Solar jet-like features rooted on the flare ribbons

Xiaohong Li, Jun zhang, Shuhong Yang,Yijun Hou

National Astronomical Observatories of China

IRIS-9 workshop, Göttingen, 2018.06.29

IRIS-9, Göttingen, 25-29 June 2018

Contributed Talk

4. Eruptions in the solar atmosphere

Solar jets rooted on flare ribbons in the major events in September 2017

Xiaohong Li[1],[2]

[1]*A. National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, China*
[2]*B. School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing 100049, China*

Employing the multi-wavelength observations from the Atmospheric Imaging Assembly on board the *Solar Dynamics Observatory*, we investigated the jets that occurred during the most impressive flare in Solar Cycle 24, an X9.3 class flare in NOAA active region (AR) 12673 on 2017 September 6. There were dozens of jets appearing as bright structures in the 1600 Å images. The footpoints of the jets were all rooted on the northwestern flare ribbon and brightened up successively as the propagation of the flare ribbon. We also investigated two jets about their performances in 131 Å. With the high tempo-spatial *Interface Region Imaging Spectrograph* 1330 Å observations, we also studied the X8.2 class flare in this AR on September 10 and found that numerous jets were rooted on the flare ribbons. We examined 15 jets, and the mean values of the lifetimes, projected widths, lengths and velocities of the jets were 87 s, 885 km, 2.7 Mm and 70 km s^{-1}, respectively. This was the first time that jets were reported to be rooted on the flare ribbons.

Solar jet-like features rooted on the flare ribbons

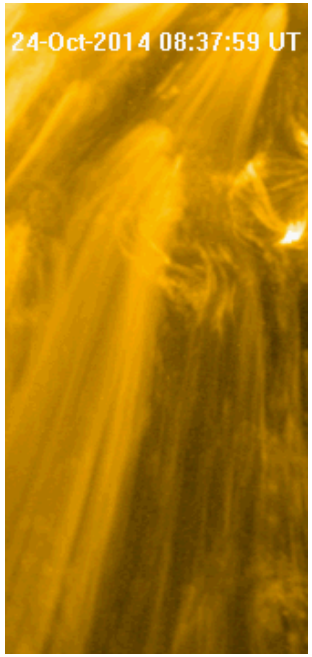
Xiaohong Li, Jun zhang, Shuhong Yang,Yijun Hou

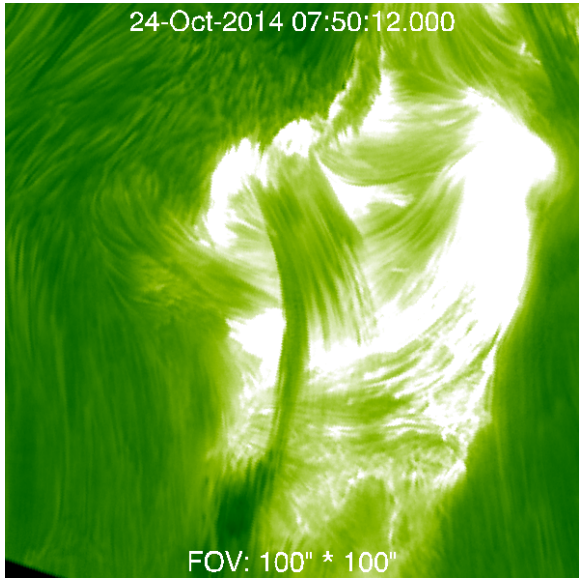
National Astronomical Observatories of China

IRIS-9 workshop, Göttingen, 2018.06.29

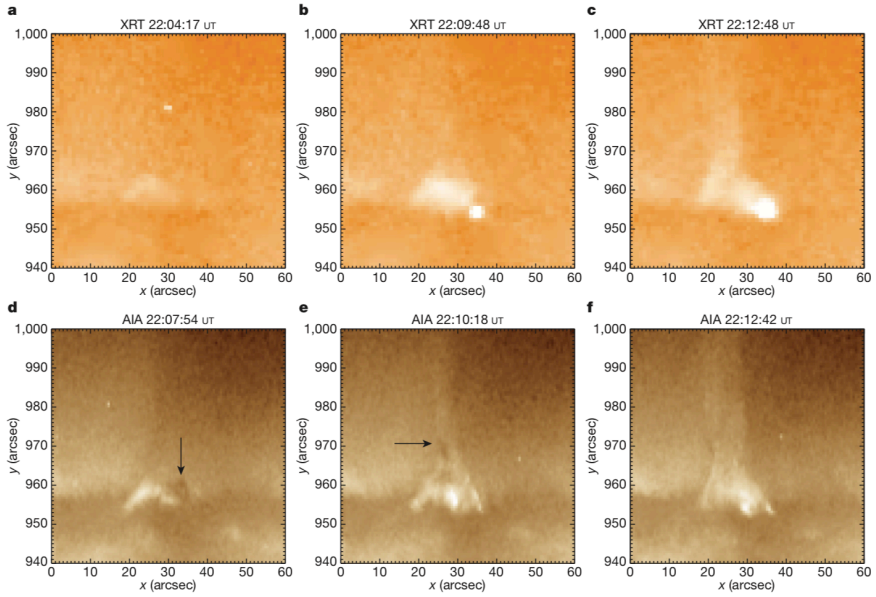
Contents

Background



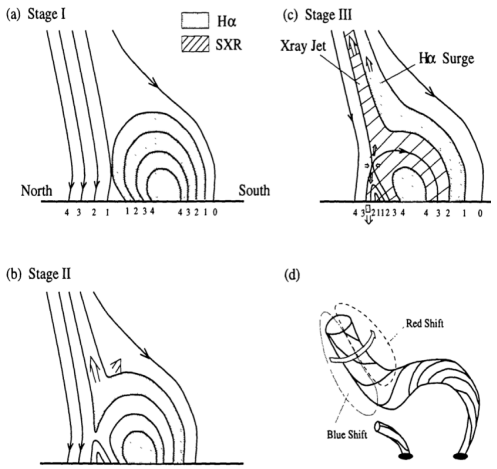


(Li et al. 2015)



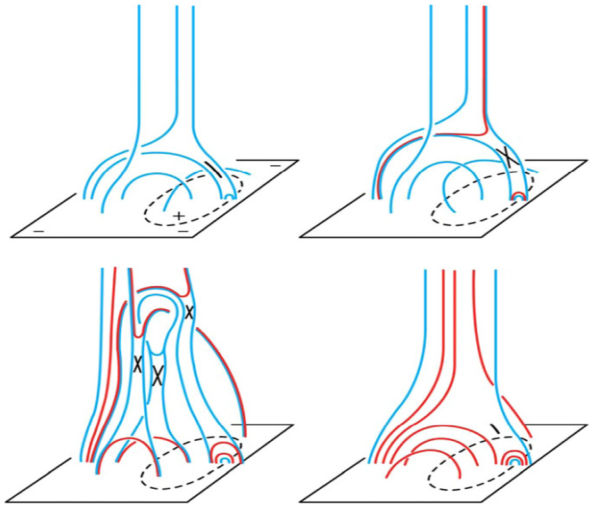
(Sterling et al. 2015)

