Macrospicules in Coronal Holes

Yohei Yamauchi (NJIT)

H. Wang (NJIT/BBSO), R.L. Moore, S.T. Suess (NASA/MSFC/NSSTC)
and T. Sakurai (NAOJ)

Introduction

Coronal Heating & Solar Wind Acceleration

Introduction

Coronal Heating & Solar Wind Acceleration

Magnetic Field

Introduction

Coronal Heating & Solar Wind Acceleration

MHD Waves $\Uparrow$ Explosive Events

Magnetic Field

Introduction

Small-Scale Dynamics

(e.g., spicules, macrospicules, microflares, jets, ...)

Introduction

Small-Scale Dynamics

(e.g., spicules, macrospicules, microflares, jets, ...)

$\Downarrow$

Coronal Heating & Solar Wind Acceleration

Introduction

Small-Scale Dynamics

(e.g., spicules, macrospicules, microflares, jets, ...)

$\Downarrow$

Coronal Heating & Solar Wind Acceleration

$\Downarrow$

Magnetic Structure and Evolution of Macrospicules from observations at Big Bear Solar Observatory (BBSO)

Macrospicules

	Macrospicule	Spicule
Height:	$7000 - 40,000$ km	$7000 - 13,000$ km
Lifetime:	$3 - 40$ min	$1 - 10$ min
Velocity:	$10 - 150$ km/s	~ 25 km/s
Temp:	$\sim$ 8000 K (HeII 304 Å)	$5000 - 15,0000$ K

