# Activities in the transition region loops

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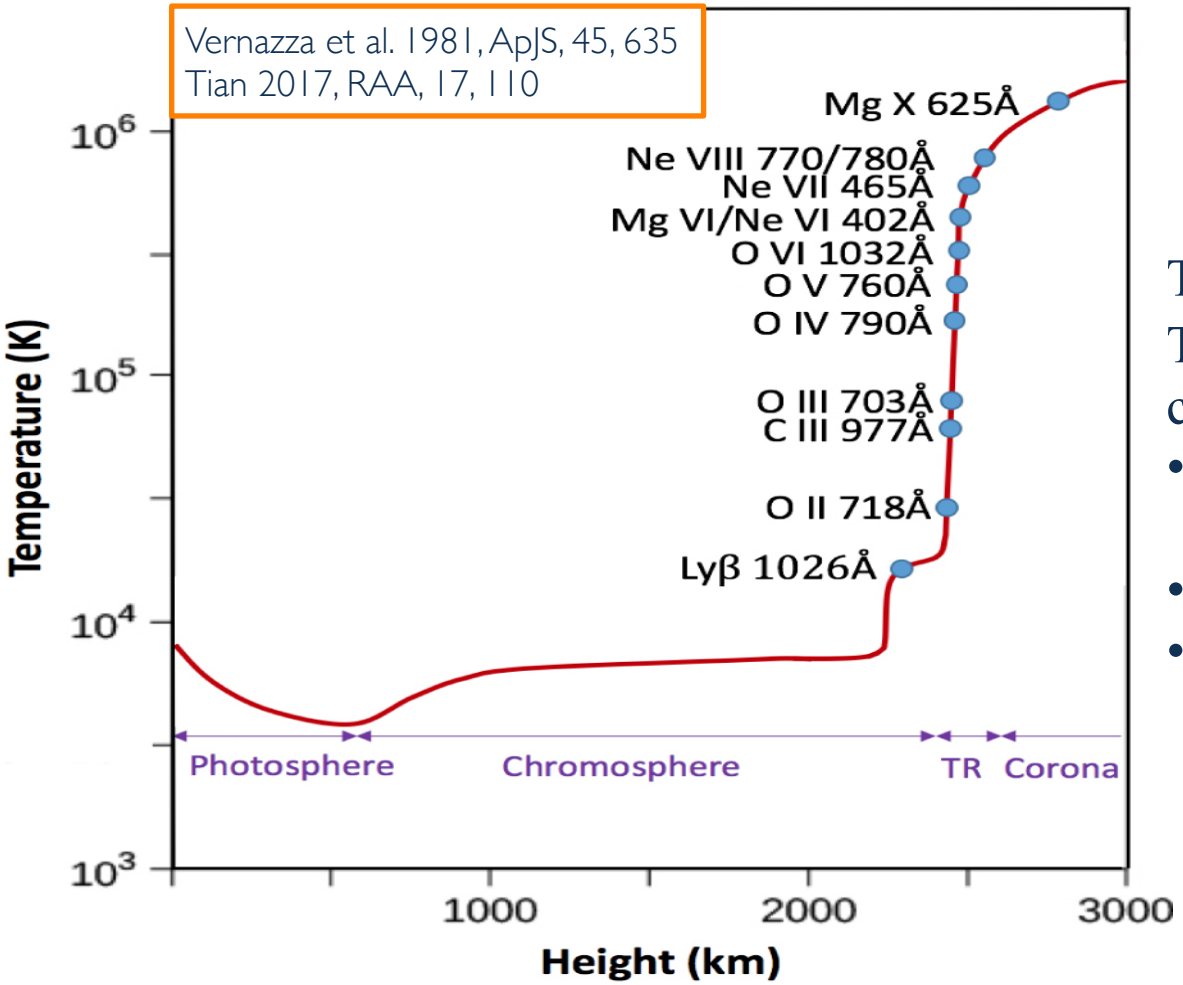
IRIS-10 meeting, Bangalore India, 2019 Nov. 5

# The big picture: Transition region (TR) in the solar atmosphere

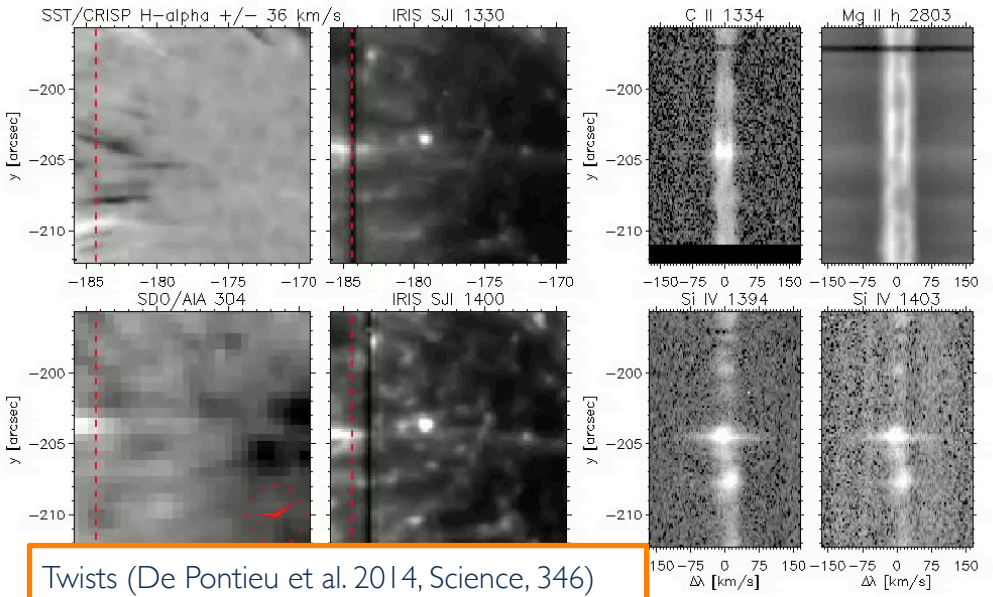



Transition region:

Transition region between chromosphere and corona;

- Temperature :20 kK — 1 MK;
- Highly dynamic;
- Normally defined in temperature regime rather than geometry.

# Highly dynamic transition region




Twists (De Pontieu et al. 2014, Science, 346)

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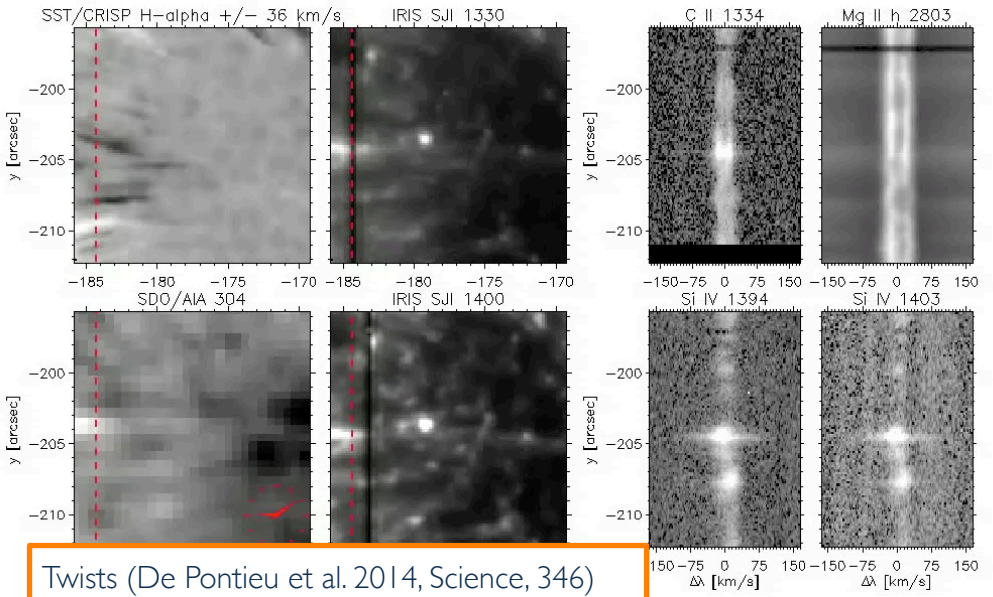


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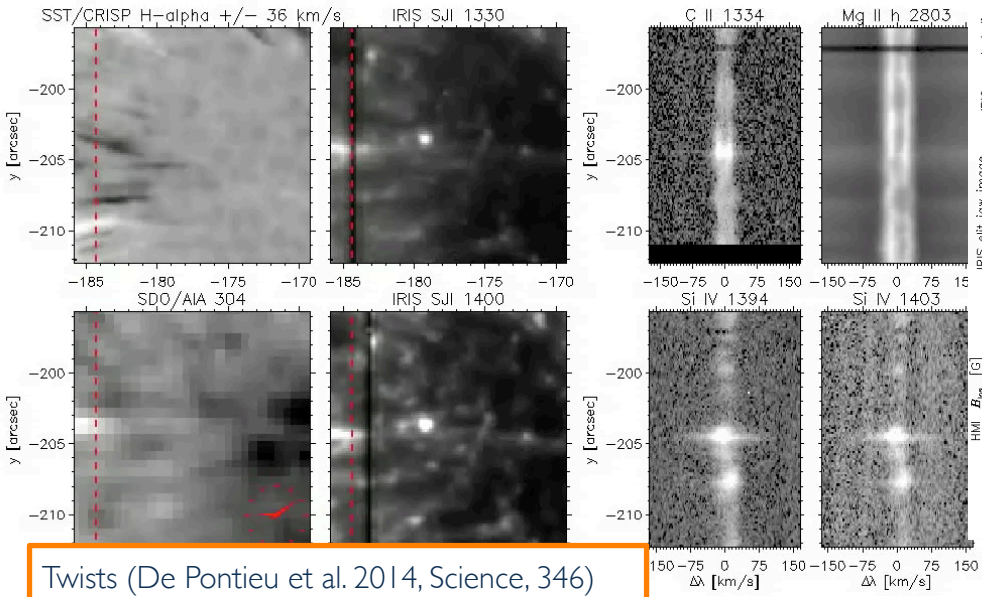


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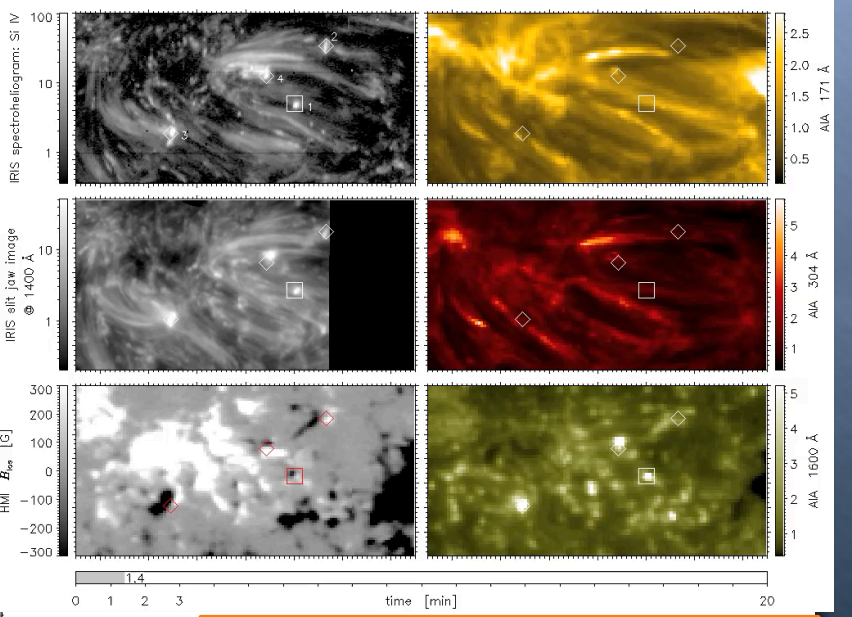


UV bursts (Peter et al. 2014, Science, 346)

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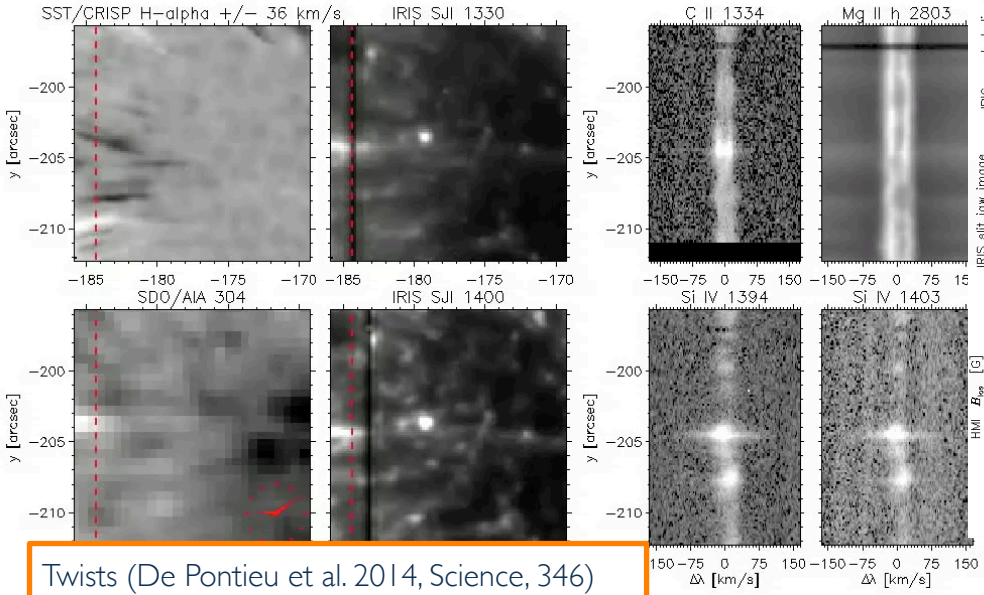
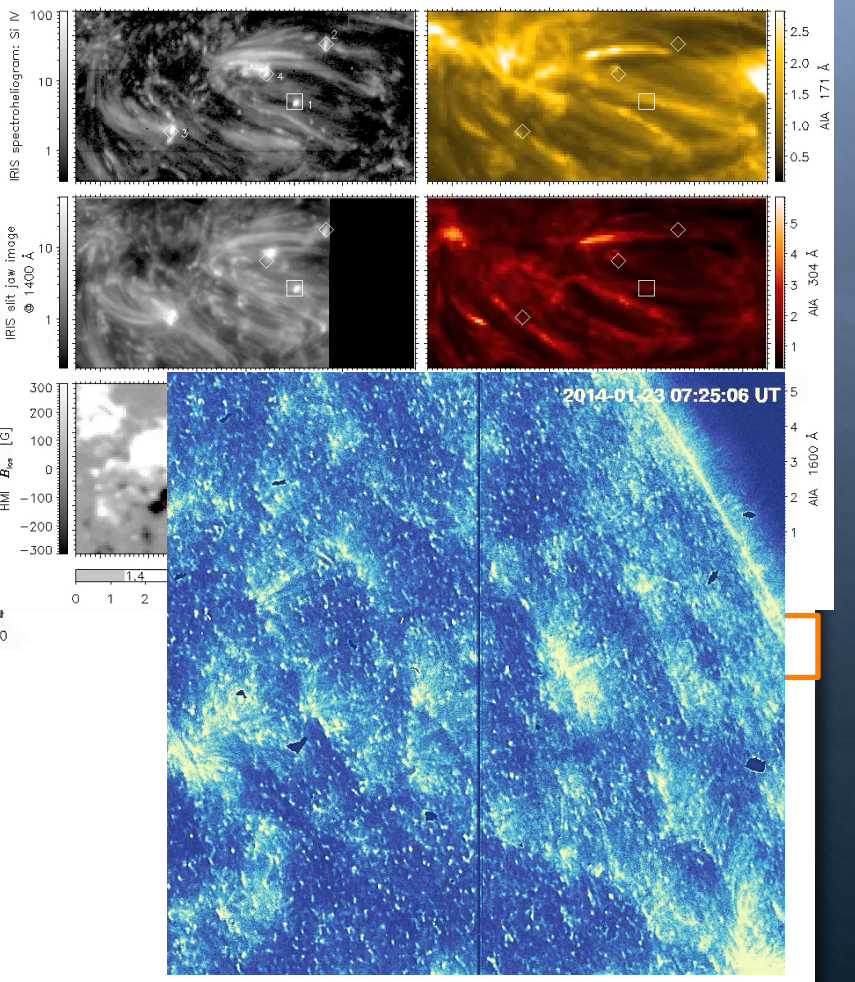



Twists (De Pontieu et al. 2014, Science, 346)




Network jets (Tian et al. 2014, Science, 346)

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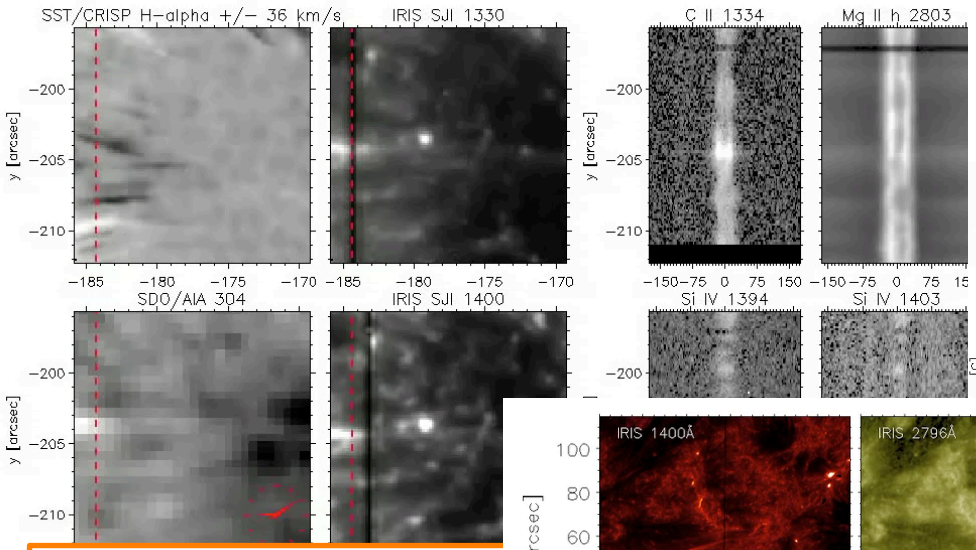





