Prevalence of Micro-jets from the Network Structures of the Solar Transition Region

Hui Tian[1], Edward E. DeLuca[1], Steve R. Cranmer[1], Bart De Pontieu[2], Hardi Peter[3], Sean McKillop[1], Katharine K. Reeves[1], Mari Paz Miralles[1], Patrick McCauley[1], Juan Martínez-Sykora[2], Rebecca T. Arbacher[4], and the IRIS team

[1]Harvard-Smithsonian Center for Astrophysics [2]Lockheed Martin Solar and Astrophysics Laboratory [3]Max Planck Institute for Solar System Research [4]Columbia University

Abstract

IRIS observations in the 1330Å, 1400Å and 2796Å passbands have revealed prevalent small-scale jet-like features with apparent speeds of ~80-250 km/s from the network structures in coronal holes and quiet Sun regions. Their widths are often ~300 km or less. Many of these jets show up as elongated features with enhanced line width in maps obtained with transition region (TR) lines, suggesting that these jets reach at least ~10^5 K and they constitute an important element of TR structures. These ubiquitous high-reaching jets are likely an intermittent but persistent source of mass and energy for the corona and solar wind. The generation of these jets in the network and the accompanying Alfvén waves is also consistent with the "magnetic furnace model" of solar wind. The large speeds suggest that magnetic forces may play an important role in the generation and acceleration of the network jets. Many network jets are likely the on-disk counterparts and TR manifestation of type-II spicules observed in the chromosphere above limb. (Tian et al. 2014)

Prevalent network jets in the solar wind source region

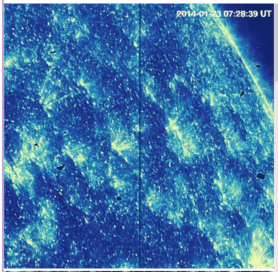


Fig. 1. A snapshot of IRIS 1330Å movie showing the prevalence of TR network jets (Tian et al. 2014). (http://www.sciencemag.org/content/346/6207/1255711/suppl/DC1)

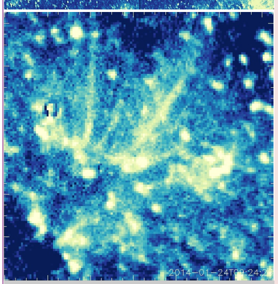


Fig. 3. A snapshot of IRIS 1330Å movie showing the footpoint dynamics. (http://kurasuta.cfa.harvard.edu/~htian/sciencem1.mov)

- Most prominent dynamic features in the networks of the TR and chromosphere in on-disk observations.
- Temperature: 10^4 K – 10^5 K
- Best seen in 1330Å (C II); shorter in 2796Å (Mg II)
- Apparent speed: mostly 80-250 km/s.
- Lifetime: 20-80 s.
- Width<300 km.
- Extension: 4-10 Mm, some reach ~15 Mm.
- Originate from small-scale bright regions in the network; Often preceded by footpoint brightenings.
- Primary signature of network jets in TR line profiles: enhanced line width caused by parallel flows or unresolved transverse motions (see also De Pontieu et al. 2014).
- Accompanied Alfvén waves: amplitude ~ 20 km/s.

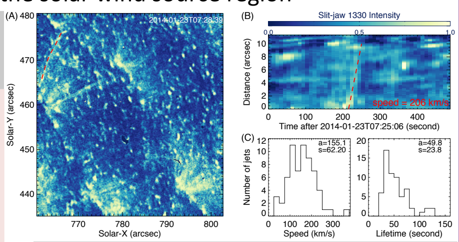


Fig. 2. Apparent speeds and lifetimes of network jets.

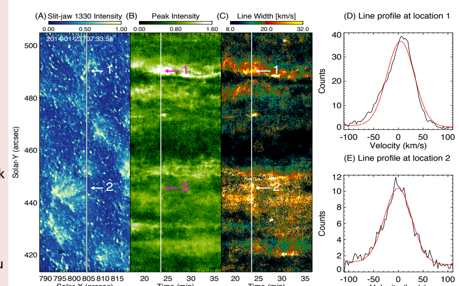


Fig. 4. Signature of network jets in Si IV line profiles – enhanced line width caused by either parallel flows or unresolved Alfvén waves.

- 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 directly imaged.
- 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?

(1) If yes, solar wind models should be updated to account for this highly intermittent component.

(2) 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.

- Support earlier observations of heating of spicules in off-limb coronal holes that feed into the solar wind (De Pontieu et al, 2011).

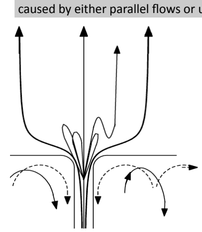


Fig. 5. The magnetic furnace model proposed by Axford & McKenzie (1993).