Macrospicules

Formation Mechanism of Macrospicule

Macrospicules

Formation Mechanism of Macrospicule

$J \times B$ Force

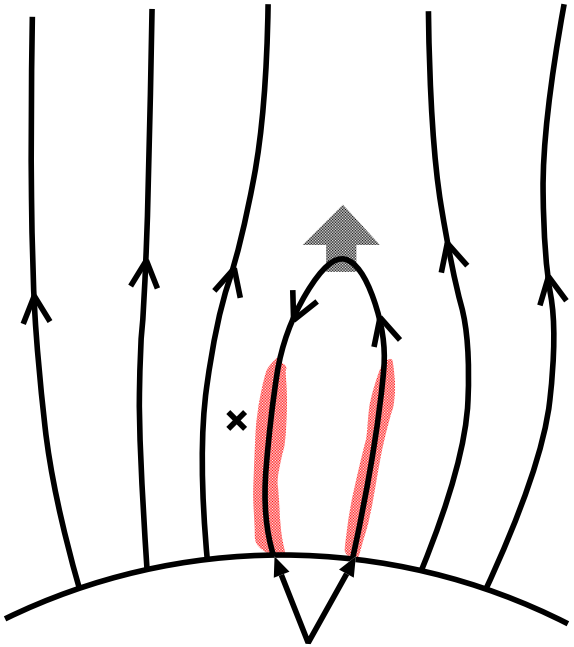
Magnetic Reconnection

Macrospicules

Formation Mechanism of Macrospicule

$J \times B$ Force = Erupting-Loop Type

Magnetic Reconnection



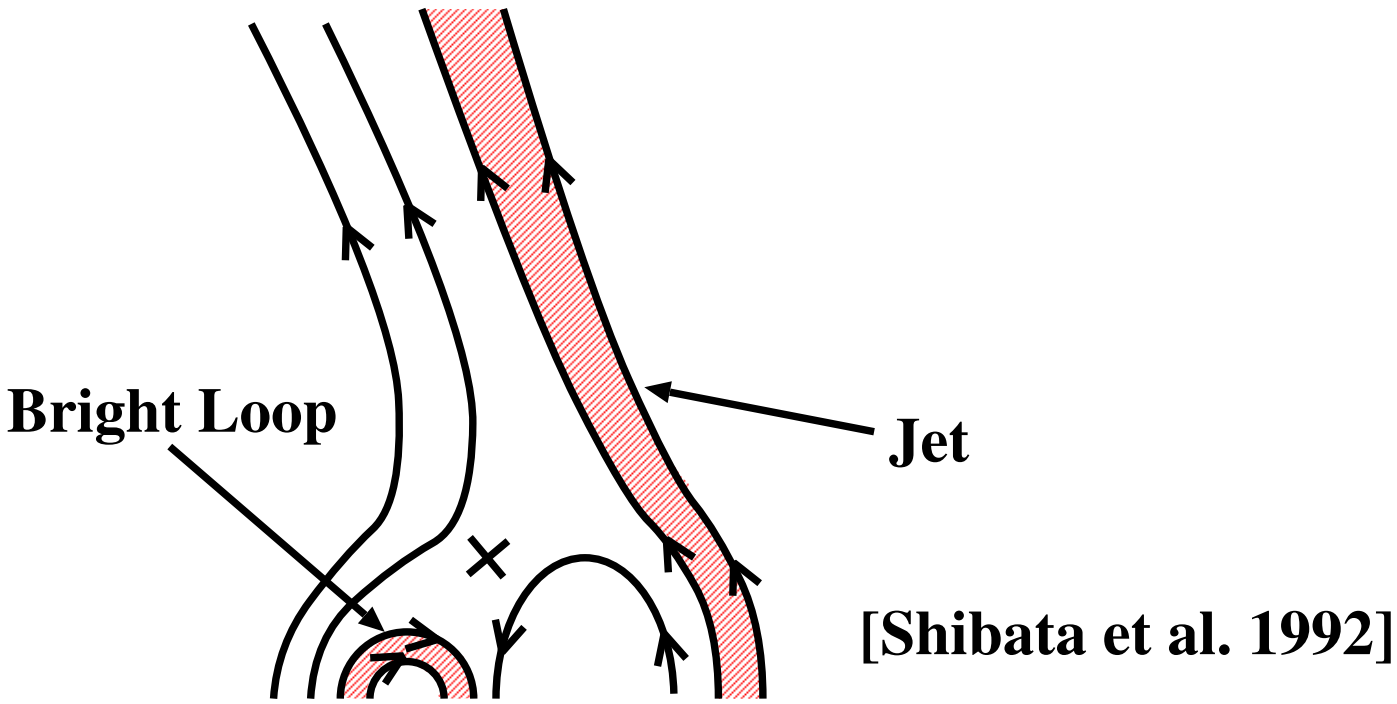
Macrospicule?

Macrospicules

Formation Mechanism of Macrospicule

$J \times B$ Force = Erupting-Loop Type

Magnetic Reconnection = Spiked-Jet Type



BBSO Observations

We used full-disk Hα images taken from observations at Big Bear Solar Observatory at solar activity minimum.

Obs. Date:	Aug 25, 1996, Aug 28, 1996, Sep 7, 1996, Oct 16, 1996, Apr 14, 1997, and May 7, 1997
Wavelength:	Hα center
Cadence:	$1 - 3$ min
Spatial Res:	2arcsec ($\approx$ 1 arcsec pixel^{-1})

Criteria of Macrospicules

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

- Bright Structure
- Height $\geq$ 15000km above the limb
- in Coronal Holes

Criteria of Macrospicules

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

- Bright Structure
- Height $\geq$ 15000km above the limb
- in Coronal Holes

$$\Downarrow$$

35 macrospicules

Criteria of Macrospicules

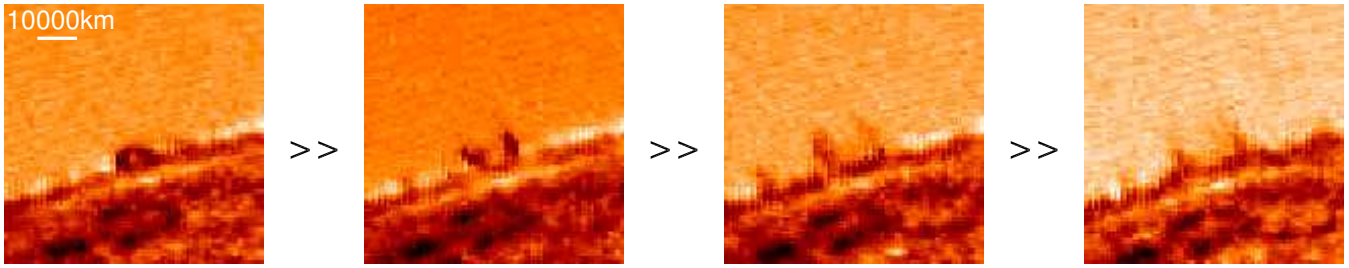
We define the criteria of the macrospicules for the investigation of structure of macrospicules:

