Role of Small-Scale Dynamics in Coronal Holes and Quiet Regions for Coronal Heating and Solar Wind Acceleration

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Abstract

Small-scale solar dynamics, e.g., spicules and macrospicules, in coronal holes are believed to play an important role in the coronal heating and solar wind acceleration. Since the network magnetic flux has a fine-scale mix of both polarities, network magnetic fields in supergranule boundary are likely to be the most important factors responsible for the dynamics. However, the formation mechanism of macrospicules remains controversial, in particular in the relation with magnetic field topology at the base of macrospicules. From H-alpha limb and on-disk observations from Big Bear Solar Observatory (BBSO), we find that most macrospicules have one or the other of two forms — a spiked jet and an erupting loop [Yamauchi et al, 2004]. It is also found that spiked-jet macrospicules are driven by reconnection processes that occur between the network bipole and open magnetic fields, as in Hα surges and X-ray jets. On the other hand, erupting-loop macrospicules have the properties of an erupting loop connecting between positive and negative flux and appear to be mini-filament eruptions [Yamauchi et al, 2005]. Here, we made high-spatial and temporal resolution TRACE UV/EUV observations of coronal holes and quiet regions in September, 2004 jointly with BBSO Hα and magnetogram observations to investigate the structure and evolution of small-scale dynamics and the relation with magnetic network activity. From H_α blue-wing images from BBSO, we identified 36 macrospicules in coronal holes and 60 events in quiet region, respectively. 85 events of 96 macrospicules were in the form of a spiked jet and were rooted in compact bipolar fields at the edges of the magnetic network. Most events showed brightening at their base in C IV 1550 Å images. These indicate that spiky macrospicules are driven by reconnection between the network bipole and open magnetic fields and they appear to be are microflares or Hα jets. We also found 7 macrospicules that were in the form of an erupting loop seated on between positive and negative network flux. They appear to be mini-filament eruptions. Our results support scenarios of coronal heating and solar wind generation through fine-scale explosive reconnection events seated in the magnetic network.

Motivation

Magnetic Network Activity in Coronal Holes and Quiet Regions
+
Small-Scale Dynamics
(e.g., spicules, macrospicules, microflares, and etc.)

MHD Waves ⇓ Heat Energy

Coronal Heating & Solar Wind Acceleration

- Small-scale dynamics in Coronal Holes and Quiet Regions ⟺ Magnetic Network Activity
- Can small-scale synamics provide energy and mass flux enough for coronal heating and solar wind acceleration in coronal holes and quiet regions?
- Is there any difference between small-scale events in coronal holes and quiet regions?