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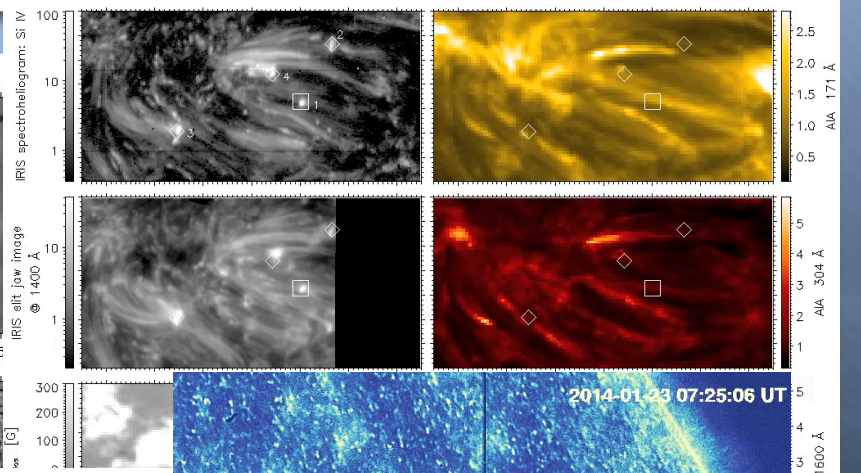


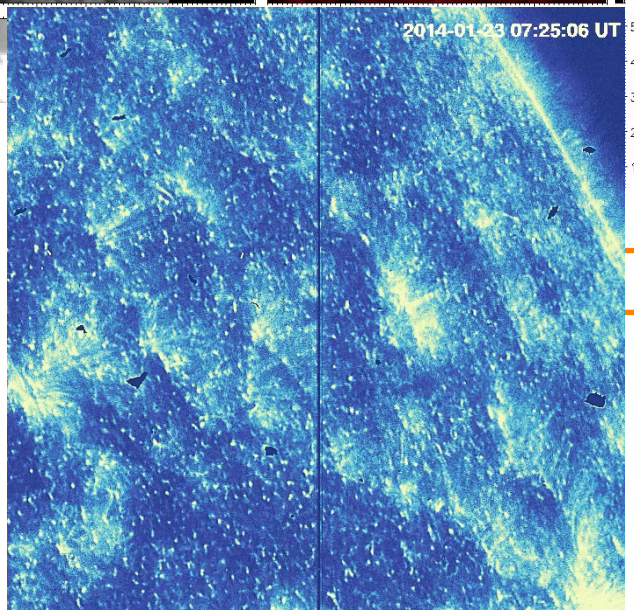


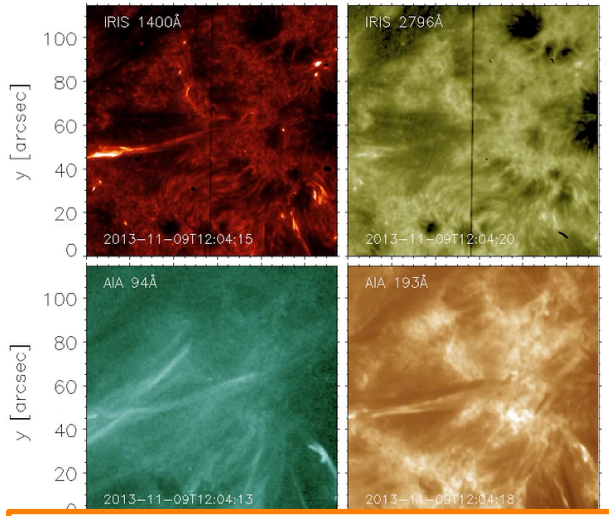


Moss activities associated with coronal loop heating (Testa et al. 2014, Science, 346)

Network jets (Tian et al. 2014, Science, 346)

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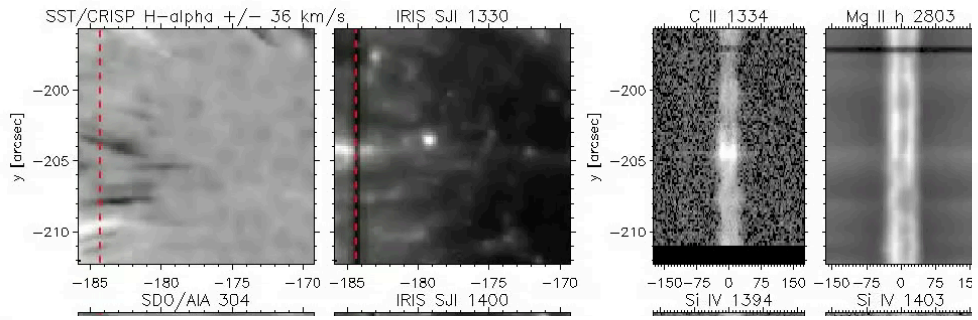





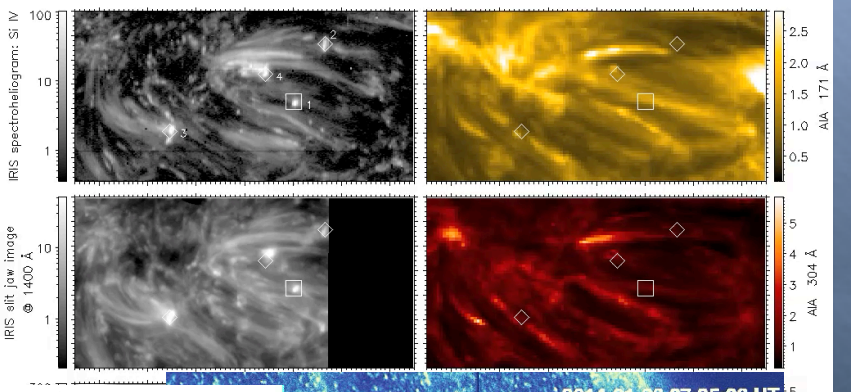


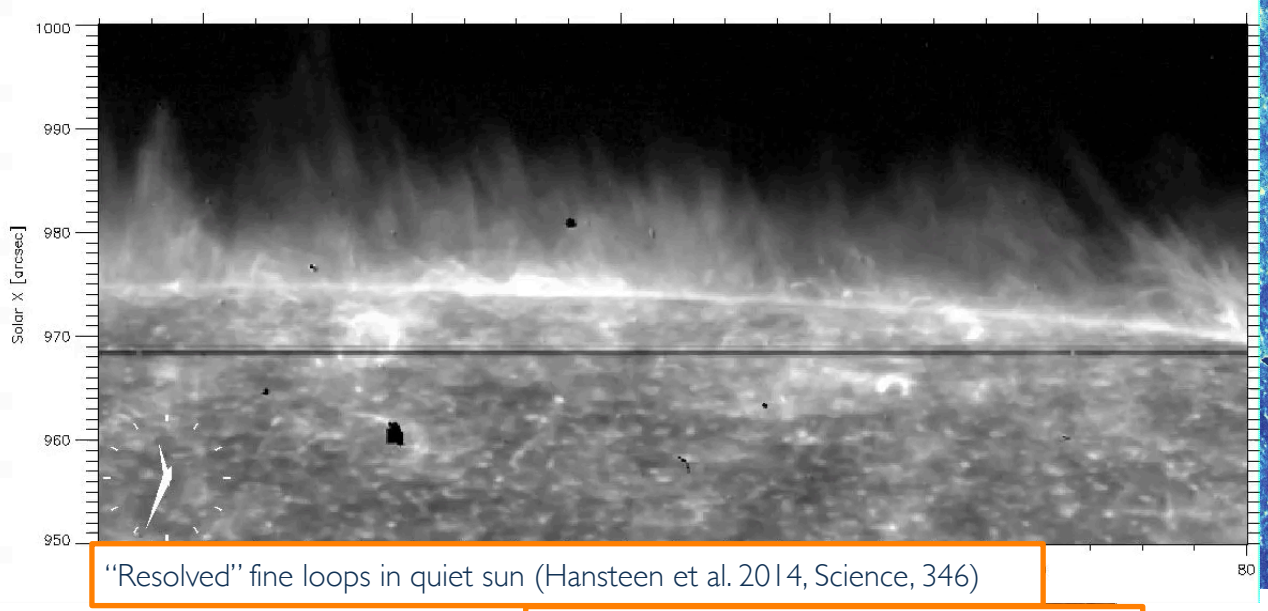


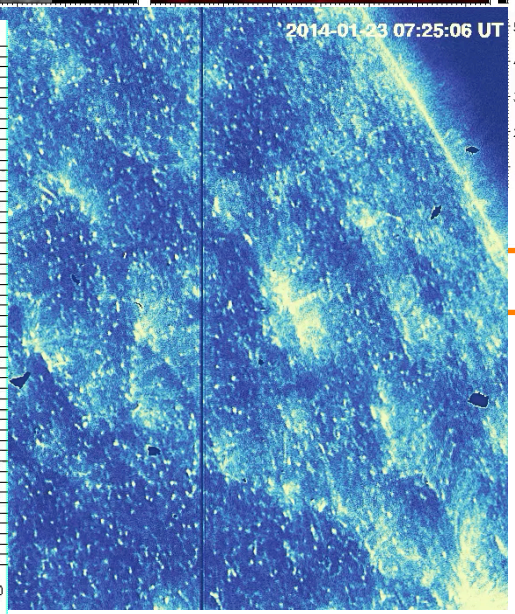


"Resolved" fine loops in quiet sun (Hansteen et al. 2014, Science, 346)

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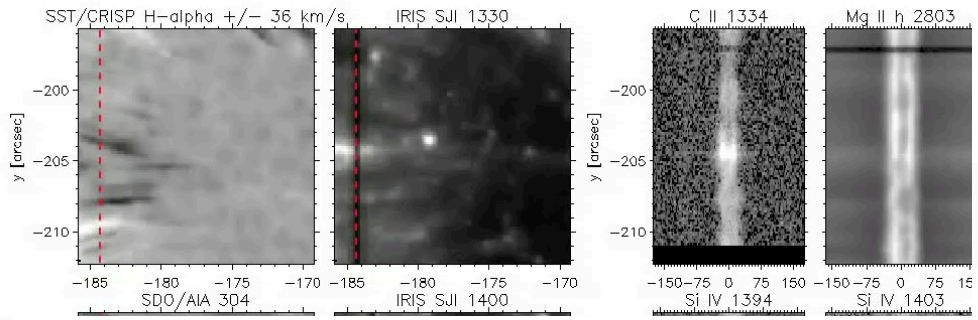





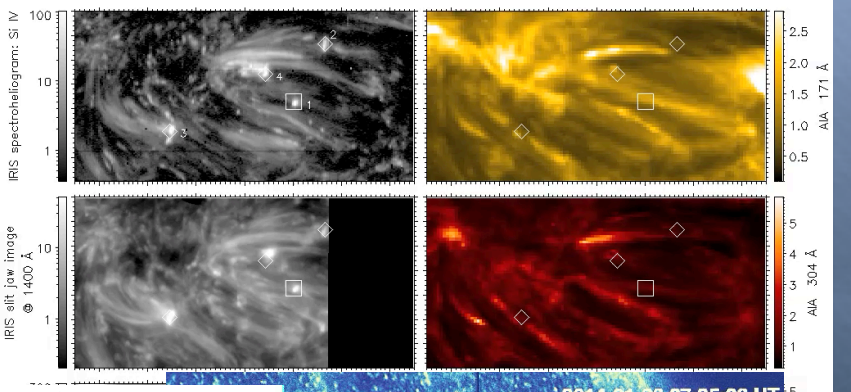


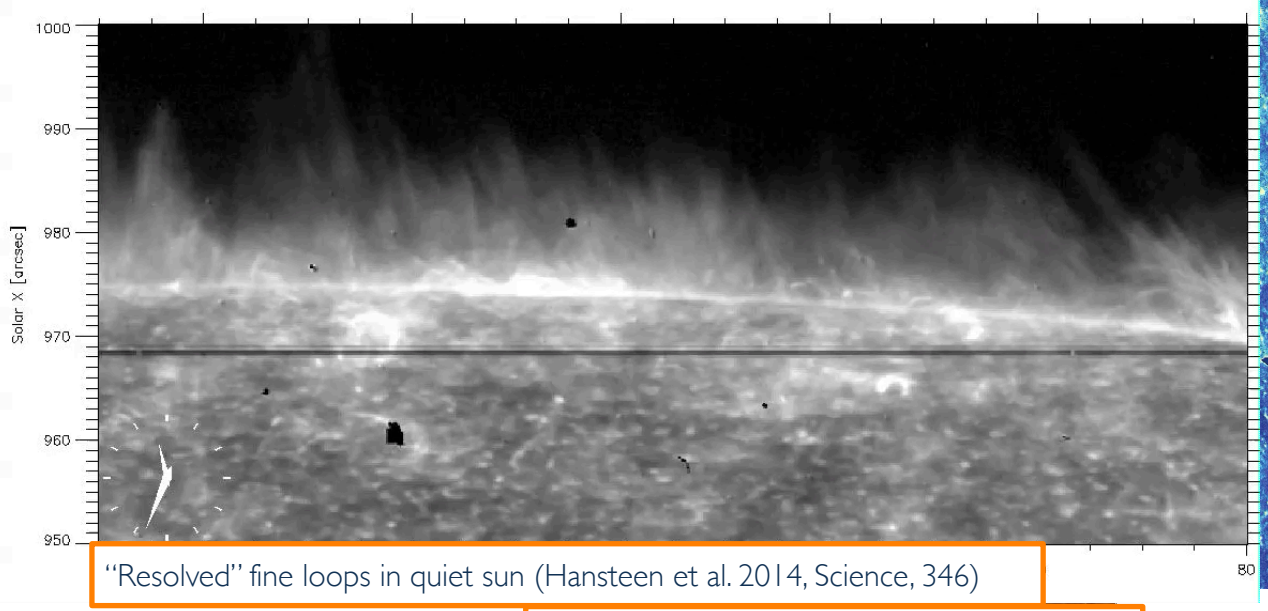


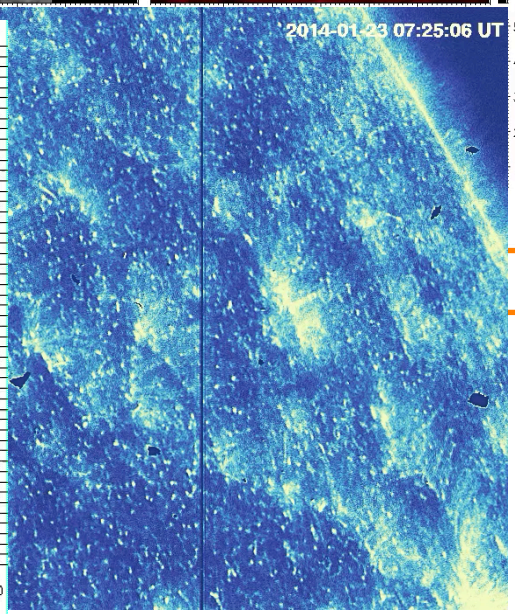


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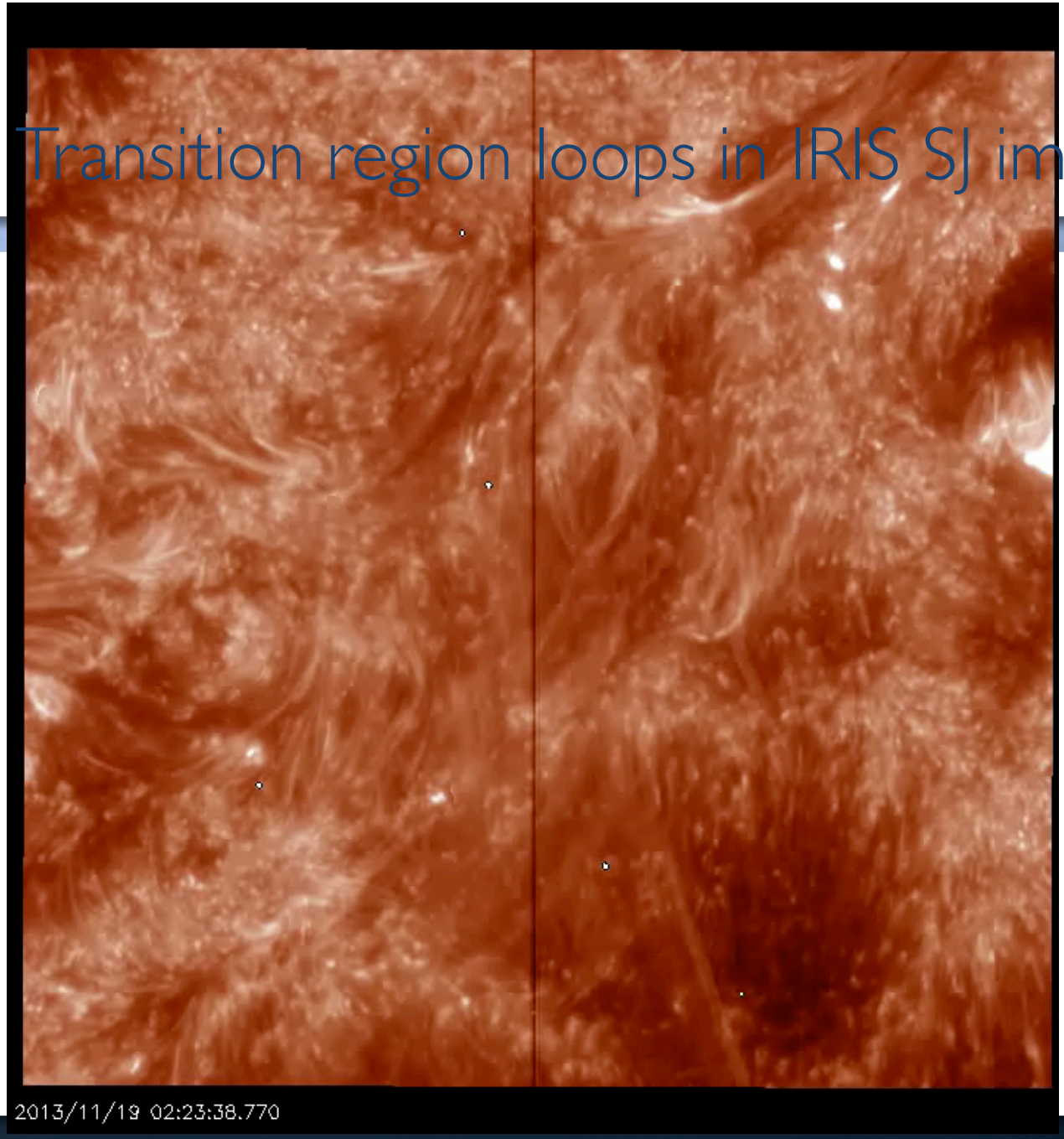
# Transition region loops in IRIS SJ images