- Bright Structure
- Height $\geq$ 15000km above the limb
- in Coronal Holes

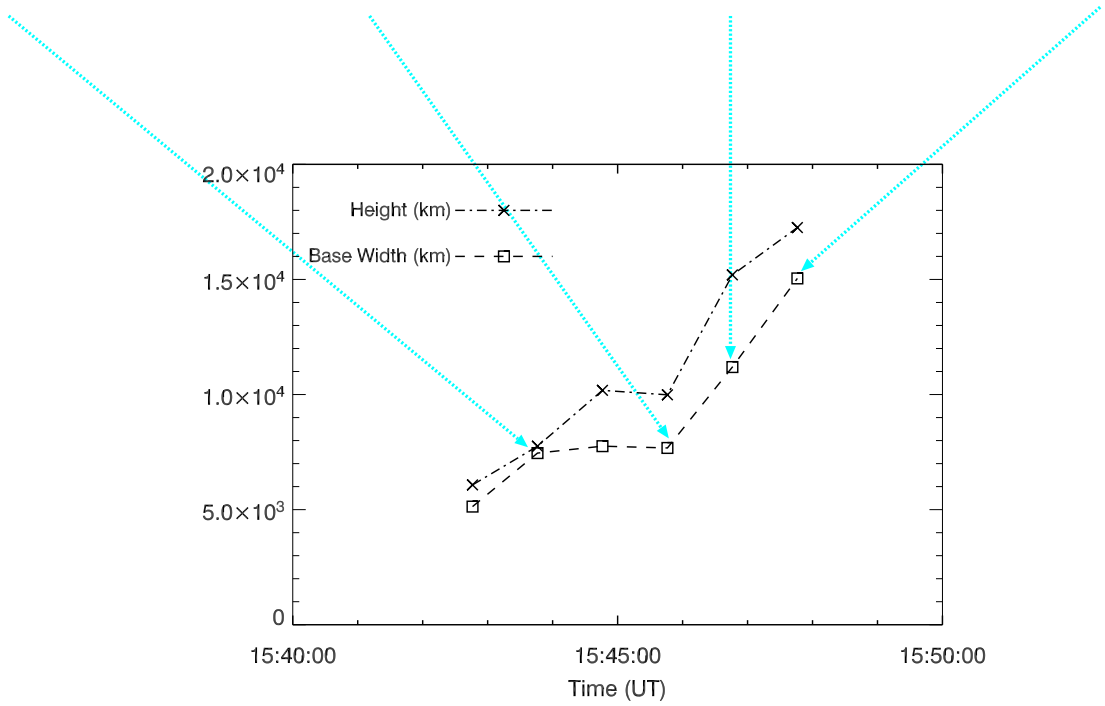
$$\Downarrow$$

35 macrospicules $\rightarrow$ 15 Erupting Loop / 17 Spiked Jet

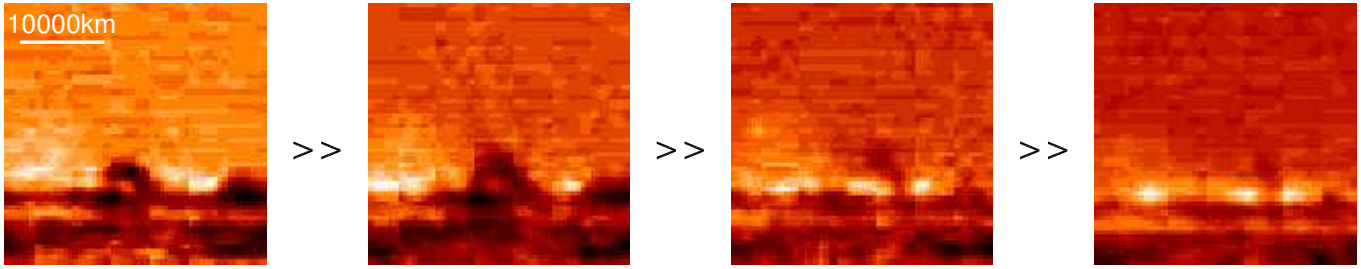
Erupting-Loop Macrospicule 1



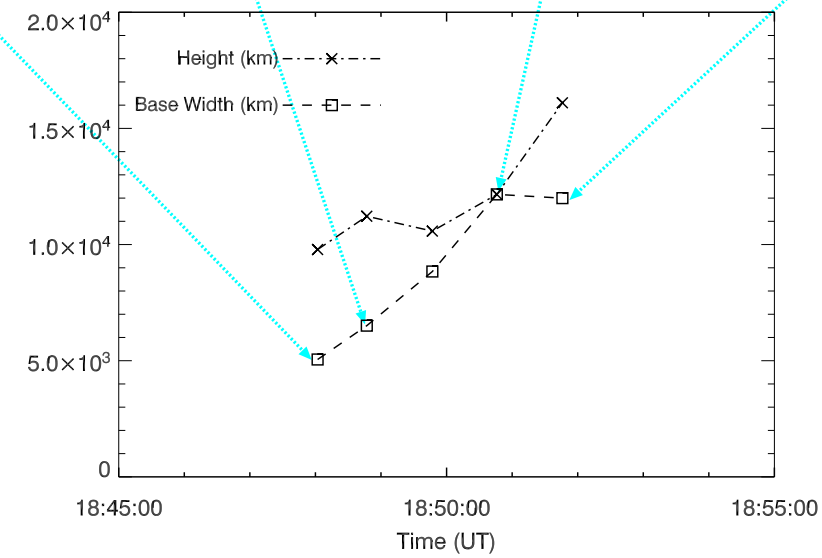
