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The Study on a Solar Storm and Its Interplanetary and Geomagnetic Effects† ⋆

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Abstract We present a detailed study on a solar storm occurred on 2014 January 7. By using the remote-sensing observations of solar activities at multiple wavelengths from the Solar Dynamics Observatory (SDO) and the Solar and Heliospheric Observatory (SOHO), the eruptions of the solar flare and coronal mass ejection (CME) are investigated. Based on the measurement of energetic protons from the Geostationary Operational Environmental Satellite (GOES) and the in-situ plasma measurement from the Advanced Composition Explorer (ACE) at the solar-terrestrial L1 point, the solar energetic particle (SEP) event and interplanetary CME (ICME) accompanied by the solar storm, and the shock driven by the ICME are analyzed. The influence of the solar storm on the geomagnetic fields is also analyzed with the ground-based magnetic data. The results in this study show that: (1) The initial time of impulsive phase of the solar flare and the ejection time of the CME are temporally in accordance with each other. (2) The solar protons are mainly accelerated by the CME-driven shock, rather than by the magnetic reconnection in the flare, and the protons are released when the CME travels to 7.7 solar radius. (3) The widths of the interplanetary shock sheath and the ICME itself are derived to be 0.22 AU and 0.26 AU, respectively. (4) The interplanetary shock and the ICME give rise to substorms and aurora, whereas no obvious geomagnetic storm is detected. The reason is that the ICME does not contain a regular structure of magnetic cloud (MC) or evident southward component of magnetic field.

Key words Solar-terrestrial relations—The Sun: flares—The Sun: Coronal Mass Ejections (CMEs)

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1. INTRODUCTION

A typical process of space weather is generally initiated by solar activities, the energy and material (such the full-band electromagnetic radiation, energetic particles, magnetized plasma clouds, etc.) are transmitted outward in the forms of flares and coronal mass ejections (CMEs), these electromagnetic emissions, energetic particles, and plasma matter propagate in the interplanetary space and interact with the interplanetary medium and geomagnetic field, thus to affect the overall solar-terrestrial space environment[1−2], and such a violent space weather process is called the solar storm. Solar storms are the driving sources of most space weather processes, which may affect the activities of spacecrafts in high-altitude environments (such as the navigation, communication, deep-space exploration, etc.), also may possibly damage the health of astronauts and pilots in high altitudes. The geomagnetic disturbances caused by space weathers may also possibly affect the long-distance ground transmissions of electric power, oil, and gas, a serious solar storm can even affect the normal production and life, and even the physical health of common people under the atmospheric layer and far away from the deep space.

The most remarkable eruptive phenomena in solar storms are flares and CMEs, the relationship between the two phenomena has been discussed for a long time, from triggering by flares to triggering by CMEs[3−5]. Zhang et al. made a kinematical analysis on the whole process of a CME from its initiation, acceleration, to the propagation, by using the observations of SOHO/LASCO/EIT[4], and by comparing with the X-ray fluxes of flares, it is found that the initial slowly lifting process of CMEs corresponds to the gradually rising phase before the impulsive phase of flares, and the fast acceleration process of CMEs corresponds to the impulsive phase of flares, and the acceleration process of CMEs stops after the impulsive phase of flares ends. Their conclusion is that the relationship between the two phenomena is not simply which one is triggered by another, instead they are closely related with each other, and both of them are the manifestation of coronal magnetic energy release.

The magnetic reconnection sites of flares and the shocks driven by CMEs are the main sources to accelerate the solar energetic particles (SEPs). At present, it is considered that the small and impulsive SEP events are originated from flares, while the large and gradual events are mainly accelerated by the shocks driven by CMEs. However, the difference between them is not evident, especially, some large events include not only the impulsive component, but also the gradual one. Hence, the acceleration site of SEPs is still a hot topic to be studied[6−8].

When CMEs propagate to the interplanetary space, the disturbances in the near-earth space environment may be caused by CMEs themselves and the shocks driven by them (besides, the coronal holes and corotating interaction regions also have important effects on the space environment[9]). Especially, when the disturbances interact with the geomagnetic field, a series of geomagnetic effects may be produced, such as auroras, geomagnetic sub-

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