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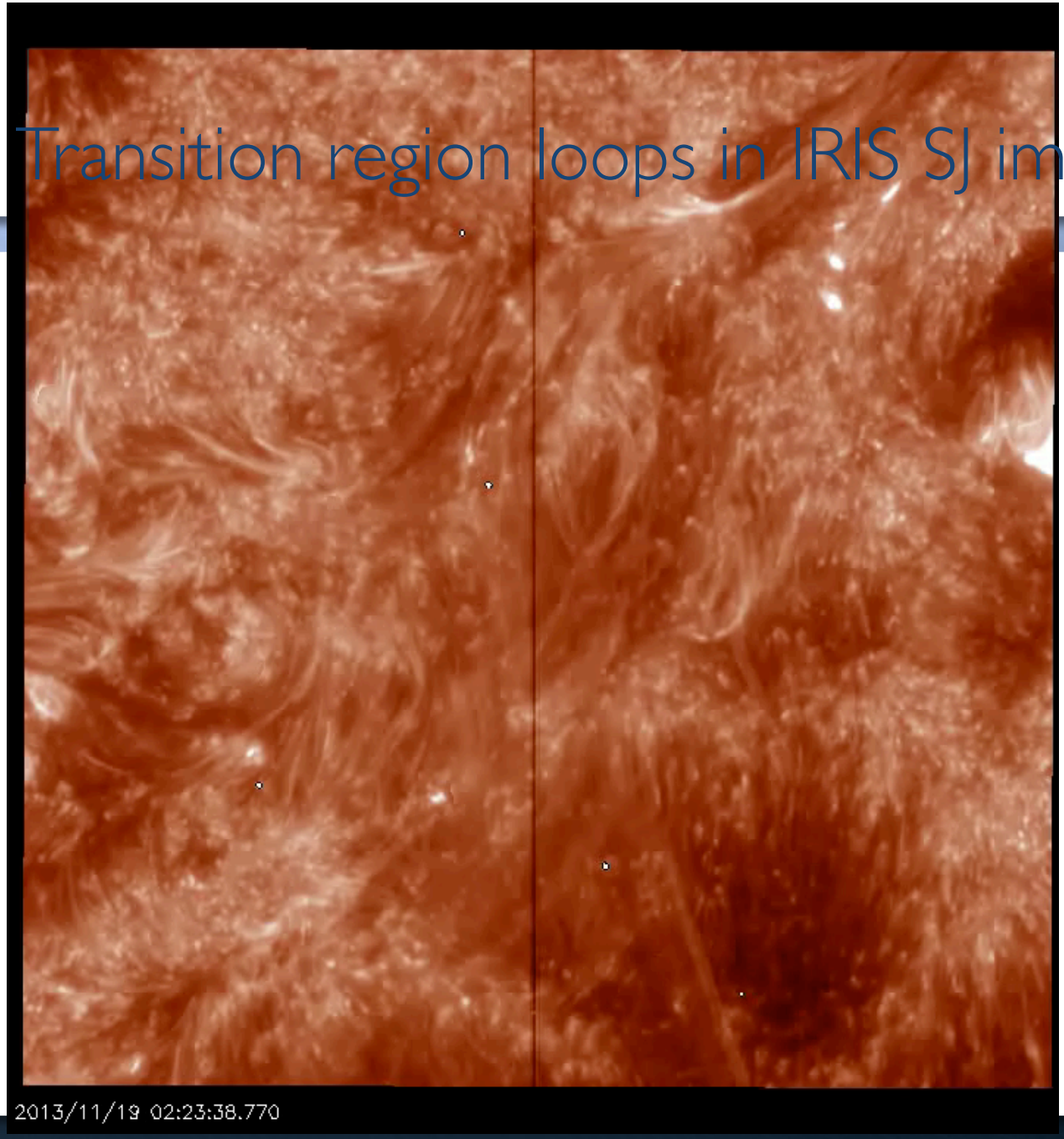

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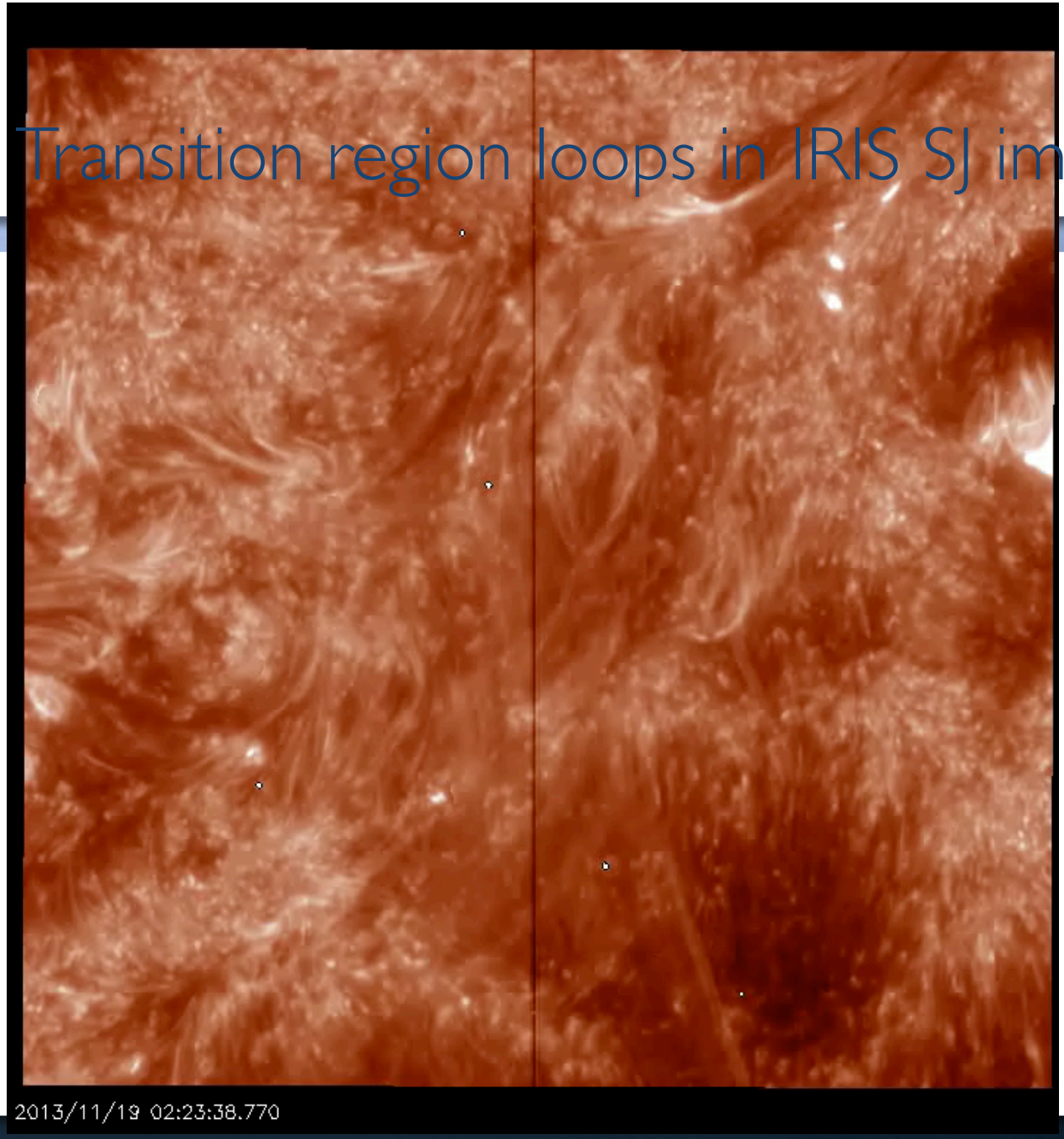
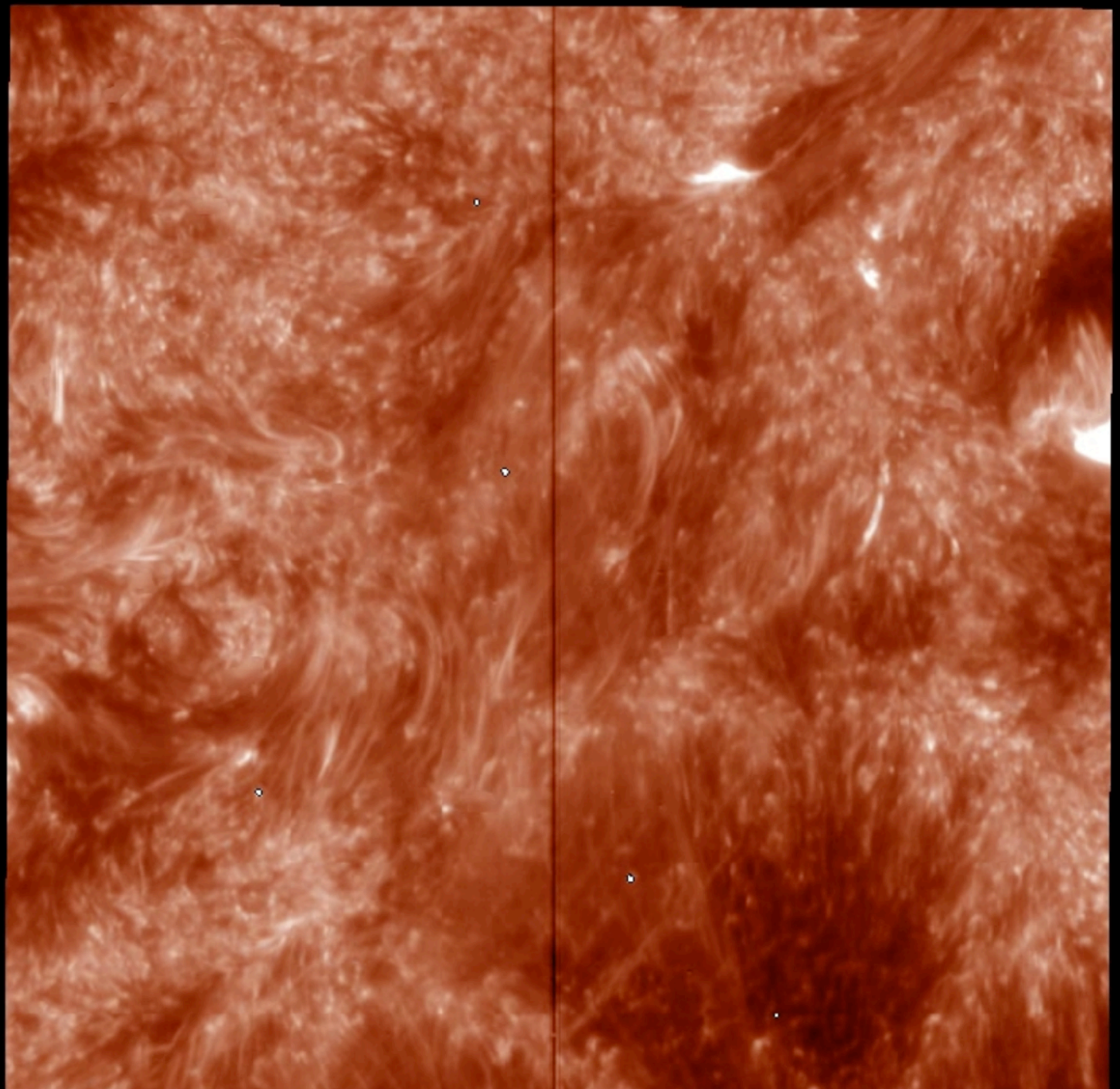
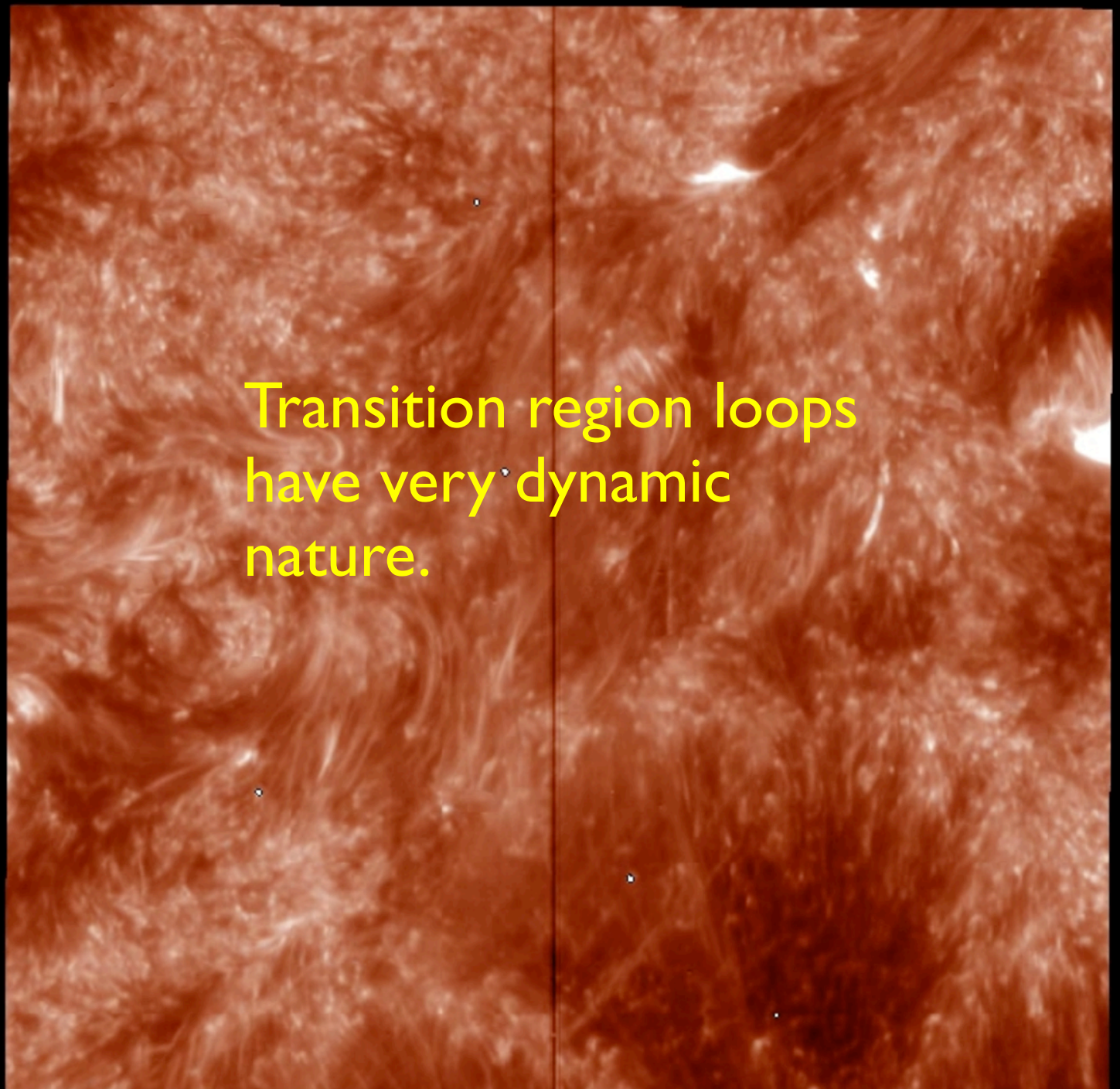
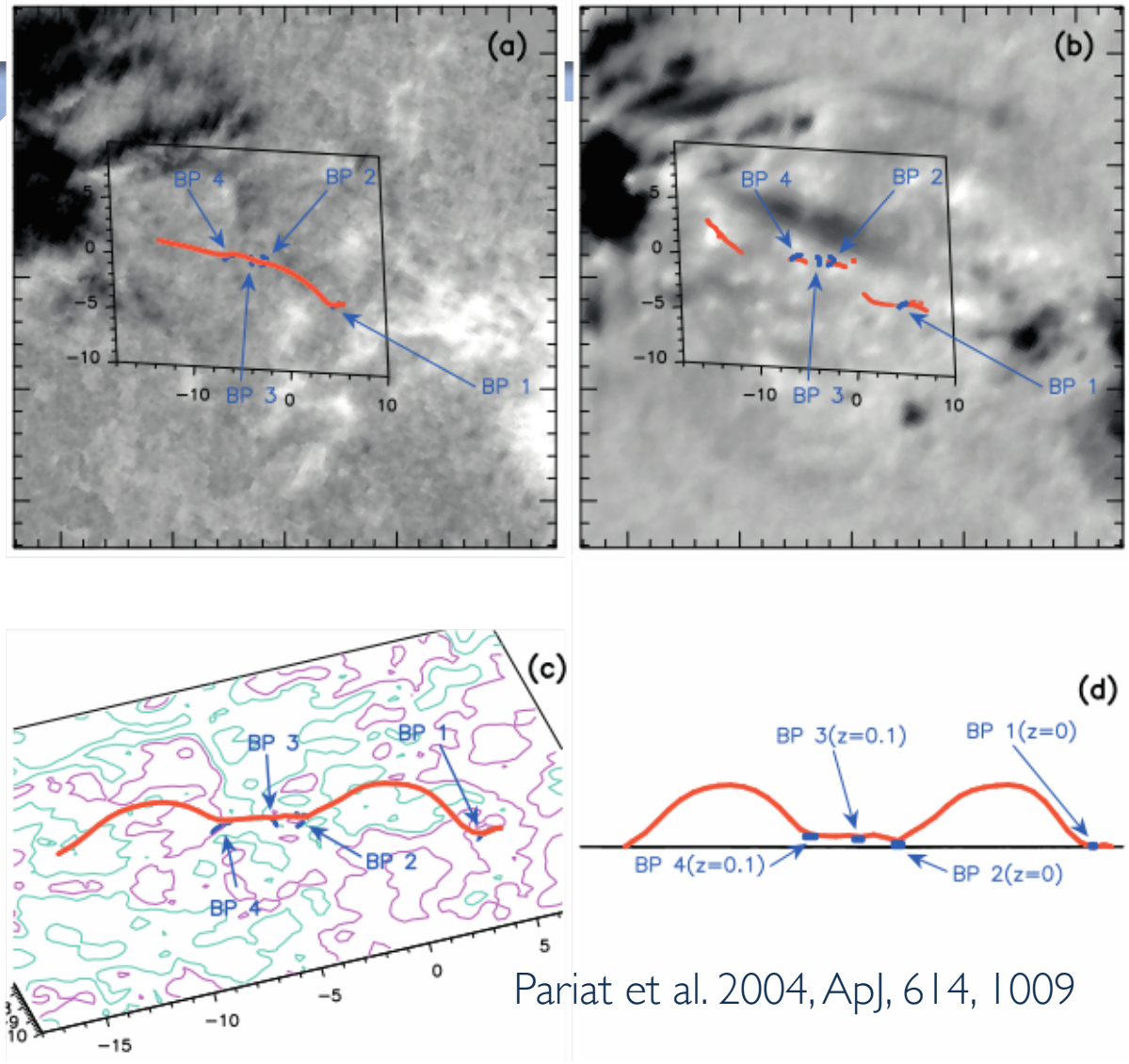





Transition region loops
have very dynamic
nature.