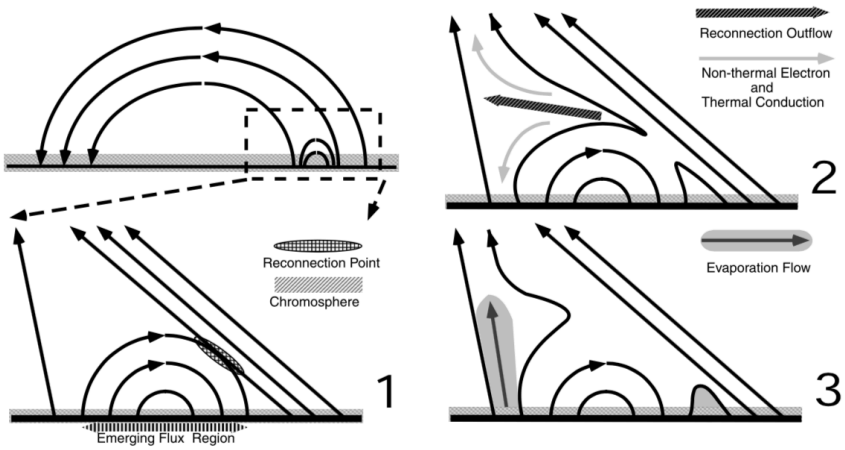
- Solar jets are plasma eruptions that are magnetically rooted in the photosphere and ejected into the corona along open field lines or the legs of large-scale coronal loops.
- Solar jets have been extensively studied in many wavelengths, e.g., Hα , ultraviolet (UV), EUV, X-ray and white light.



(Canfield et al. 1996)

(Moore et al. 2010)



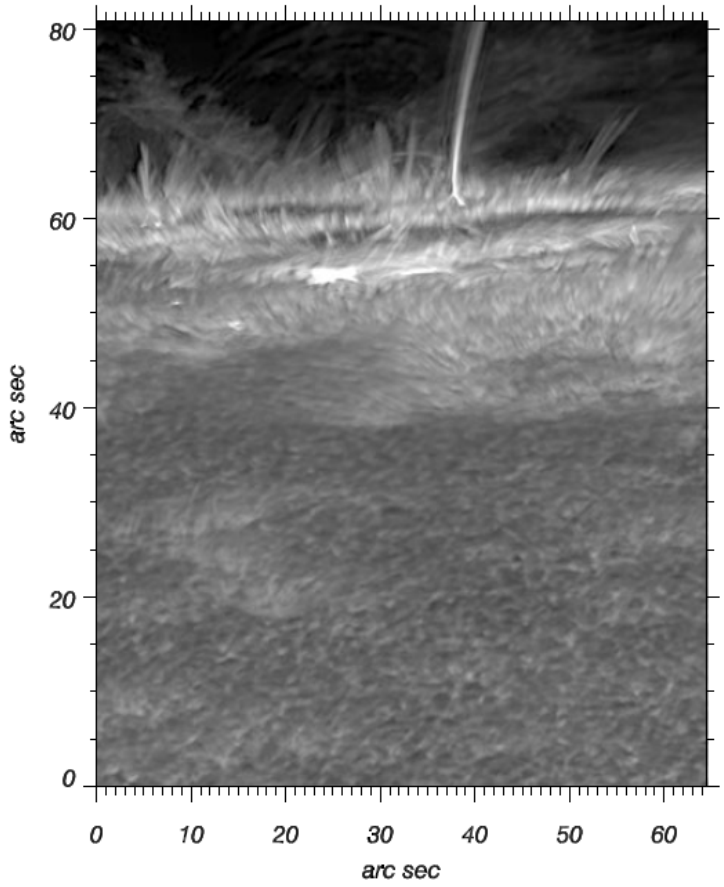


(Shimojo et al. 2001)

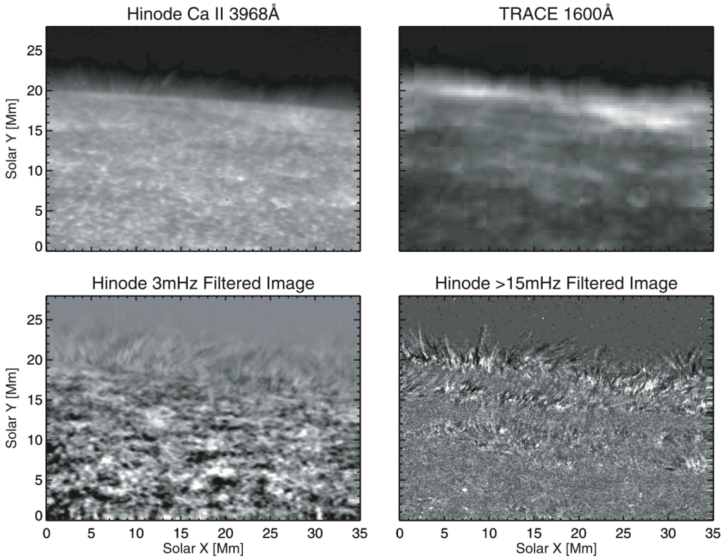
Driving mechanisms for jets:

- magnetic reconnection, which sometimes is accompanied by flux emergence and magnetic cancellation (e.g., Shibata et al. 1992; Canfield et al. 1996; Moore et al. 2010) .
- chromospheric evaporation may play a role in producing jets (Shimojo & Shibata 2000; Miyagoshi & Yokoyama 2003).

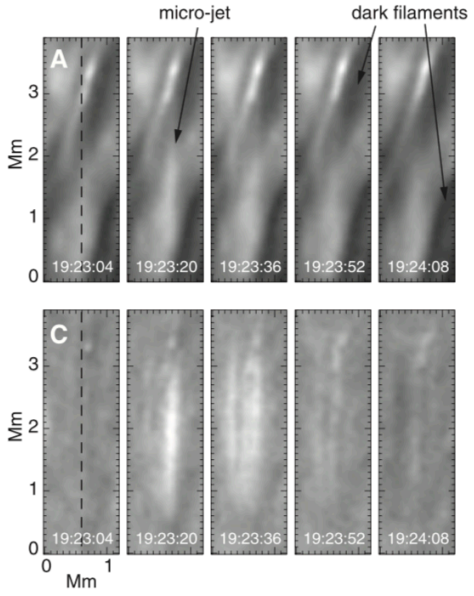
- There are many jet-like structures such as spicules, mottles and macrospicules.



