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Periodogram Analysis on Solar Activities Based on El Campo Solar Radar Observation Data† ⋆

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Abstract Solar radar can transmit radar waves toward the Sun actively at a specific waveband and receive the reflected waves. By analyzing the echoes, we can obtain the information of motion, magnetic field, and other properties of the solar atmosphere. The El Campo solar radar has done regular observations on the solar corona for 8 years from 1961 to 1969, to trace the variation of solar activities. We have made a periodicity analysis on the obtained data with the Lomb-Scargle periodogram algorithm, and found that there are the 200 day and 540 day periods existed in the variation of the measured solar radar cross section. In addition, we have selected the larger radar cross sections ($\geq 20\sigma_{\odot}$) to compare with the Dst indexes. Finally, we have summarized the El Campo solar radar experiment and give a prospect for the future development of the solar radar observation.

Key words Sun: activity—Sun: coronal mass ejection—method: Lomb–Scargle periodogram algorithm—techniques: radar astronomy

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1. INTRODUCTION

The Sun is the nearest star with the greatest impact on the Earth. The coronal mass ejection (CME) driven by magnetic field is the most violent eruptive phenomenon with the largest scale in the solar atmosphere. Its total energy can reach 10^{22} - 10^{25} J, which can throw several billion tons of magnetized plasma into the space of the solar system[1]. When CMEs reach the Earth, they can disturb the geomagnetic field. When the produced shock acts on the magnetosphere, the sunward magnetosphere is strongly compressed, while the magnetosphere opposite to the Sun is elongated to be a very long magnetotail. When the magnetic reconnection occurs in the magnetotail, the energy release rate (i.e., power) may reach an order of magnitude of trillions watt. The situation of terrestrial space environment is determined by the energetic particles and slowly-moving low-energy plasmoids ejected by CMEs[2]. The charged particles in the slowly moving low-energy plasmoids can be accelerated in the terrestrial space, and inject into the inner magnetosphere to form a circular electric current, to cause a rapid descending of the horizontal geomagnetic field, as well as a geomagnetic storm[3]. The geomagnetic storm is a violent global geomagnetic disturbance, and a strong geomagnetic storm may cause the troubles of the ground technical systems, such as the power systems, communication systems, oil pipelines etc.[4−8]. For instance, a strong geomagnetic storm in 1989 March caused a tremendous induced electric current be produced in the power grid of Canadian Quebec area, and resulted in a power cut for 9 h in the whole area[9]540−542.

The human knowledge about CMEs has only a short history of about 40 years. On 1971 Dec. 14, the OSO-7 satellite of Naval Research Laboratory of USA first detected definitely that the coronal structure was changed by a sudden mass ejection from the corona, which was called as a coronal transient event at that time[10]. Until the end of nineteen seventies and the beginning of nineteen eighties, the researchers gradually defined it as the coronal mass ejection, simply called as CME, and used it to describe the independent bright moving structures observed by white-light coronagraphs[11]. With the continuous development of astronomical techniques, and the improvements in the sensitivity, spatial resolution, and field of view of various detectors, the observations and studies on CMEs and other solar activities have entered into an unprecedented new stage. Up to now, the Solar and Heliospheric Observatory/Large Angle and Spectrometric Coronagraph (SOHO/LASCO) has detected already over ten thousand CMEs, and acquired very rich results, which have greatly enriched the human knowledge about CMEs. However, the present observations basically belong to the scope of passive detections, with an evident limitation for observing solar activities and CMEs, which is mainly reflected in three aspects: the projection effect, the shade effect of coronagraph, and the Thomson scattering. This means that the conventional observation methods can not completely reflect the real features of the solar activities and CMEs.

In the field of radar astronomy, the Sun is the second target to be studied next to the Moon. The solar radar observation is an active detection method, it uses a radar