# Why are transition region loops so dynamic?

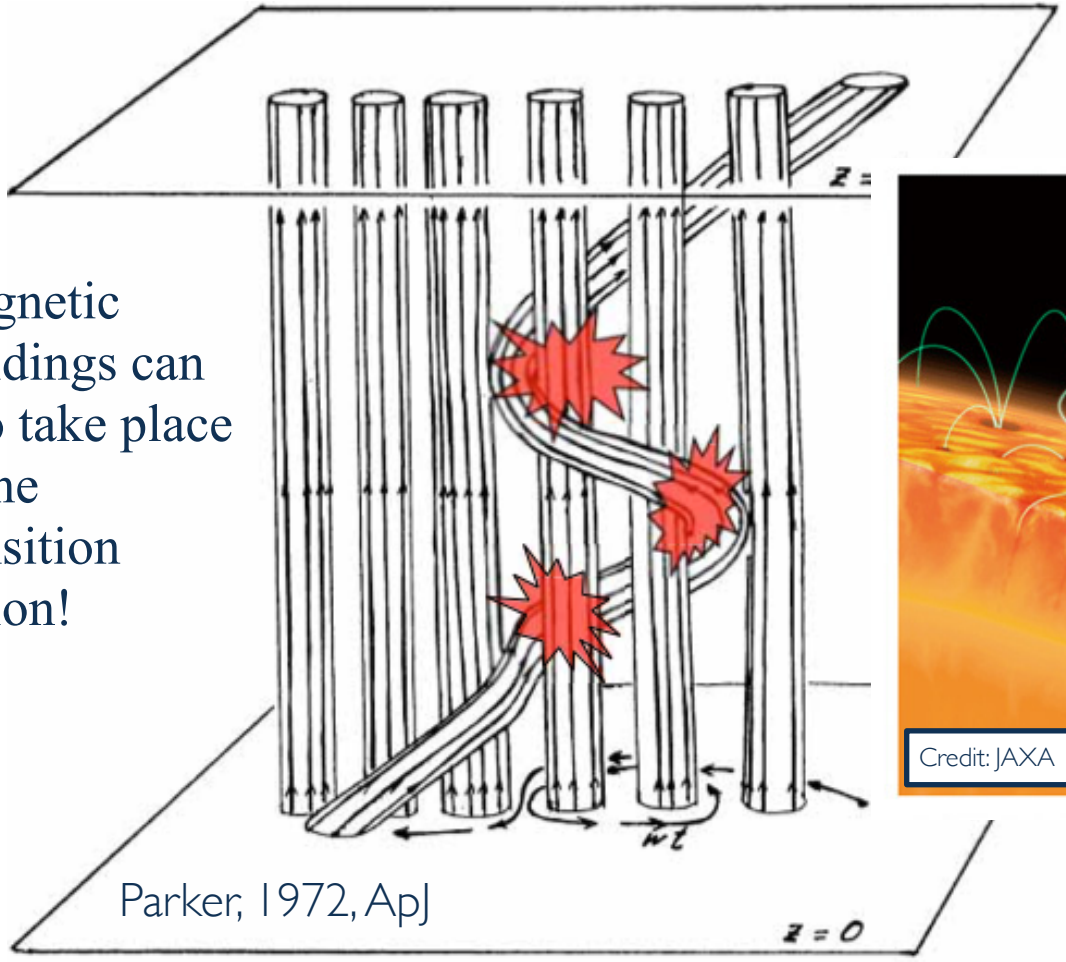



Pariat et al. 2004, ApJ, 614, 1009

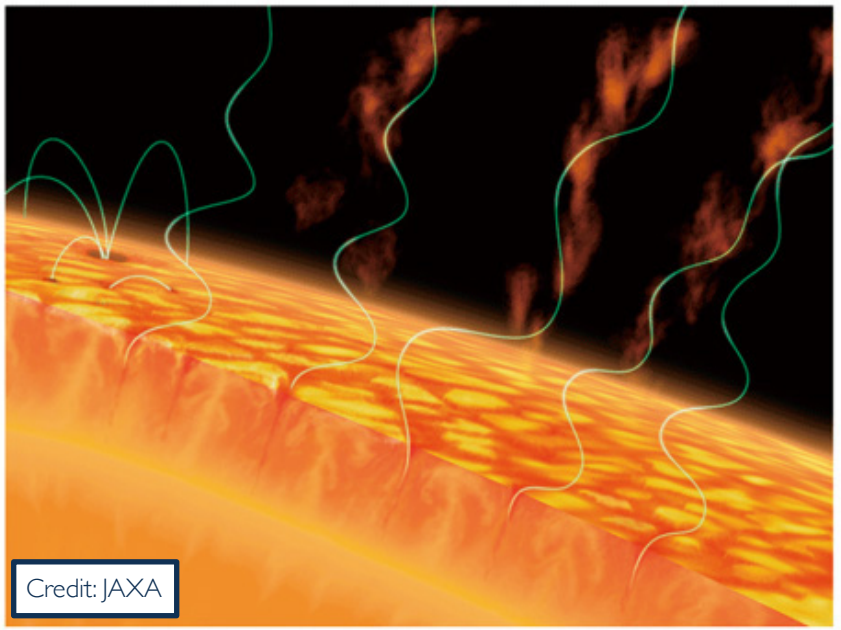
Part of emerging magnetic flux tubes (places hold loop plasma) might be dragged in the photosphere or beneath, forming serpentine flux tubes or U-loops, which can produce various energetic events in bald patches.

# What's more?

Magnetic braidings can also take place in the transition region!

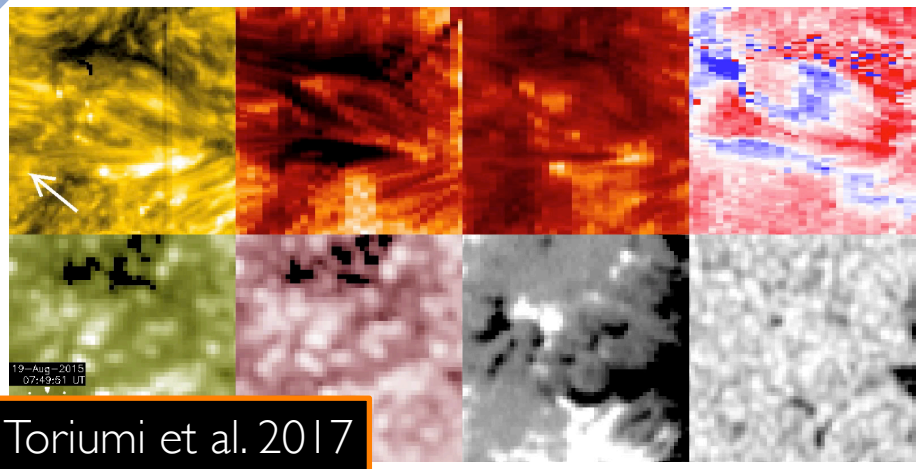



Parker, 1972, ApJ



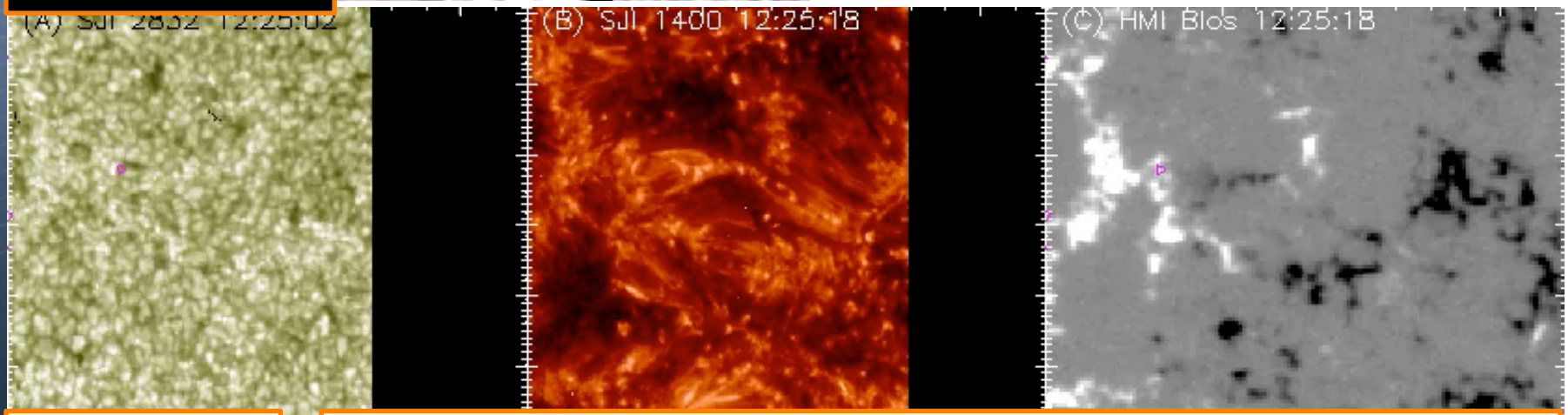

Waves in the solar atmosphere

# Transition region loops in the early stage of flux emergence



Toriumi et al. 2017

- Loops with various scales (a few arcsec to at least tens of arcsec) are existed in the same location;
- Evolve in short time scale;
- Various UV bursts (magnetic reconnection events) in the footpoints;




Tian et al. 2018

Definition of UV bursts, see a review by Young et al. 2018, SSRev., 214, 120

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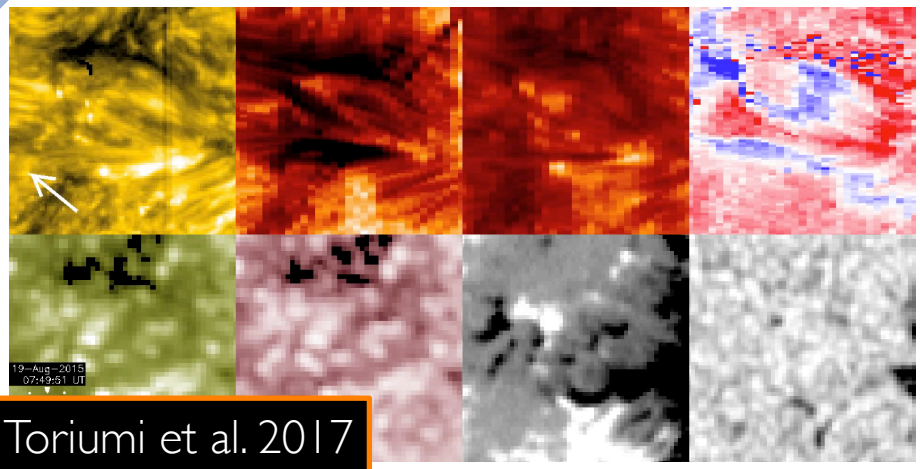

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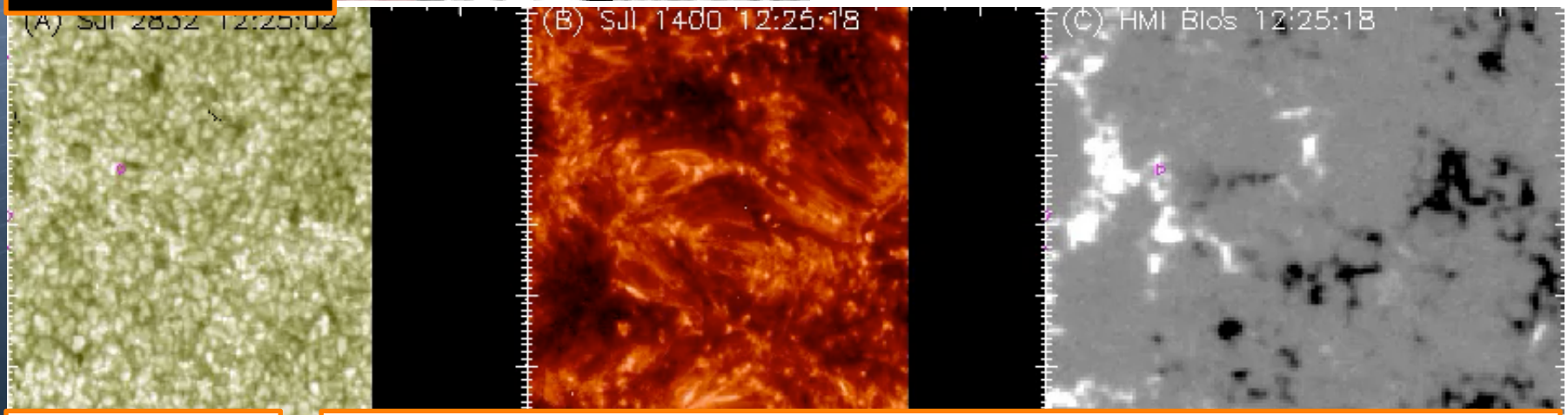


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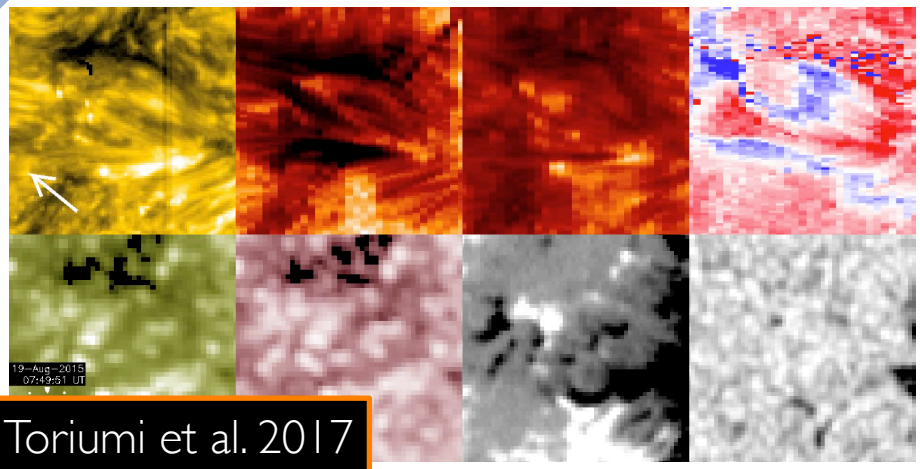

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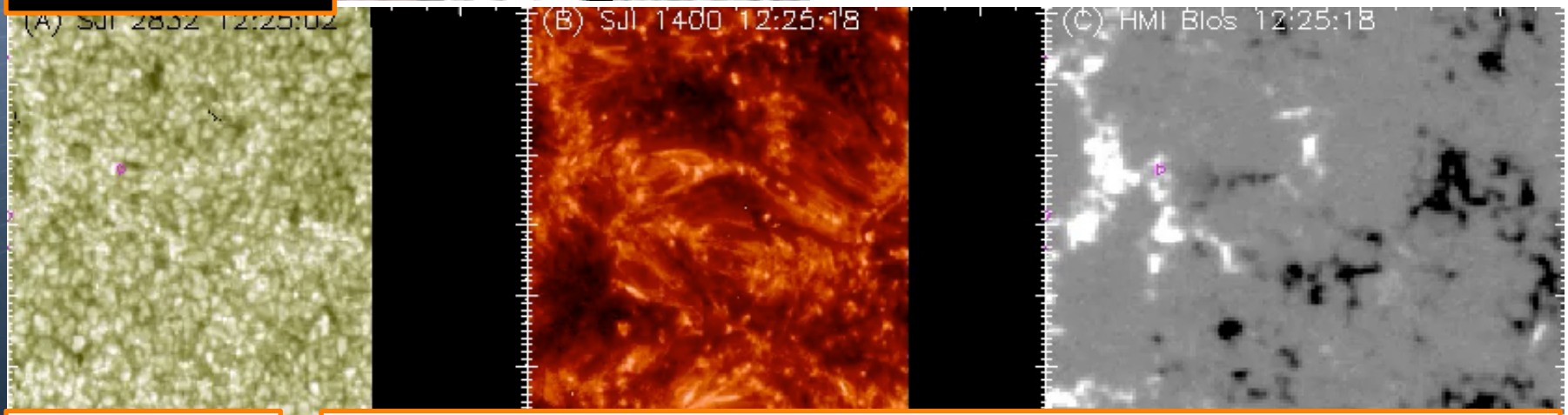


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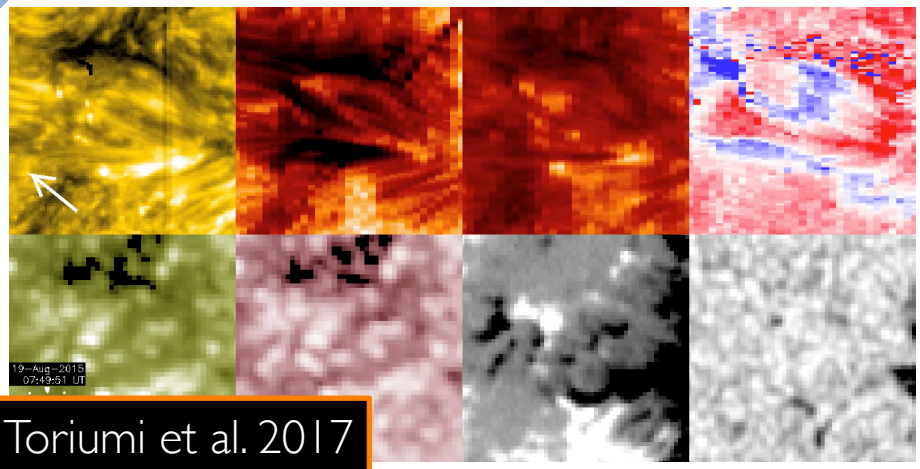