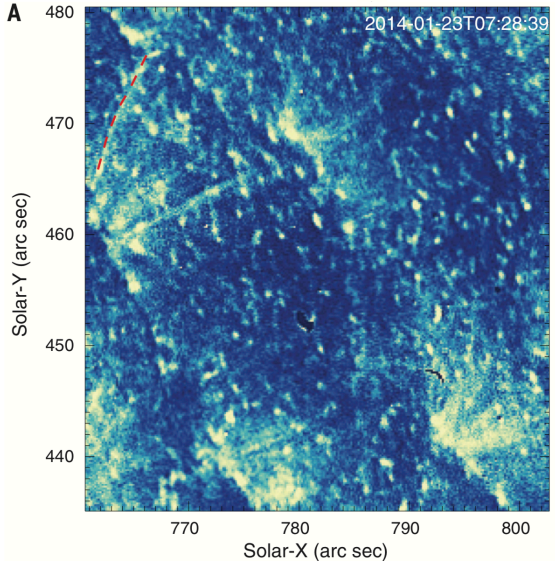
(Tziotziou et al. 2005)



(De Poutieu et al. 2007)



(Katsukawa et al. 2007)



(Tian et al. 2007)

Observations and Results

From 2017 September 4 to 10, active region (AR) 12673 produced 4 X-class, 27 M-class and plenty of lower-class flares, becoming the most actively flaring region of Cycle 24.

The X8.2 flare on 2017 September 10

- IRIS SJI 1330 Å

  0.33″/pixel 9-10 s/image

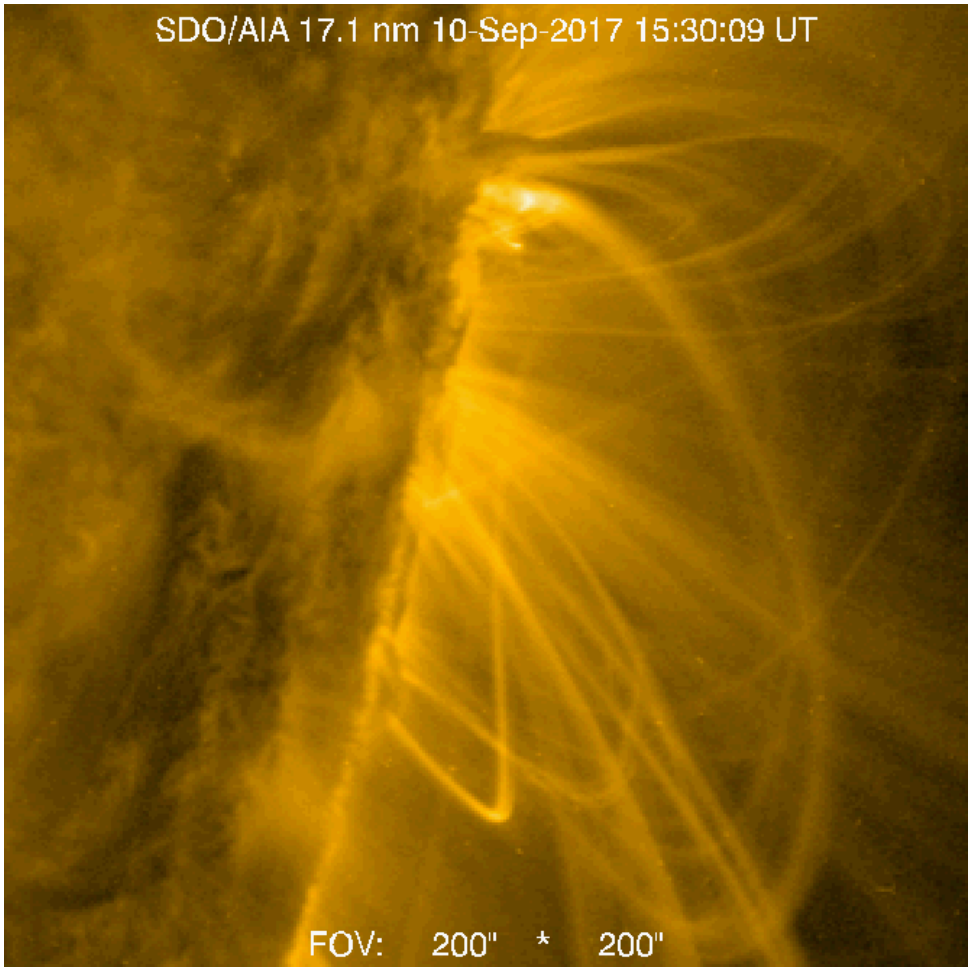
- SDO/AIA 94 Å、131 Å、 171 Å、 193 Å、304 Å

