

# Observations of Large Penumbra Jets from IRIS and Hinode

**Sanjiv K. Tiwari**<sup>1,2</sup>

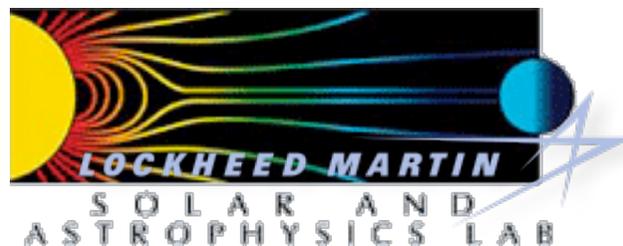
(Ron Moore<sup>3,4</sup>, Bart De Pontieu<sup>1</sup>, Ted Tarbell<sup>1</sup>, Navdeep Panesar<sup>3</sup>,  
Amy Winebarger<sup>3</sup>, Alphonse Sterling<sup>3</sup>)

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<sup>2</sup>Bay Area Environmental Research Institute, Petaluma, CA 94952, USA

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IRIS-9, Gottingen

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Contributed Talk

2. Chromospheric heating and dynamics

## Observations of Large Penumbra Jets from IRIS and Hinode

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Recent studies using *Hinode* (SOT/FG) data revealed the presence of large penumbral jets (widths  $\geq 500$  km; larger than normal penumbral microjets, which have widths  $< 400$  km) repeatedly occurring at the same locations in a sunspot penumbra, at the tail of a penumbral filament or where the tails of several penumbral filaments apparently converge (Tiwari et al. 2016, ApJ). These locations were observed to have obvious mixed-polarity flux in Stokes-V images from SOT/FG, whereas no obvious mixed-polarity field could be detected at the ostensible base of microjets. Large penumbral jets displayed direct signatures in AIA 1600, 304, 171, and 193 channels; thus they were heated to at least transition region temperatures. Because large jets could not be detected in AIA 94 Å, whether they had any coronal-temperature plasma remains unclear. In the present work, for two other sunspots, we use IRIS Mg II k 2796 slit jaw images and spectra and magnetograms from Hinode SOT/FG and SOT/SP to examine: whether penumbral jets spin, similar to spicules and coronal jets in the quiet Sun and coronal holes; whether they stem from mixed-polarity flux; and whether they produce discernible coronal emission, especially in AIA 94 Å images.

