

# Cluster observations of magnetic holes near the Interplanetary Current Sheets at 1 AU

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## Abstract

Linear Magnetic holes (LMHs) are magnetic field decreasing structures with little change in the field direction. Xiao et al. have studied the geometrical shape and occurrence rate of LMHs in the solar wind at 1 AU from the year 2001 to 2004 by using the magnetic field and plasma data provided by Cluster C1 [1]. In this work, we will investigate LMHs near the region of interplanetary current sheet. It is found that about 60% of LMHs accompanied with the small scale current sheets within 10min. This result may help us to study the formation mechanism of the LMHs in the solar wind.

## 1. Introduction

Magnetic holes (MHs) also called magnetic decreases or magnetic depressions, of which about 10-30% subset is LMHs. Turner et al (1977) discovered the MHs in interplanetary space, and they defined the ones with no significant change in the magnetic field direction as the LMHs [2]. Winterhalter et al (1994) developed a procedure to find LMHs automatically [3]. In recent years, many new studies about magnetic holes have been carried out. Zhang et al (2008) determined the geometrical structure of the LMHs in the solar wind at 0.72 AU was consistent with rotational ellipsoid [4]. Shi et al (2009a) used the methods described in Shi et al. (2005, 2006) (also had a brief introduce in Shi et al., 2009b) to study the magnetic holes in the Earth's High-altitude Cusp, and they found that these events were spatial structures [5-8].

Using the magnetic field and plasma data provided by Cluster C1 and the method similar to that used by Winterhalter et al (1994) and Zhang et al (2008), Xiao et al (2010) have investigated the LMHs in the solar wind at 1 AU, and they found that the geometrical shape of LMHs can be fitted with rotational ellipsoid and the occurrence rate is about 3.7 LMHs/d [1,3,4]. It is found that not only the geometrical shape but also the occurrence rate of LMHs has little changed from 0.72 AU to 1 AU, so it is confirmed that lots of the LMHs observed at 1 AU are formed and fully developed before 0.72AU [1]. About the formation mechanism of the MHs in the solar wind, one view is mirror instability, and also present other theory has been studied in previous studies [3, 9-10]. Sperveslage et al (2000) studied the directional changed angle between the start vector and any vector inside the MH in the solar wind from 0.3 AU to 17 AU, and they found that only for 10% of the angle larger than 40° and most of the MHs show values less than 20° [11]. In this work, we will study the angle changed in the field direction inside the LMHs in the solar wind at 1 AU, and we also investigate the relationship between these angles and the small scale current sheets. We also investigate the direction of the satellite pass through the LMHs we selected before. This work is the further study for our previous investigation.

## 2. Observation

Using the magnetic field and plasma data observed by Cluster C1, we have investigated the LMHs in the solar wind at 1 AU. The criteria we used to select the LMHs is  $B_{min}/B < 0.75$  and  $\omega < 15^\circ$ , where  $B_{min}$  and  $B$  are the minimum and average field magnitudes within 300s separately, and the  $\omega$  is the angle between the start vector and the end vector of a hole [1]. Figure 1 shows the relationship between the LMHs near small scale current sheets and the angle changed in the magnetic field direction inside the LMHs, which determined by the start vector and any vector of magnetic field inside a LMH. From the red histogram displayed in Figure 1, we find that most of the magnetic field direction inside the LMHs have changed no more than 40°, and about 74% has changed less than 20°, and this is consistent with the result of Sperveslage et al (2000)'s. The green histogram shows the LMHs near the small scale current sheets within 10min, that is, these LMHs have the angle changed no more than 10° and are observed near the small scale current sheet in  $\pm 10$ min, and it is found that about 77% of the LMHs near the small current sheet within 10min when the directional changed angles inside the LMHs are larger than 40°. But there are about 60% of LMHs

near the small scale current sheets while the angles are no more than  $40^\circ$ , and this needs further investigation. Figure 2 shows the distribution of the orientation of the magnetic field, and the  $B_x$  is the x component of the magnetic field in GSE coordinate system, and the  $B$  is the magnetic field magnitude at the beginning of the LMHs defined in the former study [1]. From Figure 2, it is found that the satellite across the LMHs in any direction.

