VARIATIONS OF PHOTOSPHERIC MAGNETIC FIELD ASSOCIATED WITH FLARES AND CMEs

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Abstract. Using high-cadence magnetograms from the SOHO/MDI we have investigated variations of the photospheric magnetic field during solar flares and CMEs. In the case of a strong X-class flare of May 2, 1998, we have detected variations of magnetic field in a form of a rapidly propagating magnetic wave. During the impulsive phase of the flare we have observed a sudden decrease of the magnetic energy in the flare region. This provides direct evidence of magnetic energy release in solar flares. We discuss the physics of the magnetic field variations, and their relations to the Moreton Hα waves and the coronal waves observed by the EIT.

1. Introduction

It is commonly believed that solar flares represent a process of rapid transformation of the magnetic energy of active regions into the kinetic energy of energetic particles and plasma flows and heat. Detection of variations of magnetic fields associated with solar flares has been one of the most important problems of solar physics for many years. Such a detection would provide direct evidence of magnetic energy release in the flares. However, the observational results are controversial (Sakurai and Hiei, 1996). It is established that flares occur in regions of strong magnetic shear which is gradually built up before the flares (e.g., Zvereva and Severny, 1970). However, there is no unambiguous evidence that the magnetic field changes during flares. One of the reasons for this situation can be that the magnetic field is measured at the photospheric level, but most of the energy release occurs in the upper chromosphere and corona. Nevertheless, one may expect some magnetic response to the flares at the photospheric level because of the connection between the corona and photosphere by magnetic field lines.

Patterson and Zirin (1981) and Zirin and Tanaka (1981) have reported on observations of ‘magnetic transients’, rapid variations of the magnetic field during flares. Patterson (1984) analyzed magnetic transients in the 27 July 1981 flare in detail and found that the transients were observed in areas of strong initial field in the sunspot umbra or at the umbra-penumbra boundary, and had a polarity opposite to the original polarity.

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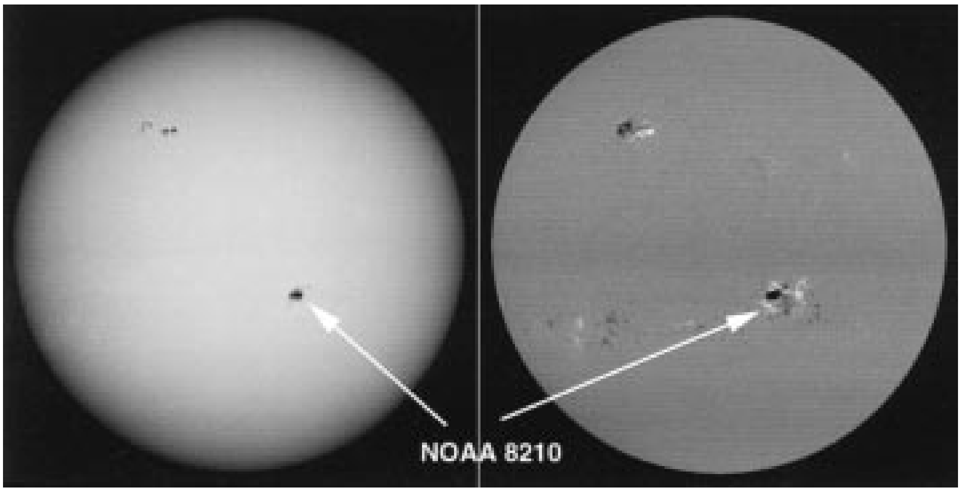

Figure 1. Left panel: MDI continuum image at 13:10 UT, 2 May 1998; *Right panel:* MDI magnetogram at 14:24 UT, 2 May 1998 (black color shows magnetic field of negative polarity, and the white color shows the field of positive polarity).

The interpretation of these observations was unclear. The variations in the observed magnetic field could be due to distortion of the Fe I 5324 Å line which was used in the observations. The distortion might be caused by flare emission. However, this interpretation requires that the flare emission be concentrated in very small-scale flux tubes which are not directly observed (Patterson, 1984). In any case, variations of the magnetic signal, associated with solar flares may provide important information about the chromospheric and photospheric effects of solar flares, and deserve further investigation (Harvey, 1985).

In this paper we report a detection of relatively weak variations of the magnetic signal in the Ni I 6768 Å line from the MDI instrument on SOHO. These variations are different from the 'magnetic transient' because they were observed outside the sunspots, in areas of relatively weak field and did not lead to the polarity reversal observed by Patterson (1984).

2. Characteristics of the 2 May 1998 Flare

The flare of 2 May 1998 occurred in active region NOAA 8210 located at heliographic coordinates S15° W15° (Figure 1). The flare is classified as X1/3B. The X-ray flux started at 13:31 UT, reached a peak at 13:42 UT, and decreased by a factor of 2 at 13:51 UT (Figure 2).

The flare started near the northern edge of the sunspot, near the neutral magnetic line of the δ-type magnetic configuration (see left panel in Figure 6). The flare was accompanied by a halo CME detected by LASCO at 15:03 UT and shown in Figure 3. Before this the EIT instrument on SOHO observed a narrow coronal