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Journal of Atmospheric and Solar-Terrestrial Physics 67 (2005) 1674–1679

Journal of ATMOSPHERIC AND SOLAR-TERRESTRIAL PHYSICS

www.elsevier.com/locate/jastp

Radio emission observed in decimetric waves associated with the onset of CMEs

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Available online 10 August 2005

Abstract

Since the first observations by Skylab and SMM satellites coronal mass ejections (CME) have been more and more investigated. However, until now their origin and trigger mechanism remain an open question no matter if they are associated to flares or not. Recent observations over a broad spectrum suggest that flare energy is released in regions from where the decimetric emission is coming. Then, investigations of decimetric radio emission observed in association with CME phenomena may give clues to solve the previously mentioned questions. Using the Brazilian solar spectroscope (BSS), observations of solar bursts dynamic spectra with high time (100, 50, 20 ms) and frequency (50–100 channels) resolutions have been carried out daily (~11–19 UT) within the range of 1000–2500 MHz. A sample of 274 CMEs were recorded by the large angle spectroscopic coronagraph (LASCO) instrument, on board the solar and heliospheric observatory (SOHO) satellite, within 11–19 UT, during the period of 1999–2002. From those, 42 CMEs are associated to BSS data and selected for analysis. It is interesting to note that in about half of the cases only one type of burst radio emission was recorded while in the remaining cases either two or more types were observed. There is a dominance of either continuum and/or pulsations. Here, we describe the association of burst radio emission with the starting time of CME phenomena.

Keywords: Radio emission; CME; Decimetric waves; Solar bursts

1. Introduction

CMEs are big plasma clouds, as magnetic bubbles that become unstable and buoyant, leaving the Sun and propagating out into the interplanetary space. These phenomena are observed in white light and were first imaged with space-borne coronagraphs in the early 1970s (Tousey, 1973; Gosling et al., 1974). Until now there are many unknown aspects and a controversy in those investigations concerning the relationship between CMEs and solar flares. While some authors show that <40% of CME phenomena are associated to flares (Munro et al., 1979; Webb and Hundhaunsen, 1987; St. Cyr and Webb, 1991), others concentrate on investigating the aspects of a significant relationship CMEs-flares (Verneta, 1997; Svestka, 1995; Sheeley et al., 1983; Kahler, 1994).

This work searches for the association of radio burst emission, using 4 years (1999–2002) of spectroscopic data from the BSS instrument (Sawant et al., 2001; Fernandes, 1997), within the 1000–2500 MHz frequency

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doi:10.1016/j.jastp.2005.03.006

range, with the CMEs recorded by LASCO C2 and C3 coronagraphs. This association may give us a clue regarding CMEs origin and trigger mechanism from near the solar surface.

2. Instrumentation, observations and analysis

BSS is a digital spectroscope that operates routinely from 11 to 19 UT, at the National Institute for Space Research (INPE), at São José dos Campos, Brazil, in the decimetric wavelength range (1000–2500 MHz) with high time (100, 50, 20 ms) and frequency (3 MHz) resolutions, in conjunction with a polar mounted 9 m diameter parabolic antenna. This instrument allows us to select a suitable observing frequency range, frequency and time resolutions. The data can be digitized and recorded in upto 100 frequency channels. Time accuracy is ~3 ms and minimum detectable flux is ~3 sfu, for different combinations of observational parameters (Sawant et al., 2001; Fernandes, 1997).

LASCO is a three-coronagraph package, which has been jointly developed for the SOHO satellite. LASCO comprised three coronagraphs, C1, C2 and C3, which together imaged the solar corona from 1.1 to $30R_s$ (C1: 1.1–$3R_s$, C2: 2–$6R_s$ and C3: 3.7–$30R_s$). C2 and C3 coronagraphs are externally occulted instruments (Brueckner et al., 1995).

The extreme-ultraviolet imaging telescope (EIT) operating on board SOHO satellite provides wide-field images of the corona and transition region on the solar disc and upto $1.5R_s$ above the solar limb. Its normal incidence multilayer-coated optics selects spectral emission lines from Fe IX (171 Å), Fe XII (195 Å), Fe XV (284 Å), and He II (304 Å) to provide sensitive temperature diagnostics in the range from 6×10^4 to 3×10^6 K. The telescope has a 45×45 arcmin field of view and 2.6 arcsec pixels which provide approximately 5 arcsec spatial resolution (Delaboudinière et al., 1995).

During the period of 1999–2002, BSS operating daily (11–19 UT) in decimetric wavelengths carried out high time and frequency resolution observations of solar bursts, using either 100 or 50 frequency channels. Those observations were also done simultaneously by the LASCO experiment on board SOHO. A total of 274 CME phenomena were recorded by LASCO. A significant portion (~16%) of that amount were recorded with an estimated start time within ±5 min of either start or end times of solar bursts recorded by BSS and selected for analysis. We want to remark also that the minimum time interval between two consecutive EIT, as well as LASCO images, is 12 min. All the LASCO–BSS associated phenomena originated from relatively low ($\leqslant 70^\circ$) heliographic coordinates as noted in Hα by NOAA instruments. However, EIT images were useful in some cases to determine the CME–BSS data association. Table 1 shows characteristics of the solar bursts recorded by BSS and associated to CME phenomena, as well as to flares.

Taking the example observed by LASCO C2 coronagraph at about 17–18 UT on April 05, 2001, Fig. 1 shows an image sequence with a CME time evolution. The white semicircle represents the Sun limb, while the larger black disk indicates the lower limit for C2 field of view. It is clear from the sequence of images that a CME starts before 17:26 UT. A sequence of 4 EIT (195 Å) images exhibiting the EUV emission from the solar disk during approximately the same time interval is shown in Fig. 2. Looking at the frames in the figure, it is clear that active region NOAA9415 located at S24 E50, near the centre, showed a noticeable increase in brightness around 17:00 UT remaining bright for more than 1 h until at least 18:24 UT. The dynamic spectrum recorded in decimetric wavelength range (1700–2000 MHz) by BSS can be seen in Fig. 3. A broad band (>300 MHz) continuum emission starting around 16:57 UT can be seen in the figure drifting from 1700 MHz to higher frequencies. These figures show one example. However, as we show in what follows the data strongly suggests an association CME (LASCO)–radio (BSS) phenomena.

We know that the decimetric activity originates in the high chromosphere-low corona, 10^3–10^4 km above solar surface, depending on the assumption of a specific density model. However, the fields of view seen by LASCO cover from ~1.0–$6.0R_s$ and 2.7–$30R_s$ (R_s is solar radius) above the solar surface for C2 and C3, respectively. This means that the field of view starts at distances of about 0.7–2.0×10^6 km from the solar surface. In terms of the travel time from the solar surface, C2 detects a CME after $\geqslant 6$ min of its departure from the solar surface, taking into account the fastest CME observed with $v\approx2000$ km/s.

For C3, this means a minimum time of around 20 min. Therefore, in a first approximation we can investigate the association of CME (LASCO) within ±5 min from the start and end times of radio bursts recorded by BSS. To estimate the starting time of all CMEs in the sample from near the solar surface, we assume:

1. CME average velocity as measured by C2; for one case, as measured by C3.
2. Taking the coronagraphs field of view, we know the height above the solar surface.
3. Then, we estimate the time elapsed from the departure of the CME from near the solar surface and, as a consequence, its estimated starting time.
4. A comparison of the CME estimated starting time with the start and end times of BSS bursts taking into account for a $\pm$ 5 min interval allows us to check for the association.