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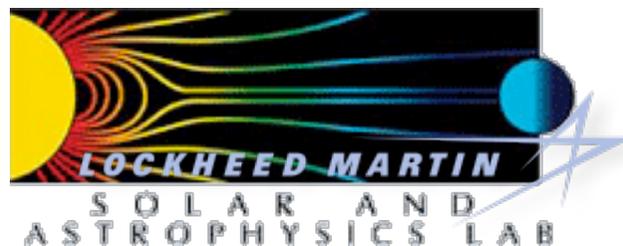
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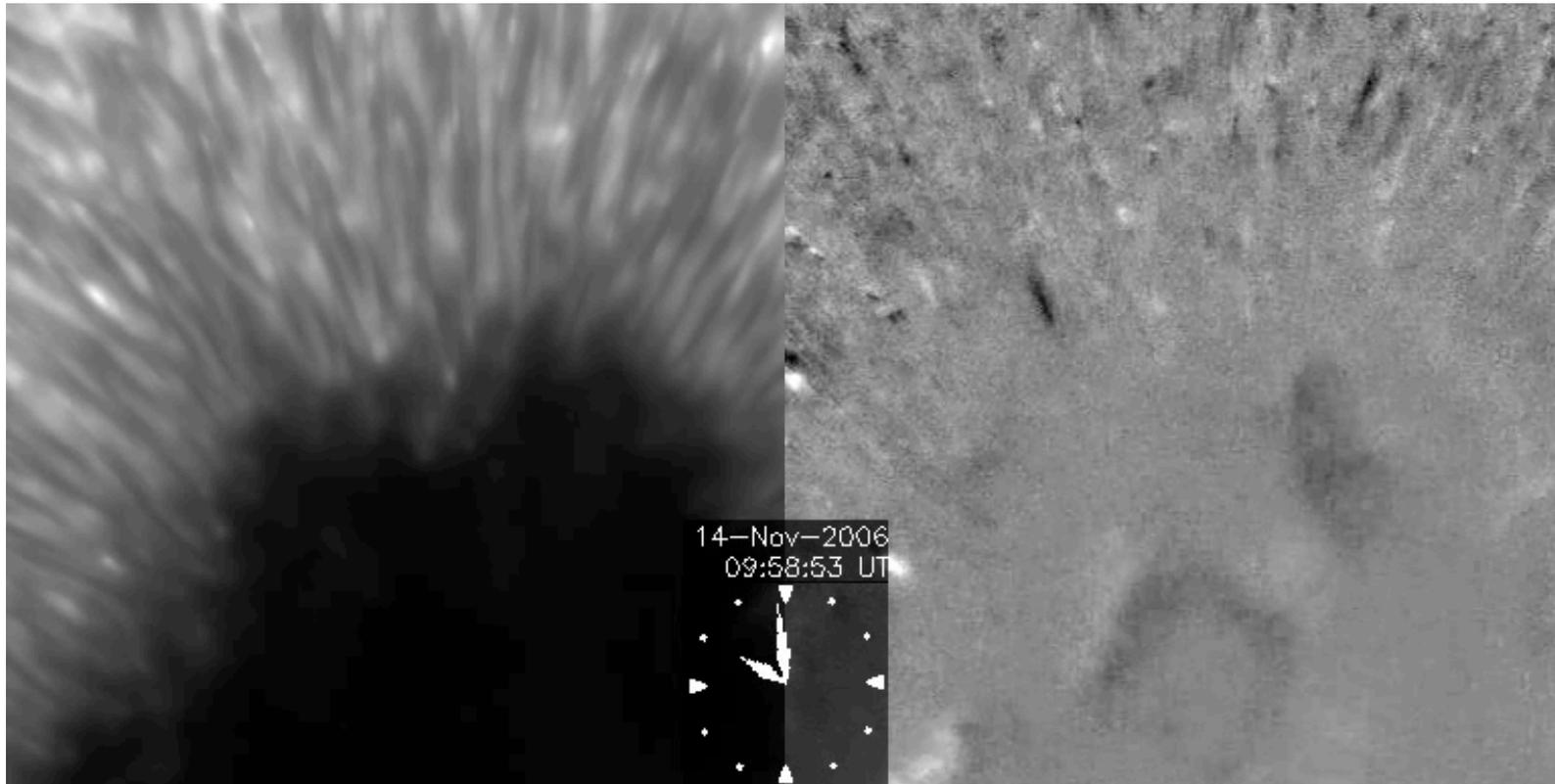
June 27, 2018

IRIS-9, Gottingen

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# Introduction:

## Hinode (SOT/FG) Observations

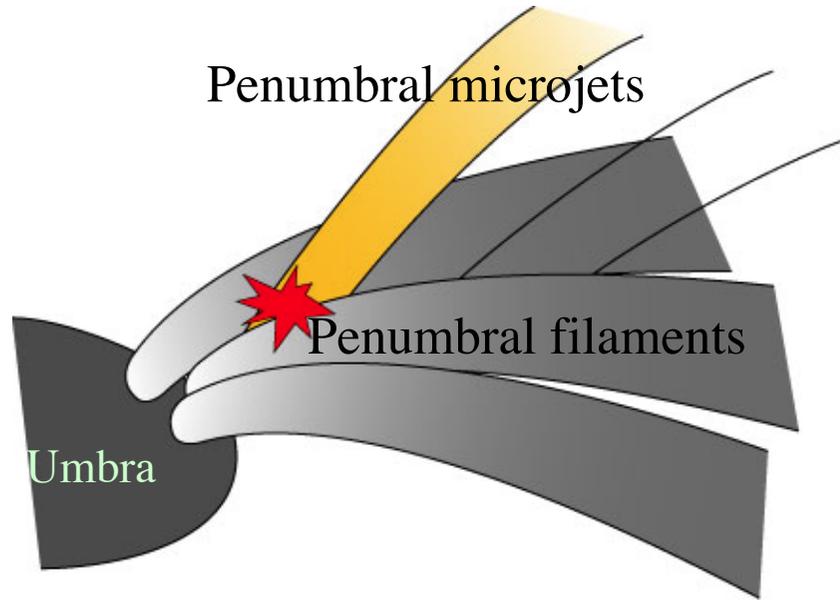


Katsukawa et al., 2007, Science

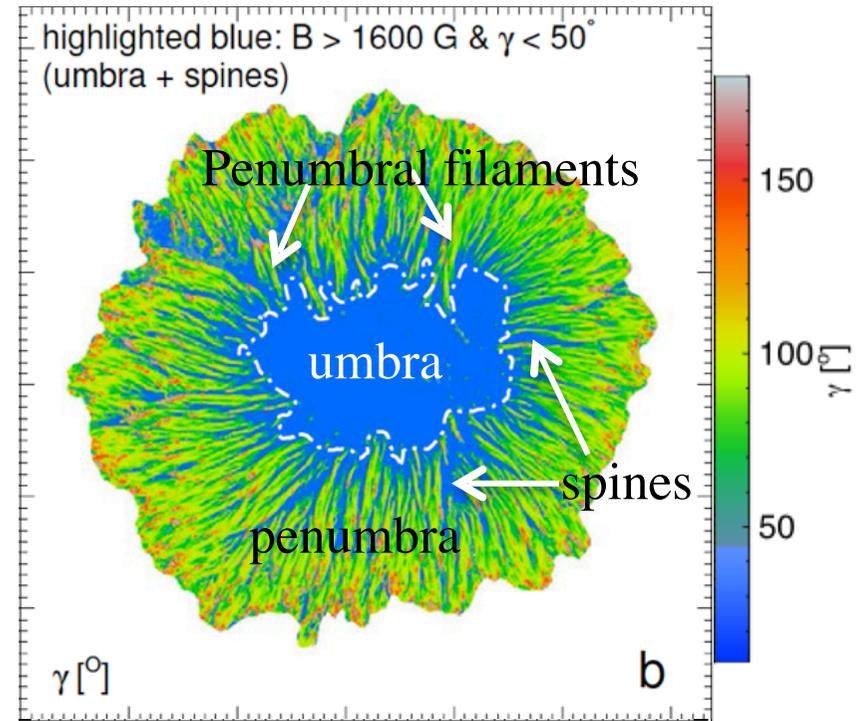
### Jet's characteristics

- Length 1000 – 4000 km
- Width 300 – 400 km
- Lifetime < 1 minute
- Apparent velocity 50-100 km/s