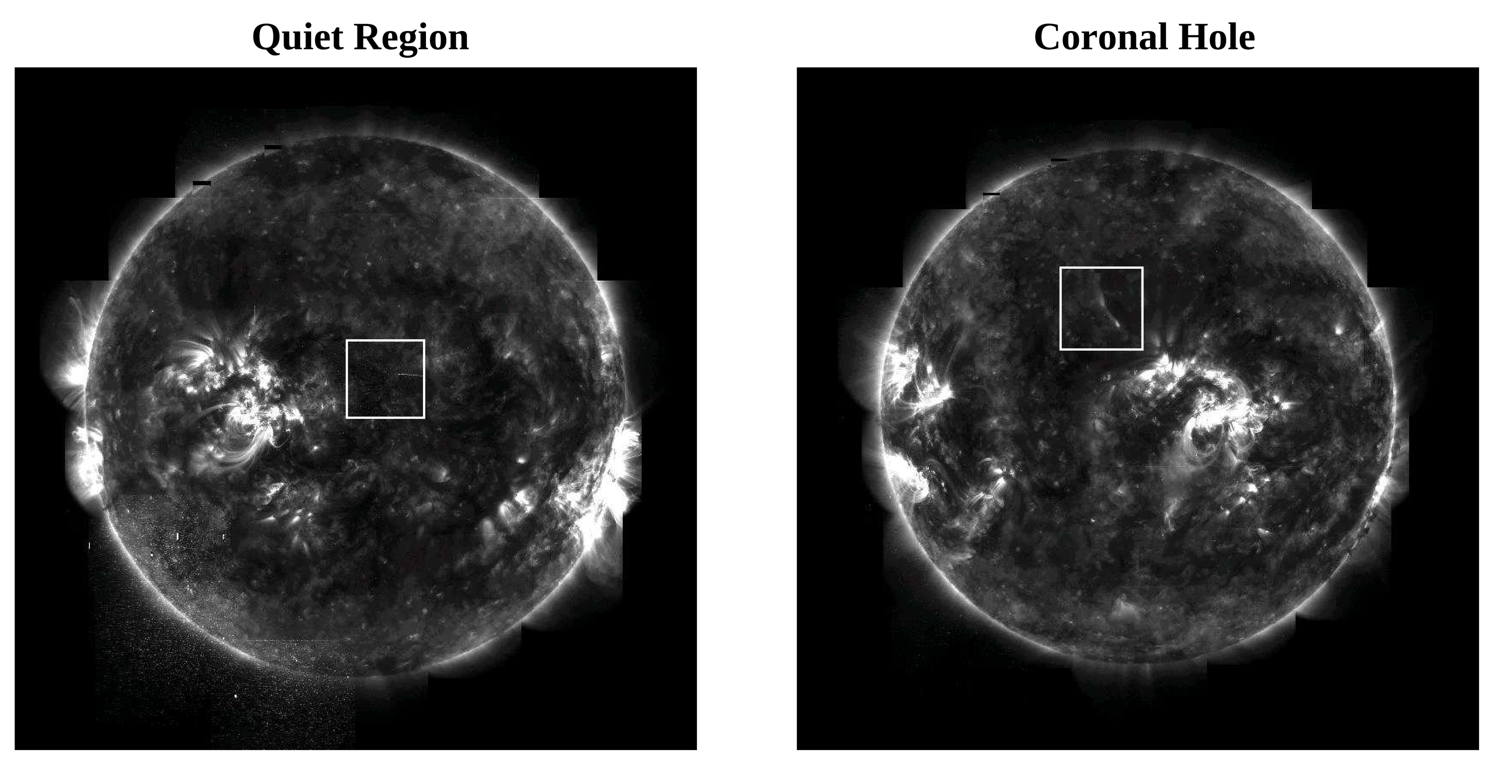
Observations

We carried out TRACE UV/EUV and BBSO Hα and magnetogram observations of coronal holes and quiet regions near the solar disk center for two weeks in September, 2004. Detail information on the observations is listed below. We analyzed the data of a quiet region and coronal hole observed on September 13 and 16, respectively, for two weeks of observations. Figure 1 shows the quiet region and coronal hole we observed.

Quiet Region: 17:00UT–23:00UT (BBSO) on September 13, 2004
14:00UT–24:00UT (TRACE)

Coronal Hole: 16:00UT–23:00UT (BBSO) on September 16, 2004
14:00UT–24:00UT (TRACE)

	Wavelength	Cadence	FOV
BBSO	Hα ± 0.65Å	40 sec	$200'' \times 200''$ (0.4 arcsec pixel^{-1})
	Ca K line	30sec	$300'' \times 300''$ (0.6 arcsec pixel^{-1})
	Magnetogram		
TRACE	1550, 1600, and 1700Å	30 sec	$256'' \times 256''$ (0.5 arcsec pixel^{-1})
	171 and 195Å	20 min	$384'' \times 384''$ (0.5 arcsec pixel^{-1})



(a) (b)

Figure 1: TRACE full disk mosaic images at Fe IX 171 Å. These images were taken on (a) September 13 and (b) September 16, 2004 and the square area marked in each full disk image indicates (a) the quiet region and (b) the coronal hole we observed, respectively.

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Criteria of Macrospicules

We define the criteria of the macrospicules for the investigation of structure of macrospicules:

Spiked-Jet Macrospicule:
1. A single-columnar jet
2. The maximum base width is greater than 1000 km

Erupting-Loop Macrospicule:
1. An entire magnetic loop is seen at the beginning of an eruption
2. Double-strand structure (the two leges of the loop) is seen at the end

Moreover, both loop and jet events must be observed from start to end to classify the structural type (loop, spike, or unclassifiable), measure the lifetime, and observe the entire evolution of the event.