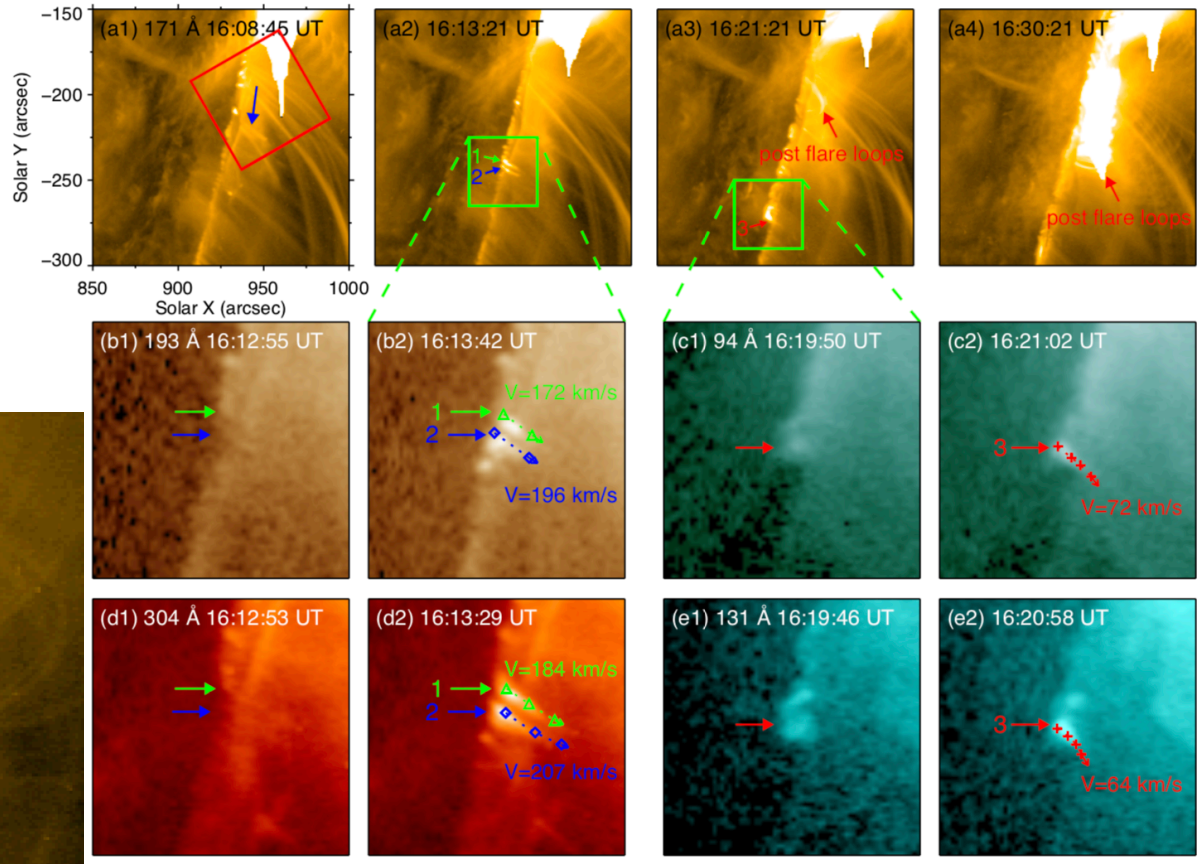
  0.6″/pixel 12 s/image

List of All 4 X-class and 27 M-class Flares in AR 12673

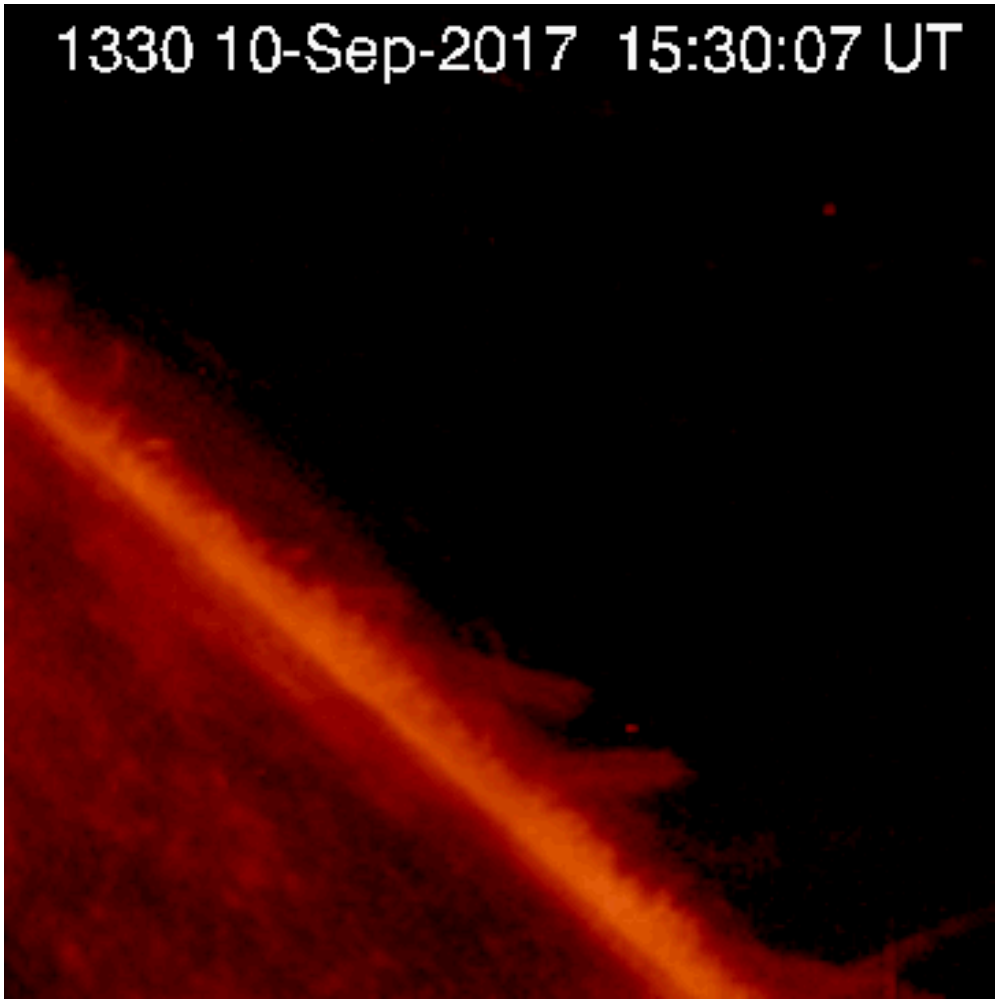
Date (UT)	*GOES* Class	Time (UT) Start	Peak	End	Duration (minutes)
2017 Sep 4	M1.2	05:36	05:49	06:05	29
2017 Sep 4	M1.5	15:11	15:30	15:33	22
2017 Sep 4	M1.0	18:05	18:22	18:31	26
2017 Sep 4	M1.7	18:46	19:37	19:52	66
2017 Sep 4	M1.5	19:59	20:02	20:06	7
2017 Sep 4	M5.5	20:28	20:33	20:37	9
2017 Sep 4	M2.1	22:10	22:14	22:19	9
2017 Sep 5	M4.2	01:03	01:08	01:11	8
2017 Sep 5	M1.0	03:42	03:51	04:04	22
2017 Sep 5	M3.2	04:33	04:53	05:07	34
2017 Sep 5	M3.8	06:33	06:40	06:43	10
2017 Sep 5	M2.3	17:37	17:43	17:51	14
2017 Sep 6	X2.2	08:57	09:10	09:17	20
2017 Sep 6	X9.3	11:53	12:02	12:10	17
2017 Sep 6	M2.5	15:51	15:56	16:03	12
2017 Sep 6	M1.4	19:21	19:30	19:35	14
2017 Sep 6	M1.2	23:33	23:39	23:44	11
2017 Sep 7	M2.4	04:59	05:02	05:08	9
2017 Sep 7	M1.4	09:49	09:54	09:58	9
2017 Sep 7	M7.3	10:11	10:15	10:18	7
2017 Sep 7	X1.3	14:20	14:36	14:55	33
2017 Sep 7	M3.9	23:50	23:59	00:14	24
2017 Sep 8	M1.3	02:19	02:24	02:29	10
2017 Sep 8	M1.2	03:39	03:43	03:45	6
2017 Sep 8	M8.1	07:40	07:49	07:58	18
2017 Sep 8	M2.9	15:09	15:47	16:04	55
2017 Sep 8	M2.1	23:33	23:45	23:56	23
2017 Sep 9	M1.1	04:14	04:28	04:43	29
2017 Sep 9	M3.7	10:50	11:04	11:42	52
2017 Sep 9	M1.1	22:04	23:53	00:41	157
2017 Sep 10	X8.2	15:35	16:06	16:31	56

(Yang et al. 2017)