05/07/97 15:43:46UT 05/07/97 15:45:46UT 05/07/97 15:46:46UT 05/07/97 15:47:46UT



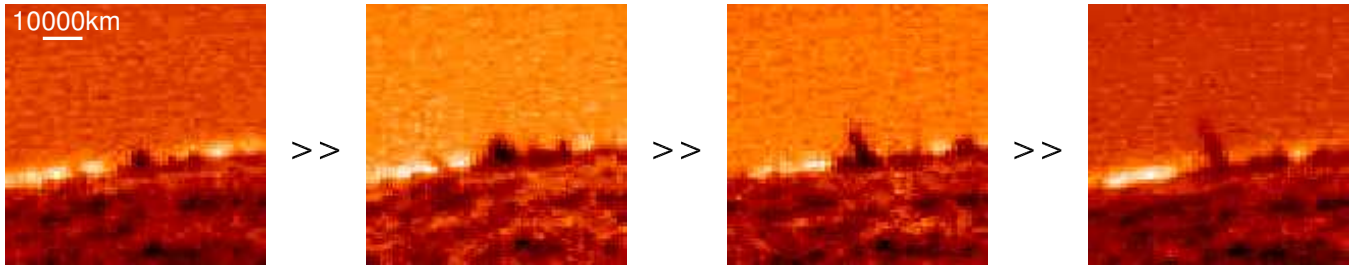
Erupting-Loop Macrospicule 2



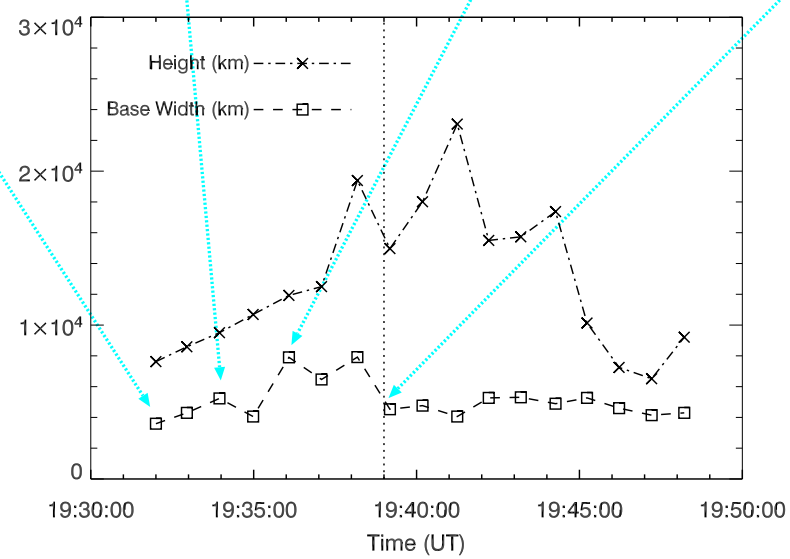
04/14/97 18:48:02UT >> 04/14/97 18:48:47UT >> 04/14/97 18:50:46UT >> 04/14/97 18:51:46UT



