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Collaborative VLA and LASCO Observations of Nonthermal Energy Release in the Corona

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Abstract. We discuss recent collaborative observations of coronal mass ejections and related activity using the Very Large Array (VLA) and the Solar and Heliospheric Observatory (SOHO). VLA observations show the onset of intense 400 cm burst emission during an X1 GOES soft X-ray burst observed by the Yohkoh spacecraft and prior to a CME observed by the Large Angle Spectroscometric C2 Coronagraph (LASCO) on board SOHO. VLA snapshot maps show that the 400 cm burst site varied discontinuously throughout the course of the flare, possibly reflecting abrupt changes in the structure of the coronal magnetic fields along which the energetic particles traveled.

1. Introduction

Radio observations of solar bursts at metric and decimetric wavelengths provide new perspectives on the complex and evolving magnetic environment of the inner solar corona and on the coronal signatures of nonthermal energy release during eruptive events such as coronal mass ejections (CMEs). These long-wavelength bursts represent the signatures of outwardly-travelling beams of nonthermal particles that provide information on the coronal electron density and the structures of the magnetic fields involved while also providing an opportunity to study the formation and propagation of coronal mass ejection-related shocks and associated particle acceleration. We have used the new 400 cm system at the Very Large Array (VLA) to detect intense burst emission during a CME observed by the LASCO C2 coronagraph on board the SOHO satellite (Willson et al. 1998). The VLA maps detected sources at a fixed radial distance above the limb, but at different locations along otherwise invisible large-scale magnetic loops in the corona, possibly linking widely-spaced active regions seen near the limb by the SOHO EIT. Nonthermal emission at 91 cm wavelength, most-likely identified as a Type I noise storm, was also detected following the CME. Both the 400 cm bursts and the 91 cm noise storm enhancements continued for a period of at least three hours, providing evidence for long-lasting nonthermal particle acceleration associated with the CME.

Here, we discuss recent collaborative observations of meter-wavelength nonthermal solar radio burst emission and coronal mass ejections using the VLA and LASCO. Full-disk VLA observations at 400 cm were used to study the spa-

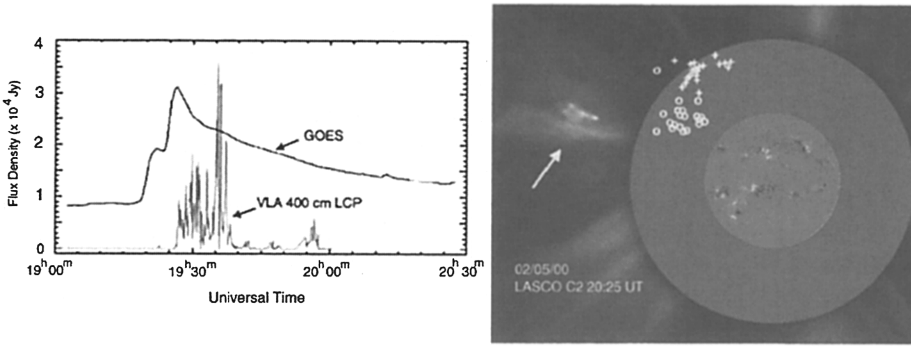

Figure 1. (left) A plot of the VLA 400 cm flux density observed during a hard X-ray burst detected by BATSE on 5 February, 2000. (right) the locations of 400 cm bursts detected by the VLA are compared with a LASCO C2 coronagraph image showing the passage of a CME (arrow) at 20:25 UT

tial and temporal variations of nonthermal radio bursts during a GOES X1 soft X-ray flare and a subsequent CME detected by LASCO. High-resolution (35") VLA snapshot maps (3 sec intervals) at 400 cm reveal impulsive burst emission in the low corona that began near the estimated start time of the CME activity and continued for several tens of minutes after it.

2. Observations

The VLA was used to observe the Sun at 400 cm (73.8 MHz) between 1600-2000 on February 5, 2000 with a time resolution of 3.3 seconds and a synthesized beamwidth of ≈35" at 400 cm. On this day, active region AR8858 (N23 E57) produced two intense soft X-ray events, an M1 flare starting ≈19:21:30 UT, followed by an X1 flare starting at 19:25:20. Intense 400 cm burst emission was observed by the VLA beginning at ≈19:25 UT and continued for the next 30 minutes. In Figure 1 we show a time profile of the 400 cm correlated flux that has been superposed on a plot of the GOES 1-8 Å soft X-ray light curve. The X1 flare was also detected in hard X-rays by the Burst and Transient Source Experiment (BATSE) while both the M1 and X1 flares were detected in both hard (HXT) soft X-rays (SXT) by the *Yohkoh* satellite. At ≈19:54 UT the LASCO C2 coronagraph detected a CME above the northwest limb for which a time-height plot indicated an average projected transverse velocity of v ≈ 765 km sec^{-1}. VLA 3.3 sec snapshot maps showed that the 400 cm burst sources were located at projected heights of h ≈0.3 - 1.25 $R_\odot$ above the northwest limb with brightness temperatures as high as $T_b = 2 \times 10^8$ K.

As shown in Figure 1, the 400 cm bursts are spatially segregated within two distinct groups, specifically a southern group that includes bursts between 19:25 - 19:31:30 UT (denoted by circles) and a northern group which includes bursts occurring after ≈19:31:30 UT (denoted by crosses). The first group appears to be located along the trajectory of the CME detected by LASCO while the second group lies ≈5' - 10' north of it. The shift in position of these bursts at ≈19:31:30 may be due to discontinuous changes in the extended magnetic field structure of the corona along which the nonthermal particles propagate or to a change in the structure of the source region that accelerated these nonthermal particles. If we assume that the CME moved outward with a constant velocity of v = 765 km sec^{-1}, then its expected height at 17:25 UT, the start time of the 400 cm burst emission, is h ≈0.65 $R_{\odot}$. This height is similiar to the height of the 400 cm bursts, suggesting that the nonthermal particles are accelerated in the same magnetic structures as the CME where the CME lifted off and may have played a role in triggering it. Examination of Yohkoh SXT images taken during this time shows that the X1 flare began ≈19:25:00 UT and it is this event, rather than the M1 flare which began several minutes earlier, that appears to be associated with intense 400 cm bursts (see http://www.tufts.edu/as/astronomy/feb052000.html). The soft X-ray images show that the M1 and X1 flares are spatially separated and emanate from relatively compact sources which appear to change relatively little during their evolution. The Yohkoh SXT images also show the appearance of a new soft X-ray arcade structure between 19:27:18 - 19:34:18 UT that lies a few arcminutes north of the M1 and X1 flare sources, suggesting a change in the magnetic field structure of the active region during this time. We speculate that it this new magnetic loop system which may have altered the production or propagation of nonthermal particles that resulted in the abrupt displacement of the later group of 400 cm bursts after 19:31:30 UT.

3. Discussion and Conclusions

We have demonstrated that the VLA can image meter wavelength (400 cm) nonthermal bursts and possibly thermal emission associated with flares and CMEs with high spatial (35") and temporal (3.3 sec) resolution. The VLA data show a good spatial and temporal association between the CME and the nonthermal 400 cm burst emission indicates that energetic radio emitting particles are accelerated at approximately the same height and time as the CME. The discontinuous change in the location of the 400 cm bursts above the CME source region suggests that magnetic restructuring may have occurred in the associated loops on relatively short (minutes) timescales, possibly as a result of the energy deposited in the loops by the X flare.

References

Willson, R.F., et al. ApJ(Letters) 504, 417