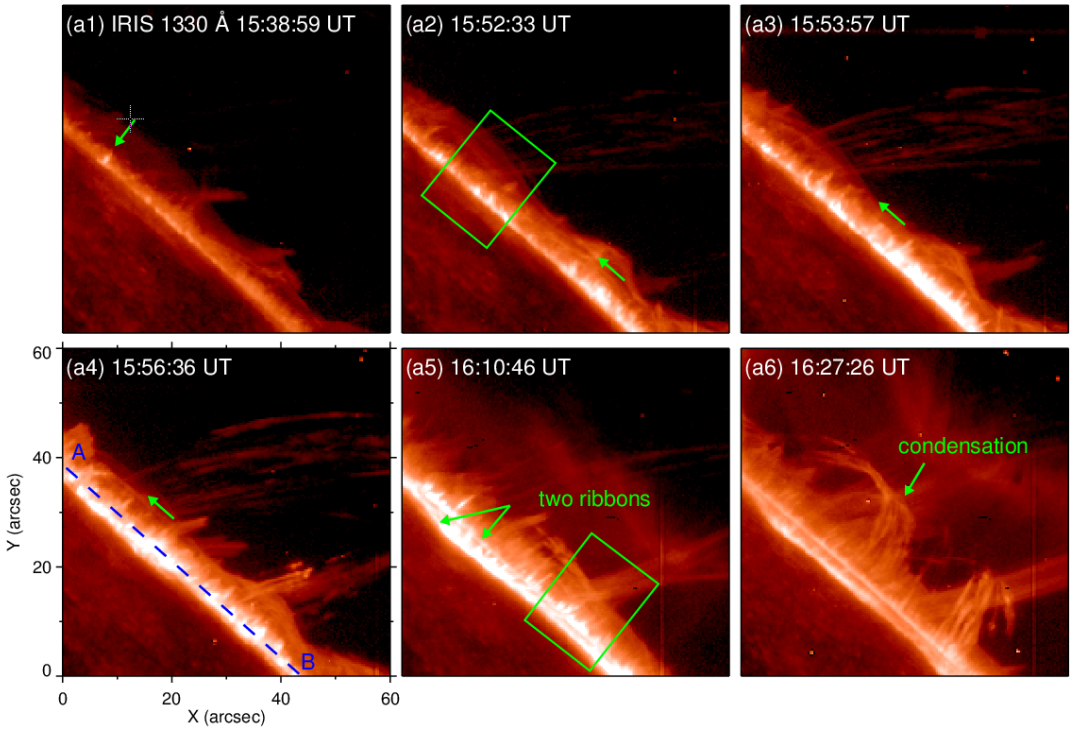


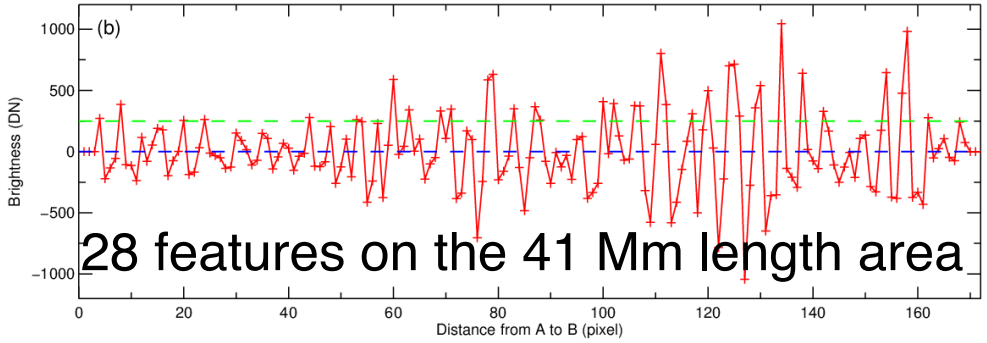


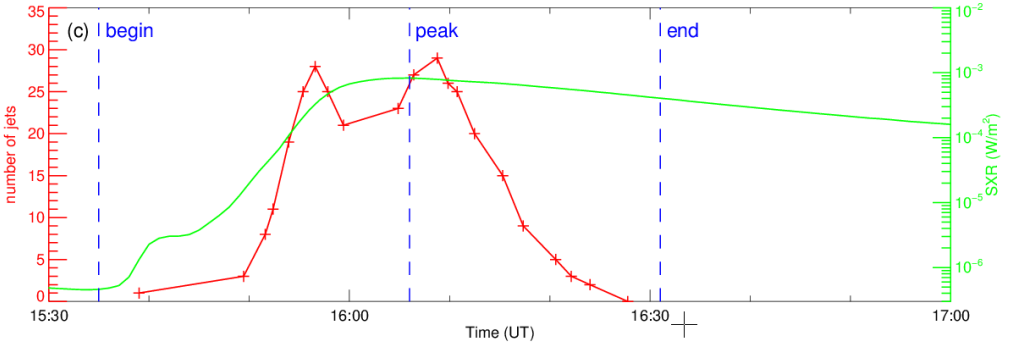
The jet-like features observed during the X8.2 flare on 2017 September 10