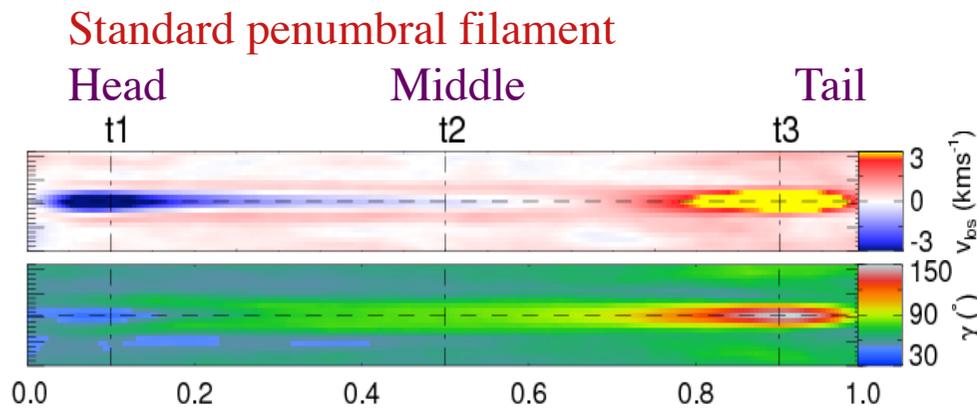
# Jet's origin: magnetic configuration



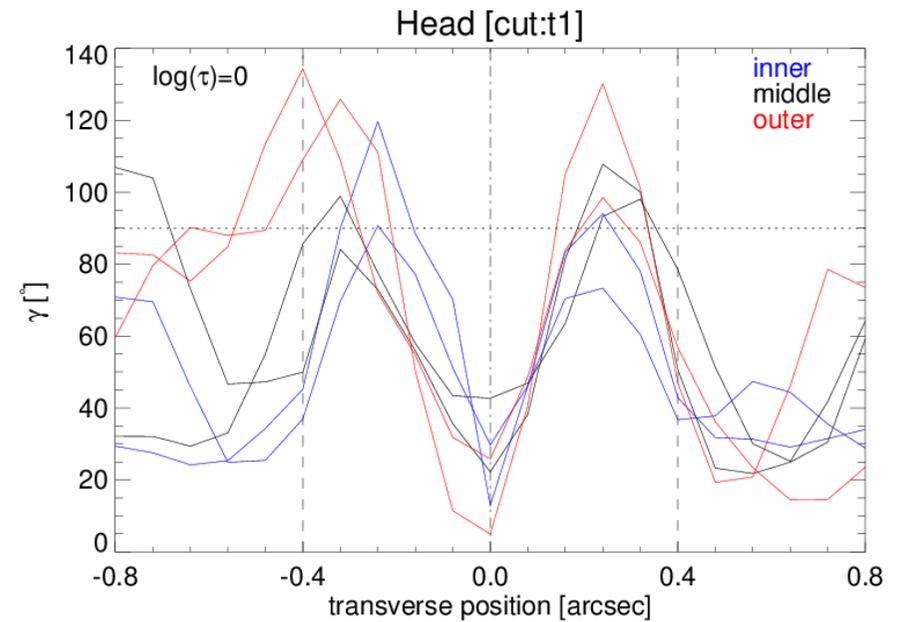
Katsukawa et al., 2007, *Science*



Tiwari et al., 2015, *A&A*

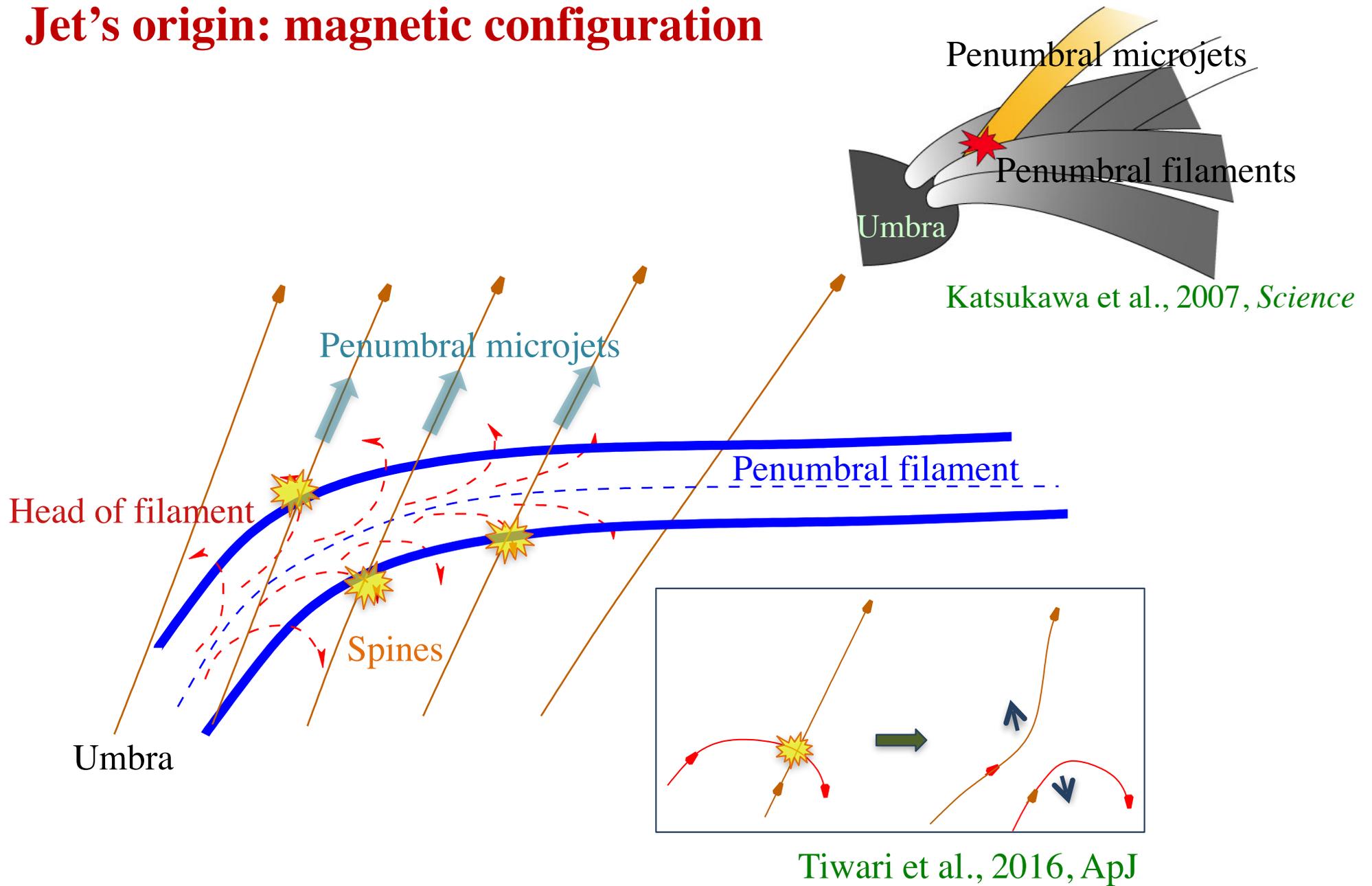


Tiwari et al., 2013, *A&A*



For opposite polarity field at sides of penumbral filaments, see also: Rempel 2012; Ruiz Cobo & Asensio Ramos, 2013; Scharmer et al 2013

