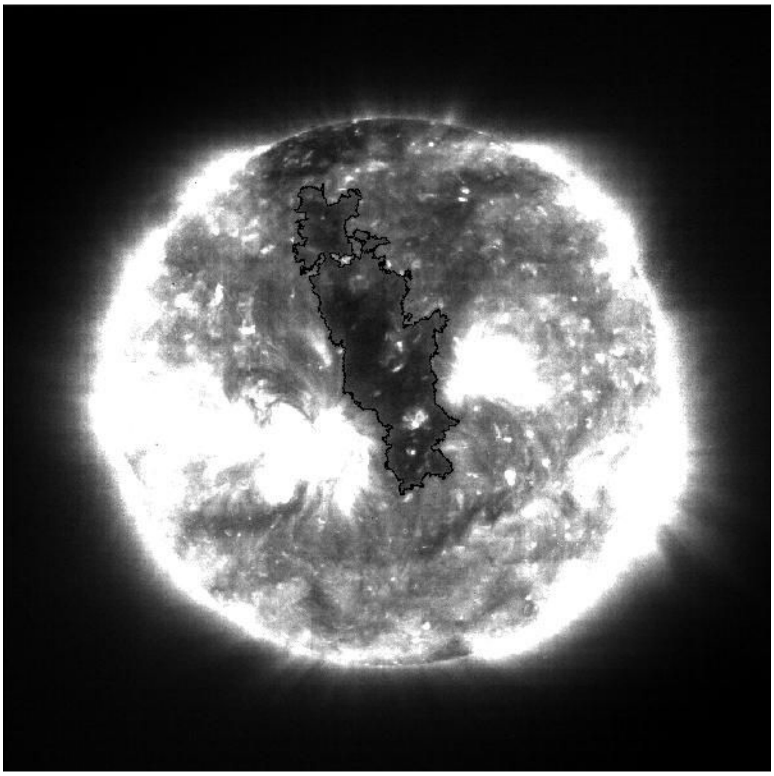

Fig. 1. Full Sun EIT/195 image for 2 July 2006 with CH2 boundaries on it

2 Data set and the coronal bright points and magnetic bipoles identification procedure

We used calibrated full disk images for 2007 from the Extreme-ultraviolet Imaging Telescope (EIT) (Delaboudiniere et al., 1995) observed in 195 Å and magnetograms from Michelson Doppler Imager (MDI) on board of the Solar and Heliospheric Observatory (SOHO). We used EIT full disk data with spatial resolution of 2.64 arc. sec. per pixel and usually five images per hour for coronal mass ejection watch routine and rarely six hours cadence for full sun one.

We used also MDI magnetograms(usually, fifteen magnetograms per day). We identified CBPs on EIT and magnetic bipoles (BPs) on MDI magnetogram using automatic procedure developed by us (Sattarov et al., 2005; Karachik et al., 2006) and calculated various parameters of CBP and BP including heliographic position, intensity, area, flux and background intensity around each CBP and BP. In this paper, we examine temporal variation of number and flux of CBPs and BPs in a low latitude CH and compare the variations with the solar wind from the coronal hole.

