2014 LWS/HINODE/IRIS Workshop

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Prevalence of Small-scale Jets from the Network Structures of the Solar Transition Region and Chromosphere

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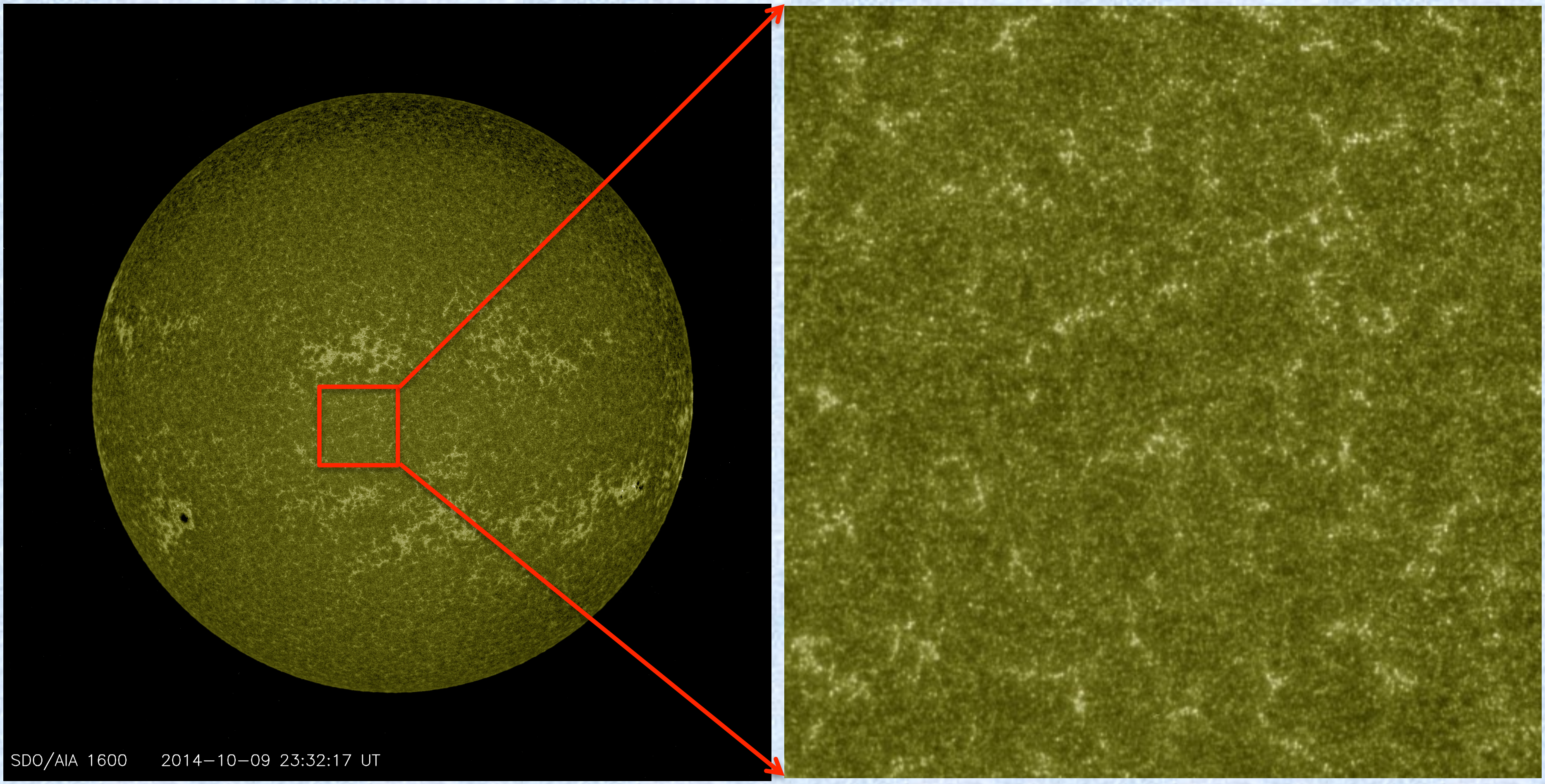
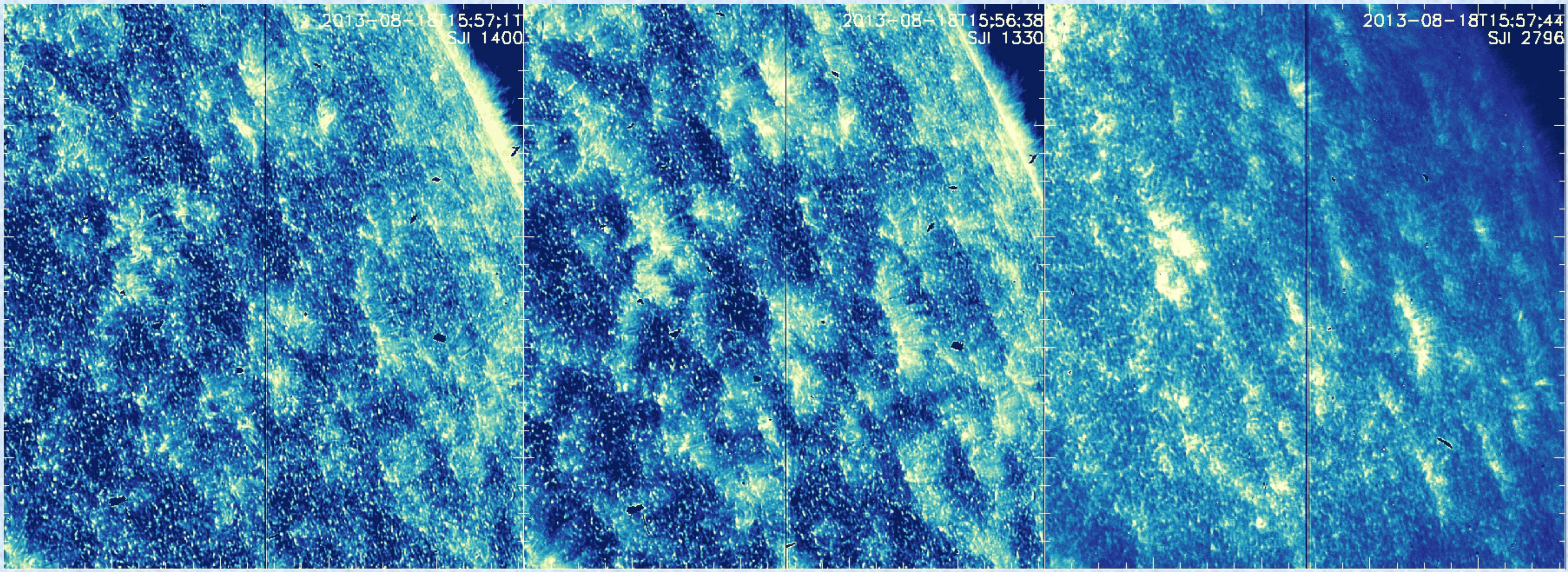
H. Tian, E. E. DeLuca, S. R. Cranmer, et al., Science 346, 1255711 (2014)