# Jet's origin: magnetic configuration

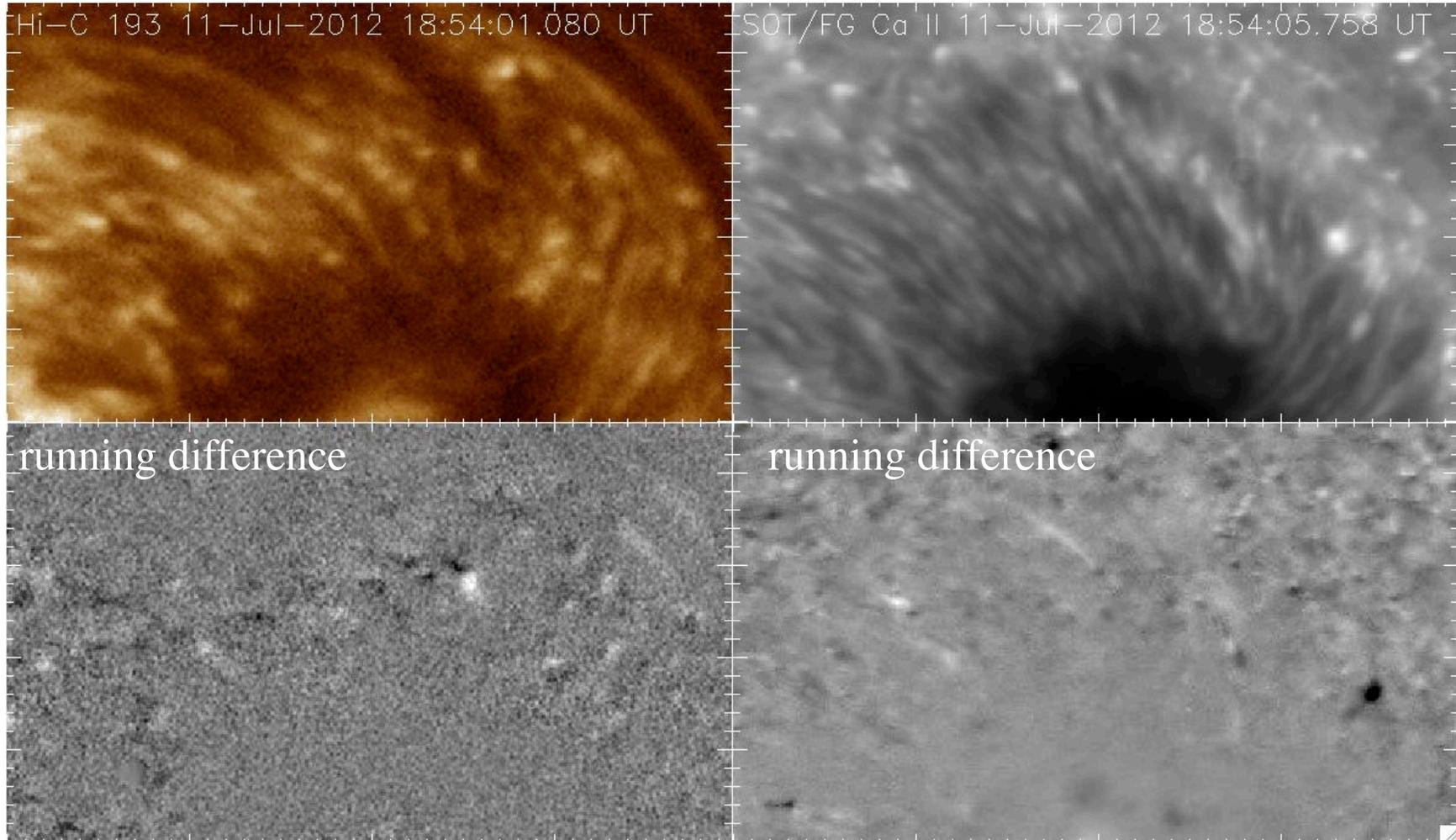


This is partly in agreement with the MHD simulations of Magara, 2010, *ApJ*!