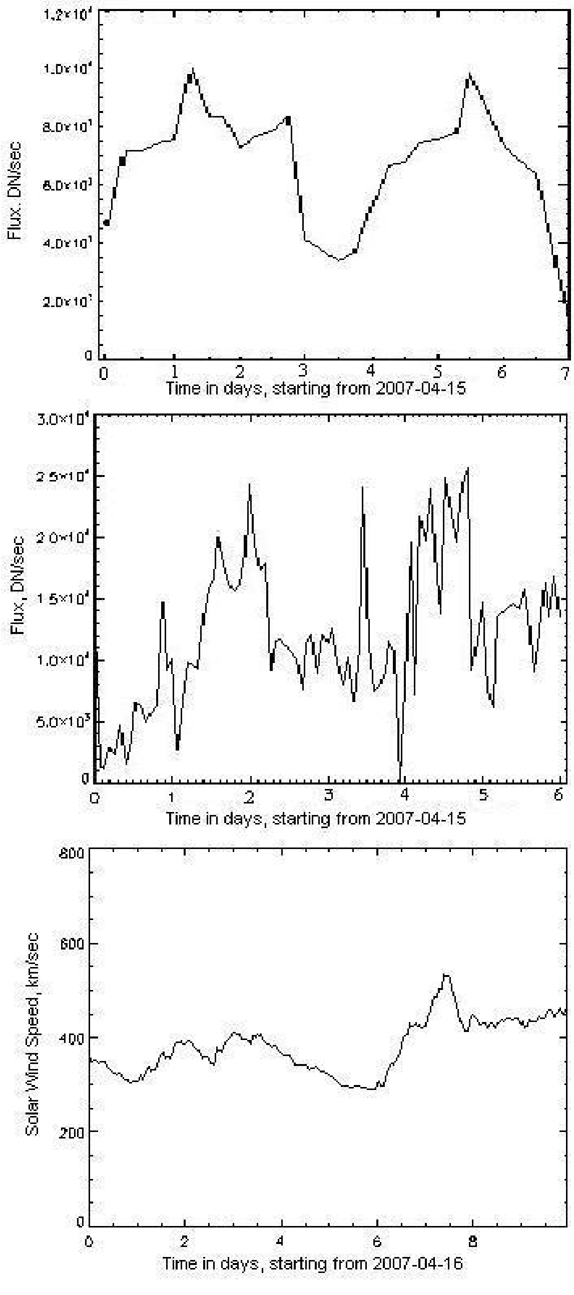

Fig. 2. Temporal variation of BPs summary flux inside CH at L ≈ 120°(April passage) (top), temporal variation of Bipoles summary flux inside the same CH (middle), temporal variation of Solar Wind speed for April (16−26) 2007 year (bottom)

2.1 Recording Coronal Hole boundaries and identification of CBP

Automatic procedure identification and study CH's bright points, used in this paper, consists of several steps: at first, a boundaries of CH are recorded. Boundaries of CH were found as half intensity (DN) level between neighbors inside and outside regions of the CH, which is neatly seen on EIT full Sun disk data in pass bands 195 and 284. For this procedure we used EIT data for the date when the CH was in the center of the disk. Fig. 1 presents a sample of EIT/195 image with CH's contouring on it. The records of CH boundaries (in Carrington longitudes and latitudes) in disk center are used below for identification, survey of parameters of coronal bright points and magnetic bipoles.

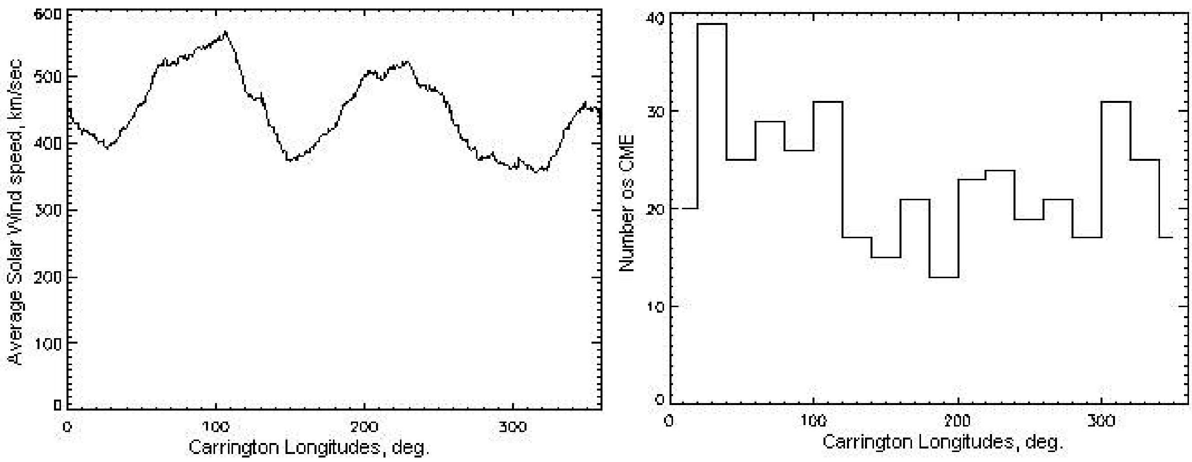

Fig. 3. Distribution of mean solar wind (left, ACE data) and number of fast coronal mass ejections (right, SEEDS data) on solar surface for 2007

At the second step the procedure of identification and finding heliographic coordinate and parameters (area, flux, maximal intensity and others) of CBP and BP inside the CH is realized by the method stated in Sattarov et al. (2005). The automatic method identifies CBP relatively to local background, so we find many CBPs in relatively dark CH's regions. The method defines boundaries and heliographic coordinates (Carrington longitude (CL) and latitude) of each CBP center and records background with standard deviation of sub image in which the CBP is located. Bipoles were identified by closeness and intensity of opposite magnetic poles. On the base of the survey the temporal variation of CBPs number and their summary flux and BPs inside the low latitude CHs were studied. Fig. 2 presents example of the temporal variation of CBP (top), BP (middle) flux inside CH1 and fast solar wind (bottom) from the coronal hole for 11−23 April 2007. The CH1 is widely extended along solar equator. CBPs and BP flux extremes inside it were observed on 16 and 20 April 2007. First extreme of CBP flux takes place (top) one day before than extreme of BP flux (middle), while the second extremes take place simultaneously. During 16–26 April 2007 ACE Advanced Composition Explorer Satellite has registered two maximums of fast solar wind with interval of four days between them (bottom, Fig.2) as CBPs and BPs fluxes. Solar wind delay is 3 days, which is agreed with travel time from Sun to Earth at velocity 550 km/sec.

