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The chromospheric line-of-sight velocity variations in a solar microflare

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Abstract

The variations of the chromospheric line-of-sight velocity in the active region NOAA 11024 are studied before, during, and after a solar microflare on 2009 July 4. At the day of the observations the main emergence phase was in this active region. The new emerging flux has interacted with the pre-existing magnetic field.

The spectropolarimetric observations were carried out with the French–Italian THEMIS telescope (Spain, Tenerife). We used Hα spectra of the high resolution obtained over 21 min. The spatial resolution was ~1 arcsec. The time interval between the spectra was 2.84 s. Doppler velocities were measured in the microflare location and its surroundings. We have revealed strong temporal variations of the line-of-sight velocity in the chromosphere. The velocities changed in the range −33–10 km/s. We revealed the velocity oscillations with the amplitude of 4–5 km/s. 12–14 min before the microflare both upward and downward motions with velocity values reaching about 20 km/s are found on the outer edge of the region studied. The amplitude of the oscillations increased. It may be the signature of the magnetic reconnection.

Keywords: Sun; Solar flares; Chromosphere; Line-of-sight velocity

1. Introduction

It is known that a flare is one of the most dynamic solar events. Flares often occur as a result of the magnetic reconnection when the magnetic flux emerges from the convective zone and interacts with the old magnetic field of an active region (e.g. Heyvaerts et al. (1977)). Two-ribbon flares result from the reconnection of magnetic arcades opened by the filament (or flux rope) eruption. Enormous energy is carried from the place of the reconnection by the flows of nonthermal particles, heat, large-scale flows, and waves. The magnetic reconnections may occur at different levels of the solar atmosphere. Initial slow reconnections may occur in the lower atmosphere (e.g. Chae et al. (2003), Ishii et al. (1998), Moon et al. (2004)). Some features of these processes have not yet been clarified.

All the levels of the solar atmosphere are perturbed during the flares. The evaporation, the appearance of the condensations may be observed in the chromosphere (e.g. Falchi et al. (1992), Fisher (1989), Li and Ding (2011)). Motions in the chromosphere of solar flares were investigated in a number of the works (e.g. Cauzzi et al. (1996), Ding et al. (1995), Falchi et al. (1992, 2006), Ichimoto and Kurokawa (1984), Keys et al. (2011), Li and Ding (2004), Teriaca et al. (2006)). Ding et al. (1995), Ichimoto and Kurokawa (1984), and others have revealed the red asymmetry of the Hα line profiles in the initial phase of the flares interpreted as chromospheric downflows with velocities of tens of km/s. These chromospheric downflows may be the signature of the chromospheric condensation (Fisher, 1989). Falchi et al. (2006), Teriaca et al. (2006) have observed the chromospheric downflows with

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velocities between 4 and 20 km/s and upward motions at transition region and coronal levels in C-class flares. Keys et al. (2011) used high spatial and temporal resolution observations from the Swedish Solar Telescope to study the chromospheric velocities of a C-class flare. The authors presented the velocity maps (line-core Doppler shifts displayed in km/s derived from the Hα scans, Fig. 3 of their paper). They found both red-shifted and blue-shifted LOS Hα velocities with values up to 17 km/s. Velocity maps showed considerable mixing of both the magnitude and direction of the velocities over the entire flare ribbon (Keys et al., 2011). Babin and Koval (2010) have analyzed high-resolution Hα spectra and revealed complex fine structure of LOS velocity field in the flare of 2B/M2.3-class.

The significant changes of chromospheric LOS velocities were revealed at all stages of the flares. Alikaeva and Chornogor (2004) detected the chromospheric upflows before the flares and in their impulsive phase. Cauzzi et al. (1996), Chornogor and Alikaeva (2004), Keys et al. (2011), Kondrashova and Prokudina (2006) found a change in the movement direction around the peak of the hard X-ray flux. Such change in direction of the velocity may be explained by the evaporation caused by the heating of the chromosphere by the non-thermal particles and heat flows from the released energy region. Chornogor and Alikaeva (2004) have revealed quasi-periodic variations in the chromospheric LOS velocity and the intensity of the Hα line with an approximately 3 min period during bright flare.