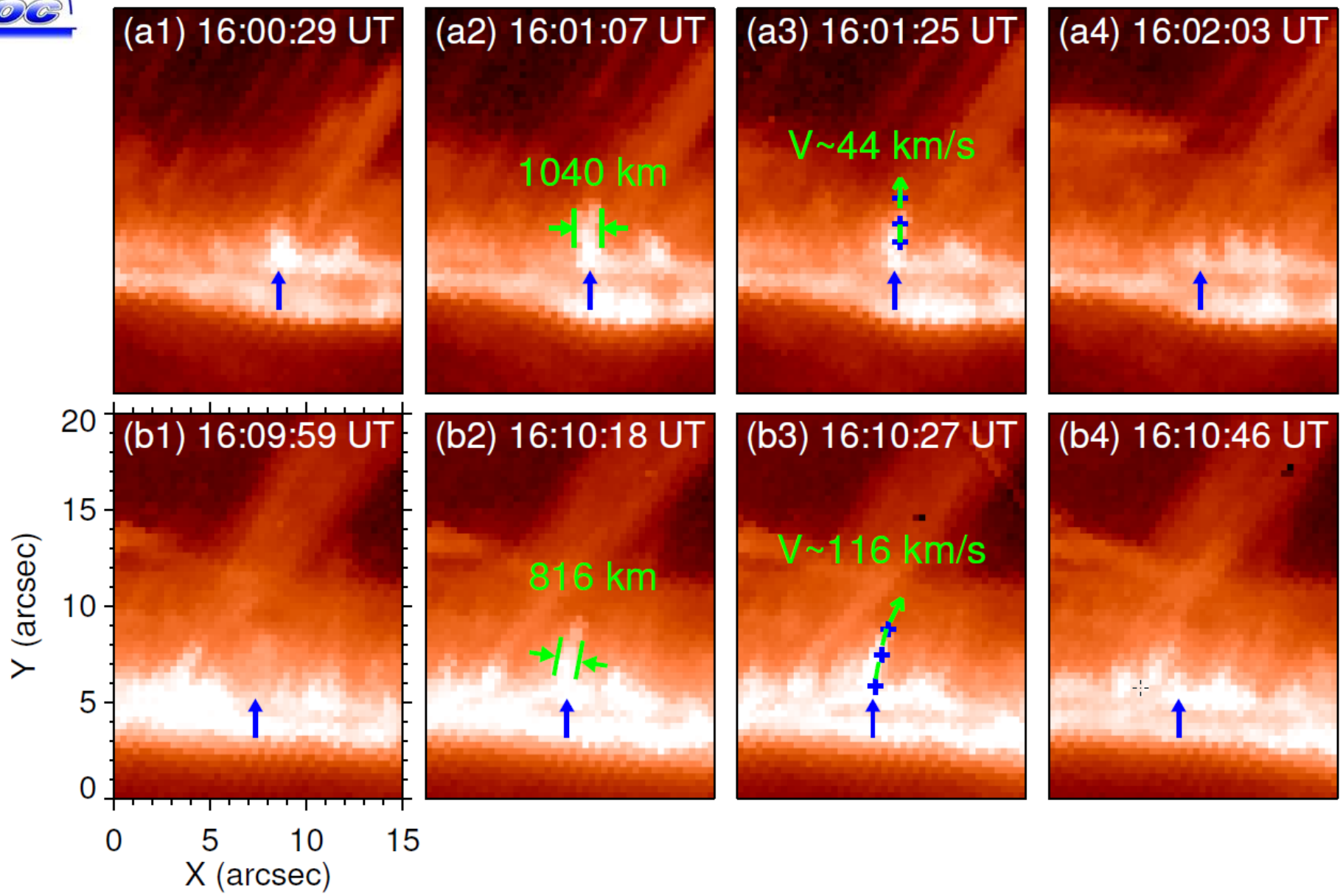


The jet-like features observed by IRIS 1330 Å









IRIS 1330 Å images displaying the evolutions of two jet-like features

No.	Lifetime (s)	Width (km)	Length (Mm)	Velocity (km s^{-1})
1	94	1128	2.4	65
2	56	1021	2.1	87
3	187	1337	3.5	28
4	56	694	3.2	95
5	65	749	3.1	137
6	84	684	3.8	73
7	140	1040	2.7	44
8	84	887	2.7	55
9	65	816	2.9	116
10	56	683	2.0	106
11	93	1195	3.4	63
12	112	783	2.4	39
13	56	749	2.2	61
14	65	669	2.4	53
15	84	818	2.0	32

Mean value

Lifetime : 87 s

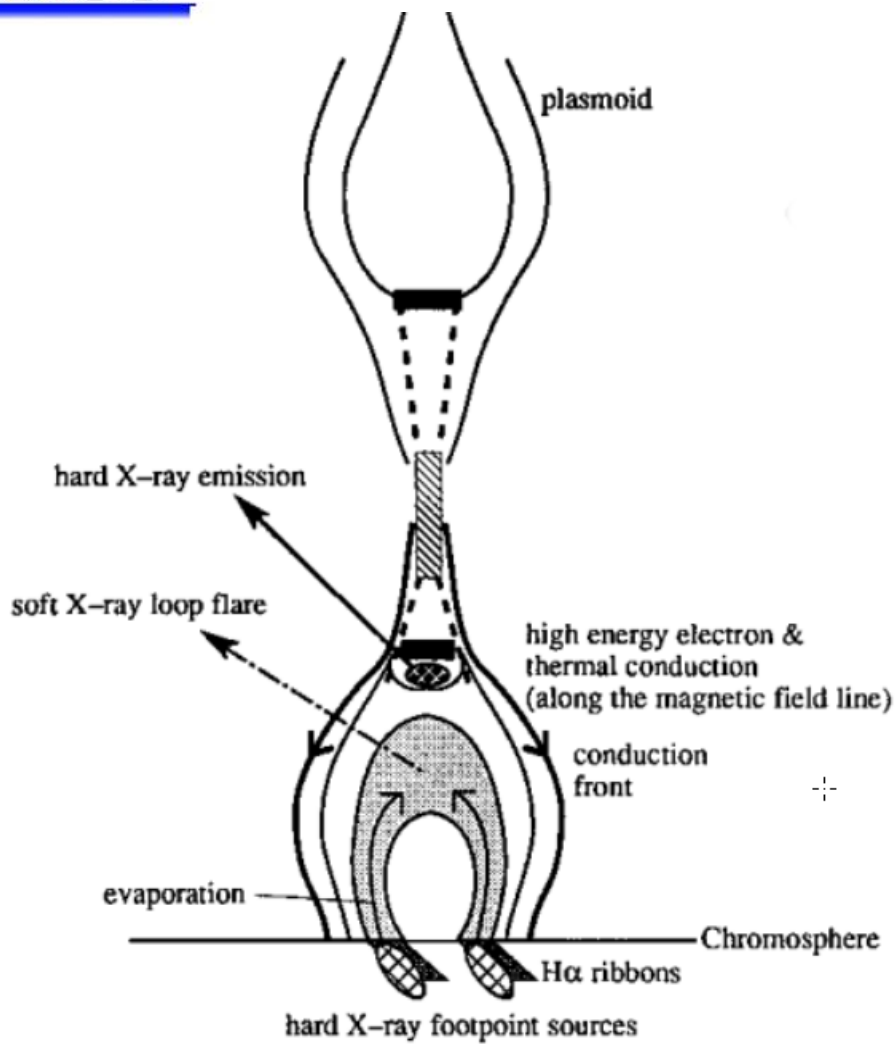
Width： 885 km

Length： 2.7 Mm

Velocity： 70 km/s

Similar to the properties of spicules!