# Transition-region/coronal signatures

Hi-C 193 Å

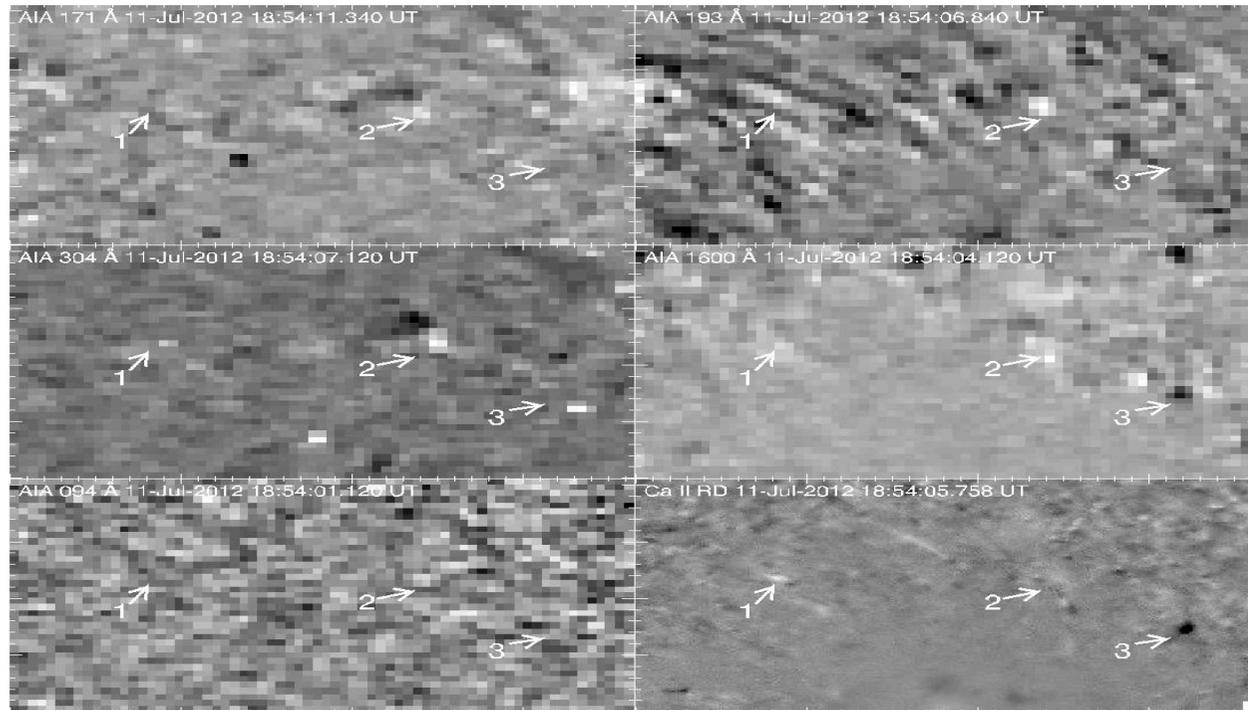
SOT/FG Ca II H-line



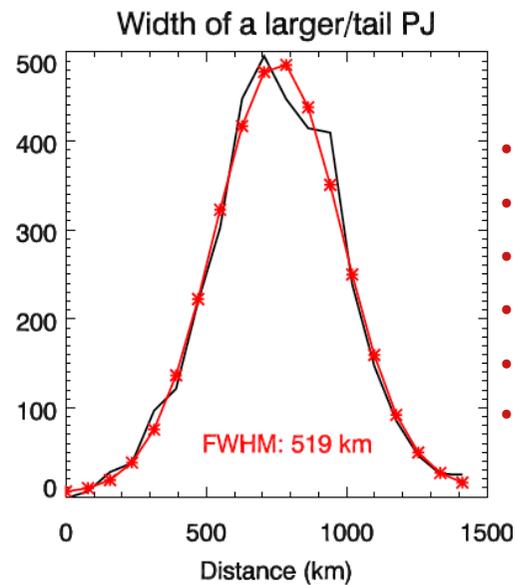
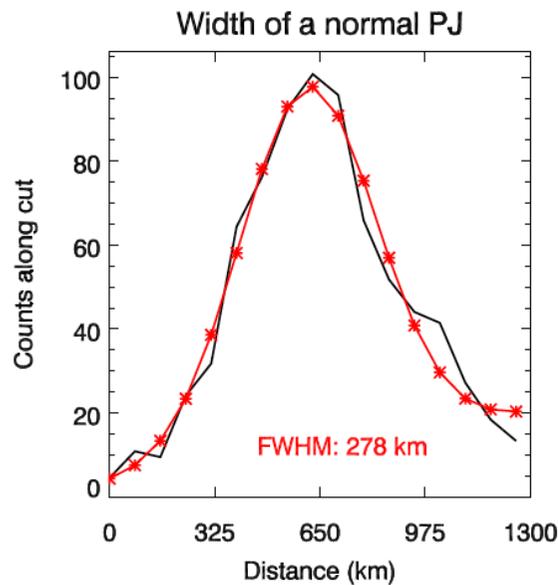