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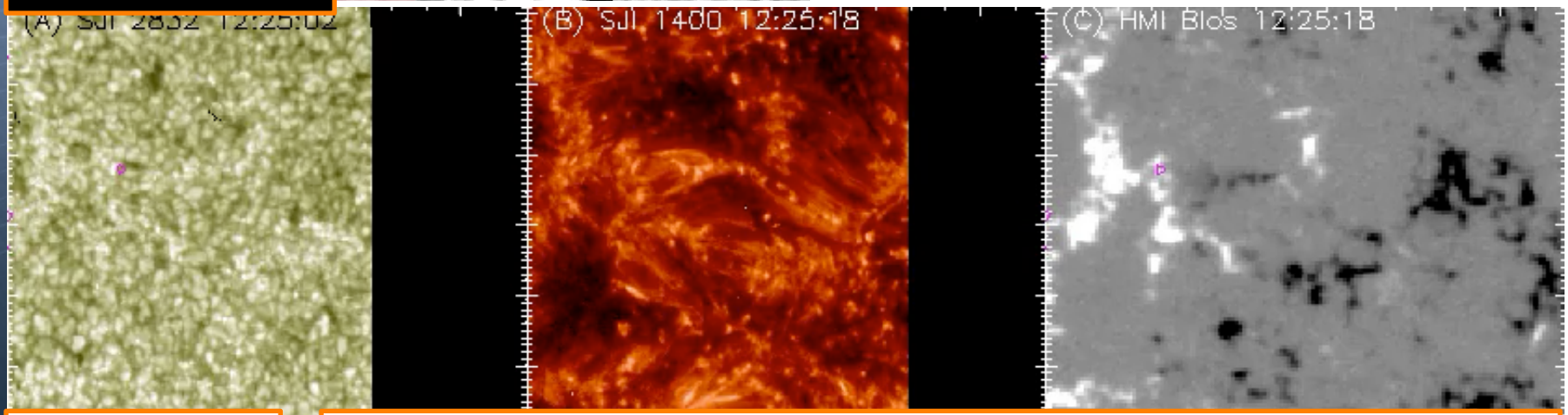


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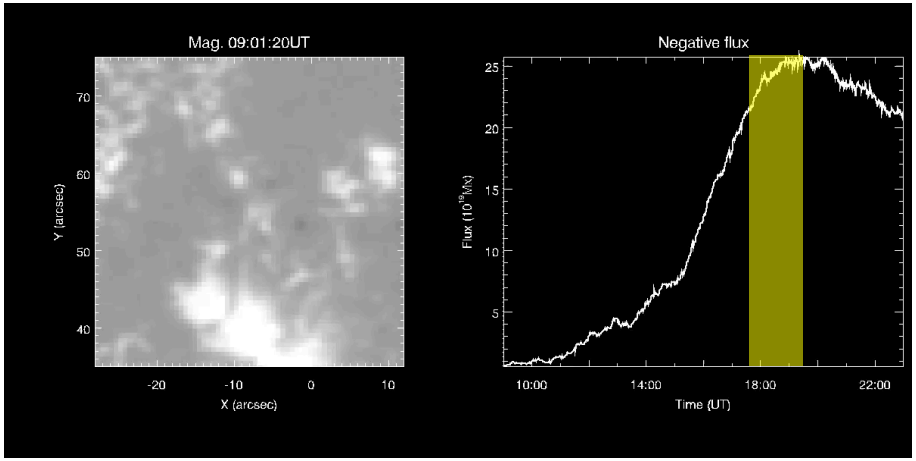
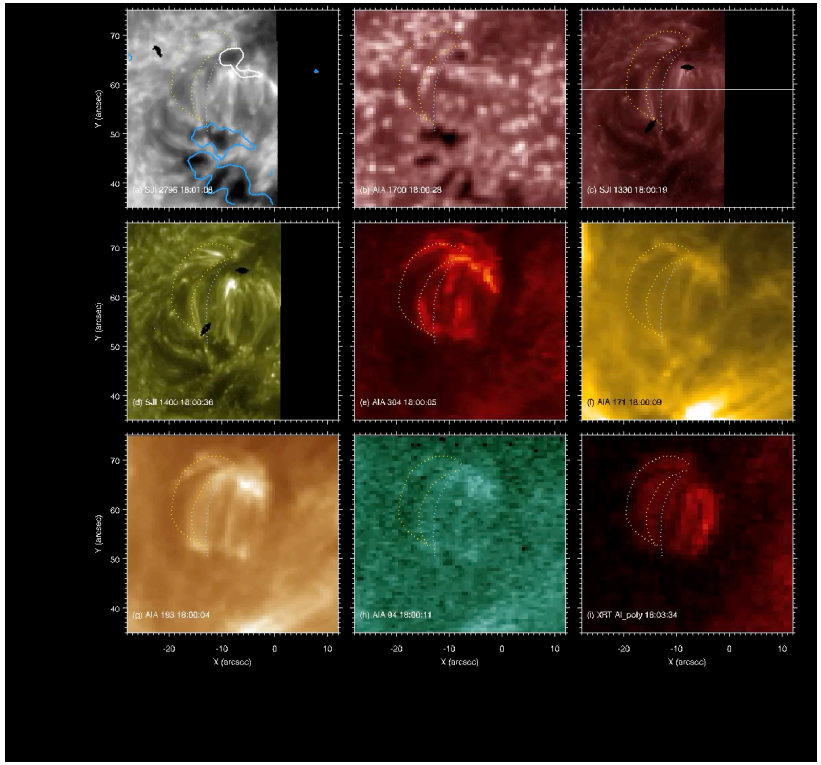
# Loops in the late stage of emergence




IRIS and SDO observations of a small flux-emergence region. Please note the negative polarity (north footpoint) is moving away from emerging site (see Huang, 2018, ApJ, 869, 175).



The cyan dotted lines denote a loop thread that is clearly seen in the XRT image, and the yellow dotted lines denote two loop threads that are clearly seen in the AIA 304 Å image.

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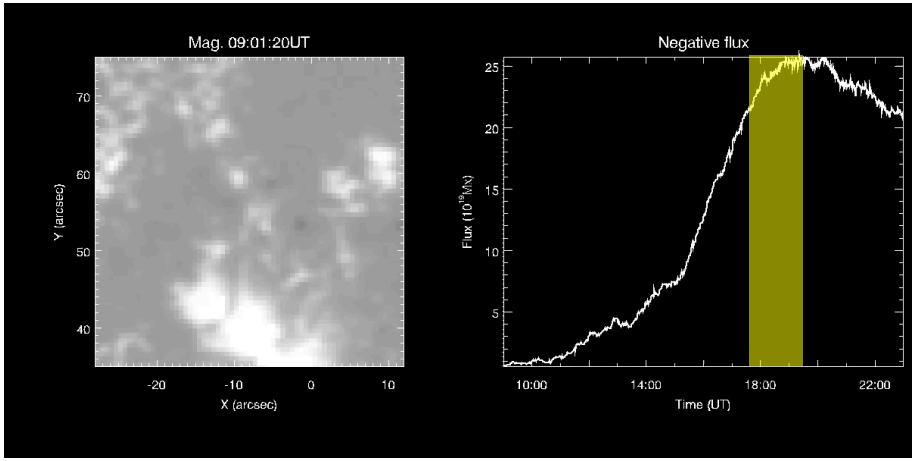


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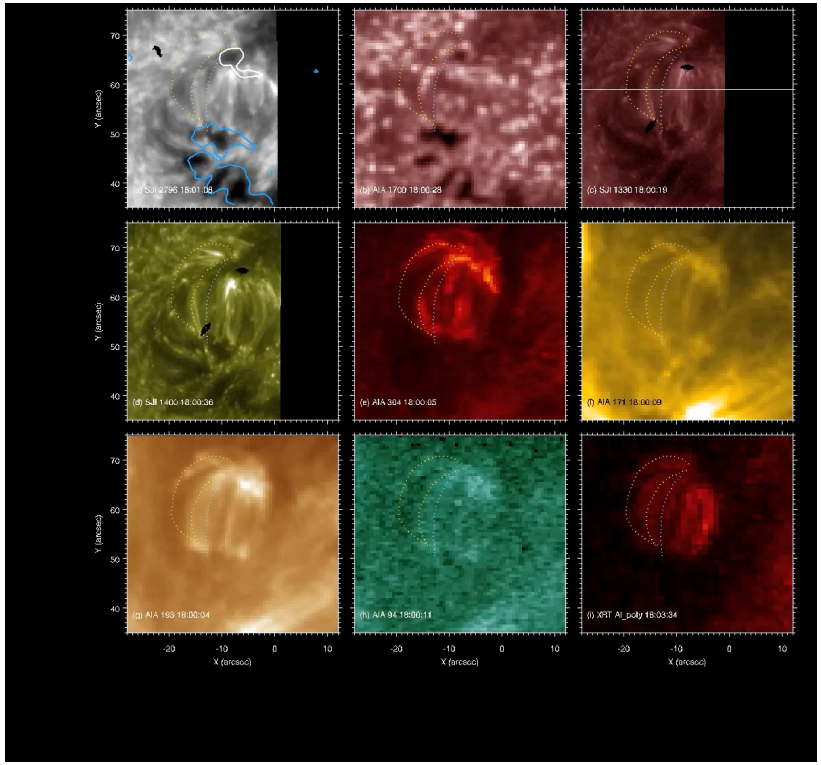

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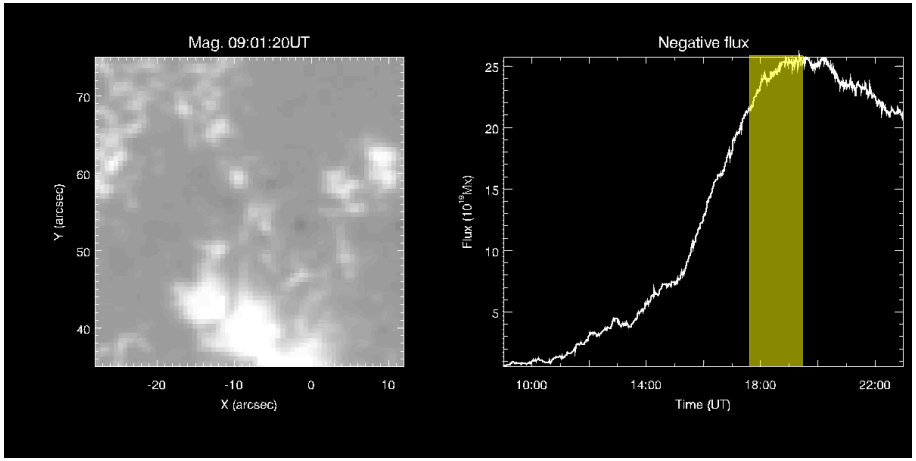


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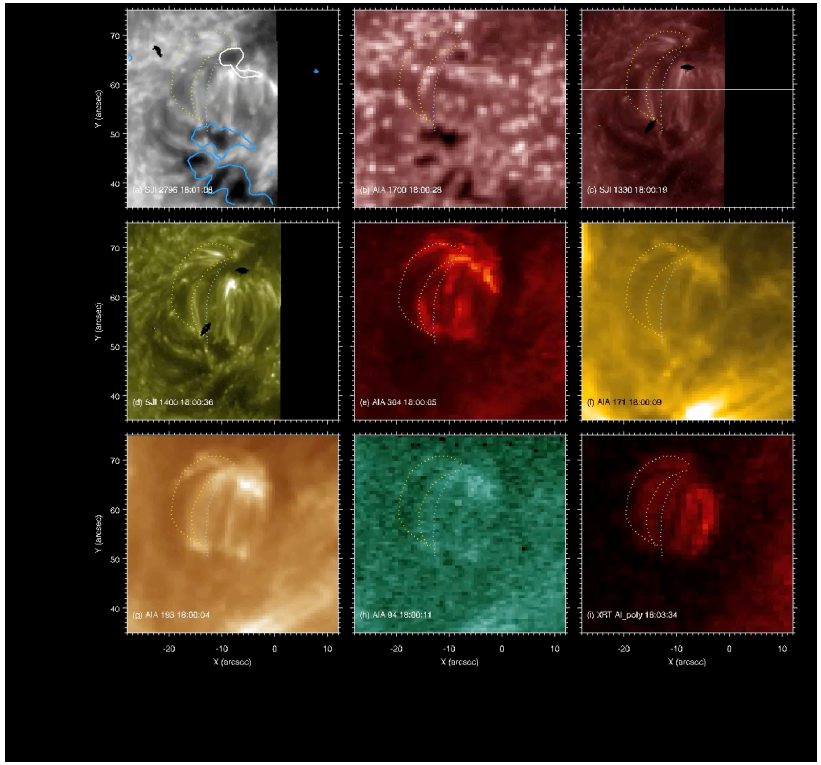

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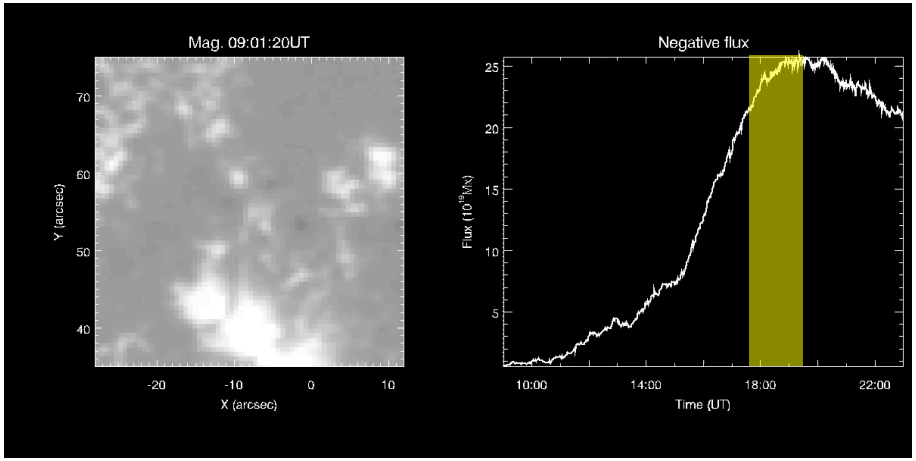


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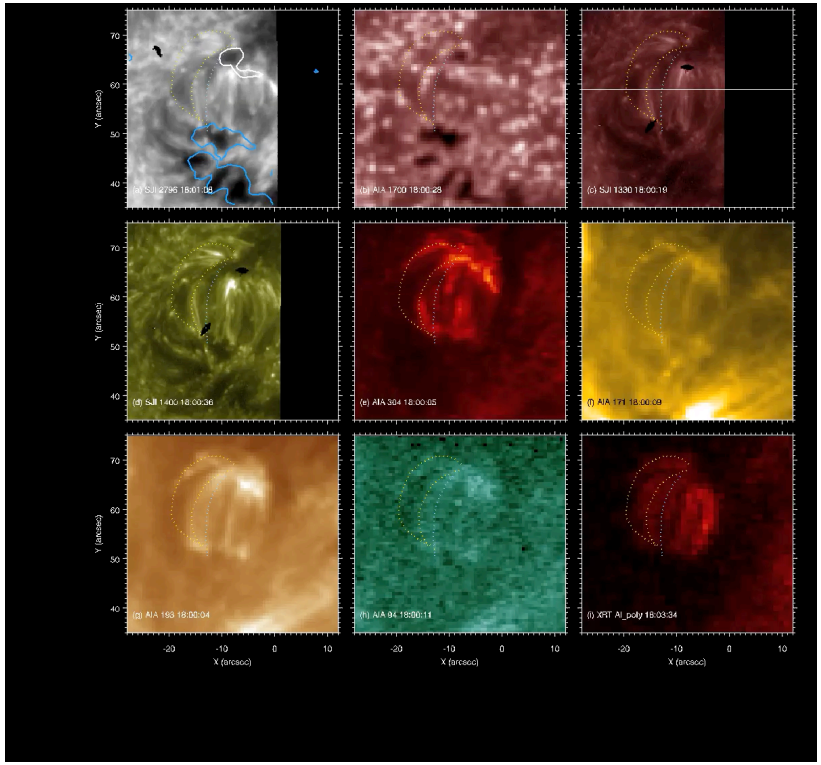

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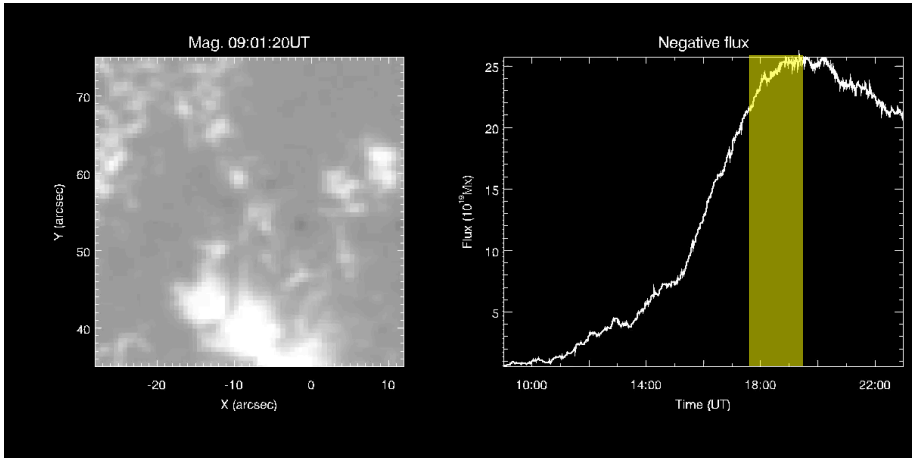


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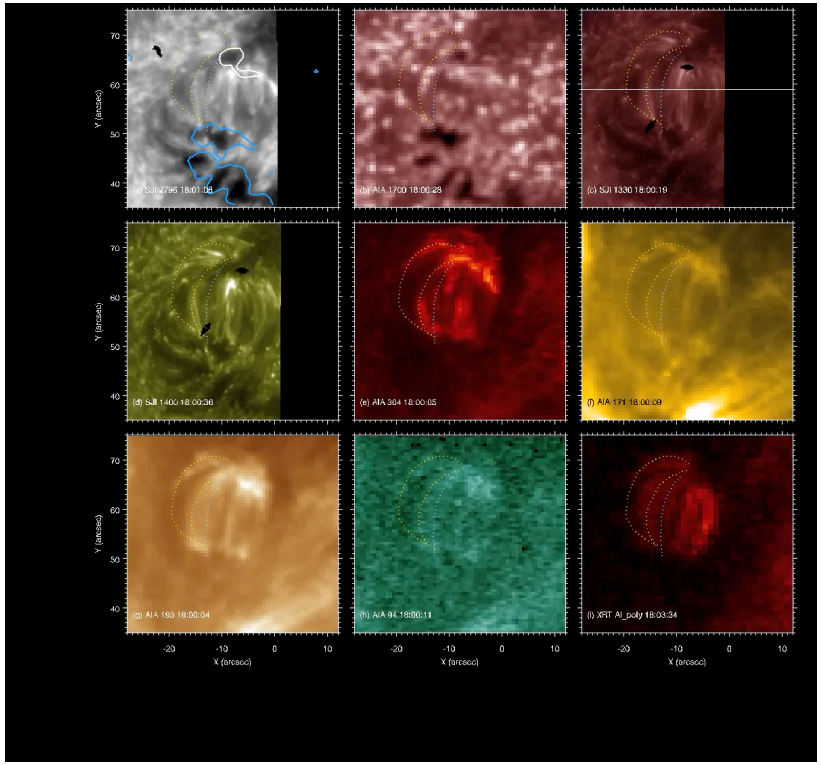