Properties of 15 jet-like features observed by IRIS on September 10

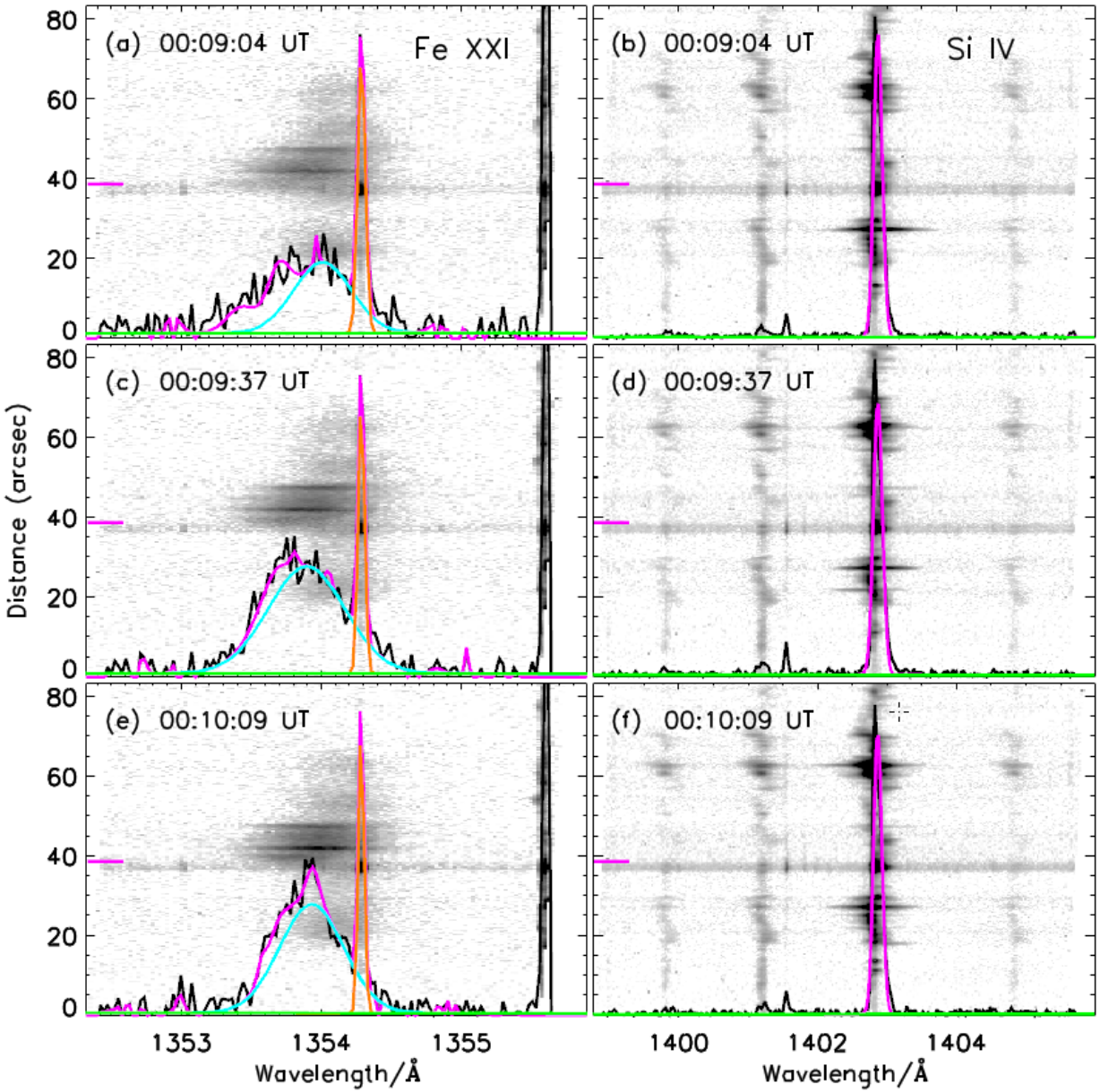


(Magara et al. 1996)

- Chromospheric evaporation is the upward expansion of the chromosphere after it has been heated to coronal temperature by high-energy particles or conduction fronts that has propagated down from the coronal energy-release site during the impulsive, rise and main phases of the flare. The evaporation fills the flare loops with hot dense plasma (Hudson 1991; Dennis & Zarro 1993; Veronig et al. 2005; Milligan & Dennis 2009).
- We suggest that these jet-like features are driven by chromospheric evaporation.

- Chromospheric evaporation has been extensively investigated using spectroscopic observations.

- The most direct spectral signature of chromospheric evaporation is the blueshift of hot emission lines, indicating the presence of hot and fast (from tens of km s^{-1} to several hundreds of km s^{-1}) plasma upflows.



(Li et al. 2017)

AR 12192 is a intensely flaring region of Cycle 24 which produced 6 X-class and 29 M-class flares from October 18 to 29, 2014.

Event	Date	Start Time (UT)	Peak Time (UT)	Duration (minutes)	*GOES* Level
X-class Flares:					
XF1	2014 Oct 19	04:17	05:03	91	X1.1
XF2	2014 Oct 22	14:02	14:28	48	X1.6
XF3	2014 Oct 24	21:07	21:41	66	X3.1
XF4	2014 Oct 25	16:55	17:08	76	X1.0
XF5	2014 Oct 26	10:04	10:56	74	X2.0
XF6	2014 Oct 27	14:12	14:47	57	X2.0

(Chen et al. 2015)