Hi-C and Hinode (SOT/FG): 0.2 arcsec  $\approx$  145 km

# Ca II H-line movie for one hour

Running difference: CaII H-line 3968 Å



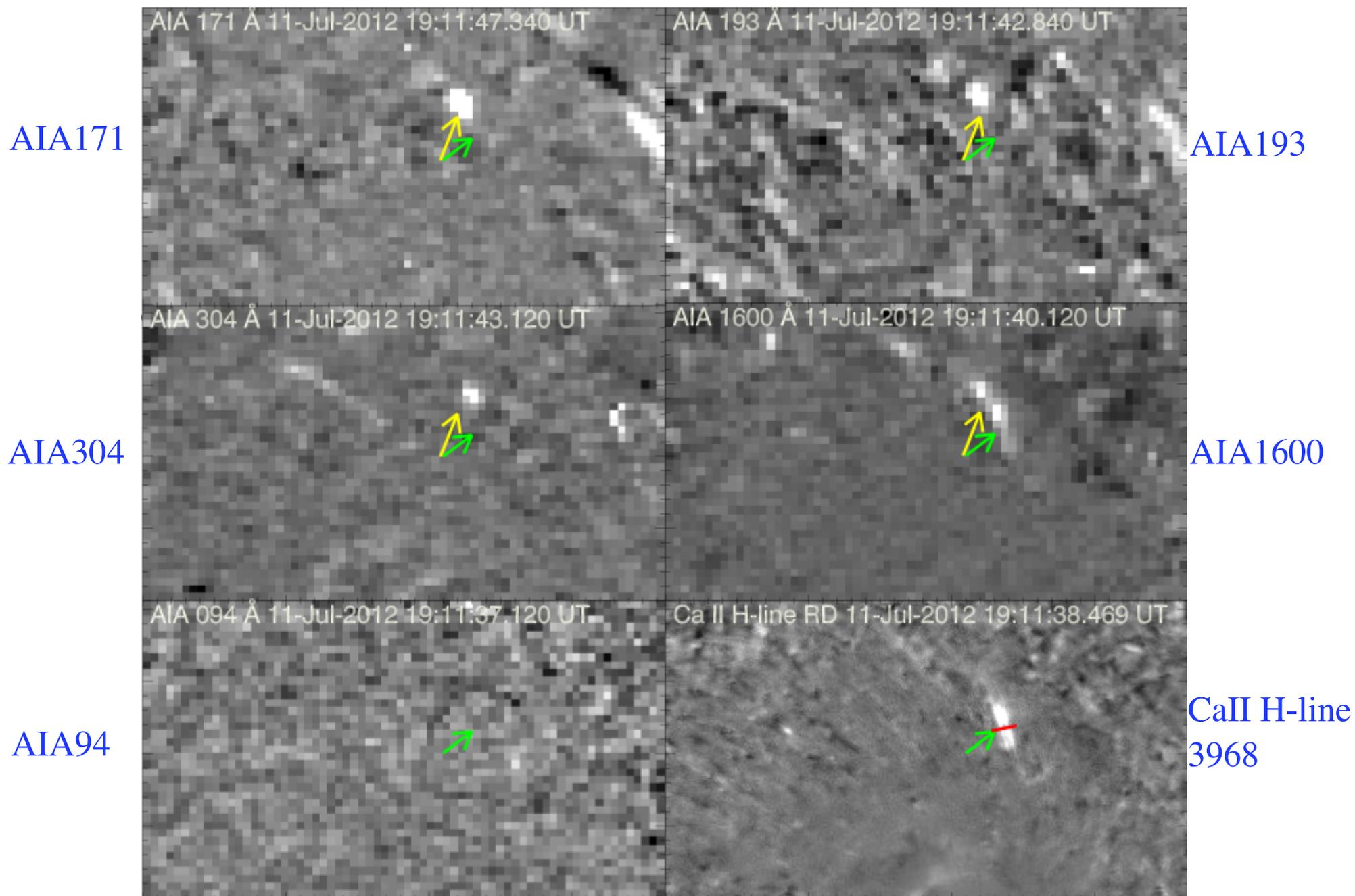
Widths of a normal jet and a larger jet using a Gaussian function fitting