Network structures in the transition region and chromosphere



Prevalent network jets - morphology

99s cadence; 175”x175” FOV



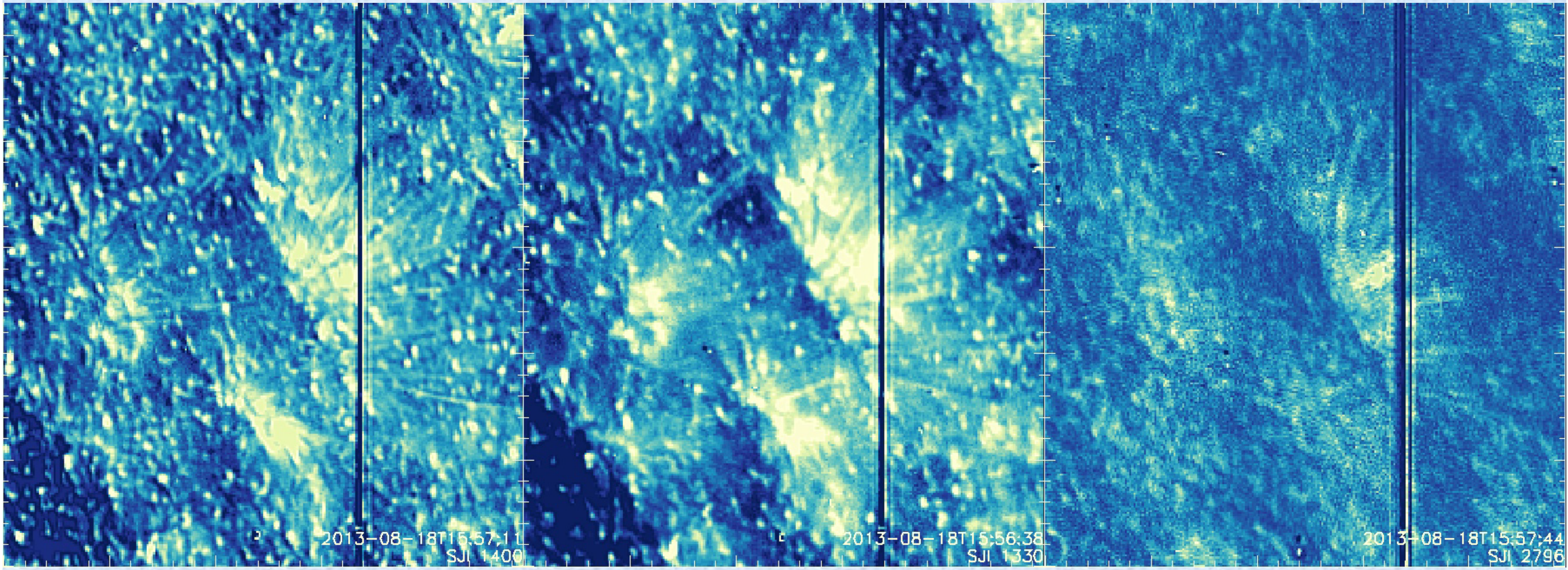
Si IV C II Mg II

- Most prominent dynamic features in the networks of the TR and chromosphere in on-disk observations
- Best seen in 1330Å (C II)

Movie at http://www.sciencemag.org/content/346/6207/1255711/suppl/DC1

A closer look at these network jets

99s cadence; 41”x44” FOV

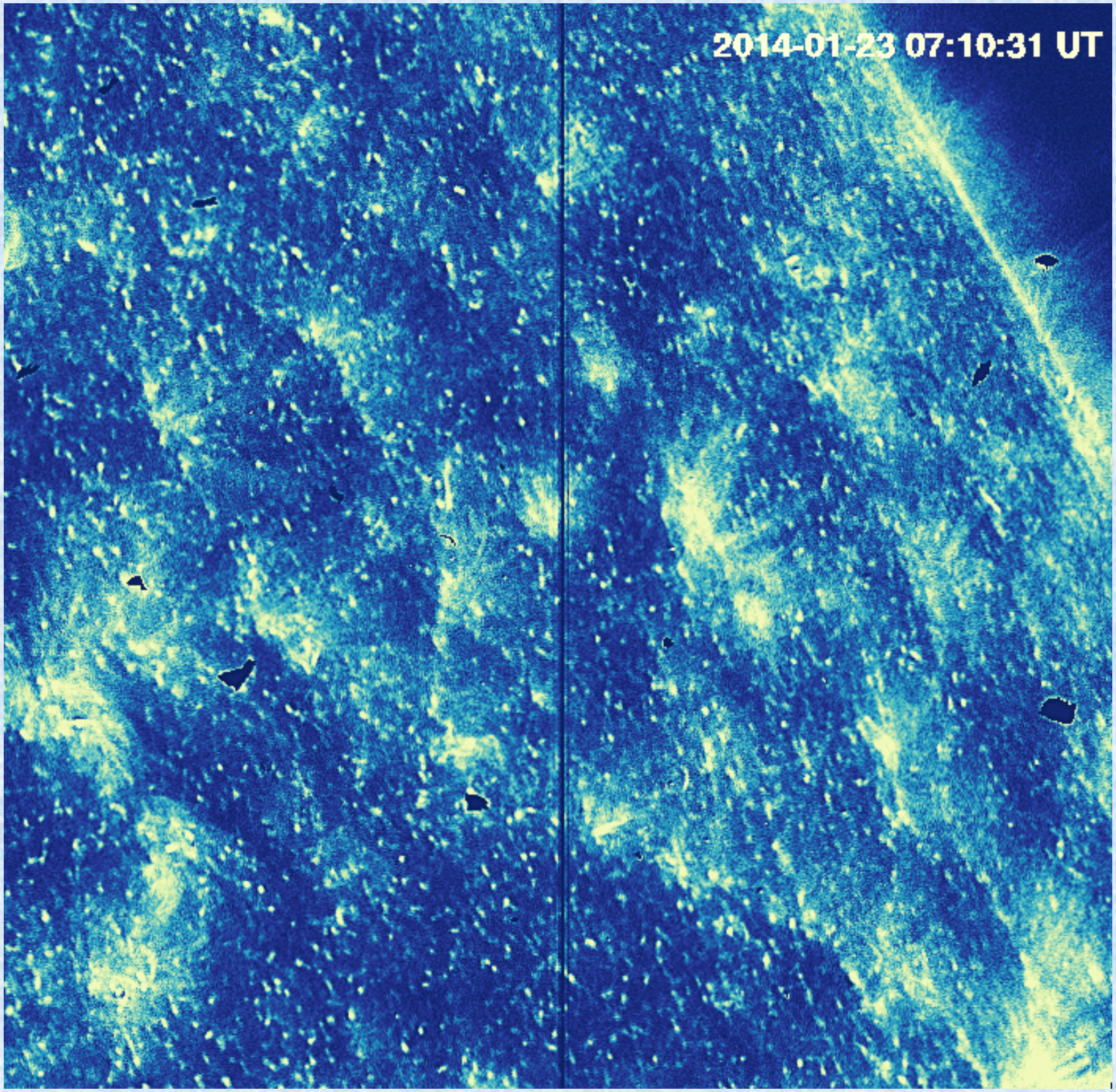


Si IV C II Mg II

- Temperature: 10^4 K – 10^5 K
- Shorter in Mg II

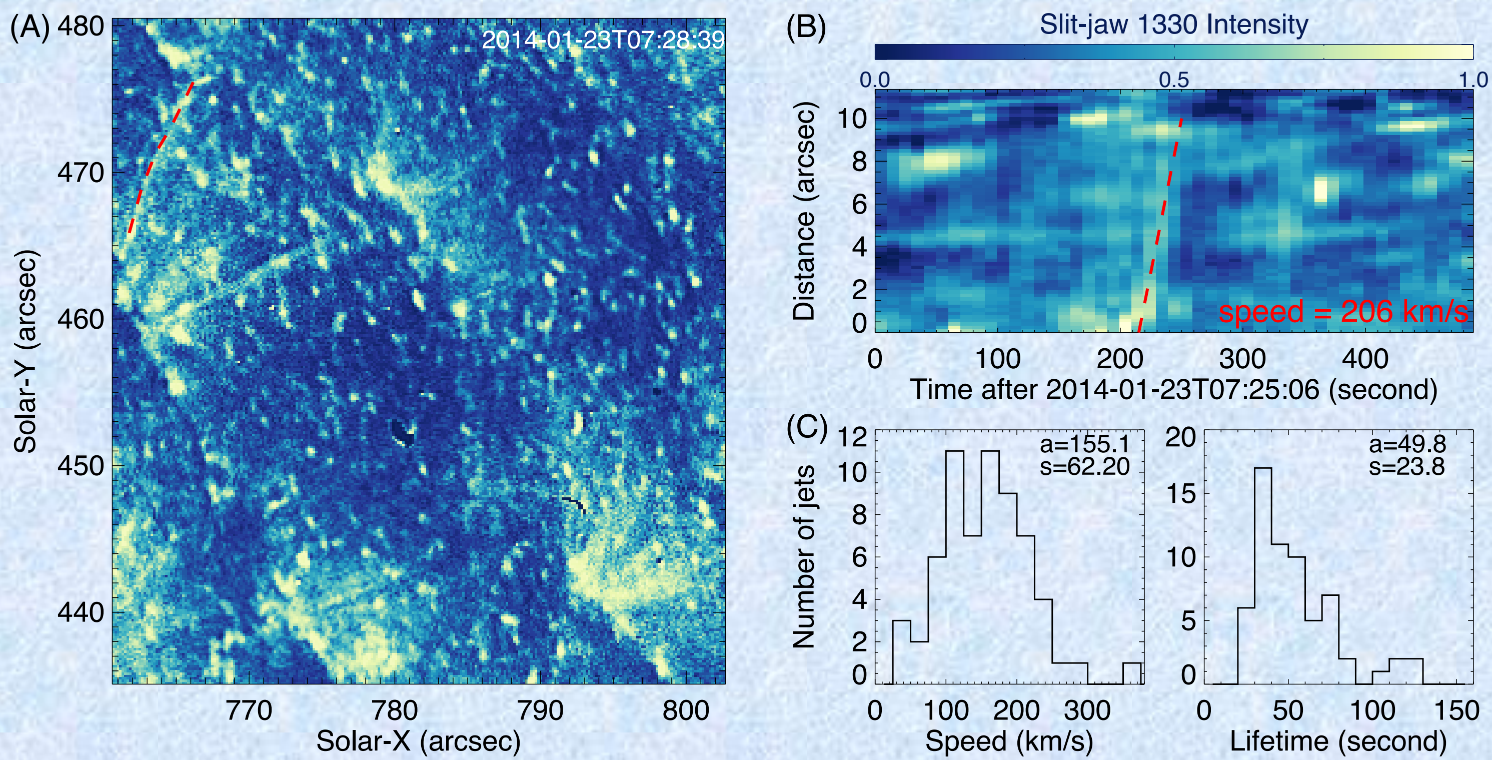
Movie at http://kurasuta.cfa.harvard.edu/~htian/sciencem2.mov