Inside CH1 at April 2007 two regions of CBP and BP evolution were observed: at longitudes 140º and 120º (longitudes of CBP evolution regions are given below, in second column Table 1).

3 CBP output of the low latitude Coronal Holes

We have studied a CBP productivity inside CH, in general, at low solar activity period (2007), when it was lack of solar wind sources outside CH. Overall, we studied fourteen CH observations, which were successive passages of three coronal holes (CH1, CH2, CH3). Carrington longitudes of boundaries of the CH are given in second column of Table 1.

We have found total number and flux of CBPs (BPs) in CH from each EIT/195 (MDI) data and drawn up temporal variation of the total number and flux of CBPs (BPs) for all passages of the three CHs across by solar disk. At that we have studied CBP output of only nearly ecliptic parts (latitudes ±20+B, B is latitude of solar disk center) of CH. Fig. 2 presents a sample of the temporal variations for April 2007 passage of CH1. The temporal variations of number and flux of CBP (BP) in all passages of all CH show that CBP's productivity of CH changes, in general, in the same way as in Fig.2. Although, sometimes, as in Fig. 2, the increase of CBP's number precedes the increase of CBP's flux. From the temporal variations of number and flux of CBPs (BPs) we have found dates of their maximums which are given in fourth column of Table 1.

During coronal mass ejection watch periods there were 1 EIT image every 15 minutes. On base of such thick line of EIT and MDI data we have build up a move and check CBP and BP evolution CHs, so the data on Table 1 is pretty real.

Table 1. Solar Wind, Coronal Hole (CH), date of coronal bright points and bipoles flux and number maximums for year 2007

Date, Year and interval of observ.	Obs. CH bounders, maxBP and real CH bounders Carrington Longitudes, deg., Source	Solar wind data			Maximum of CBP		Observed difference of maximums, $\Delta t = t_{wind} - t_{cbp}$, days
		Velocity, Km/sec	Duration, days	Date of max. (In brackets begin data of SW)	CBP's flux, date	CBP's number	
2007 11.5−21.5 Apr	100−148 CH1 Sr(140, 6)	300−400	4	18 & 19 Apr	16. BFL = 17.04	16. 17.04	2.5
2007 11.5−21.5 Apr	100-148 CH1 M = 140 Sr(120, 6)	450−550	4	23.0 (22.7 & 23.4) Apr	20.0 Apr BFL = 19.5.04	20.0 Apr 19.5.04	3.0

4 Discussions and conclusions

In this report an evolution of coronal bright points and magnetic bipoles inside of three Coronal Holes for five passages (2007) have been studied. It was received temporal variations of CBP and BP number and fluxes inside of the CH for period their every passage through the solar disk. It was found that inside CH some CBP flare (intensification and expansion) and BP emergence (formation and expansion) are observed. BP emergence, usually, took place no more than one day after CBP flare. The CBP flare and BP emergence took place near solar central meridian. It is supposed that the flare and emergence have causal relationship and consequently coronal mass ejection took place.

In 2007 solar activity was very low, so majority of fast solar wind comes from coronal holes. During 2007 on solar surface three CH were observed: at Carrington longitudes near 30 (CH2), 120 (CH1) and 280 (CH3). As one can see in Fig.3 ACE solar wind velocity and SEEDS data distribution on solar surface have three extremes also. SEEDS data belong to 4-5 solar radius distance from solar center and show velocity near and more than 200 km/sec. Therefore fast solar wind from ACE connected with the coronal mass ejections from SEEDS. Coronal mass ejections are perhaps connected with the CBP flare and BP emergence.

References

Ahmed I.A., Webb D.B. // Solar Phys. 1978. V. 58. P. 223.
Akasofu S.-I. // Proc NASA Conf. Publ. 1980. NASA CP−2280. P. 221.
Davis J. M. // Bull. Am. Astron. Soc. 1980. V. 12. P. 518.
Delaboudinnière J.-P. et al. // Solar Phys. 1995. V. 162. P. 291.
Fillipov B., Golub L., Koutchmy S. // eprint arXiv:0711.4320. 2007.
Golub L., Krieger A.S., Harwey J.W., Vaiana J.S. // Solar Phys. 1977. V. 53. P. 111.
Kamio S. et al. // Publ. Astron. Soc. Japan. 2007. V. 59. No. s3. P. S757.
Karachik N., Pevtsov A.A., Sattarov I. // Astrophys. J. 2006. V. 642. P. 562.
Kotoku J. et al. // Publ. Astron. Soc. Japan. 2007. V. 59. P. S735.
Sattarov I., Pevtsov A.A., Karachik N.V., Sherdanov Ch.T. // Multi-Wavelangth Investigations of Solar Activity: Proc. IAU Sym. N. 223 / Cambridge. UK: Cambridge University Press. 2005. P. 667.
Wang J.-M. et al. // Astrophys. J. 1998. V. 508. P. 899.