Solar Plages: Observational Study of Their Chromospheric Heating and Spicular Mass Ejections


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Abstract. We investigated the chromospheric dynamics of plage area. From our spectroscopic analysis of the CaII K line, we have found that their periodic variations are due to the propagation of acoustic waves from the lower layers. Another observational work on Hinode CaII H images, gave us a new result that there are numerous spicular jets in plage area, thanks to the stable observing condition of Hinode. The present paper is an extended abstract of our works which will be published fully in our future papers.

1. Introduction

Spectroscopic observations in CaII K solar chromospheric line with Domeless Solar Telescope at Hida Observatory, Kyoto University and superb imaging observations with Hinode/SOT gave us a unified view on the solar plage chromosphere. The acoustic waves emanating from the photosphere play an important role in heating the plage chromosphere and in driving the mass ejection by forming acoustic shocks.

2. Time-sequenced Spectroscopic Observation of Ca II K Line in a Plage

The observation was done on June 16, 2007. The target region is shown in the left panel of Figure 1.

Figure 1. Target plage region and the temporal variation of CaIIK Spectra
Locating the spectrograph slit on a fixed point in the plage, we obtained CaII K spectrograph sequentially with a cadence of 1 sec for a time around 60 min. The time variation of the CaII K spectrum at a plage point shows oscillatory behavior shown in the right panel of Figure 1. The power spectrum is dominated by 3-min and 5-min components as is shown in Figure 2.

We extracted 3-min and 5-min components selectively and show the temporal behavior in Figure 2 and 3.

![Figure 2](image.png)

Figure 2. Power spectra in the plage (solid line) and in the quiet region (broken line). The right panel shows the temporal variation of the 3-min component of CaII K spectra.

The evolution of CaII K line reminds us strong similarity to those of chromospheric grains analyzed by Carlsson and Stein (1997). The origin of the oscillatory behavior of CaII K line profile was studied with the help of 1-dim numerical simulation of acoustic wave propagation (period = 3 or 5 min) in an atmospheric model and non-LTE radiative transfer calculation of CaII atom. The temporal variation of CaII K line profiles thus derived has well reproduced the observed one as is shown in Figure 3.

So we suggest that the periodic behavior of CaII K line profile is due to the acoustic waves propagating from the photosphere to the corona forming shocks in upper layers.

3. Plage Spicules

On Aug 14, 2007, we did a cooperative observation of solar plage between Domeless Solar Telescope and Hinode/SOT. Hinode/SOT CaII H images allowed us to follow the temporal evolution of spicule jets from the plage area.

We applied an image processing (MADMAX, Koutchmy and Koutchmy (1991)) to the observed images which enhanced the fine slender structures. We clearly identifies many spicule features ejected from the intergranular lane (Figure 4).

The characteristics of the spicule features are:
(1) Up and down motion with a mean speed of 22km/s,
(2) Ballistic way of motion with constant deceleration (-300 ~ -50 m/s²),
(3) Maximum speed linearly correlated with the value of deceleration (shock driven jet),
Figure 3. The left panel shows the temporal variation of the 5-min component of CaII K spectra. The right panel is the simulated one with 1-dim simulation of acoustic wave propagation and the non-LTE MULTI code.

Figure 4. The bottom left panel shows the original Hinode CaIIH image of the plage observed. The top left panel is a processed image by MADMAX. The right panel shows the temporal evolution of the plage jets.
Comparison between the observation and theoretical simulations. The left panel shows the comparison in the scatterplot between the maximum velocities and the heights (Shibata and Suematsu (1982)). The right panel shows the one between the maximum speed and the deceleration. The observed data distribute nearly in the same zone predicted by Hansteen et al. (2006).

(4) Simultaneous CaII H spectra showed the dominance of blue asymmetric emission. These characteristics are consistent with the prediction of acoustic shock acceleration of chromospheric jets. Comparison with the theoretical works such as Shibata and Suematsu (1982) and Hansteen et al. (2006) are shown in Figure 5.

4. Summary

Plage spicules clearly found in this work are driven by acoustic shock waves and will be a source of mass supply to the plage corona. The acoustic shocks are produced by the periodic propagation of acoustic waves from the lower layers, and probably contribute to heat up the chromosphere of plage region similar to the quiet region of the solar atmosphere.

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