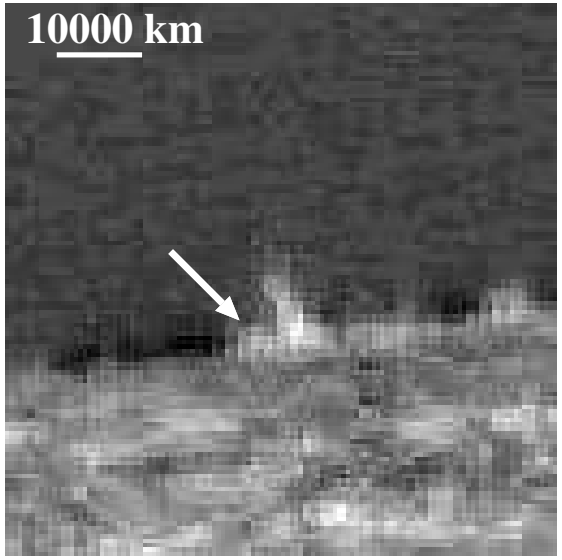
Spiked-Jet Macrospicule



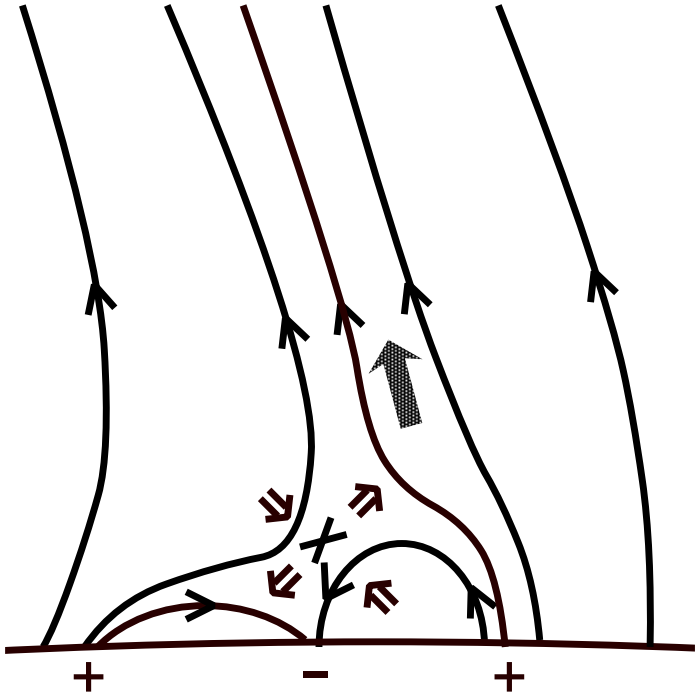
08/28/96 19:32:00UT 08/28/96 19:33:57UT 08/28/96 19:36:05UT 08/28/96 19:39:11UT