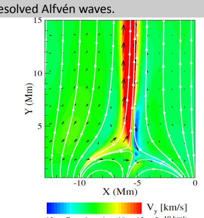


Fig. 6. The reconnection driven solar wind scenario (Tu et al. 2005) simulated by Yang et al. (2013).

Filamentary TR structures associated with network jets

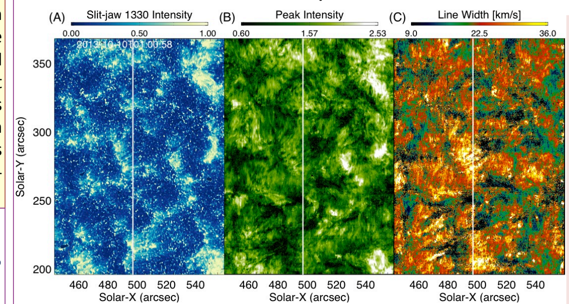


Fig. 7. Filamentary structures in Si IV intensity & line width maps associated with network jets.

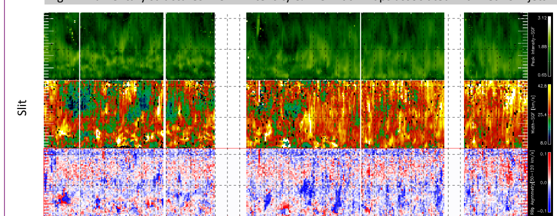


Fig. 8. Temporal evolution of the Si IV peak intensity, line width and profile asymmetry in the range of 50-120 km/s. The vertical direction represents a 18"-segment on the slit.

- Network jets/TR counterparts of spicules (Tian et al. 2014, Pereira et al. 2014) and small low-lying loops (Hansteen et al. 2014) appear to be the dominant structures of the TR.
- Many network jets are likely on-disk counterparts and TR manifestation of type-II spicules (De Pontieu et al. 2007, Rouppe van der Voort et al. 2009), thus providing support to heating of spicules (De Pontieu et al. 2011, Rouppe van der Voort et al. 2014).
- IRIS is likely performing direct imaging of the weak high-speed upflows inferred from SUMER line asymmetries (McIntosh & De Pontieu 2009).
- Higher speeds of network jets in IRIS SJI

(1) Weaker temporal/spatial averaging, less LOS integration

(2) The apparent motions are not all caused by mass flows, e.g., ionization front, shocks

(3) Correlated changes between line width and blue wing enhancement suggest that at least a significant fraction of the apparent motions are mass flows.

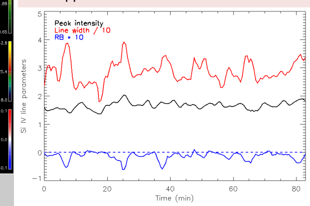


Fig. 9. Temporal evolution of Si IV line parameters averaged over a 3"-segment on the slit.

Heating and generation of network jets

- Coronal propagating disturbances and TR network jets are propagating in the same directions.
- Blue shifts of Ne VIII 770Å at loop footpoints in network junctions: mass supply to coronal loops (Tian et al. 2009) & solar wind (Hassler et al. 1999, Tu et al. 2005).
- Investigation of spatial correspondence between these blue shifts and network jets is underway.
- Pressure driven jets hardly reach speeds higher than 60 km/s. Lorentz-force driven jets can produce such high speeds (Goodman 2014).

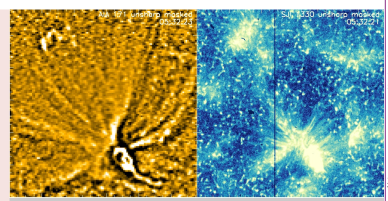


Fig. 10. A snapshot of a movie of unsharp masked AIA 171 and IRIS 1330 images.

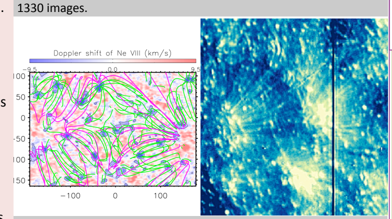
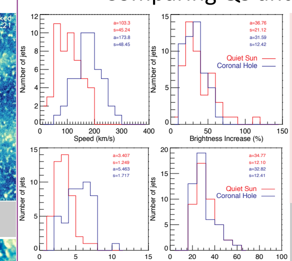


Fig. 11. Left: Dopplergram of Ne VIII 770Å in a quiet Sun region (Tian et al. 2009); Right: An IRIS 1330Å image showing some network jets (Tian et al. 2014). (http://kurasuta.cfa.harvard.edu/~htian/sciencem2.mov)

Comparing QS and CH



- QS jets appear to be slower & shorter.
- Bright low-lying loops with ~5 Mm size often in QS but seldom in CH.

Fig.12. Histograms of network jet parameters.

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