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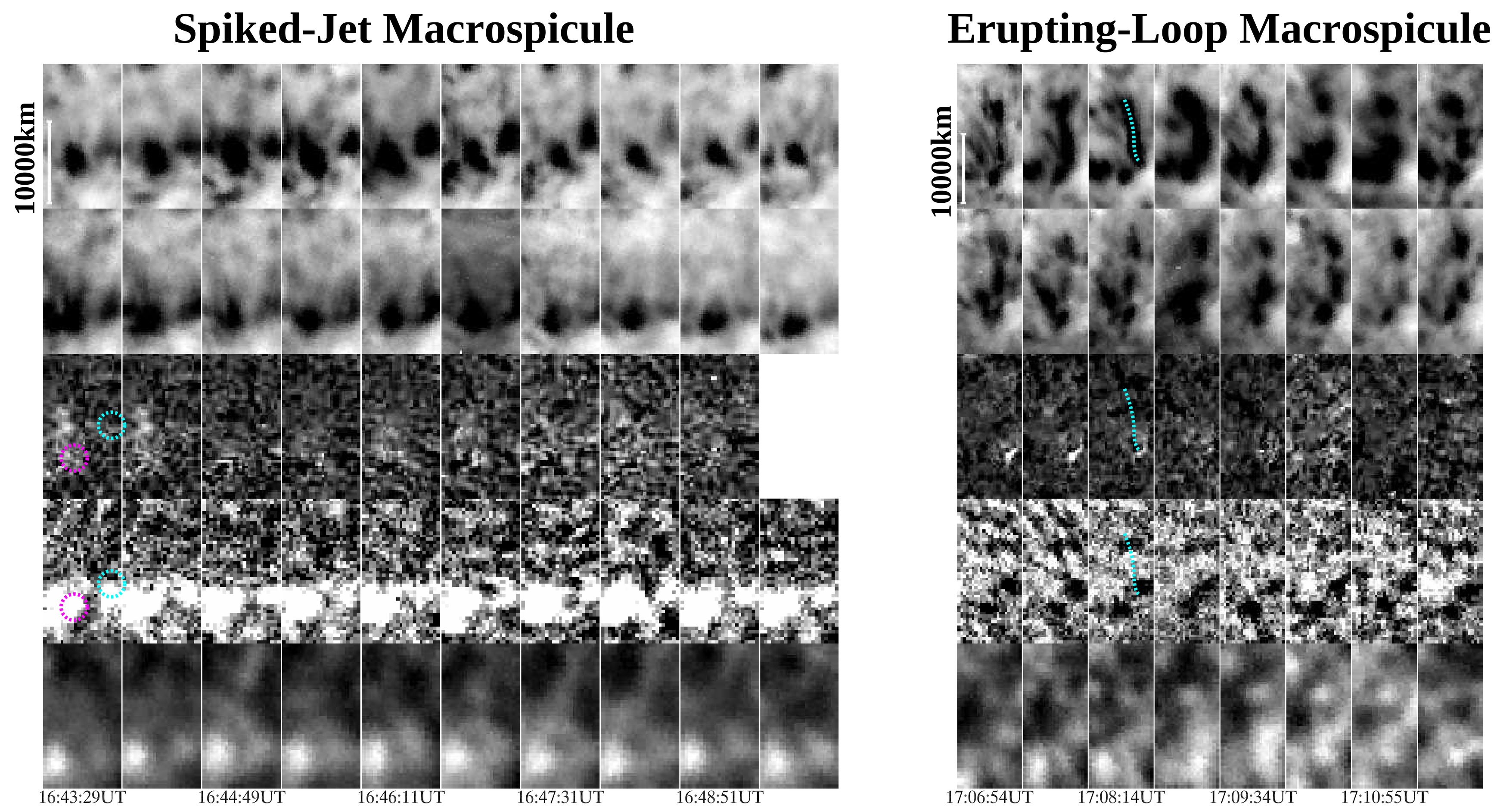
36 events (Spiky 29; Loop 5; Unclassifiable 2) in Coronal Hole
60 events (Spiky 56; Loop 2; Unclassifiable 2) in Quiet Region

Results



(a) (b)

Figure 2: Time evolutions of (a) two spiked-jet macrospicules observed at 16:43:29UT – 16:49:31UT on September 13 and (b) an erupting-loop macrospicule at 17:06:54UT – 17:11:35UT on September 16. Images from the top to the bottom are those in Hα-0.65Å, Hα+0.65Å, C IV 1500Å, magnetogram, Ca K line. Blue and red circles in (a) indicate the footpoints of the spiky macrospicules and the dotted lines in (b) indicate the outline of the erupting loop.

Summary and Discussion

- We made TRACE UV/EUV observations in September, 2004 jointly with BBSO Hα and magnetogram observations. We analyzed the images to study the structure of macrospicules as manifestation of small-scale dynamics in coronal holes and quiet regions and their time evolution in relation to the magnetic network activity.
- We identified 36 macrospicules in a coronal hole and 60 macrospicules in a quiet region. Most events (85/96) were in the form of a spiky jet, 7 were in the form of a single-column spiked jet, and 4 events were unclassifiable.
- There is no difference of the life time between spiky and loop macrospicules. The averaged life time of all macrospicules is about 7 ± 3 min. The birthrates of macrospicules in coronal holes and quiet regions are 3 and 5 events/s, respectively. These are consistent with previous studies [*e.g.*, Bohlin et al., 1975; Dere et al., 1989; Wang, 1998]
- Spiked-jet macrospicules were seated on compact bipoles in the edges of the magnetic network. Most spiky events (65/85) show brightening at their footpoints in C IV 1550Å images. These suggest that spiked-jet macrospicules are driven by reconnection processes that occur between the network bipole and open magnetic fields, as in Hα surges and X-ray jets [*e.g.*, Shibata, 2001]. Moreover, 65 spiky events were seen in Hα blue-wing images at the beginning of the events and were seen in red-wing images. This indicates that materials of the events were lifted up and returned to the chromosphere. 20 events of 85 were seen only in blue-wing images, which indicates the plasma of the events erupted to the corona.
- Erupting-loop macrospicules show the properties of an erupting loop connecting between positive and negative flux and appear to be mini-filament eruptions.
- Our results support scenarios of coronal heating and solar wind generation through fine-scale explosive reconnection events seated in the magnetic network [*e.g.*, Axford & McKenzie, 1992, 1997; Fisk et al., 1999; Falconer et al., 2003].
- The fraction of erupting-loop macrospicules in coronal holes is 3 times larger than quiet regions. However, we do not find any significant difference between macrospicules in coronal holes and quiet regions from this study

  ⇒ We will look into the data in more detail and increase number of events to discuss this topic more precisely.
- As a future work, we will estimate plasma density and temperature of macrospicules from TRACE EUV images. Using these parametersas well as the birthrates estimated with BBSO data, we will examine whether the amounts of energy and mass fluxes from macrospicules (and from their smaller counterparts, spicules) are enough for coronal heating and solar wind acceleration.