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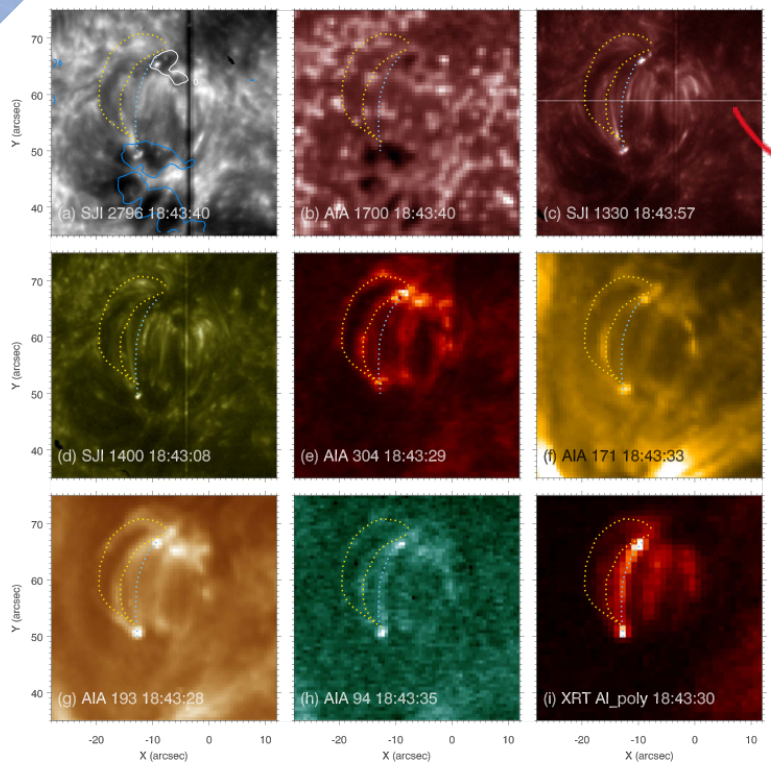
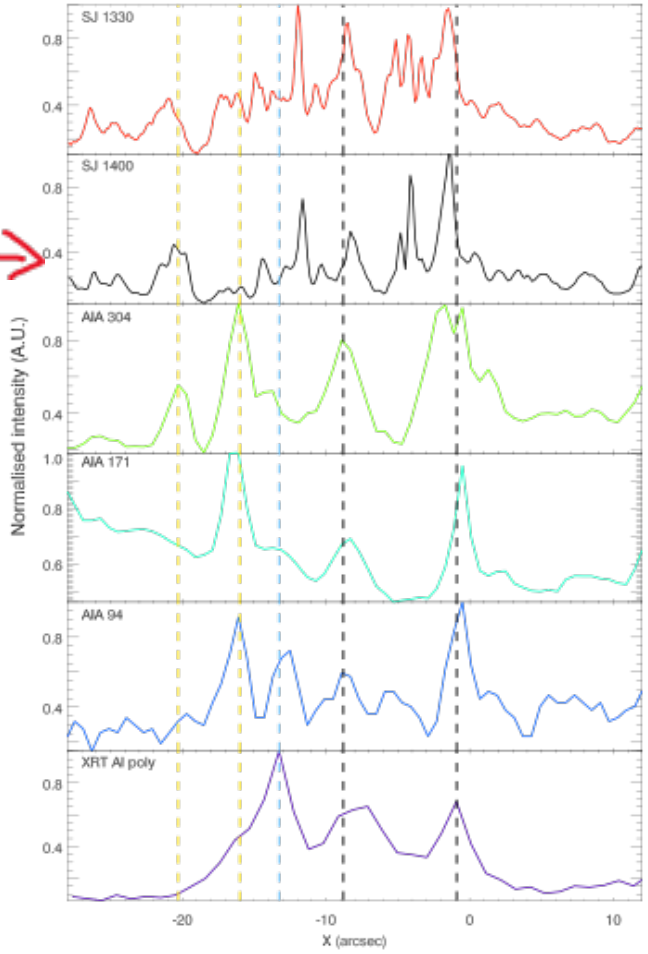
# Loop system associated with late phase flux emergence consists of loop threads in various temperatures.

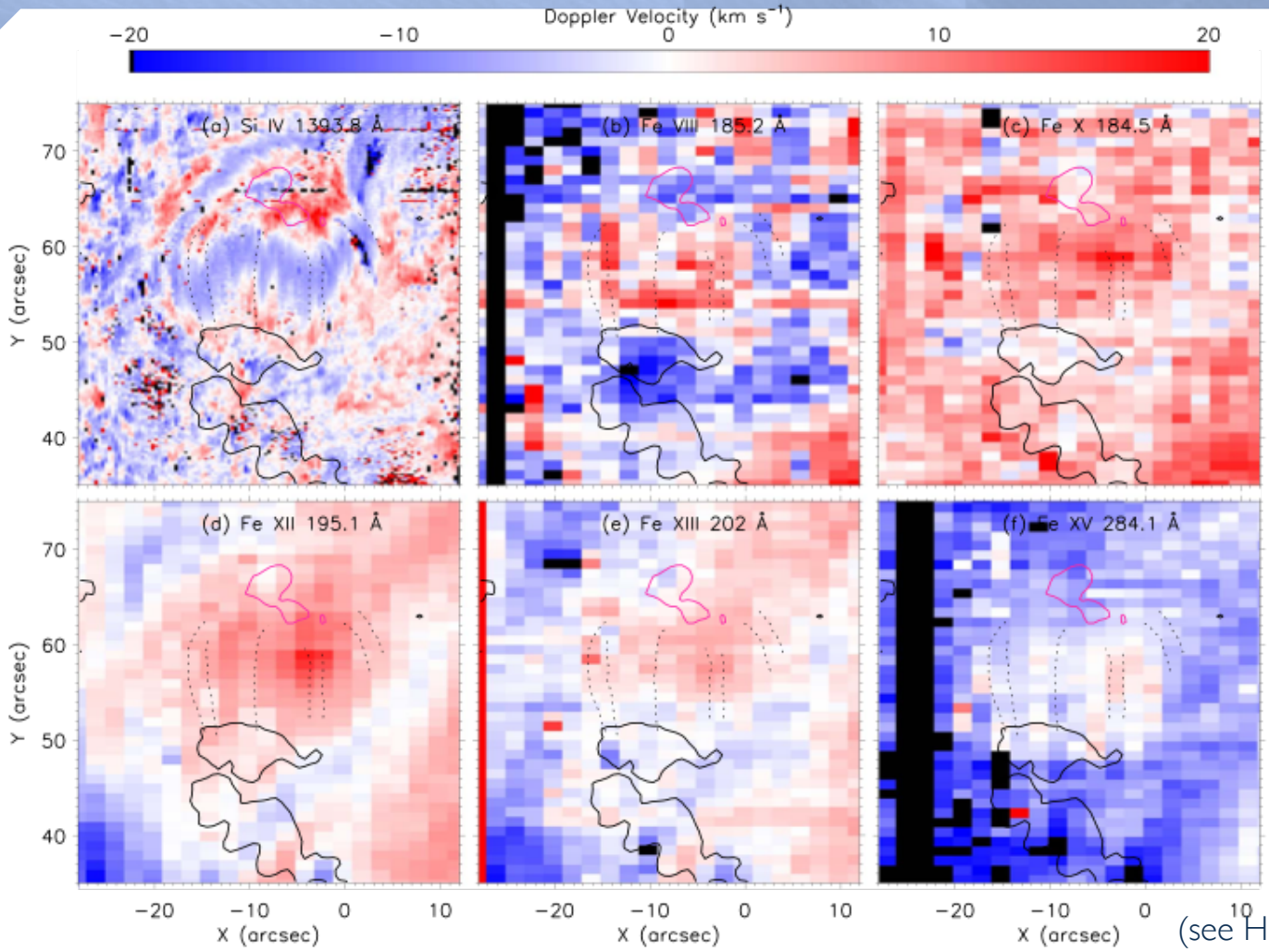



Most of the loop threads seen in SJ 1330/1400 images do not have response in "hot" AIA and XRT channels.

(see Huang, 2018, ApJ, 869, 175)

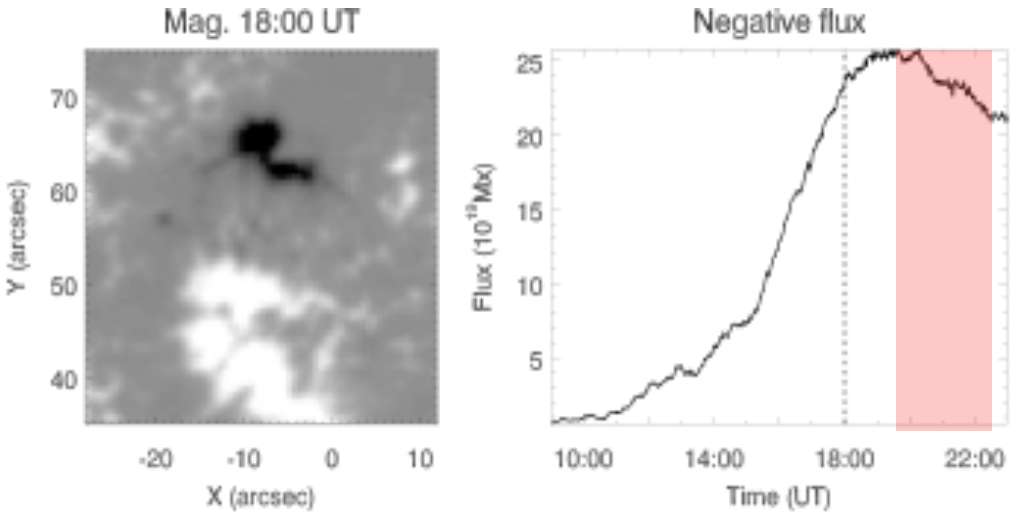
# Flows in the loop system at late-phase flux emergence




Significant upflows are seen in the TR loops at late-phase flux emergence, while the coronal counterparts are dominated by downflows.

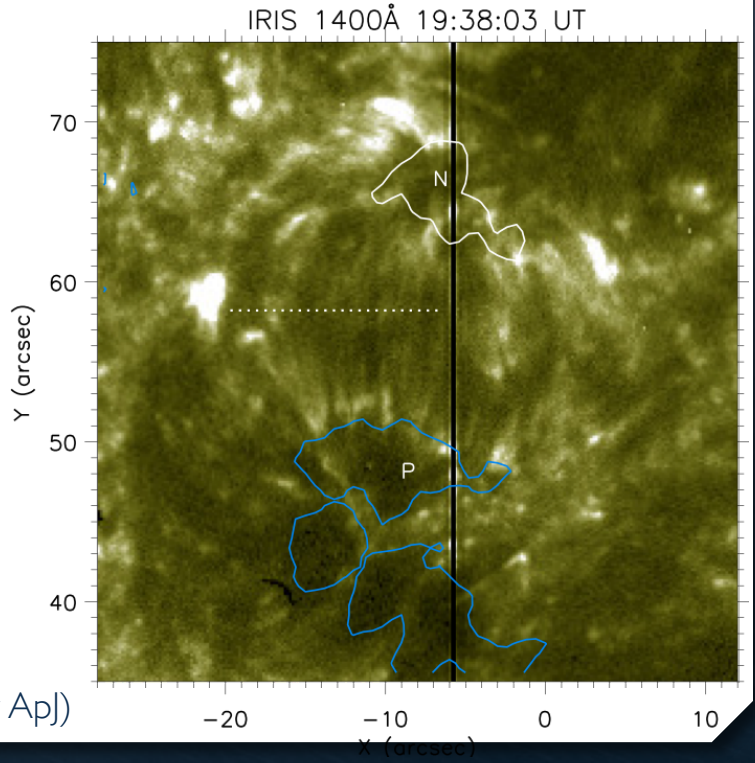
(see Huang, 2018, ApJ, 869, 175)

# Behaviours of TR loops in even later stage of flux emergence



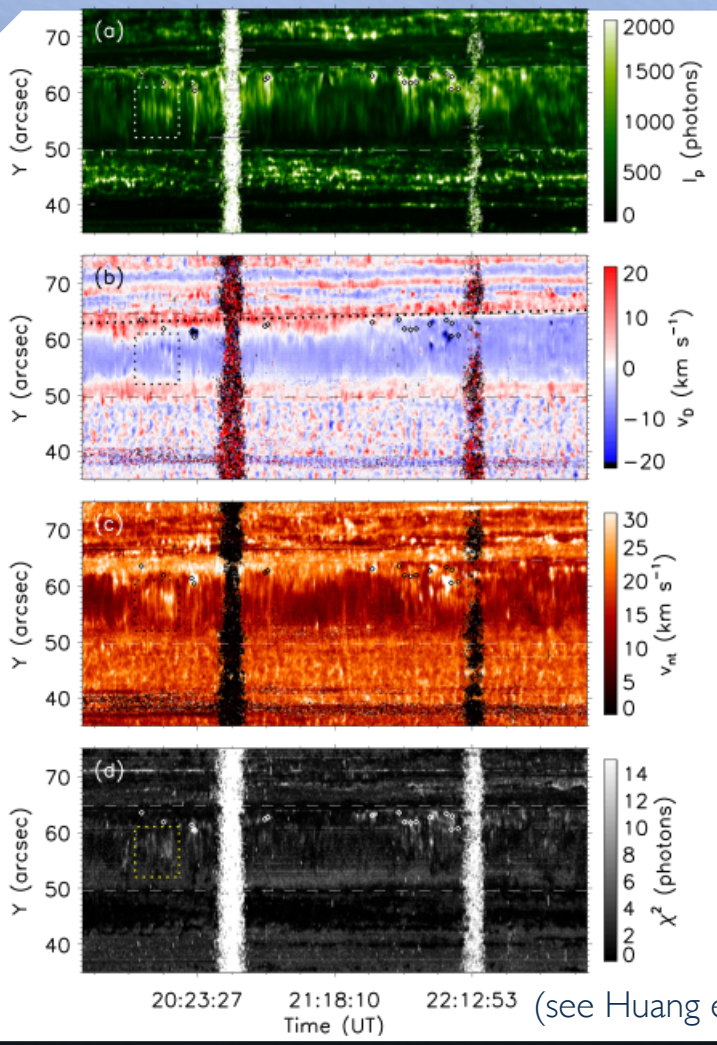

IRIS sit-and-stare mode with an exposure time of 15 s and a cadence of 16.4 s.

The slit is almost align to the loops.




(see Huang et al. 2019, accepted by ApJ)

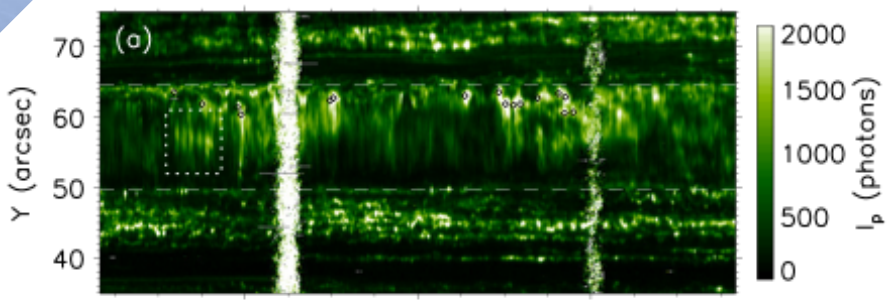
# Transition region loops in the very late stage of flux emergence (sit'n'stare view)

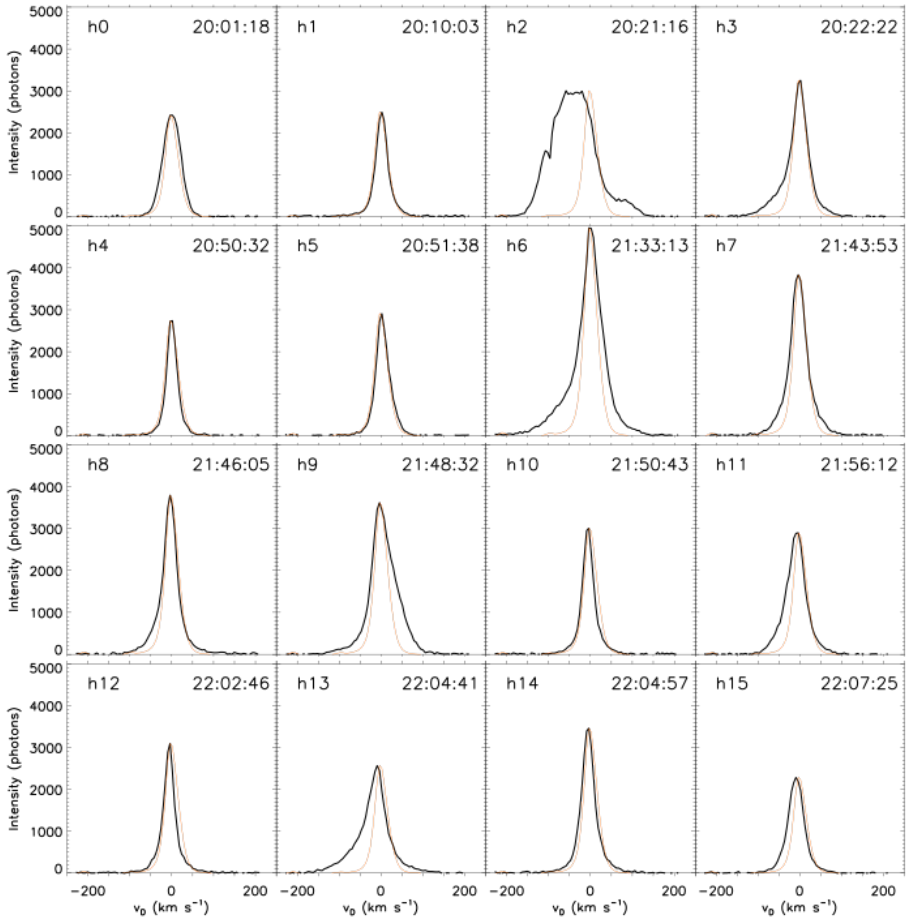



- Repetitive bright threads;
- Compact brightenings (heating events) are concentrated in the north footpoint region (i.e. moving polarity);
- A quasi-periodic brightening occurs near the loop top;
- Upflows in the bodies of the loops ;
- Downflows in the footpoints and they are faster in the north footpoint region;
- Nonthermal velocities are generally larger in the north footpoint region, especially in some compact brighteings and the quasi-periodic brightenign;
- The chi-square values are larger in some compact brightenings and the quasi-periodic brightening.

