RADIO DETECTION OF A RAPID DISTURBANCE LAUNCHED BY A SOLAR FLARE
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ABSTRACT

We report the direct observation of motion associated with a solar flare at a speed of 26,000 km s\(^{-1}\). The motion is seen from a radio source at 0.33 GHz, which suddenly starts moving during the flare. At its peak, the radio source covers a quiet region of dimension 500\(^\circ\). Emission from any given location is sporadic. The disturbance itself does not seem to radiate, but it excites coronal features that continue to radiate after it passes. The inferred velocity is larger than any previously inferred velocity of a disturbance in the solar atmosphere apart from freely streaming beams of accelerated electrons. The observed motion of the source at a fixed frequency, low polarization, and moderate bandwidth are more consistent with the typical properties of moving type IV radio bursts than with classical coronal shock–associated type II bursts, but any disturbance at such a high velocity must be highly supersonic and should drive a shock. We speculate that the disturbance is associated with the realignment of magnetic fields connecting different portions of an active region.

Subject headings: shock waves — Sun: atmospheric motions — Sun: corona — Sun: flares — Sun: radio radiation

1. INTRODUCTION

The study of moving disturbances in the solar atmosphere is an important topic for several reasons: such disturbances may lead to shocks in the solar wind which have terrestrial consequences, and, because they may be studied in detail at relatively close range, they may reveal physical processes that are important but difficult to study in more distant astrophysical settings. A number of such disturbances are recognized. Some of the earliest detections were inferred from radio observations: beams of accelerated electrons freely streaming at \(\sim 40,000\) km s\(^{-1}\) which produce type III radio bursts (Wild 1950a), coronal shocks at 500–2000 km s\(^{-1}\) which produce type II radio bursts (Wild 1950b; Wild, Murray, & Rowe 1954), and moving features at 200–1600 km s\(^{-1}\) which produce moving type IV radio bursts (Weiss 1963). In the chromosphere, “Moreton waves” are detected in Hz images of solar flares at velocities as high as 4000 km s\(^{-1}\) (Moreton 1961; Athay & Moreton 1961; Ramsey & Smith 1966). Erupting prominences with speeds of hundreds of kilometers per second have been known for some time, and coronal mass ejections were detected when the first space-borne coronagraph operated on Skylab (MacQueen et al. 1974). More recently, the Soft X-Ray Telescope (SXT) on the Yohkoh satellite has detected ejecta at soft X-ray–emitting temperatures with velocities of 30–300 km s\(^{-1}\) (Shibata et al. 1992), and the EUV Imaging Telescope on the SOHO has detected flare-associated disturbances from the motion produced in coronal features as the disturbance passes by (Thompson et al. 1999): velocities are of order 100–250 km s\(^{-1}\).

In this Letter, we report radio observations of motion of a disturbance in the solar corona which reaches a speed as high as 26,000 km s\(^{-1}\), i.e., faster than any other known form of coronal disturbance apart from free-streaming electrons. The motion occurred in association with a GOES class C9 flare whose other properties have already been described extensively by Silva et al. (1996). In this Letter, we focus on imaging observations of the event made at 0.333 GHz with the Very Large Array radio telescope.

2. THE OBSERVATIONS

The flare occurred at about S16°W18° in AR 6944, starting at 20:21:30 UT (all times quoted in this Letter will be in UT) on 1992 January 7. Both radio and X-ray data show two main peaks, occurring at around 20:22 and 20:25, respectively (Silva et al. 1996). The VLA was operated in frequency-switching mode for these observations. During the first peak from 20:21 to 20:24, the VLA was observing in the 5 GHz band; these observations were discussed by Silva et al. (1996). During the second peak from 20:24:21 to 20:27, the VLA observed at 0.33 and 1.4 GHz simultaneously, and we discuss these lower frequency data here. The time resolution of the data is 3.3 s; the VLA was in the B configuration and the 0.33 GHz images shown are restored with a 40° circular beam. The effective resolution is probably somewhat larger than this because of coronal scattering (Bastian 1994). Radio images at nine selected times are shown in Figure 1, overlaid on a Kitt Peak magnetogram of the region. The flare occurred in a complex consisting of two adjoining labeled regions occupying the bottom right-hand corner of the images, AR 6993 to the north and AR 6994 to the south. AR 6994 was magnetically the more complex of the two regions (Silva et al. 1996). Two continuum “noise storm” sources were present at 0.33 GHz throughout the day and are labeled “NS” in the panels. These sources are commonly present over the leading spots of vigorous active regions and produce continuum emission, typically from 0.1 to 0.4 GHz, which can vary on timescales as short as minutes (Kai, Melrose, & Suzuki 1985). They are not associated with flares. On this day, the western NS source was the stronger of the two and lay over the positive-polarity leading spot of AR 6993. This source was 100% left circularly polarized

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