In our study we present the results obtained from the analysis of the spectra acquired during a microflare in the active region NOAA 11024 on 2009 July 4. The spectra of high spatial and temporal resolution were obtained with the THEMIS (Heliographic Telescope for the Study of the Magnetism and Instabilities on the Sun) telescope. We study the LOS chromospheric velocity variations associated with the microflare.

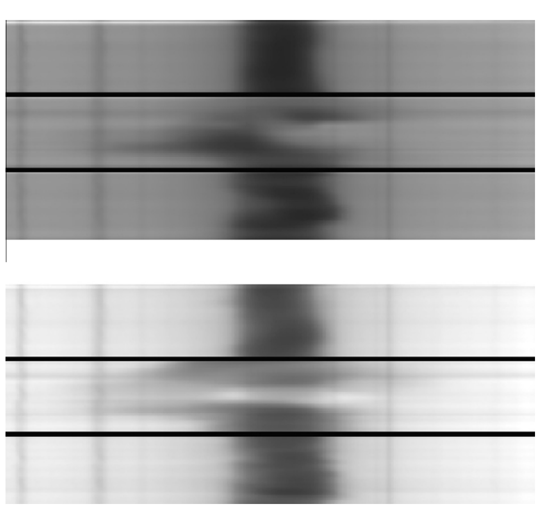

Fig. 1. Hα spectra obtained during our observations at 11:50:17 UT (before the flare) and 12:04:36 UT (at the flare maximum) on 2009 July 4. The vertical direction corresponds to the direction of the slit. The wavelength range along the x-axis is from 6560 to 6567 Å.

2. Observations

Active region (AR) NOAA 11024 appeared as field of facula on 2009 July 29 on the southern hemisphere of the solar disc. At the day of the observations at THEMIS, on 2009 July 4, this AR was located near the central meridian. SOHO/MDI continuum image and MDI magnetogram of the active region under study is given in Kondrashova (2013). The spot group was bipolar, it had the complex structure of the magnetic field. Fast emergence of new magnetic flux was observed in AR at large and small scales. The main emergence phase was detected in this AR (Valori et al., 2012). The new emerging flux has interacted with the pre-existing magnetic field. The magnetic reconnections caused the increased activity. Microflares and surges occurred during that day. We studied one of the microflares.

The spectropolarimetric observations of the active region were carried out with the French–Italian THEMIS telescope. The spectrograph slit width was 0.5 arcsec. The pixel sampling of the observations was 0.2 arcsec, while the actual spatial resolution, limited by the seeing conditions, was below 1 arcsec. The slit was located near to the center of the active region, just at the place of polarity inversion.

In the current work we used a fixed-slit time series which started at 11:47 UT. It includes 436 spectral images. The time interval between the individual spectra was 2.84 s. The spectra of the AR were acquired over 21 min. We used the spectral region, containing the chromospheric line Hα. The time interval between the selected spectra ranged from 2.84 to 14 s. According to the Space Weather Prediction Center (SWPC) data, B3.1 class X-ray burst started at 11:59 UT and reached its maximum at 12:07 UT. The flare was characterized by a soft spectrum of non-thermal electrons (3–12 keV). The Hα line brightening in the spectra was observed from about 12:03.5 UT and lasted about 2 min. Fig. 1 shows Hα spectra obtained at 11:50:17 UT (before the flare) and 12:04:36 UT (at the flare maximum).

The field of view of THEMIS is divided into three parts, each of them about 16 arcsec long. The intervals between them are indicated by black horizontal lines. The distance along the y-axis between these lines is part of AR under consideration. The flare is in the center of this part.

Doppler velocities have been determined for five spectral transects in the microflare region and its surroundings using the wavelength shift of the local minimum of the Hα line profiles. The distance between these transects was 1 arcsec. Transects 1 and 5 relate to the region outside the flare. Transect 3 relates to the center of the flare, 2 and 4 to the edges of the flare region. Doppler velocities based on the asymmetries of the Hα line were derived for transect 3 as well. The error of the velocity determination is of about 0.3 km/s.