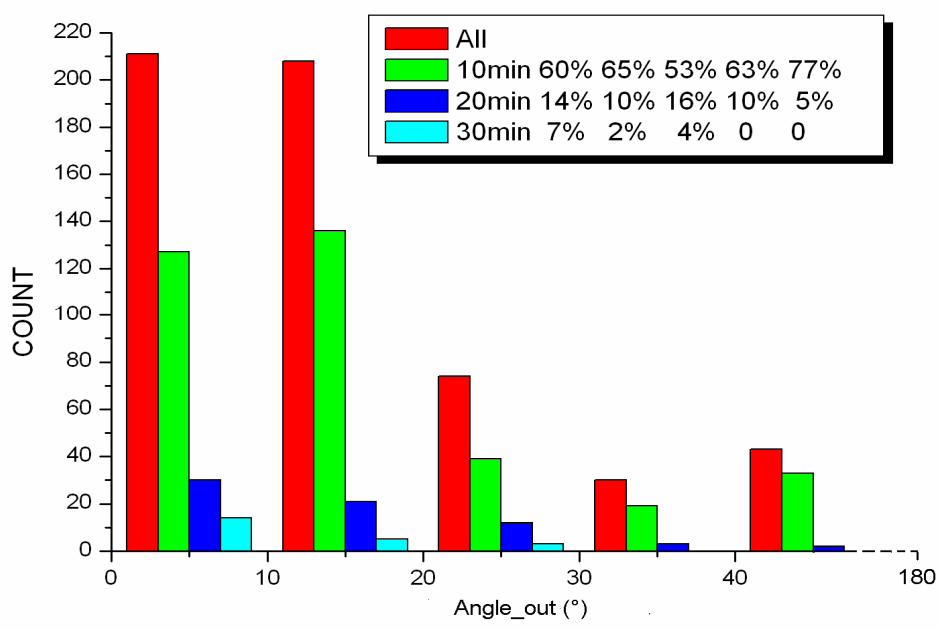


Figure 1. Distribution of the LMHs near small scale current sheets to the angle between the start vector and any of the vector inside a hole. The X shows the angle changed in the magnetic field inside the LMHs, and the Y is the counts for the LMHs. The red histogram represents the whole LMHs with a bin of  $10^\circ$ , and the green one shows the LMHs near small scale current sheet within 10min, and the blue histogram is the LMH events near the current sheet in 10min to 20min, and the light blue one is the LMHs nest to the current sheet in 20min to 30min.

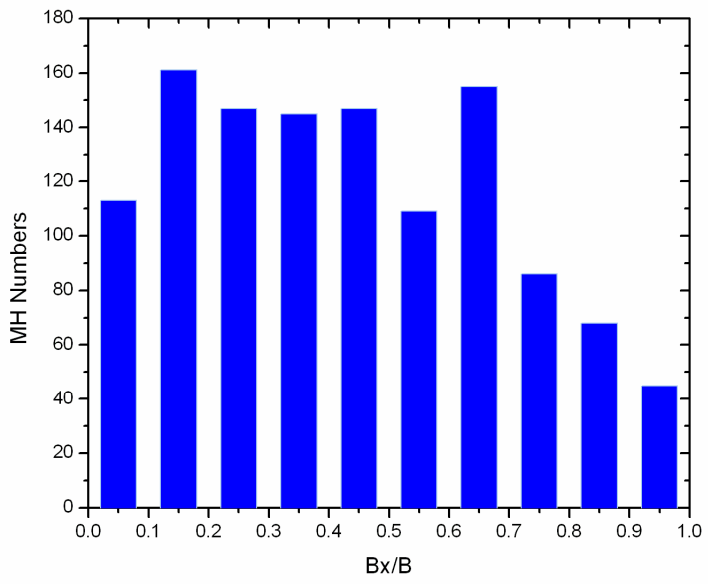


Figure 2. Distribution of the orientation of the magnetic field of the LMHs.

### 3. Conclusion

Using the magnetic field and plasma data detected by Cluster C1 and the LMHs selected in our previous study, we have studied the LMHs which near the small scale current sheets. It is found that about 77% of LMHs near the small scale current sheet within 10min, while the angles in the magnetic field direction inside these LMHs changed more than  $40^\circ$ . It shows that not only the events with the directional change angles larger than  $40^\circ$  but also many of the LMHs with the angle changed less than  $40^\circ$  similar to near the small scale current sheet within 10min. It is inferred that some LMHs may be generated accompanied with the small current sheet.

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