The X1.0 flare on 2014 October 25

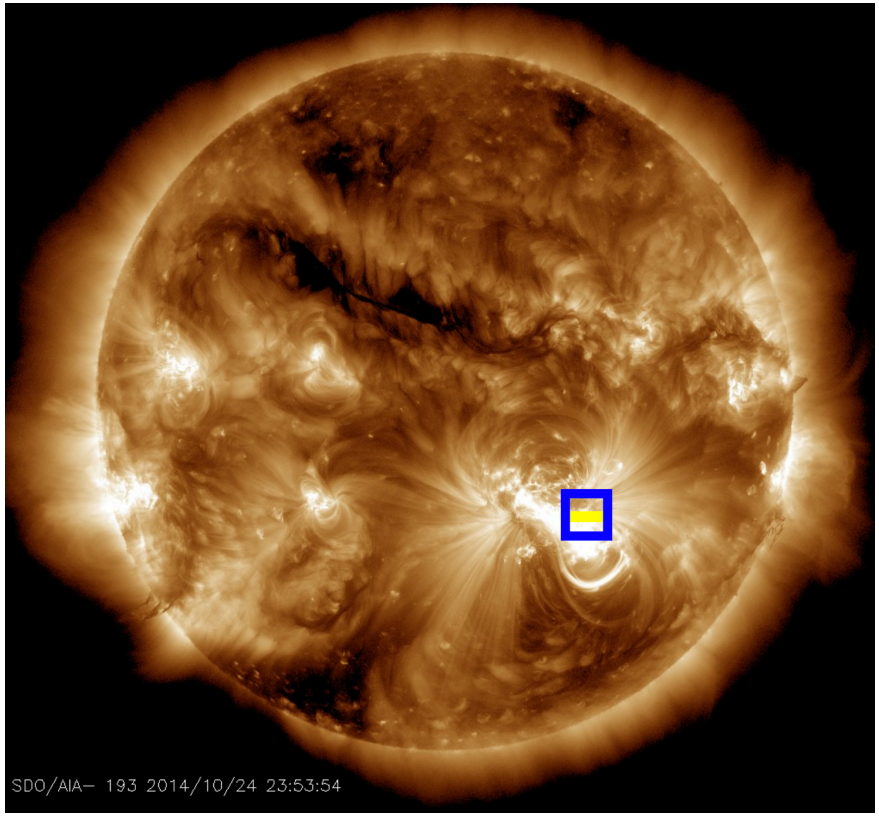
- IRIS SJI 1330 Å

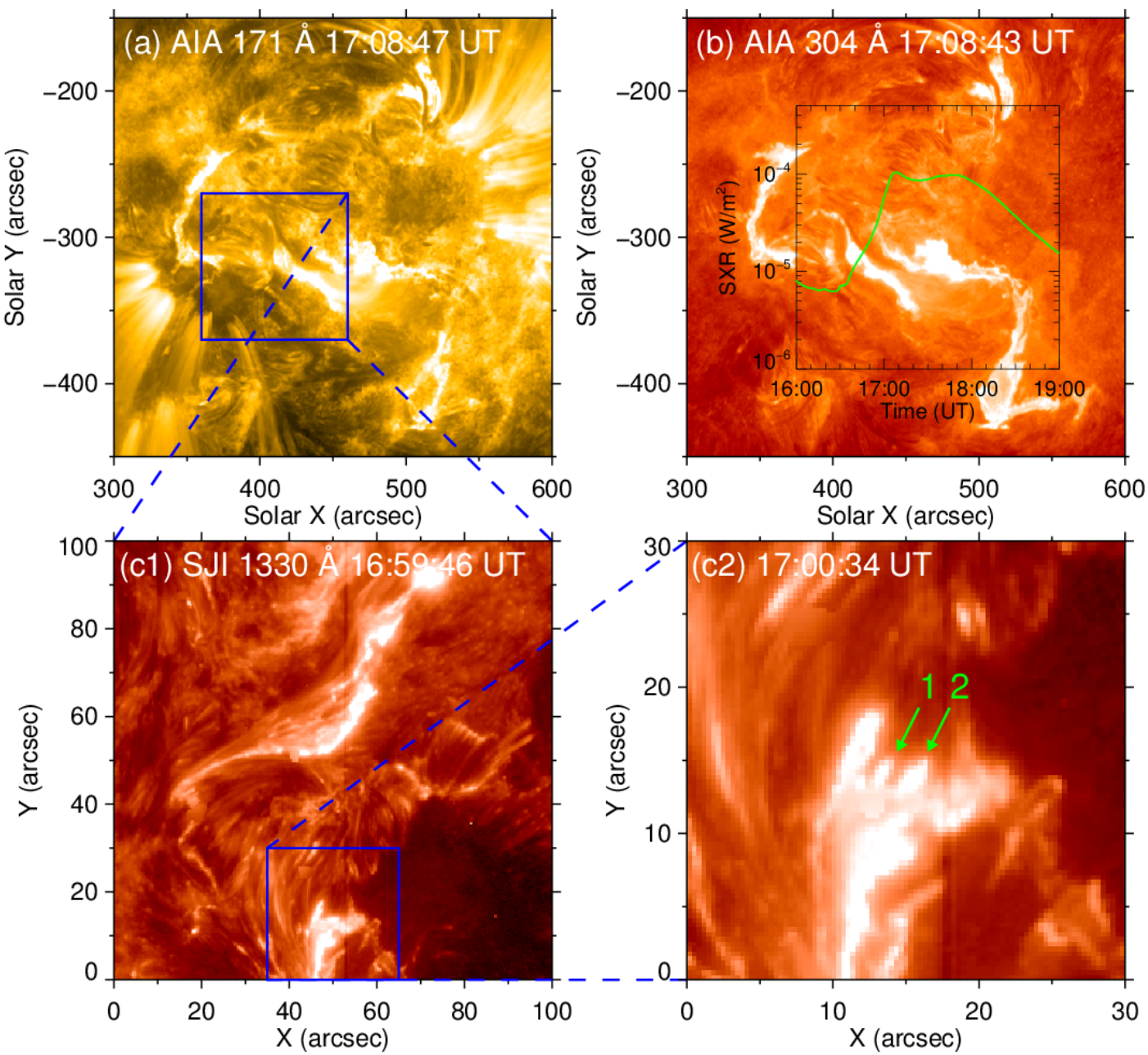
  0.33″/pixel 16 s/image

- Raster 5 s/image

  Fe XXI 1354.08 Å (log T ~7.05)

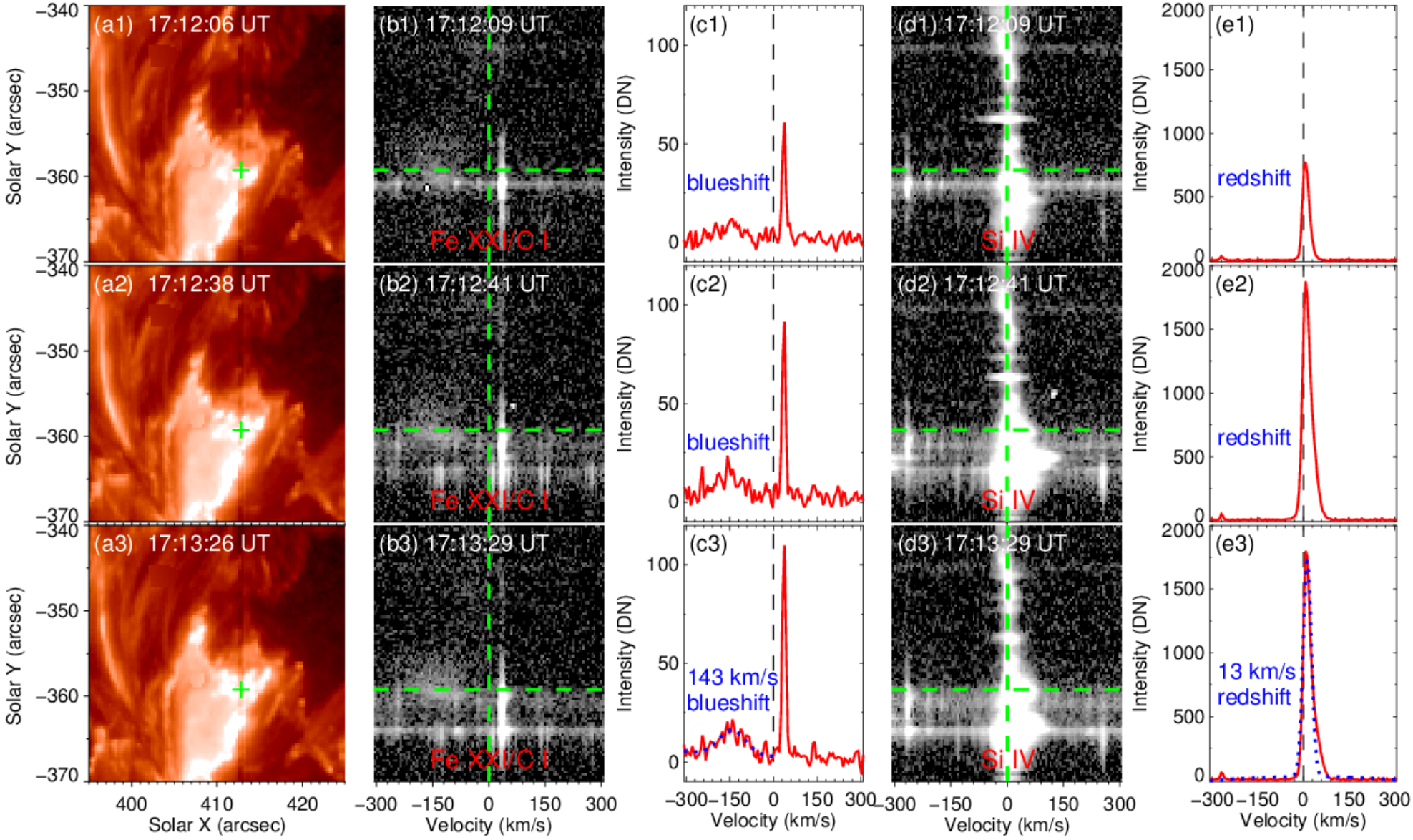
  Si IV 1402.77 Å (log T~4.8)





Projected	1	2
Length (Mm)	0.9	1.2
Width (Mm)	1.9	2.6
Velocity (km/s)	52	48

Overview of the X1.0 class flare on 25 October 2014



IRIS 1330 Å images and spectra at the “Fe XXI” and “Si IV” windows

Conclusions

- First report the jet-like features which are rooted on the flare ribbons.
- The driving mechanism of these jet-like features may be chromospheric evaporation.

Thank you for your attention!

Any suggestions would be welcomed!