A small-scale H-alpha eruption in the north polar limb of the Sun observed by New Solar Telescope

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Abstract
The 1.6 m New Solar Telescope (NST) at Big Bear Solar Observatory (BBSO) is the recently constructed world largest optical solar telescope on the ground. Up to date it has been partly operated, i.e., observations have been made at Nasmyth focus only without adaptive optic (AO) system. The AO system plans to be installed in this summer. Using the NST, we have observed the north polar limb in H-alpha line center wavelength on 2009 August 26. A remarkable H-alpha eruption was observed from 18:20 UT to 18:45 UT and it had a relatively slower speed of about 10 km/s in early stage. Then the eruption was slightly accelerated up to 20-30 km/s and appeared to be deflected along the pre-existing magnetic field. The eruption also showed several interesting characteristics such as bifurcation, rotation, horizontal oscillation, and direction and thickness change of its structure during eruption. In this paper, we will report the observational properties of the small-scale eruption observed by the NST and discuss their implication on magnetic reconnection.

1. INTRODUCTION
The NST was installed at the end of last year and this may be a most early observation by using the NST. The NST is recently constructed world largest optical solar telescope on the ground. Currently, observations have been made at Nasmyth focus only. Originally, the NST has two focuses; Nasmyth focus without Adaptive Optic (AO) system and Coude focus with AO. Instruments after Coude focus can be normally operated with AO system such as Fast Imaging Solar Spectrograph (FISS), Infrared Imaging Magnetograph (IRIM), Vector Imaging Magnetograph (VIM), and so on. AO system was installed recently and going on the test observations in these days. Figure 1 is a schematic diagram and a full-view of the NST. In the figure you can see the primary mirror (M1 cell) and Nasmyth bench.

In this work, we will report a small-scale H-alpha eruption in the northern polar region of the Sun observed by the NST. Unfortunately, this observation did not have any other supporting data in the same or different wavelengths such as STEREO and Hinode and so on. But I will introduce some observational properties and add some discussions.

2. OBSERVATION
The observation was made on 2009 August 26 from 18:20 UT to 18:45 UT. Observing target is north polar limb in H-alpha line center wavelength. The CCD has a dimension of 2K×2K. For this observation we obtained 2×2 binning data. So, the pixel size is 0.07". For the analysis, we made dark subtraction and flat field correction. We also used speckle reconstruction technique. In this early phase of NST observation, before applying AO technique, the most powerful analysis method is speckle reconstruction. Actually, speckle reconstruction makes one reconstructed image from several short-exposed images in order to minimize the seeing effect. Reconstruction code was originally developed by NSO people. Since we do not know the method in detail, the speckle reconstruction code looks like a black box. Sometimes the result is good and sometimes the result was not good. And we do not know the exact cause of different results. When we make observation, we take one burst. One burst contains 70 images with an exposure of 50 ms. After applying speckle reconstruction, we get one image (see Figure 2). And the time cadence between bursts is 15 s.
Fig. 1 A schematic diagram (left) and a real full-view (right) of the NST.

Fig. 2 (Left) a snapshot of the burst which shows an image before applying speckle reconstruction. (Right) a reconstructed image after applying speckle reconstruction.

(a) Initial phase
Figure 3 shows temporal evolution of the eruption. The eruption was started at 18:33 UT in the north polar limb with a speed of about 10 km s$^{-1}$ and there may be under-lying loop activities before the eruption. Around 18:35 UT, the eruption seemed to be slightly accelerated and the speed reached about 20-30 km s$^{-1}$. The eruption also appeared to be deflected along the pre-existing magnetic field.

(b) Middle phase
In the middle phase of the eruption, there are several interesting features: bifurcation, rotation, and twist accumulation. During a span from 18:37 UT to 18:38 UT, we can see a rotational motion near the top of the eruption. At 18:38:36 UT, the eruption has a clear bifurcation structure, i.e., the structure seemed to be separated into two threads during its eruption. In addition, the eruption structure appeared to be thick as time goes by. It may be due to the twist accumulation.

(c) Late phase
In the late stage, the thickness of the eruption becomes small after twist propagation. Thickness change ranges from 500 to 1000 km. Maximum height reaches up to 15000 km above the limb. After 18:42 UT, the structure fades out.

(d) Final phase
The eruption was disappeared along the pre-existing magnetic field.

3. OBSERVATIONAL PROPERTIES OF THE ERUPTION

Duration is more than 10 minutes and the thickness ranges from 500 to 1000 km. The height reached up to 15000 km and the speed ranges from 10 - 30 km s$^{-1}$. The eruption shows several interesting features; bifurcation, rotation, horizontal oscillation, direction change and so on.

(a) Identity of the eruption
For the identity of the small-scale H-alpha eruption, we would like to consider the physical parameters of spicules and surges. First, spicules are jet-like chromospheric structures observed in H-alpha at the solar limb. The speed and the height are 20-150 km s$^{-1}$ and 1000-10000 km, respectively. Their lifetimes last 10-300 s and most of them have the lifetime less than
De Pontieu et al. (2007) divide the spicules into two classes: type I and type II. Type I shows up-and-downward motion, longer lifetime, and small velocity. Type II shoot up and fade out, carry Alfvén waves, and shows short lifetime and large velocity. Type I may be driven by MHD acoustic shock and type II by magnetic reconnection. Second, H-alpha surges are straight and slightly curved ejections consisting of smaller streamers. Their heights, velocities, and lifetimes are $(5-20) \times 10^{4}$ km, $50-200$ km s$^{-1}$, and 10-20 min, respectively. They show highly filamentary structures in high resolution observation and are associated with satellite sunspots or moving magnetic features. They may be produced by magnetic reconnection between emerging flux and pre-existing surrounding flux. So, our event seems to correspond to small H-alpha surge according to its observational properties.

(b) Kinematic evolution
Figure 4 shows height-time plot of the eruption and there is a slight acceleration from 14 to 27 km s$^{-1}$ around 18:35 UT. This may be an indication of magnetic reconnection related to the eruption.

(c) Rotating motion
In Figure, we can find the signature of rotational motion of the ejection. Regarding this rotational motion of the eruption, Jibben & Canfield (2004) found that magnetic reconnection of twisted flux tubes with their less twisted surroundings can account for the production and rotating motion of the surges. It can be an explanation for the rotation and thickness change of our event.

(d) Horizontal oscillation
The eruption also shows the horizontal oscillation with respect to its erupting axis. For the identity of this oscillation, we need more investigation.

Fig. 3 Time series images of the eruption from 18:34 UT to 18:45 UT.
4. SUMMARY AND REMAINING PROBLEMS

Now, we can summarize our observation for the small-scale H-alpha eruption on 2009 August 26;
(a) The eruption is a small H-alpha surge.
(b) It shows a slight acceleration around 18:35 UT. This may be an indication of magnetic reconnection.
(c) Rotation and thickness change can be explained by the result of Jibben & Canfield (2004): twist propagation.
(d) It also shows several interesting features; bifurcation and horizontal oscillation.

It remains to be investigated in terms of the following questions;
(a) Regarding the rotational motion, how can we measure the propagating twist?
(b) What is magnetic field configuration related to this eruption?
(c) What is the identity of the oscillation: standing or propagating waves?

REFERENCES