Prevalent network jets - dynamics



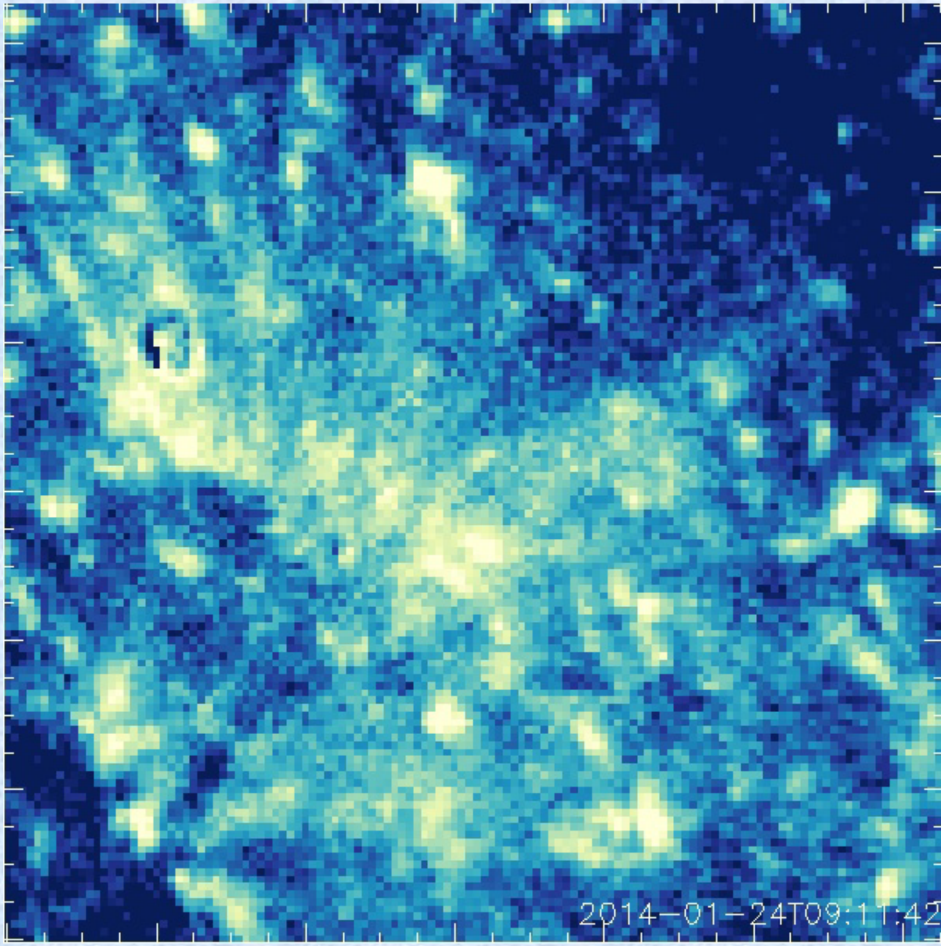
10s cadence;
120”x120” FOV

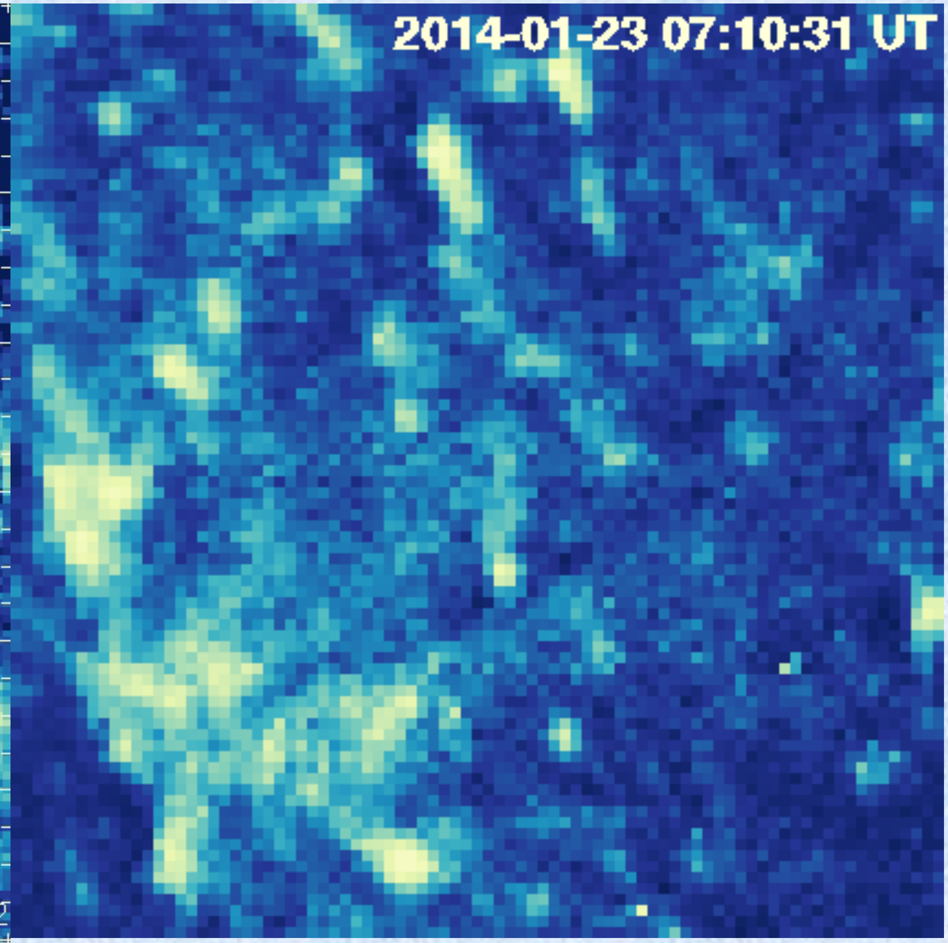
Characteristics of network jets



- Apparent speed: mostly 80-250 km/s
- Lifetime: 20-80 s (limited by the cadence)
- Width: less than 300 km
- Extension: 4-10 Mm, some reach ~15 Mm