(see Huang et al. 2019, accepted)

# Si IV 1394 Å profiles of the compact brightenings

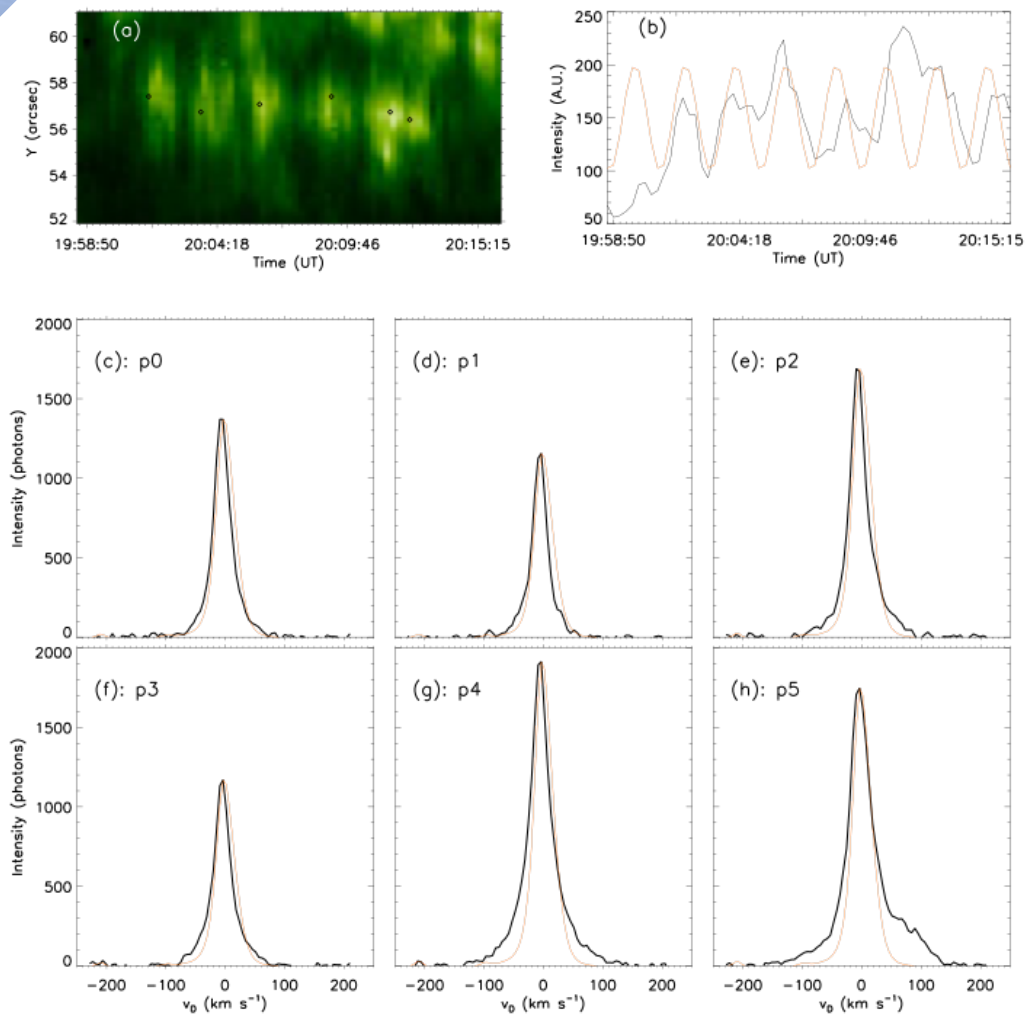



- In 16 events:
  - 7 present non-Gaussian profiles, including one with distinguished blending from absorption line of Ni II;
  - 9 show profils without significant broadening but only intensity increasing.

(see Huang et al. 2019, accepted)

# The quasi-periodic brightening




- Period: ~130 s;
- Brightening along the slit has no lag;
- Has signatures of bi-directional flows at velocities of about 50 km/s.

- The compact brightenings and the quasi-periodic brightening can provides hints to the formation and heating of TR loops at the late phase of emergence…...

# Magnetic reconfiguration between arch filament threads and coronal loops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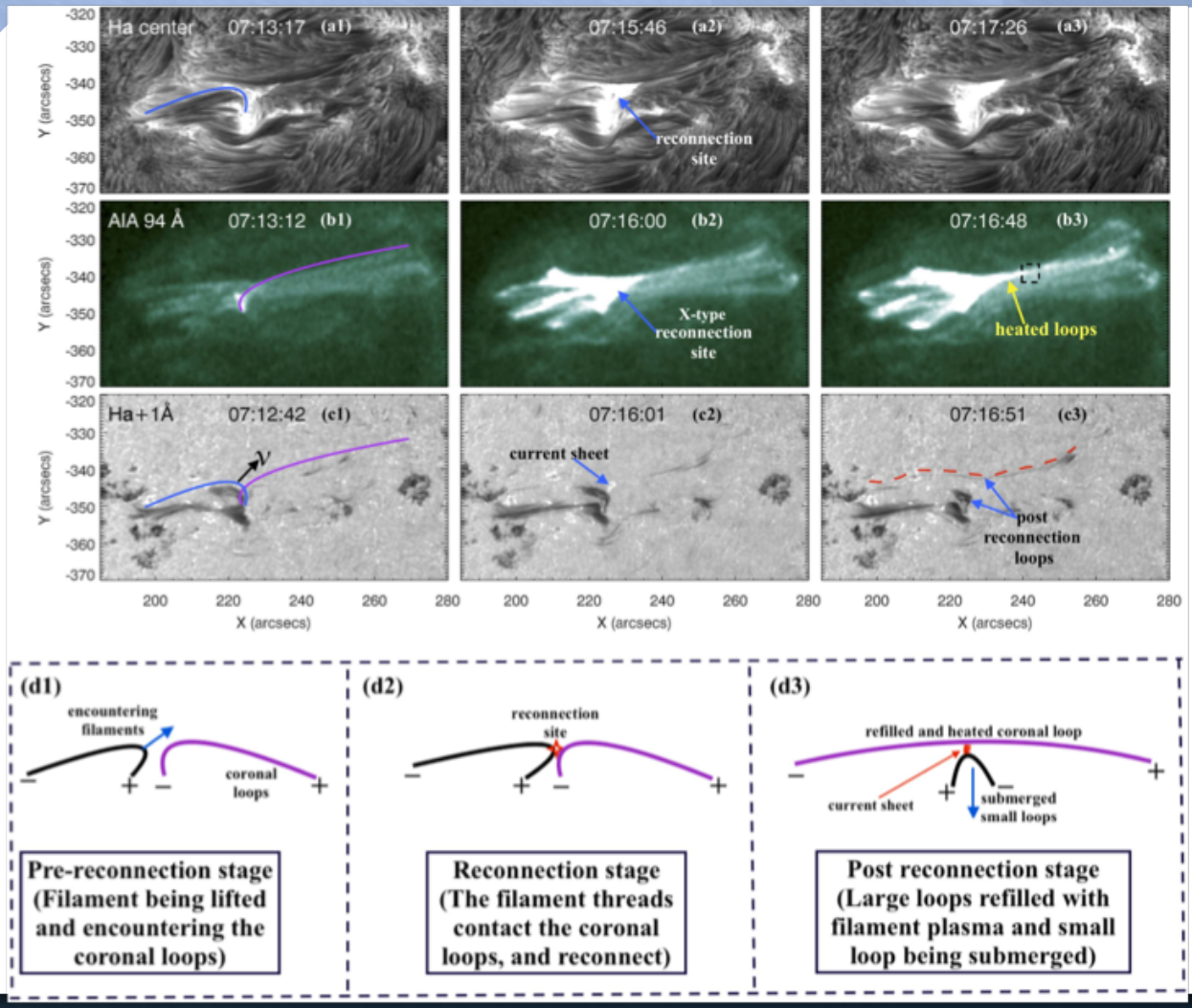
53, 26

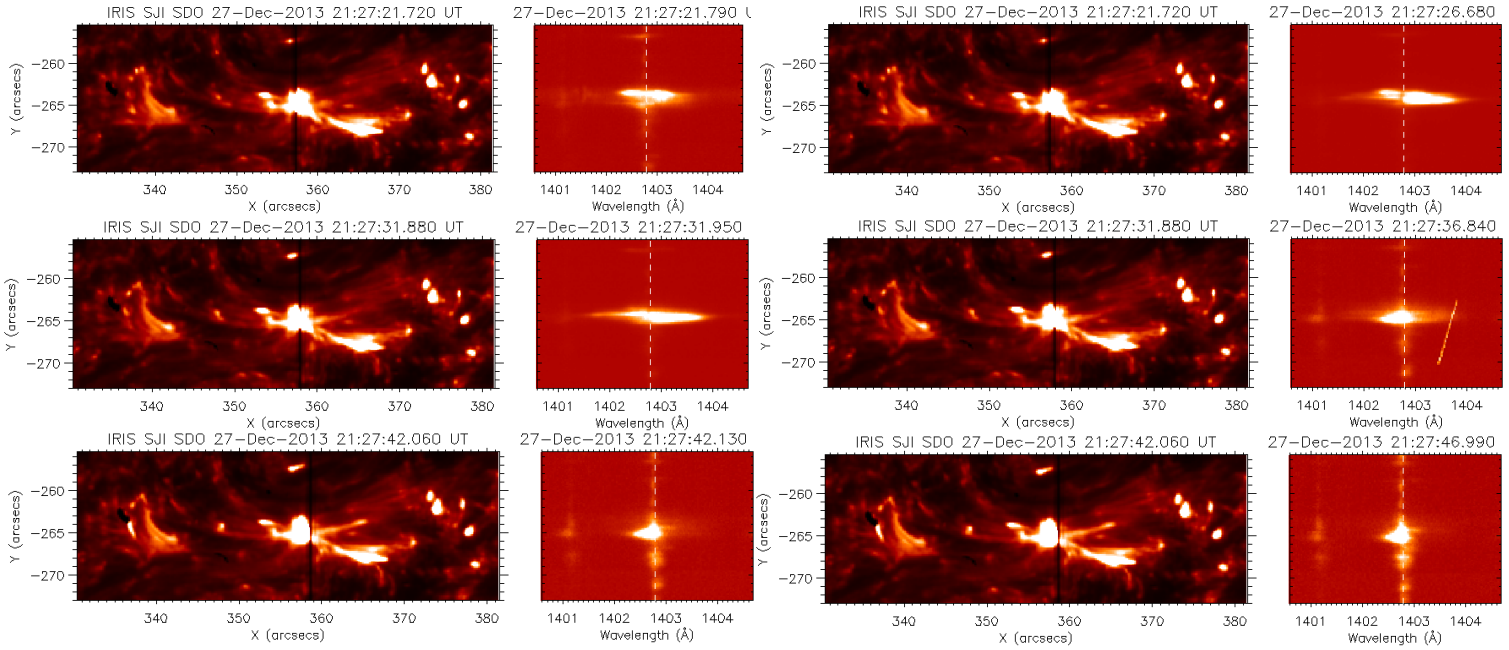
# Magnetic reconfiguration between arch filament threads and coronal loops




Observations from the New Vacuum Solar Telescope (NVST) and SDO reveal a magnetic reconnection process between cool arch filament threads and hot coronal loops. Such reconnection process could heat, fill and reconfigure the coronal structures.

Huang et al. 2018, ApJL, 853, 26

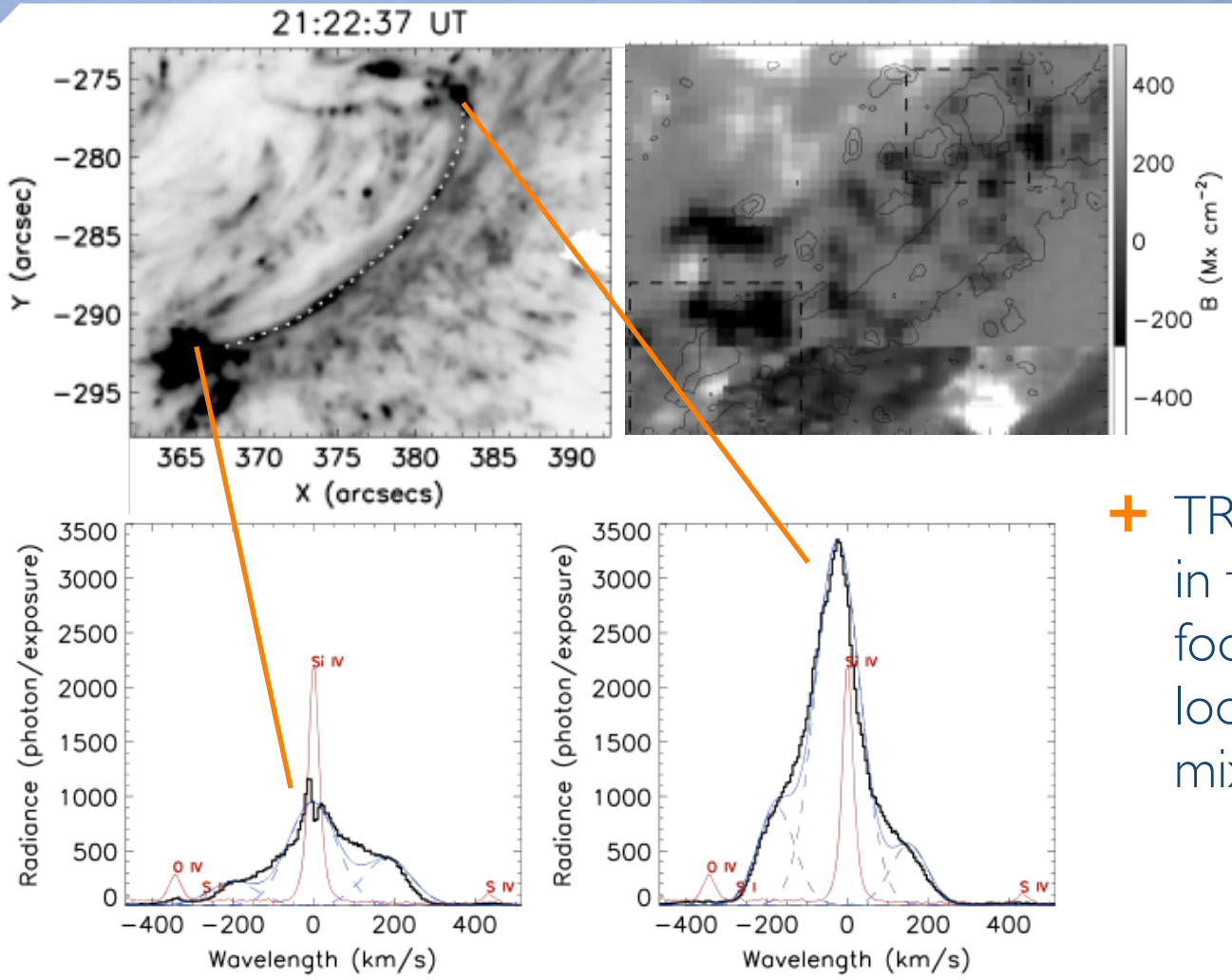
# UV bursts in the conjunction footpoint of transition region loops




Huang et al, 2015, ApJ, 810, 46

- Flows in the event show blue-shift dominant in one place but red-shift dominant in the other side.

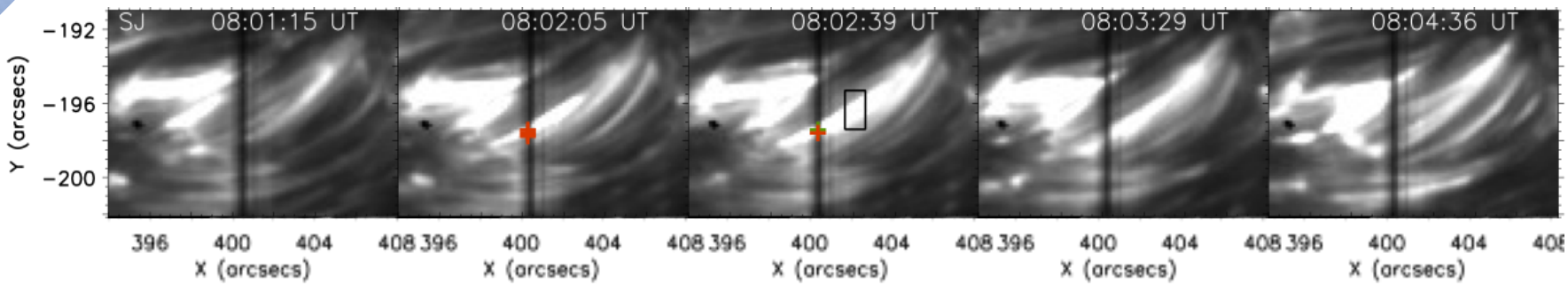
# TR explosive events (EEs) and TR loops

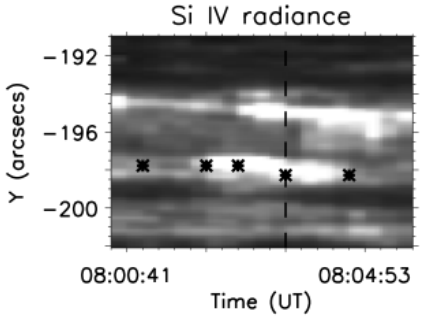


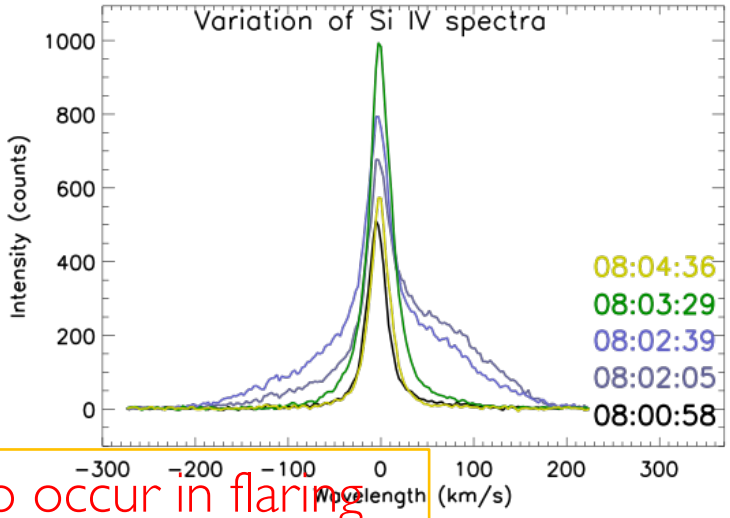

Huang et al.2015, ApJ, 810, 46

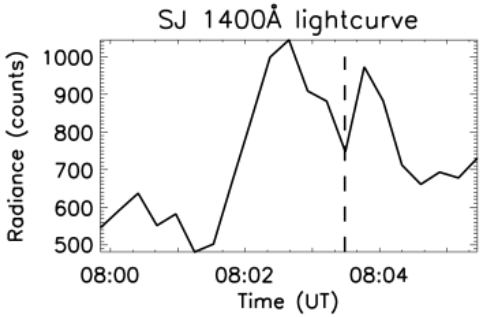
+ TR explosive events in the active footpoints of TR loops, which consist of mix polarities.