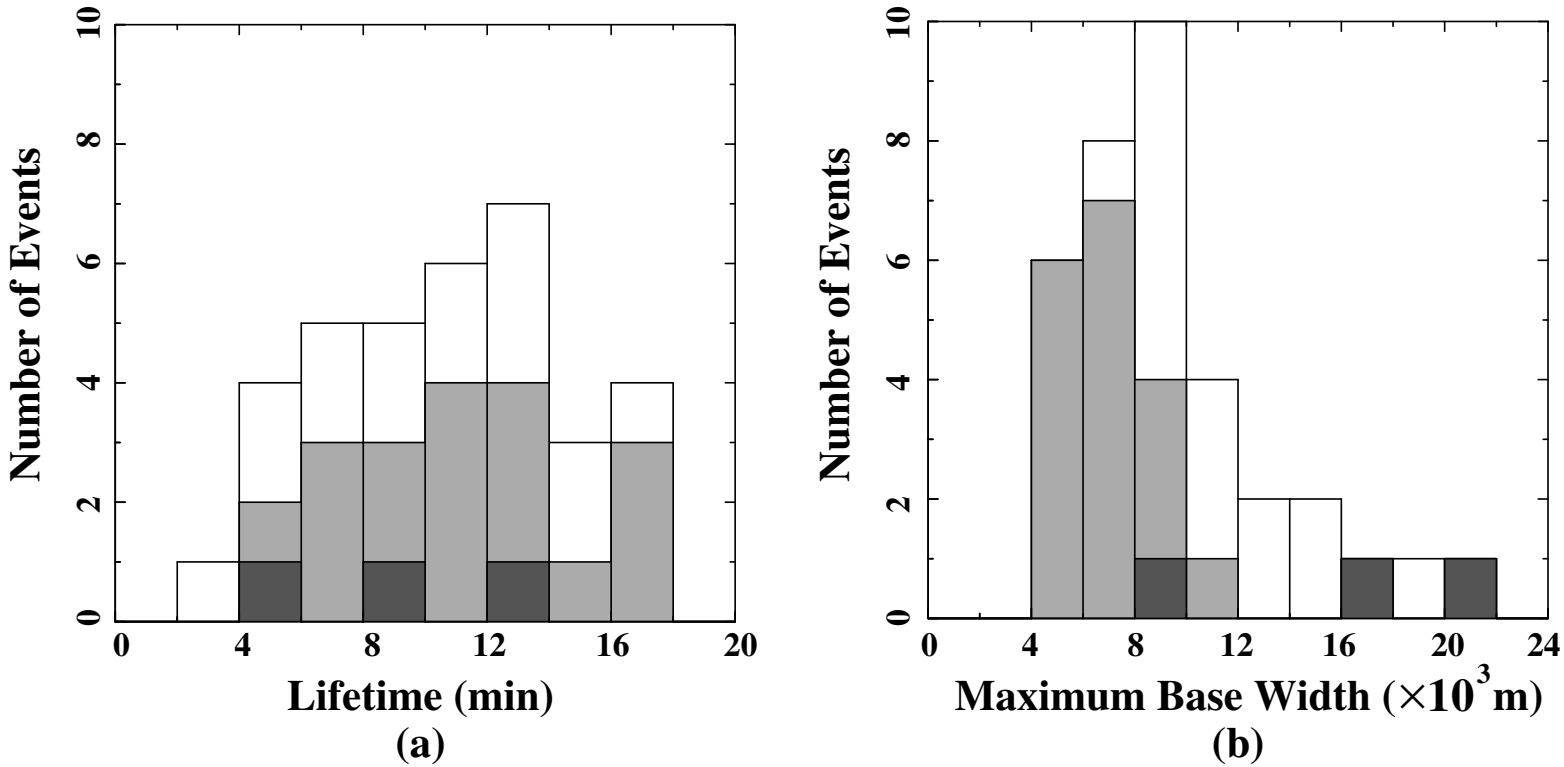
Spiked-Jet Macrospicule



19:36:05UT



Results


Number of Events
0
2
4
6
8
10
0
4
8
12
16
20
Lifetime (min)
(a)
Number of Events
0
2
4
6
8
10
0
4
8
12
16
20
24
Maximum Base Width (×10^3 m)
(b)

Conclutions

- We investigated magnetic structure and evolution of macrospicules in coronal holes from BBSO Hα observations.
- We identified a total of 35 macrospicules. 15 out of 35 events were in the form of an erupting loop, 17 were in the form of a single-column spiked jet, and 3 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 10 min, which is consistent with previous studies [*e.g.*, Bohlin et al., 1975, ApJ, **197**, L133].
- The width of the erupting-loop macrospicule is wider than the spiked jet event. The average loop-base width is about 11000km. On the other hand, the average spike-base width is 7000km.