Footpoint dynamics

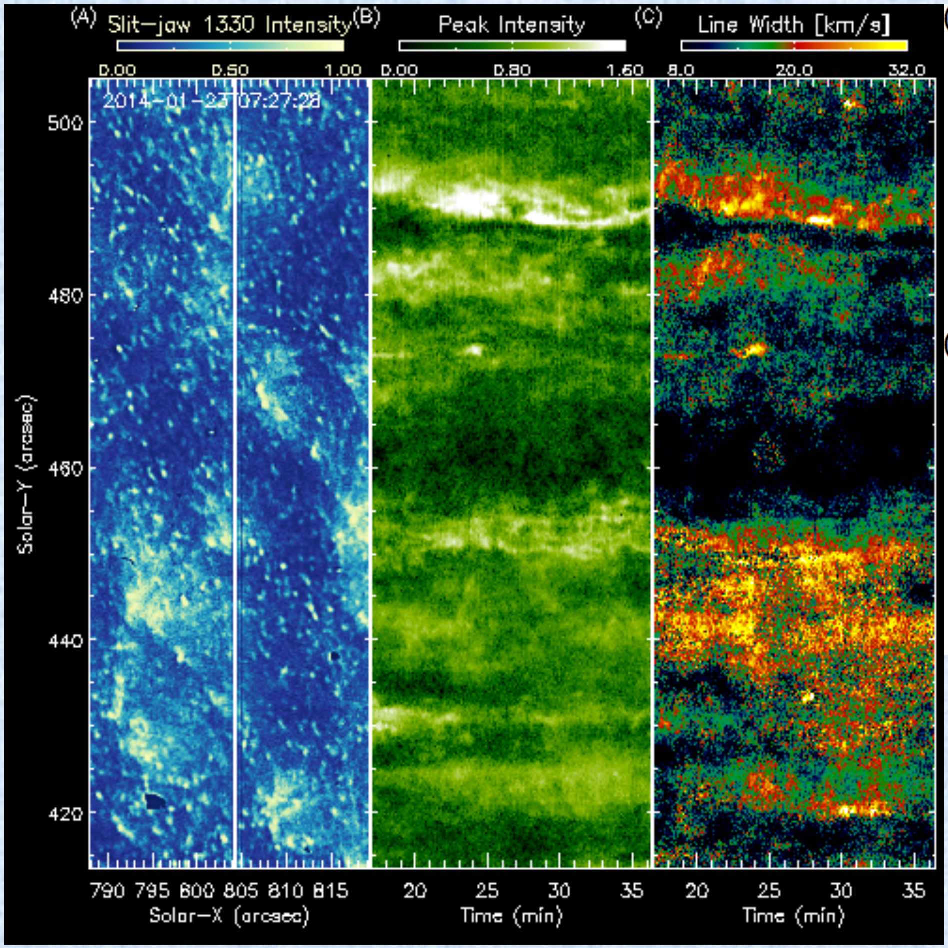


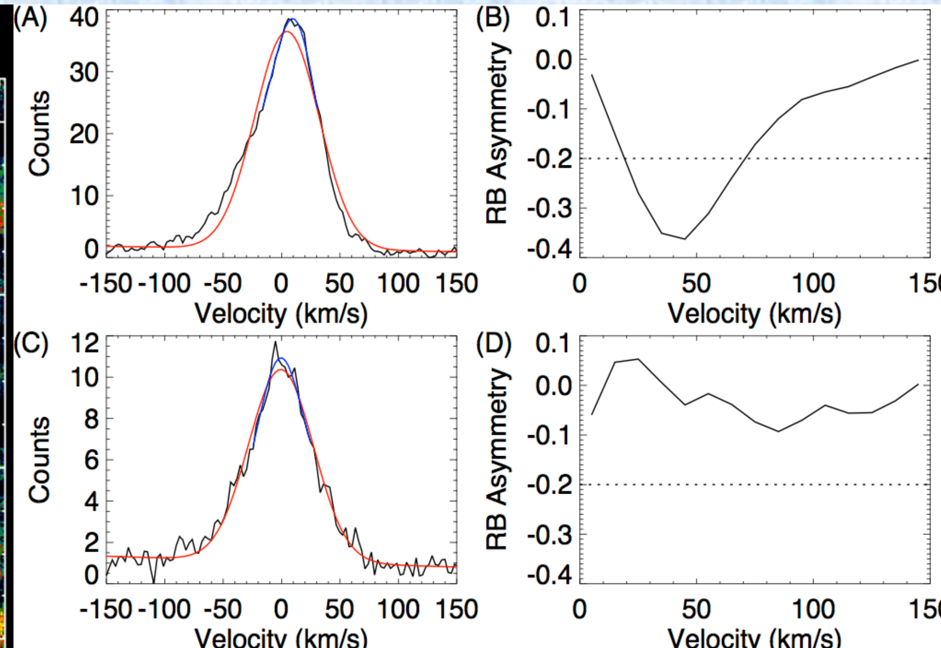


- Originate from small-scale bright regions in networks
- Often preceded by footpoint brightenings

Movie at http://kurasuta.cfa.harvard.edu/~htian/sciencem1.mov

Signature in Si IV spectral line profiles – enhanced line width



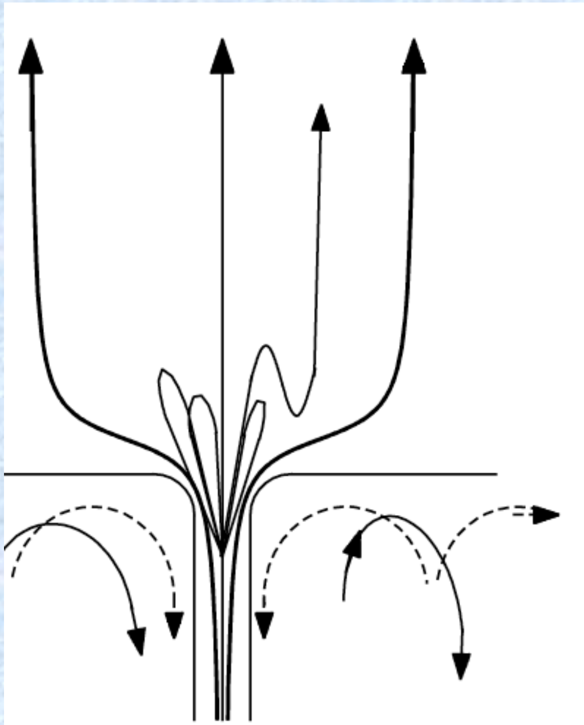


- Parallel flows (A)
- Unresolved transverse waves (C): amplitude ~ 20 km/s
- Small-scale twists (De Pontieu et al. 2014) often also associated with Alfvén waves

Movie at http://www.sciencemag.org/content/346/6207/1255711/suppl/DC1

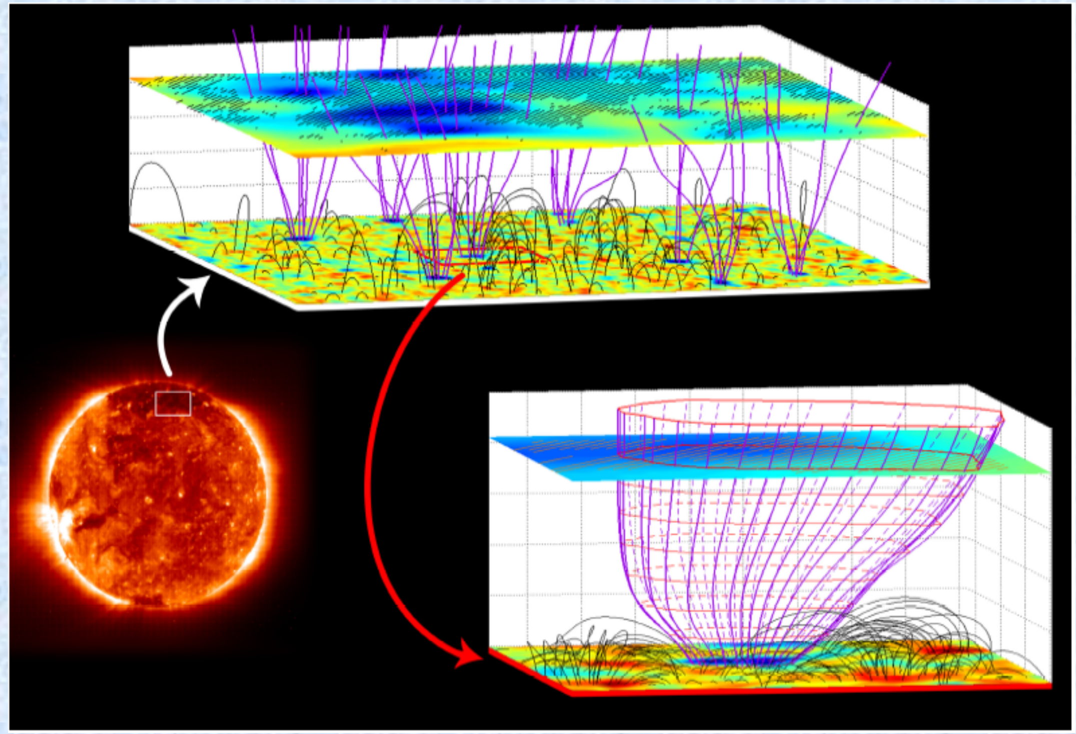
Implication for solar wind origin (I)

Magnetic furnace model



Axford & McKenzie 1993

Funnels from networks

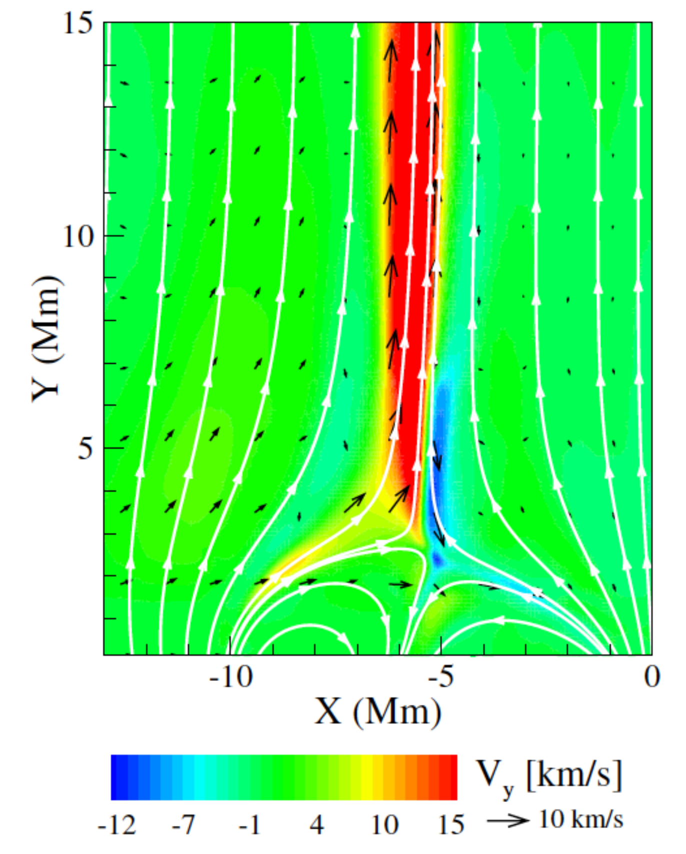


Tu et al. 2005

- Networks are suggested origin sites of the solar wind
- Solar wind models usually predict a steady outflow with a speed of a few km/s in the interface region. Such steady network outflows have never been imaged.