# TR explosive events and TR loops



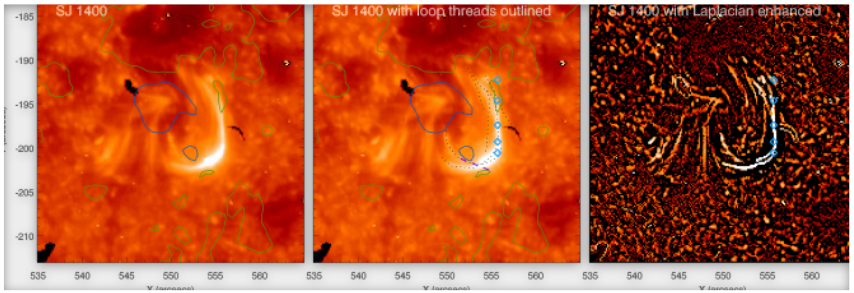




+ Explosive events also occur in flaring TR loops, BUT not all flaring loops produce EEs.

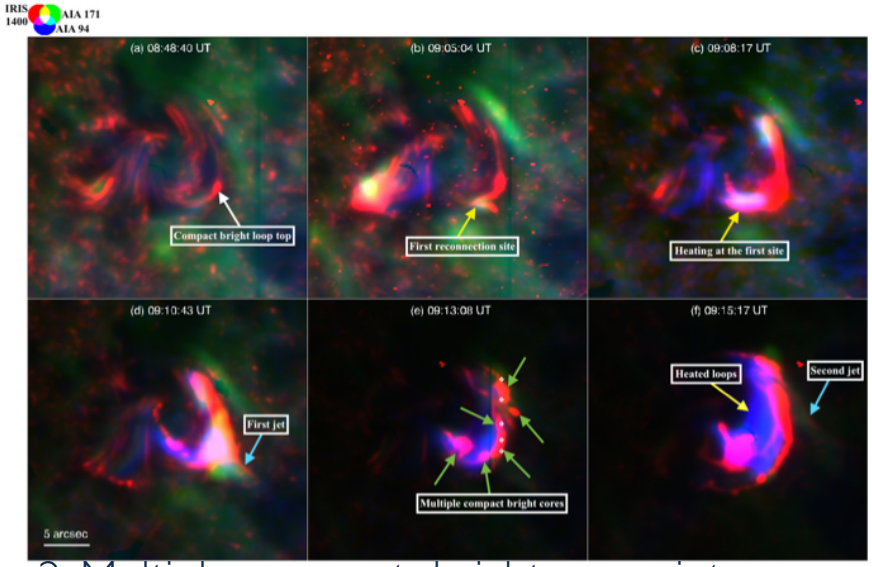
Huang et al.2017, MNRAS, 464,1753

# Fine structures in spiral loop system

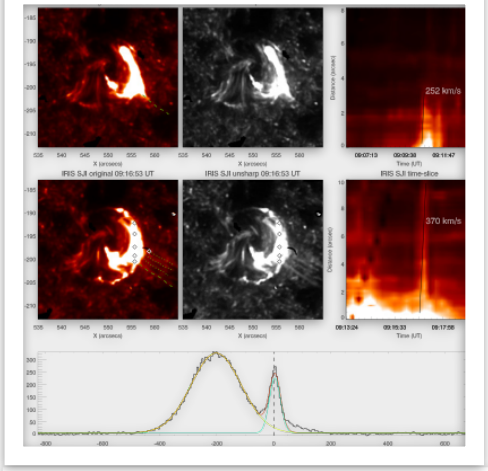
Huang et al. 2018, ApJ, 854, 80



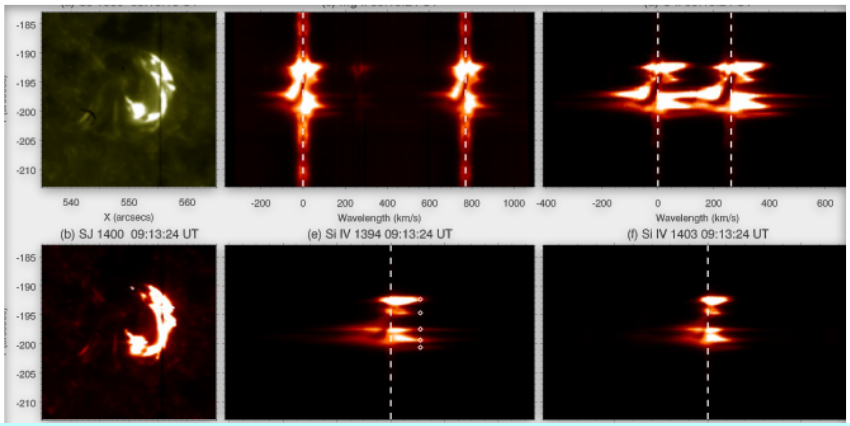

1. Spiral loop system with bundle of loops




2. Multiple compact bright cores, jets and heated loops

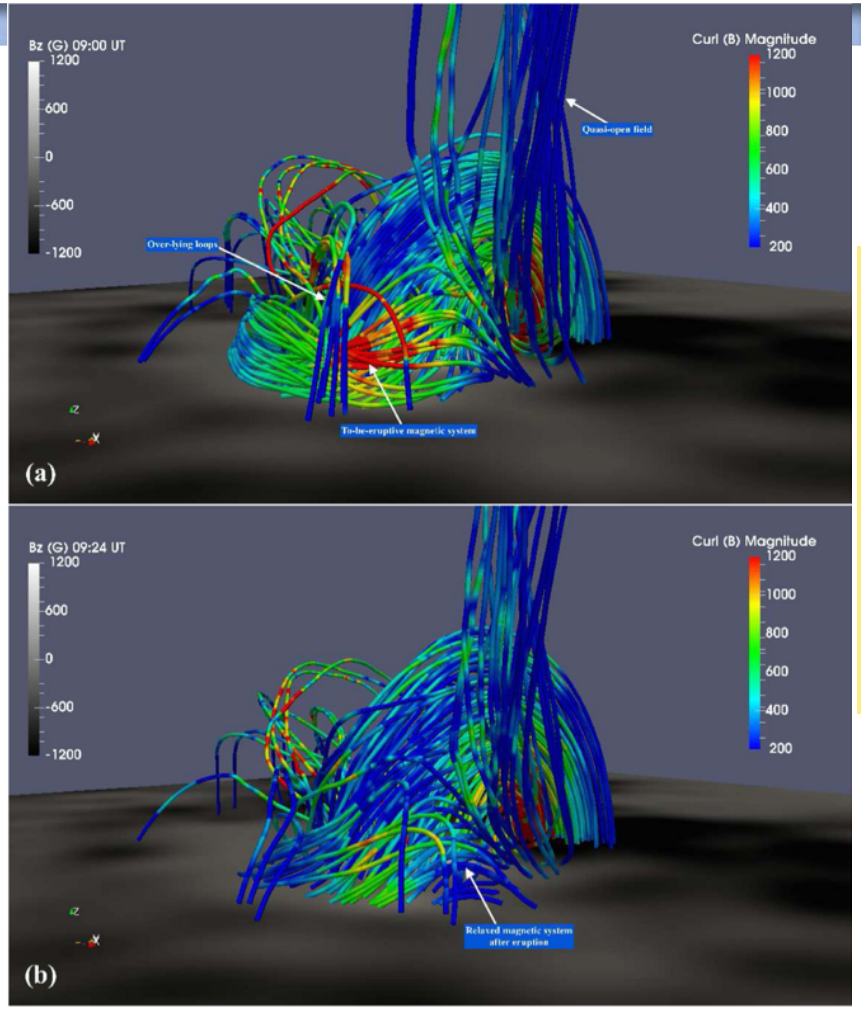



3. Multiple threads in jets.




4. Well-separated explosive events along the eruptive loops

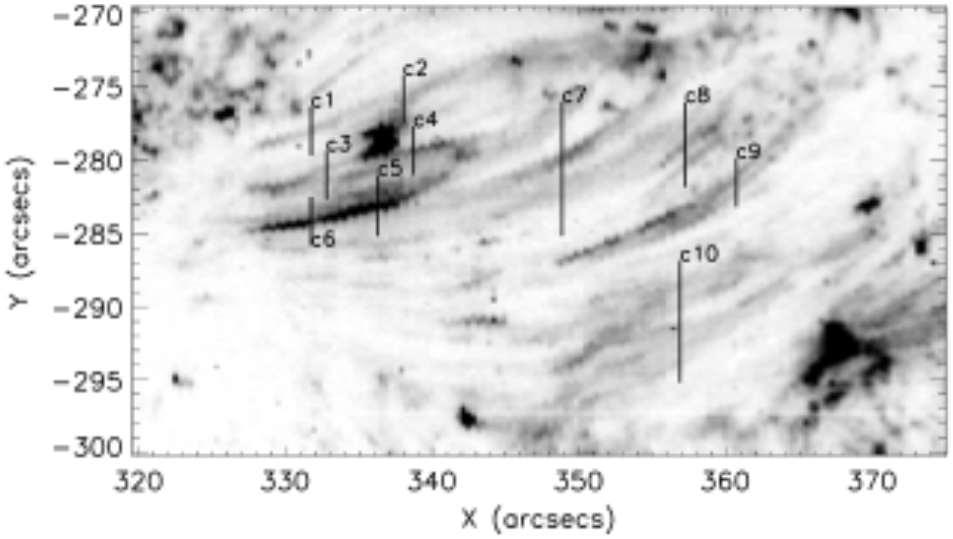
# Fine structures in spiral loop system

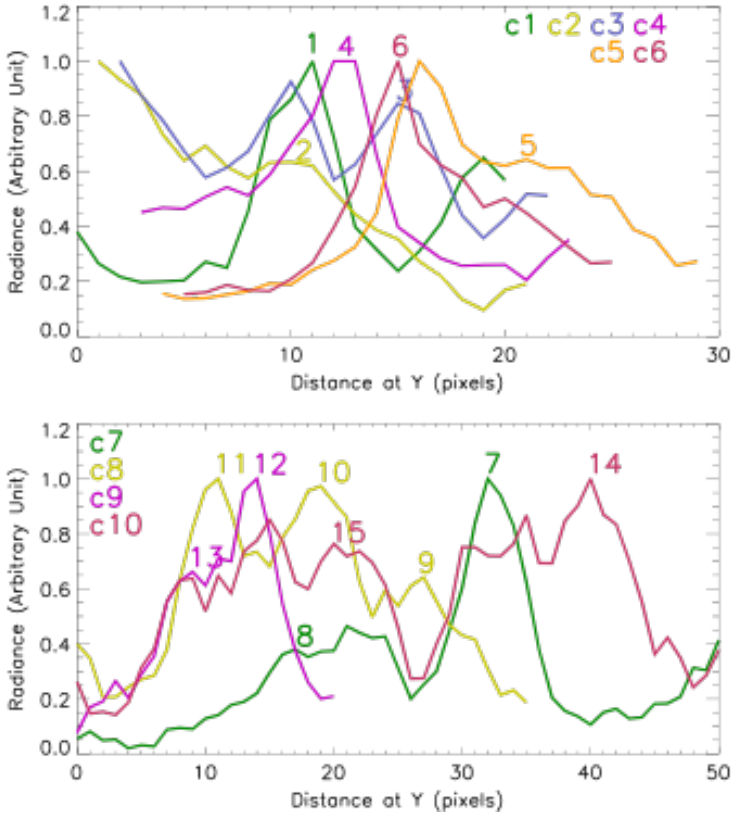



Magnetic topology before and after eruption of the spiral loop system: indication of the release of current in the eruptive loops.

Huang et al. 2018, ApJ, 854, 80

# The size of relative stable transition region loops

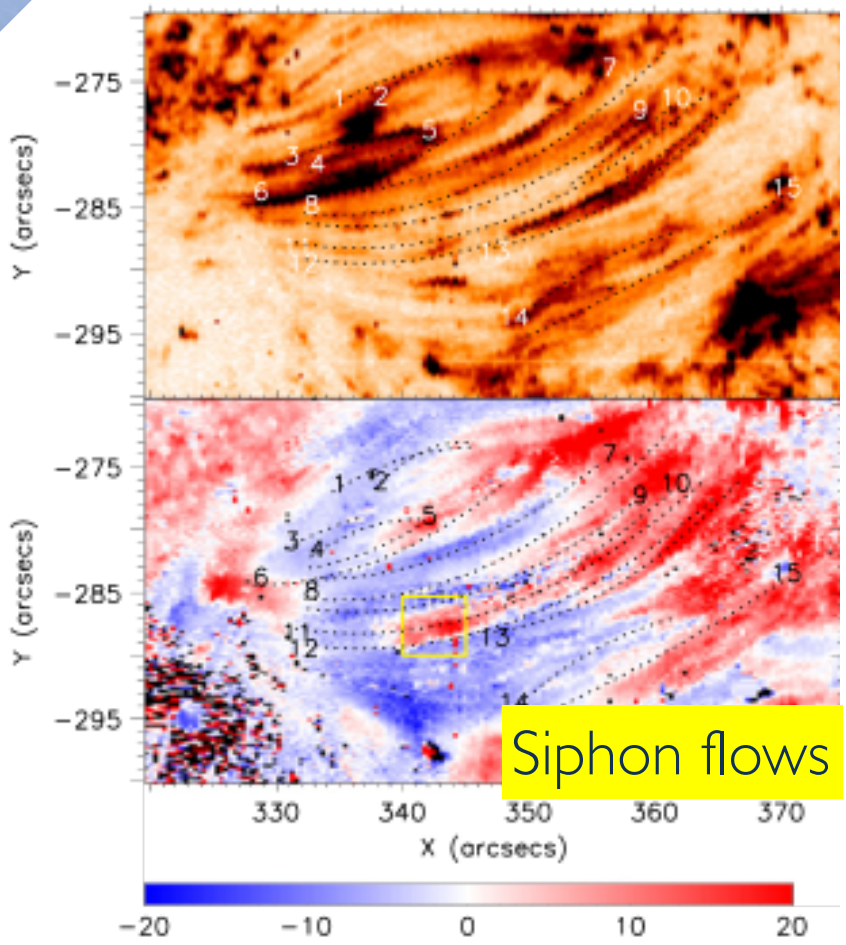


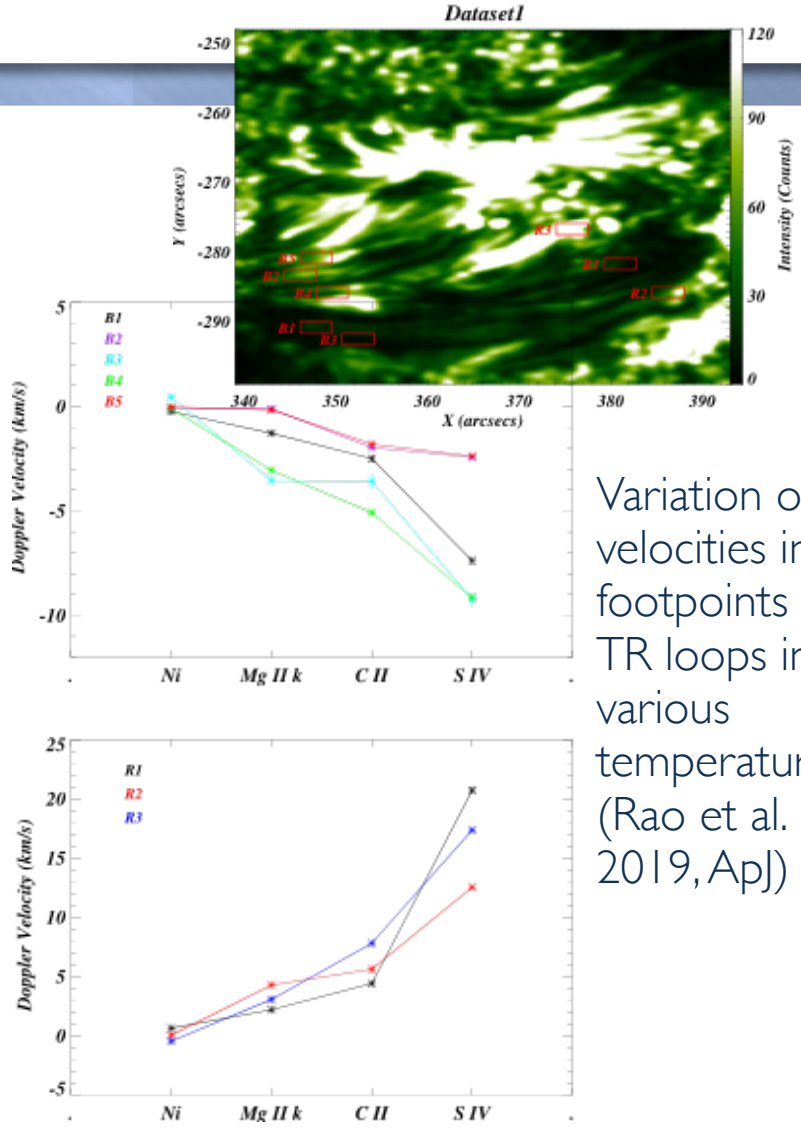

Length: 7 000 km ~ 30 000 km;
Cross-section: 382 km ~ 626 km.

Huang et al. 2015, ApJ, 810, 46

# Flows in transition region loops




Huang et al. 2015, ApJ




Variation of velocities in footpoints of TR loops in various temperatures. (Rao et al. 2019, ApJ)

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- **Transition region loops are fine structures with sub-arcsecond cross-sections.**
- **Transition region loops are normally very dynamic due to experiencing of flux emergence.**
- **UV bursts are abundant in the transition region loops in the early phase of emergence.**
- **Transition region loops in the late phase also show significant upflows in the loop tops and downflows in the footpoint.**

# Summary

- **UV bursts can also be seen in the transition region loops at the late phase of emergence. (Example of UV bursts in late phase emergence also reported in Guglielmino et al. 2018).**
- **Quasi-periodic phenomena also present in transition region loops.**
- **Activities of transition region loops can produce transition region explosive events, UV bursts and eruption of jets.**
- **Magnetic reconfiguration between cool loops and hot coronal loops can heat, refill and rebuild the coronal loops.**
- **Siphon flows could be seen in transition region loops, and the flows show variations from temperature to temperature.**