8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Source Compositions and Geoeffectiveness of Interplanetary Coronal Mass Ejections

Shuo Yao[1], Chaoran Gu[1, 2], Xuedong Feng[1], Dongni Li[1], Zexin Cheng[1], Shuyi Meng[1]
[1] School of Geophysics and Information Technology, China University of Geosciences, Beijing, China
[2] Institute of Experimental and Applied Physics (IEAP), University of Kiel, Germany
e-mail (speaker): yaoshuo@cugb.edu.cn

Among the three parts of CMEs, identification of erupted prominence in situ is still unclear. Besides, signatures of multiple parcels of plasmas combined in the formation of CME also deserve study. Apart from interplanetary magnetic field (IMF), if the components of ICME contribute to the geoeffectiveness is another important question for space weather forecast.

We present a series of statistical studies on the heavy ion compositions, IMF, and proton moments to investigate the signatures of prominence materials and other combined source materials in ICMEs. The data are measured by ACE and WIND at 1 au from 1998 to 2011 when more than 300 ICMEs are detected. Firstly, we use 3-sigma rule to check the abnormal cold carbon ions compared to quiet solar wind. About one third of the studied ICMEs contain these carbon-cold materials, which are possibly erupted prominence.

Further, we use a machine learning classifier to check the origin of cold materials reported by different criteria, shown in Figure 1. Most unknown-origin cold materials are identified as prominence materials, while few are identified as solar wind. The relation between fraction of C6+ and average charge of C (avQC) is most distinct for prominence cold materials (PCs) from quiet solar wind (QSW) and ICMEs excluding prominences (ICMEEs).

Excluding prominence, other source materials of ICMEs are checked by the charges of carbon, oxygen, and irons. We designed quantitative criteria based on normal distribution. The charge distributions are classified into three types from cold to hot, shown in Figure 2, showing clear dependence on solar activity.

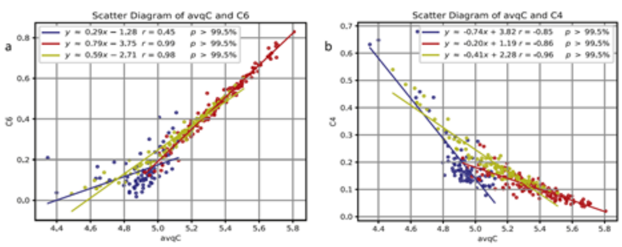

Figure 1. The relations between fractions of C6+ and avQC and between fractions of C4+ and avQC in QSW, ICMEEs, and PCs. Blue dots represent the PCs, yellow dots represent the QSW, and red dots represent the ICMEEs.

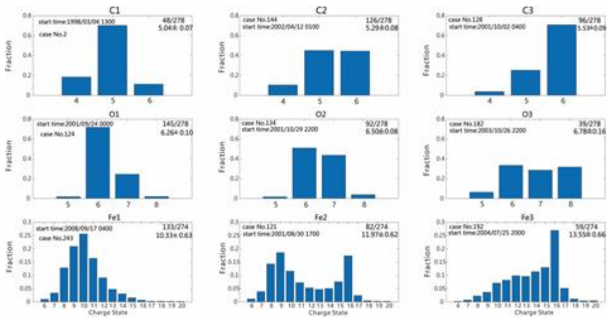

Figure 2. Three types of charge distributions of C, O, and Fe ions in ICMEs.

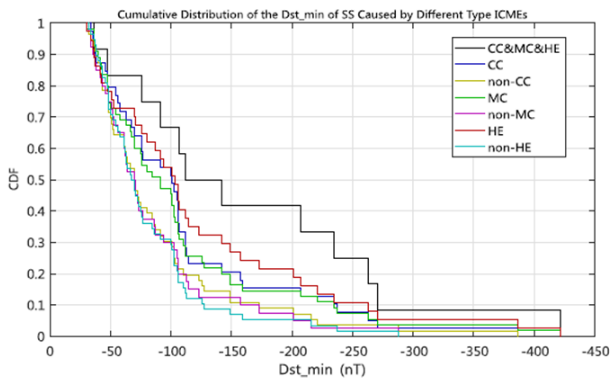

Figure 3. Cumulative distribution of Dst minimum of the 95 single storms caused by different types of ICMEs.

To separate plasmas from different sources, an inversion technique is developed based on ionization temperature of iron and kappa distribution of electrons. The results show that four populations stably exist, which are from chromosphere, low corona, normal corona, and even hotter corona.

According to the different components of ICMEs, we check the related geomagnetic storm level by hypothesis test. Interestingly, the helium-enhanced cold materials (CC and HE) with magnetic flux rope (MC) tend to drive stronger level storms, shown in Figure 3. The above results support the observed injection of enhanced twisted flux ropes to prominence and the significantly stronger geoeffectiveness of three-part CMEs.

This work is supported by NSFC under contract No. 42074204.

References

[1] Gu, Yao*, and Dai, ApJ, 900, 123 (2020)
[2] Li and Yao*, ApJ, 891, 79 (2020)
[3] Cheng, Yao*, and Meng, ApJS, 265, 25 (2023)