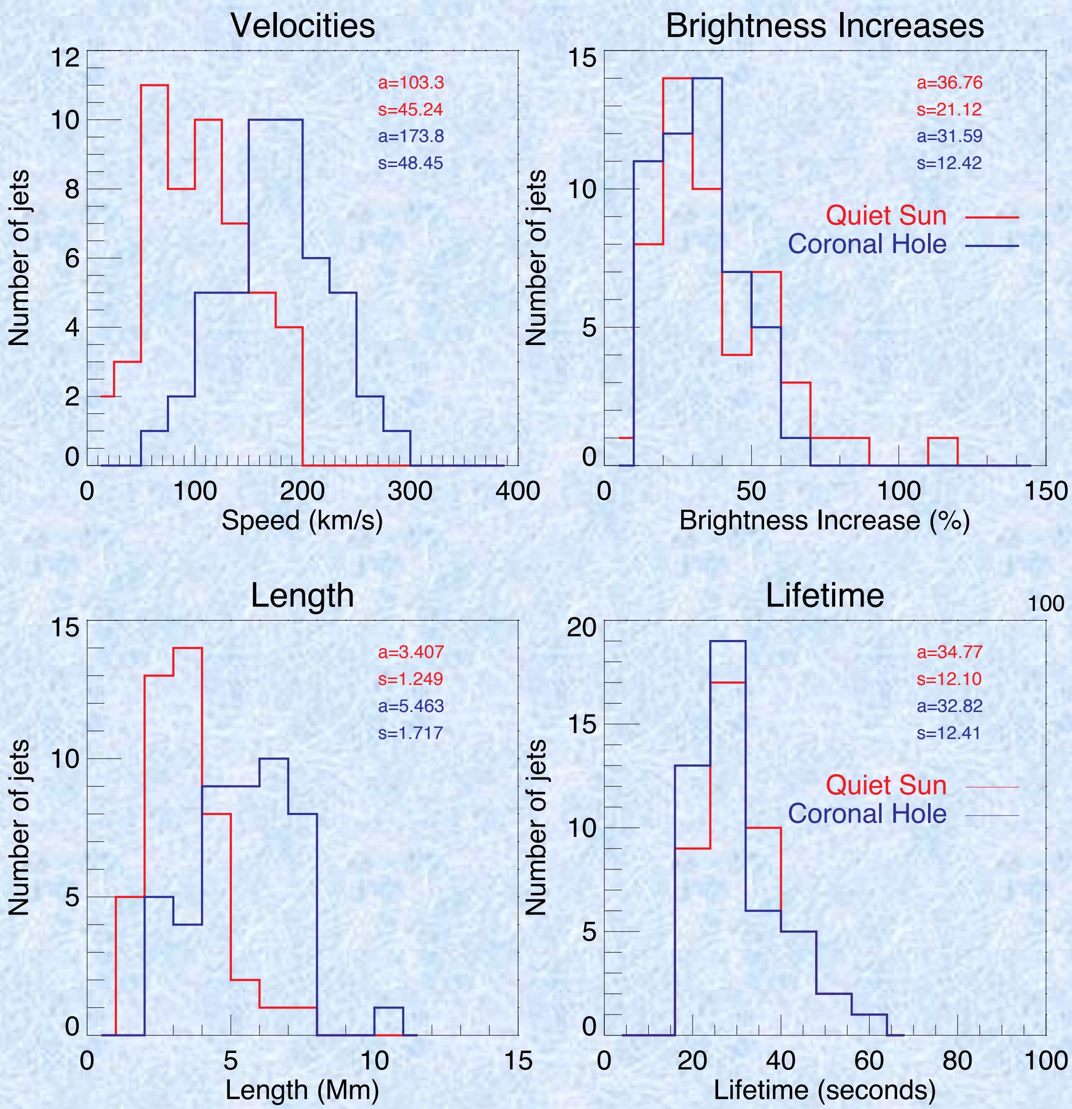
Implication for solar wind origin (II)

- Mass loss rate: (2.8-36.4) x 10^{12} g s^{-1}
- Energy flux: 4-24 kW m^{-2}
- Are these intermittent high-speed jets the nascent solar wind?
- If yes, solar wind models should be updated to account for this highly intermittent component.
- If no, at least their interaction with/ impact on the wind should be carefully evaluated, because they are the most prominent dynamic features in the solar wind source region.



Yang et al. 2013

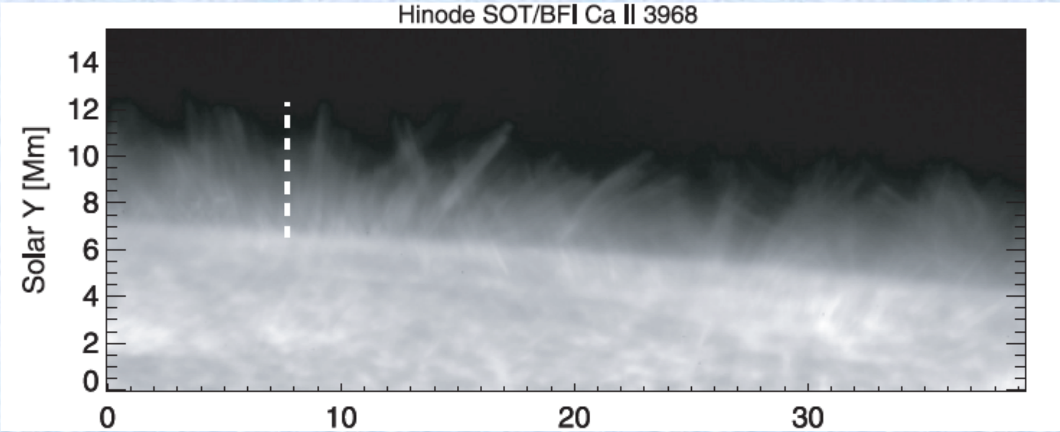
Comparison between QS and CH - preliminary results



Two data sets: same pointing

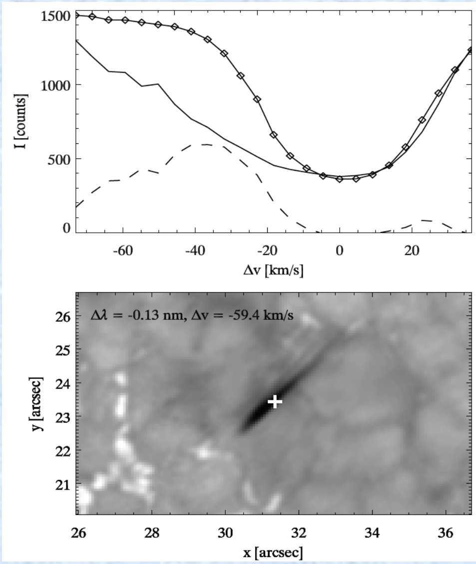
Many network jets are likely the on-disk counterparts and TR manifestation of type-II spicules

