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Transient Magnetic and Doppler Features Related to the White-Light Flares in NOAA 10486

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Abstract Rapidly moving transient features have been detected in magnetic and Doppler images of super-active region NOAA 10486 during the X17/4B flare of 28 October 2003 and the X10/2B flare of 29 October 2003. Both these flares were extremely energetic white-light events. The transient features appeared during impulsive phases of the flares and moved with speeds ranging from 30 to 50 km s^{-1}. These features were located near the previously reported compact acoustic (Donea and Lindsey, *Astrophys. J.* **630**, 1168, 2005) and seismic sources (Zharkova and Zharkov, *Astrophys. J.* **664**, 573, 2007). We examine the origin of these features and their relationship with various aspects of the flares, *viz.*, hard X-ray emission sources and flare kernels observed at different layers: *i*) photosphere (white-light continuum), *ii*) chromosphere (Hα 6563 Å), *iii*) temperature minimum region (UV 1600 Å), and *iv*) transition region (UV 284 Å).

Keywords Active regions, magnetic fields · Active regions, velocity field · Flares, dynamics

1. Introduction

Catastrophic changes in the coronal magnetic field topology are believed to trigger energetic transient events, such as, solar flares and CMEs. The MHD catastrophe leads to the reconnection of magnetic field lines in the corona that results in a wealth of observed post-flare phenomena. As flares derive their energy from stressed magnetic field, it is expected that the magnetic stress or non-potentiality would relax toward a lower energy state after the release of excess energy available in the active region. It was first suggested several decades ago by Giovanelli (1939) that flare energy release should be associated with observable magnetic

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field changes. Extensive efforts have been made since then to detect such changes using photospheric magnetic field measured by ground-based instruments (Patterson and Zirin, 1981; Patterson, 1984; Wang *et al.*, 1992; Ambastha, Hagyard, and West, 1993; Chen *et al.*, 1994; Hagyard, Stark, and Venkatakrishnan, 1999), and more recently, by space-borne instruments (Kosovichev and Zharkova, 2001; Qiu and Gary, 2003; Wang, 2006).

A wide variety of results have been reported on the pre- and post-flare changes in magnetic field parameters. However, these remained mostly unreliable because of poor sensitivity, spatial resolution, cadence and coverage of the available magnetographs. Furthermore, serious questions have also been raised about the nature of observed magnetic field changes as these measurements are expected to be affected by flare-induced line profile changes (Harvey, 1986; Qiu and Gary, 2003). Nevertheless, with the availability of recent high-quality, high-cadence magnetic field observations, there is a mounting evidence of rapid, permanent changes in longitudinal and transverse magnetic fields during the course of large flares (Sudol and Harvey, 2005).

There are some other physical processes accompanying the sudden energy release occurring in the solar corona that may influence the magnetic field measurements. A large number of charged particles, *i.e.*, electrons and protons, accelerated during the flare energy release in the corona can precipitate along magnetic field – lines and lose their energy in the lower atmosphere. During this process, microwave radiation is produced by gyrosynchrotron process and hard X-ray (HXR) emission through a thick-target bremsstrahlung process (Brown, 1971; Emslie, 1978). White-light flares (WLFs), the most energetic of all flares, were suggested to be associated with direct heating by non-thermal or accelerated particles, specifically quasi-relativistic electrons (Rust and Hegwer, 1975; Hudson *et al.*, 1992; Neidig and Kane, 1993). This is observationally supported by the HXR footpoints, *i.e.*, sites of nonthermal particle acceleration, matching well with WLF ribbons (Fletcher and Hudson, 2001; Metcalf *et al.*, 2003). However, only very high energy electrons having energy exceeding a few MeV are expected to penetrate to deeper photospheric layers due to the increasing density. Only these high energy electrons can contribute to direct heating that may not be adequate to produce WLF emission. It was inferred from the TRACE[1] WL and *Yohkoh*/HXT data that WLF ribbons originate in the chromosphere and the temperature minimum region, and that the enhanced WL emission is caused by ionization and subsequent recombination of hydrogen. Energy thus deposited in the chromosphere by the electron beam is then transported to the lower atmosphere by a back-warming process. Observed changes in magnetic field parameters during the impulsive phase of a flare would be affected by a variety of these effects.

Localized sign reversal of magnetic polarity, termed as “magnetic anomaly”, has been observed during the impulsive phase of some flares (Qiu *et al.*, 2002; Qiu and Gary, 2003). Such a sign reversal has also been attributed to the change in the spectral line profile, from absorption to emission, by numerical models (Machado *et al.*, 1980; Vernazza, Avrett, and Loeser, 1981; Ding and Fang, 1989; Ding, Qiu, and Wang, 2002). However, non-LTE calculations for the spectral line Ni I 6768 Å, used for magnetic field measurements in GONG[2] and SOHO/MDI[3] instruments, have shown that this absorption line can turn into emission only by a large increase of electron density and not by heating the atmosphere by any other means. Consistent with this, Qiu and Gary (2003) discovered sign reversals in locations of

[1]Transition Region and Coronal Explorer.

[2]Global Oscillation Network Group.

[3]Solar and Heliospheric Observatory, Michelson Doppler Imager.