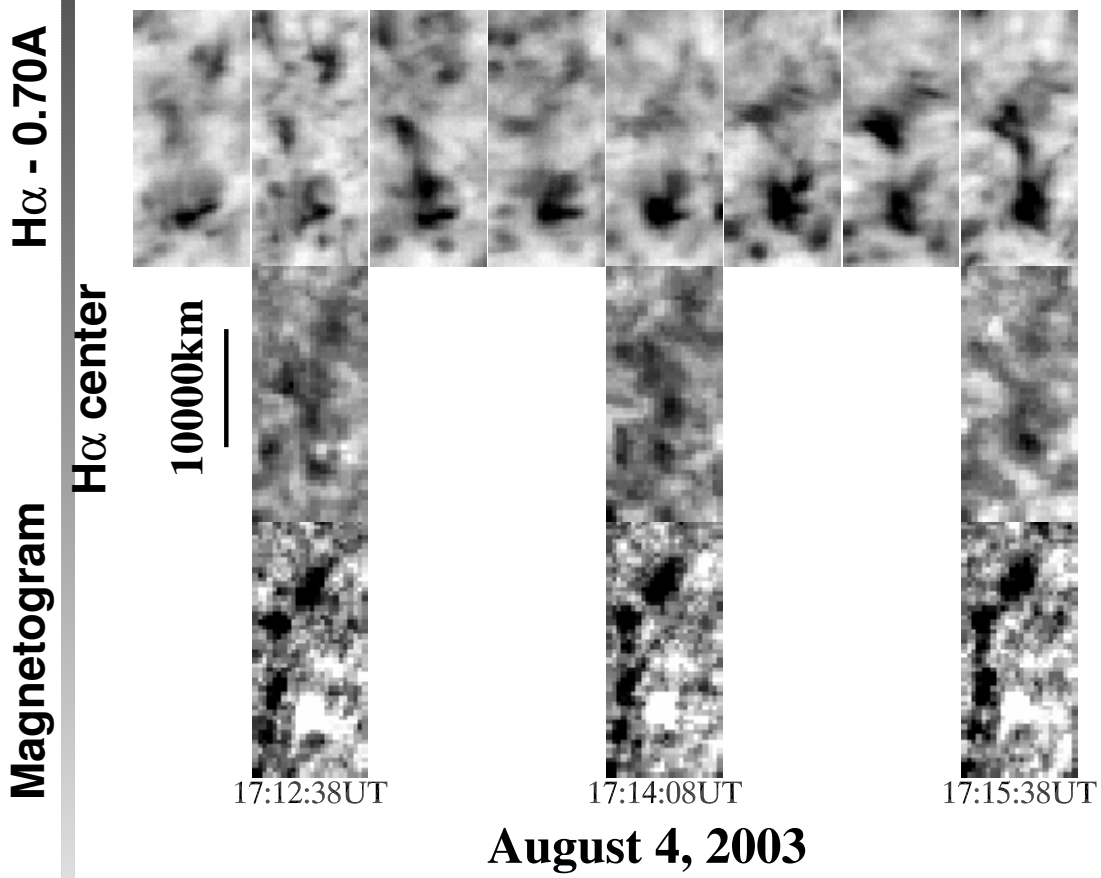
$\Downarrow \quad \Downarrow \quad \Downarrow$