Type-II spicules in the chromosphere above limb



De Pontieu et al. 2007

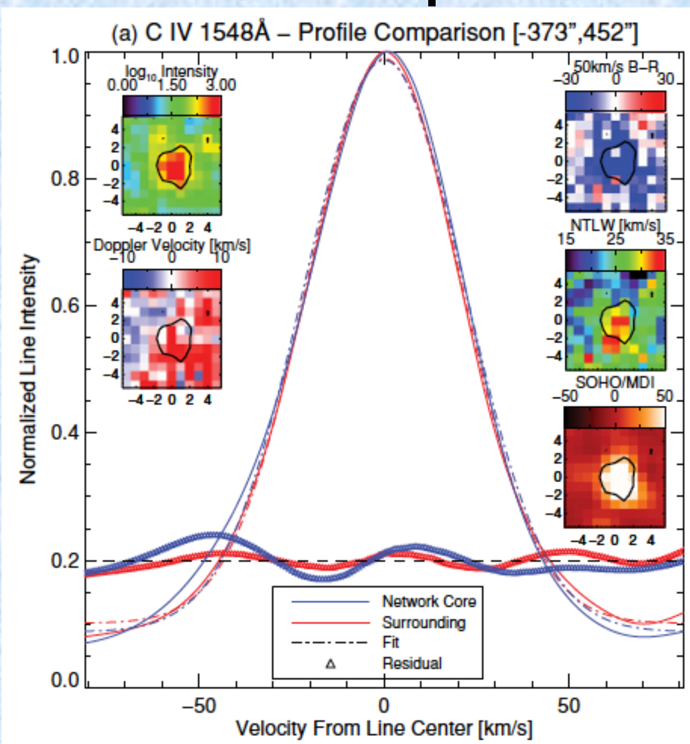
RBEs in Hα and Ca II

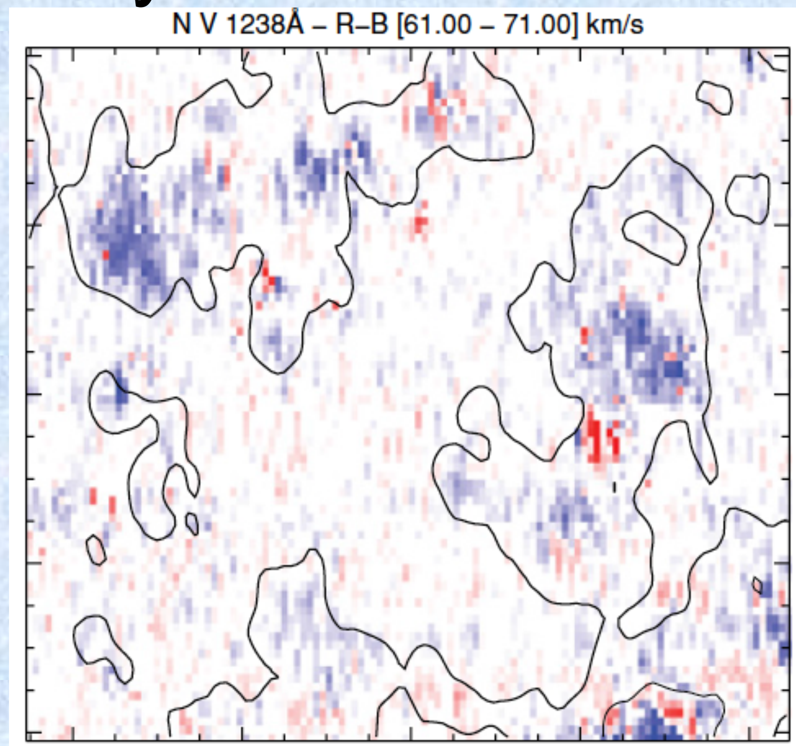


Rouppe van der Voort et al. 2009

- Linear jet morphology and transverse motions resemble those of chromospheric spicules
- Speeds (~150 km/s) larger than those of type-II spicules (~70 km/s) and RBEs (~35 km/s)
- Type-II spicules/RBEs are likely the lower-temperature and less-accelerated parts or phase of network jets in IRIS FUV passbands (see also Pereira et al.2014)
- IRIS observations provide support to earlier results of spicule heating (De Pontieu et al. 2011).

IRIS is likely performing direct imaging of the high-speed upflows inferred from spectral line asymmetries

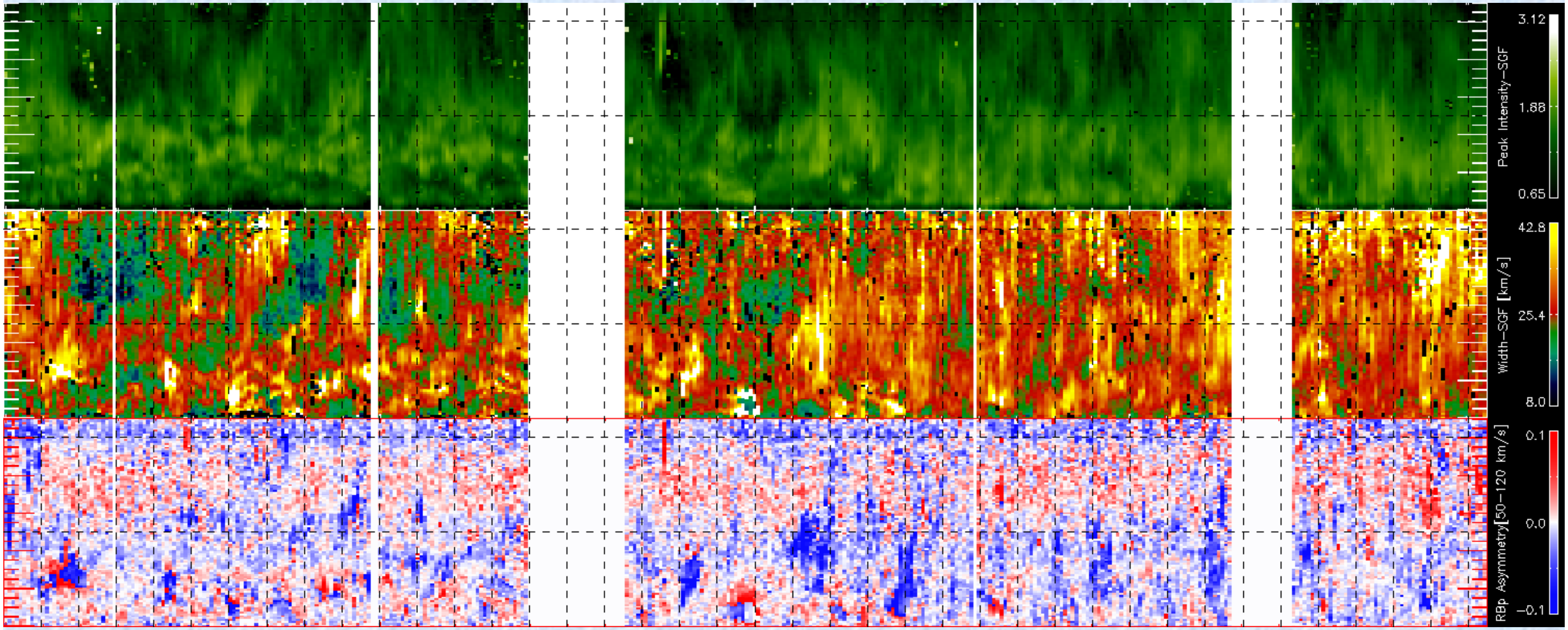


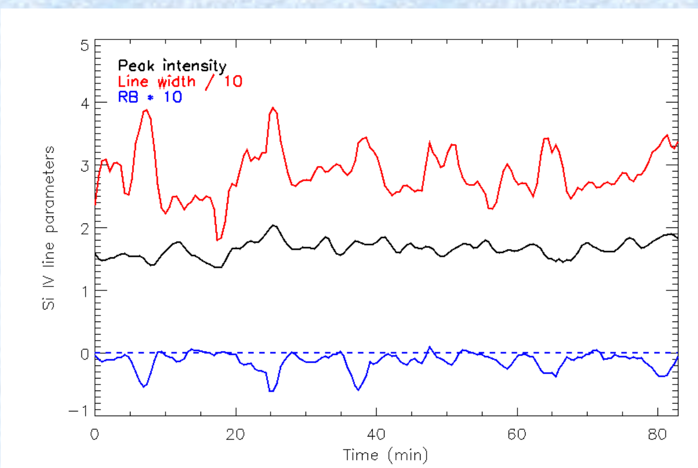


McIntosh & De Pontieu 2009

- The weak blue wing enhancement of SUMER TR lines suggests the possible presence of a weak plasma component with speeds of 50-100 km/s.
- Higher speeds in IRIS SJI 1330: temporal/spatial averaging effect, LOS integration of different jets, or the apparent speeds are not all caused by mass flows (e.g., thermal evolution, rapid ionization by heating, shocks?)

Correlated change of Si IV line parameters

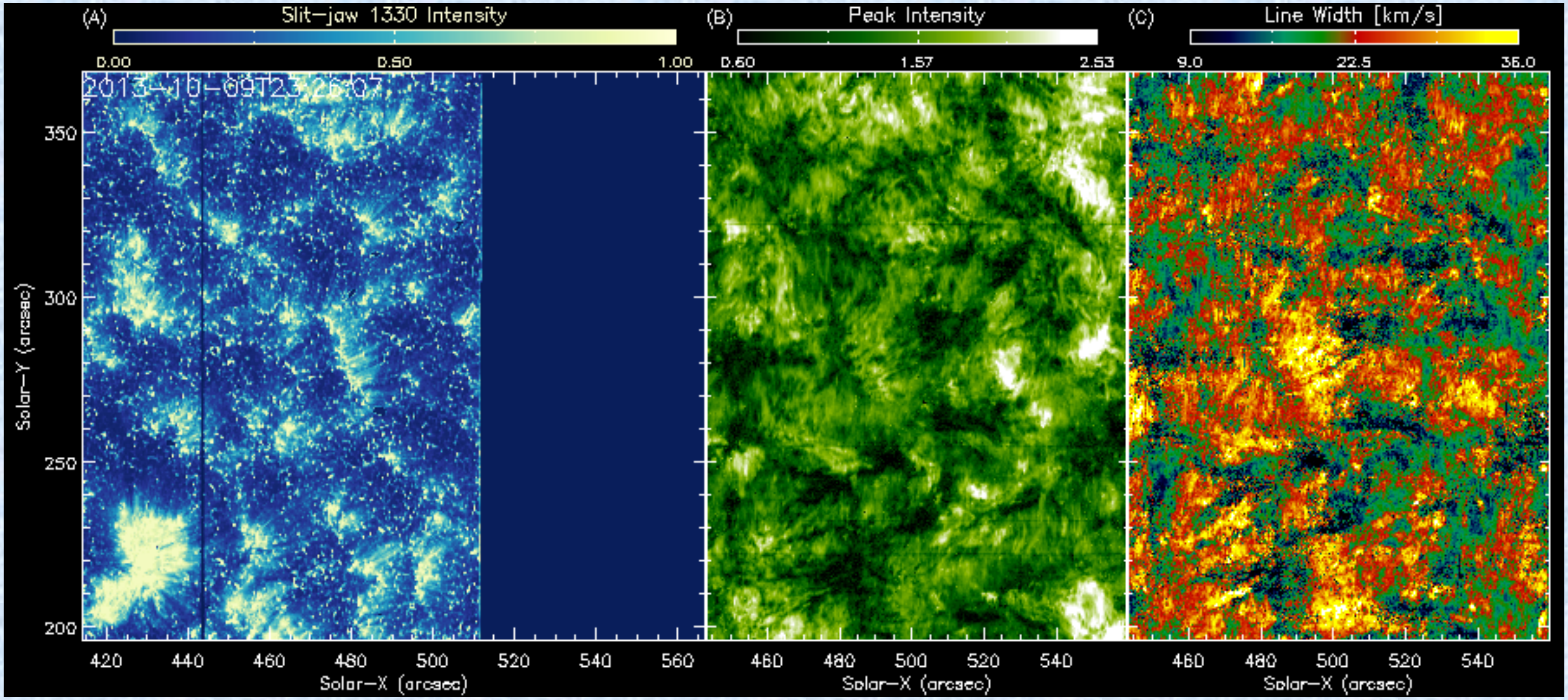




Enhanced line width and blue wing enhancement show correlated change, suggesting that at least a significant fraction of the apparent motions are mass flows.

Time steps 170-327

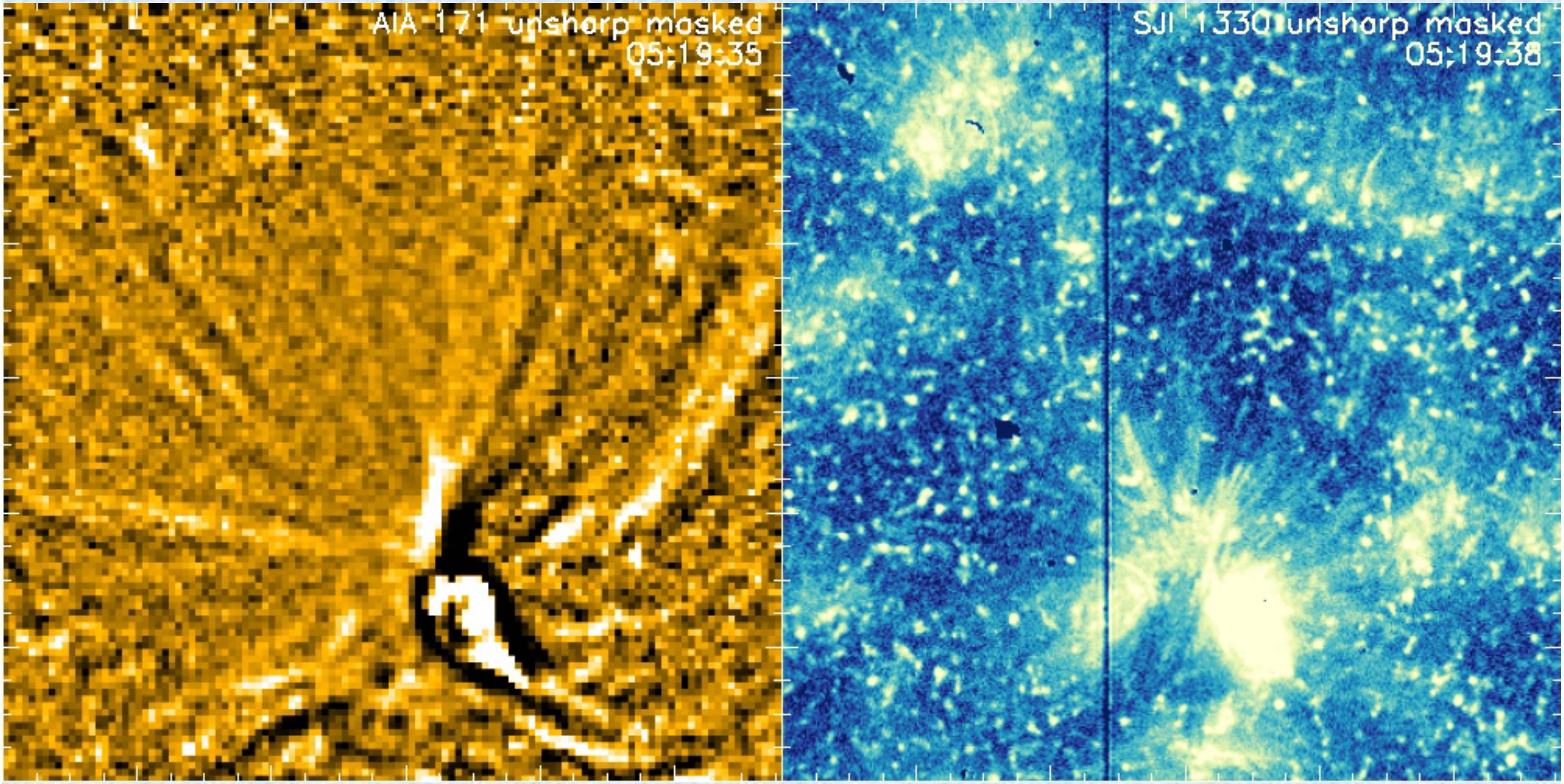
Network jets constitute an important element of the TR structures



- Many filamentary structures associated with network jets
- Network jets/TR counterparts of spicules (Tian et al. 2014, Science; Pereira et al. 2014, ApJL) and small low-lying loops (Hansteen et al. 2014, Science) appear to be the dominant structures in the TR.