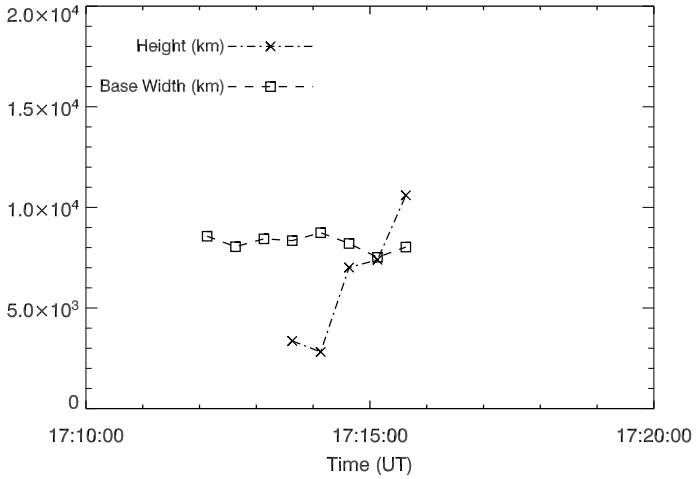
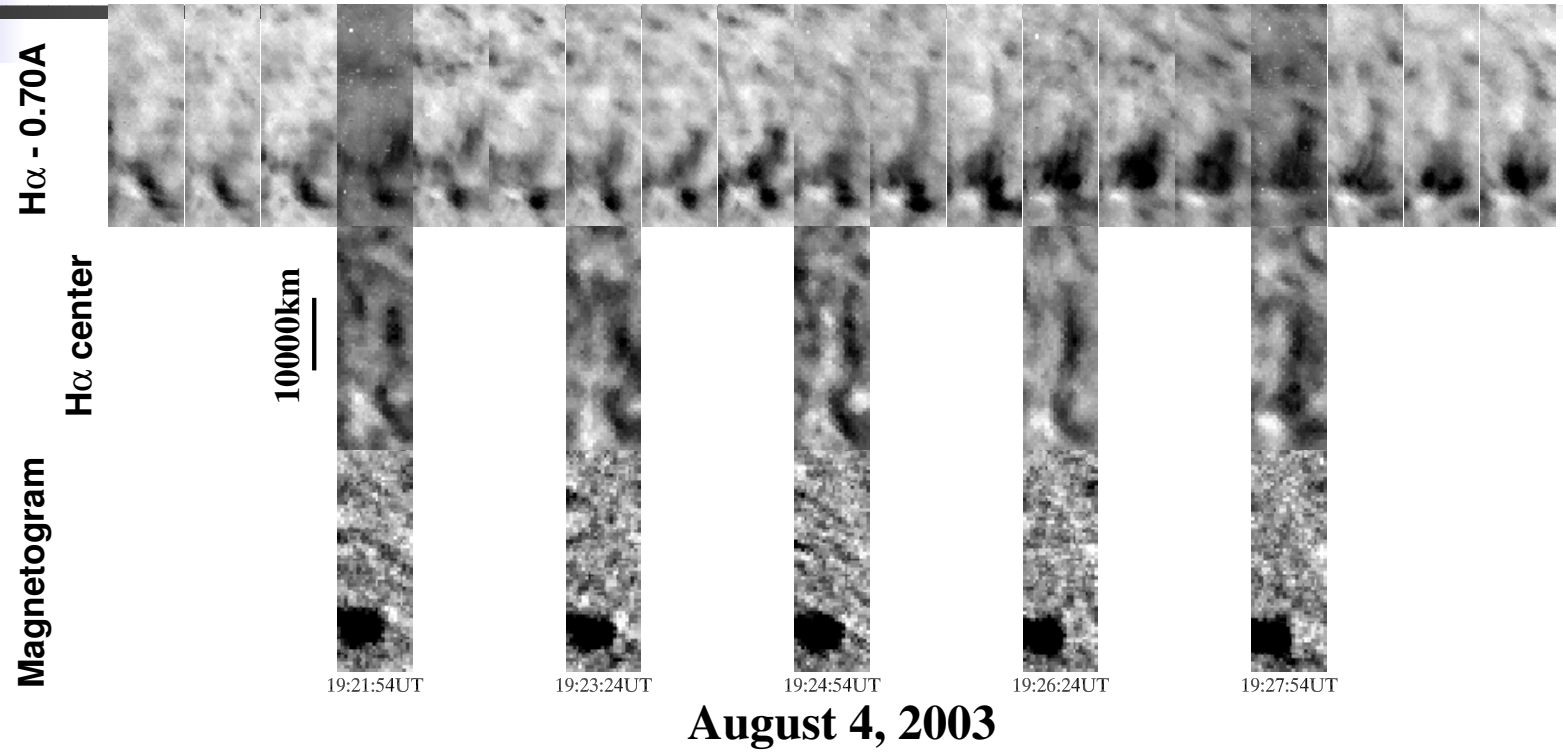
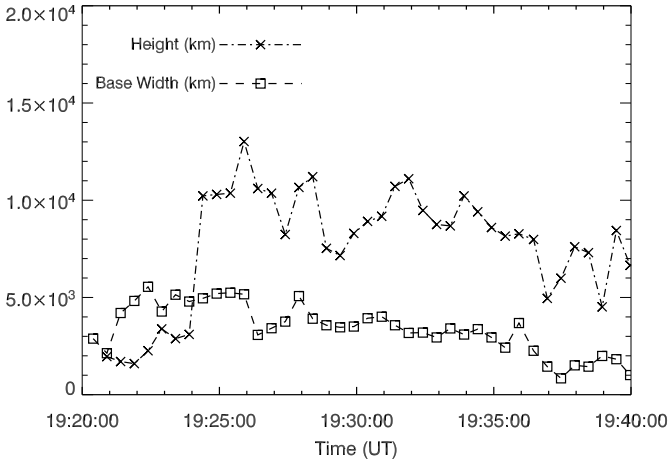
- We conclude that network-scale erupting magnetic loops are a common occurrence in coronal holes.
- The spiked-jet macrospicules show the appropriate structure and evolution to be driven by reconnection between network-scale closed field (a network bipole) and the open field rooted against the closed field.

Conclutions (cont.)

- This evidence for reconnection in a large fraction of our macrospicules supports models in which the coronal heating and solar wind acceleration in coronal holes are driven by explosive reconnection events seated in the network [*e.g.*, *Axford & McKenzie*, 1992, 1997; *Fisk et al.*, 1999; *Falconer et al.*, 2003].
- We are investigating on-disk counterparts of erupting-loop and spiked-jet macrospicules from high spatial and temporal BBSO Hα and magnetogram observations.
- We will make TRACE UV/EUV observations in September jointly with BBSO Hα and magnetogram observations. We will study small-scale dynamics in coronal holes and non-CH quiet regions and the relation with magnetic network activity in more detail by deriving parameters of density, plasma temperature, and magnetic structure from the observations.

On-disk Erupting-Loop Macrospicule





On-disk Spiked-Jet Macrospicule