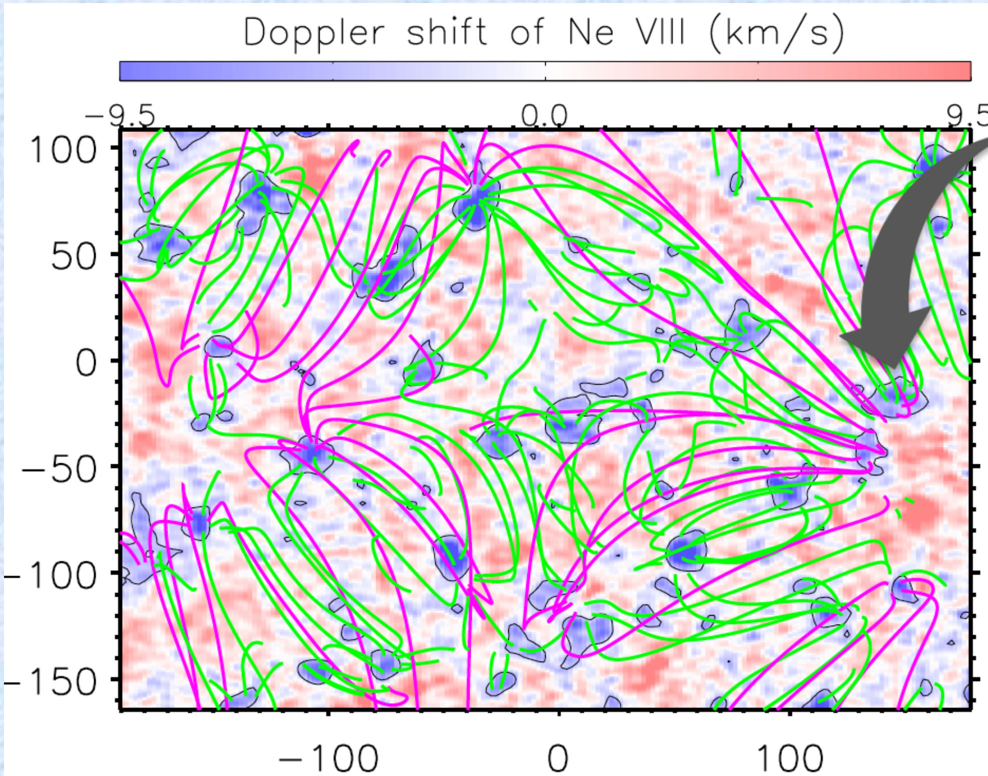
Movie at http://www.sciencemag.org/content/346/6207/1255711/suppl/DC1

Heating of the network jets (I)

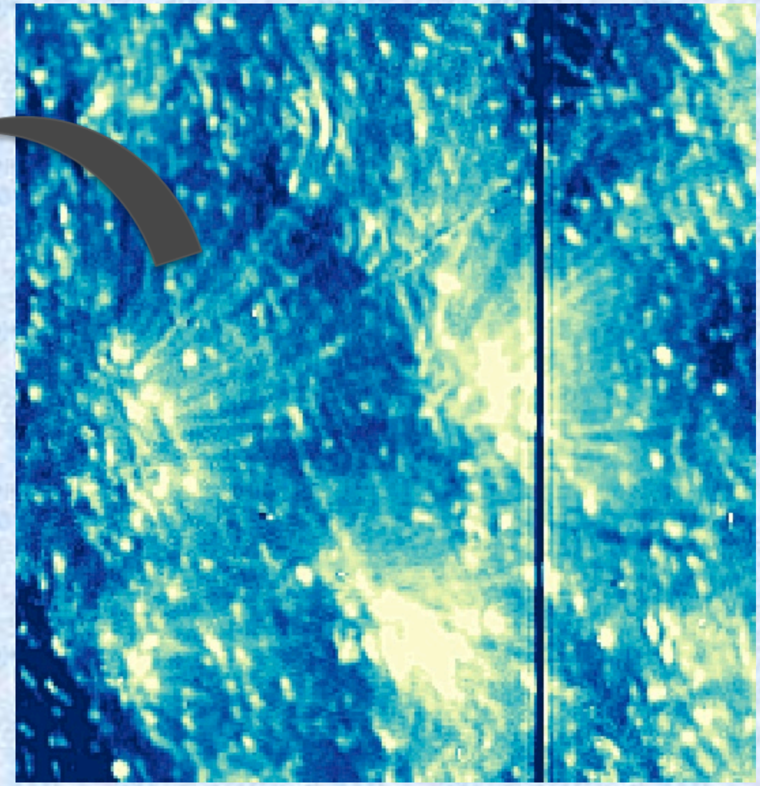


- Coronal propagating disturbances and TR network jets are propagating in the same directions.
- Also in offlimb observations, De Pontieu et al. (2011) traced some spicules from chromospheric passband to AIA EUV passbands, indicating spicule heating to coronal temperatures.
- However, the AIA coronal passbands also have a response at TR temperatures.

Heating of the network jets (II)



Tian et al. 2009, ApJ

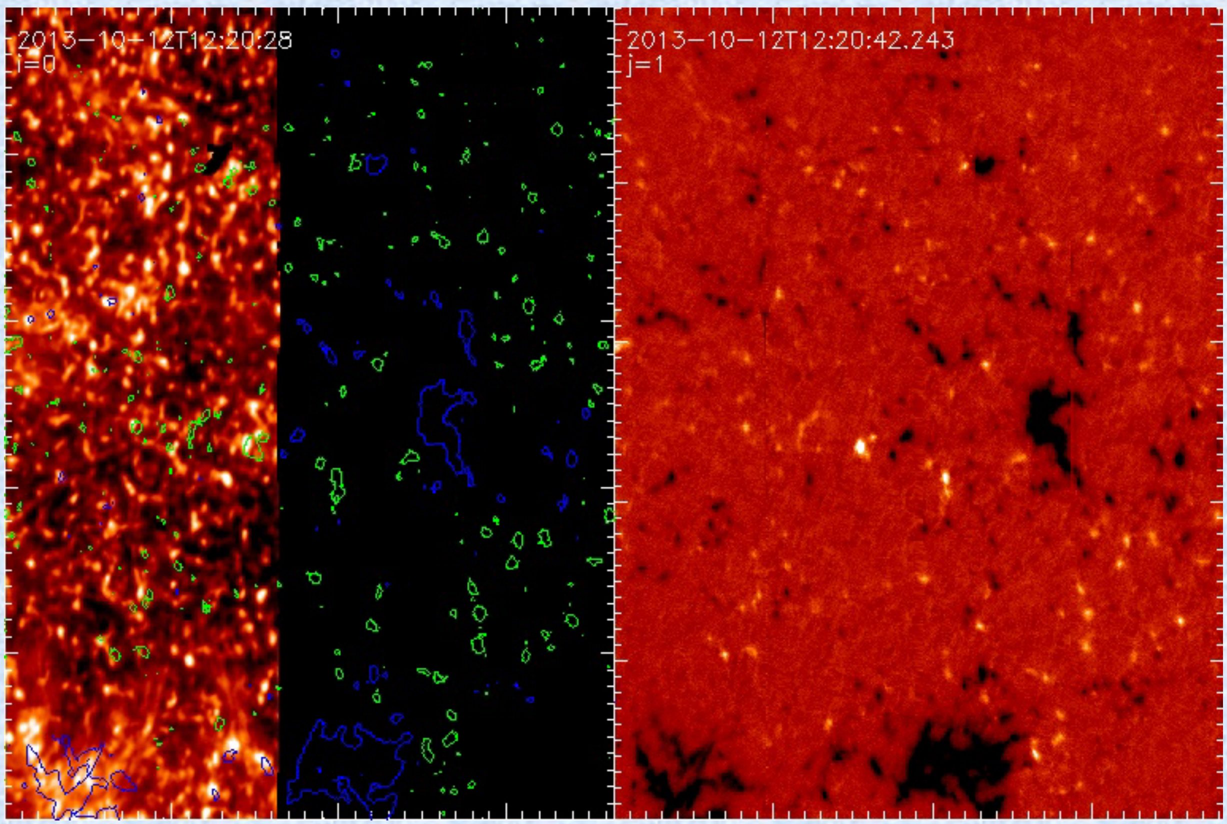


Tian et al. 2014, Science

- Blue shifts of lower-corona line Ne VIII at loop footpoints in network junctions: mass supply to coronal loops (Tian et al. 2009) or even the solar wind (Hassler et al. 1999).
- Need to examine the spatial correspondence between these blue shifts and network jets – deep-exposure large raster scans of Si VII/Fe VIII by HINODE/EIS (IHOP 270).

Generation mechanism – magnetic force may play a role

IRIS/SJI 1400 HINODE/SOT/NFI Stokes-V



- Reconnection
  - large speed
  - but only a few inverted Y-shape structures: reconnection region not resolved, or other mechanisms
- Pressure driven jets hardly reach speeds higher than 60 km/s
- Lorentz-force driven jets can produce such high speeds (Goodman 2014)

Summary

- IRIS observations reveal the prevalence of intermittent small-scale jets with apparent speeds of 80-250 km/s from the networks.
- These network jets originate from small-scale bright regions, often preceded by footpoint brightenings and accompanied by transverse waves with ~20 km/s amplitudes.
- Many network jets reach ~10^5 K and constitute an important element of the TR structures.
- Many network jets in the FUV passbands are likely the on-disk counterparts and TR manifestation of type-II spicules.
- These network jets are the most prominent dynamic TR features in the solar wind source region, likely an intermittent but persistent source of mass and energy for the solar wind.
- Their generation mechanisms and heating to coronal temperatures can be investigated with coordinated HINODE observations.