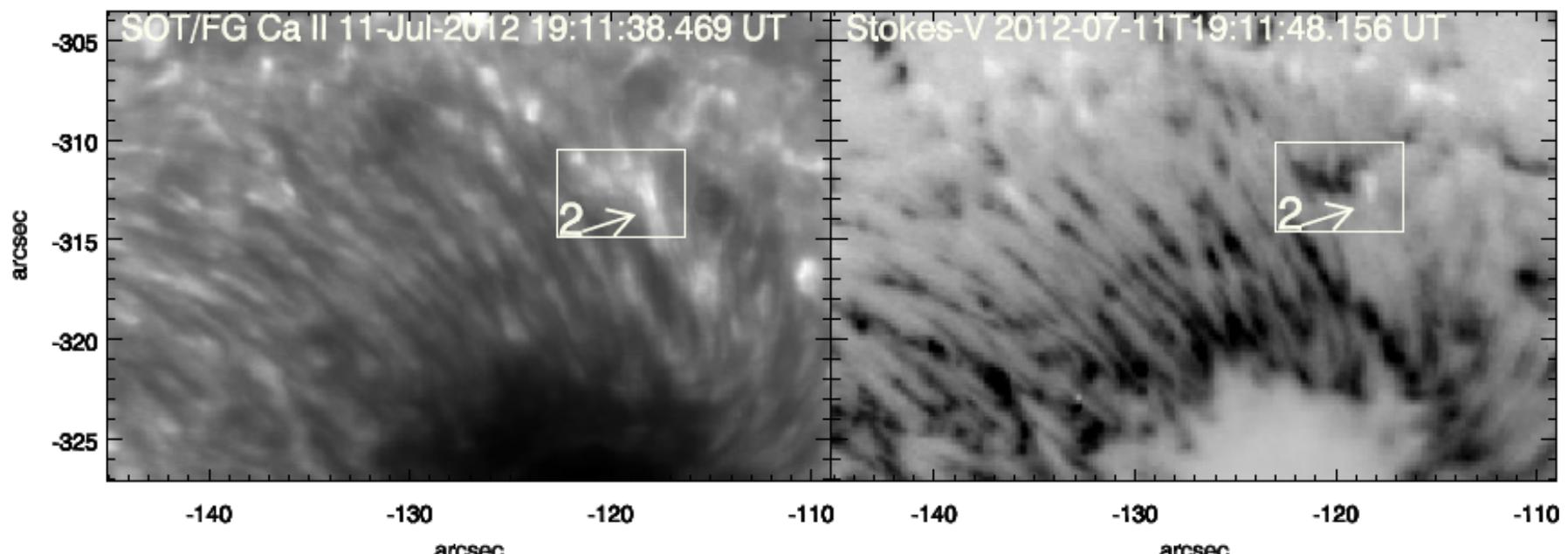
- Width of the widest jet: 600 km
- Speed of fastest jet found: 250 km/s
- Length: 420 km (subject to projection)

Tiwari et al., 2016, ApJ

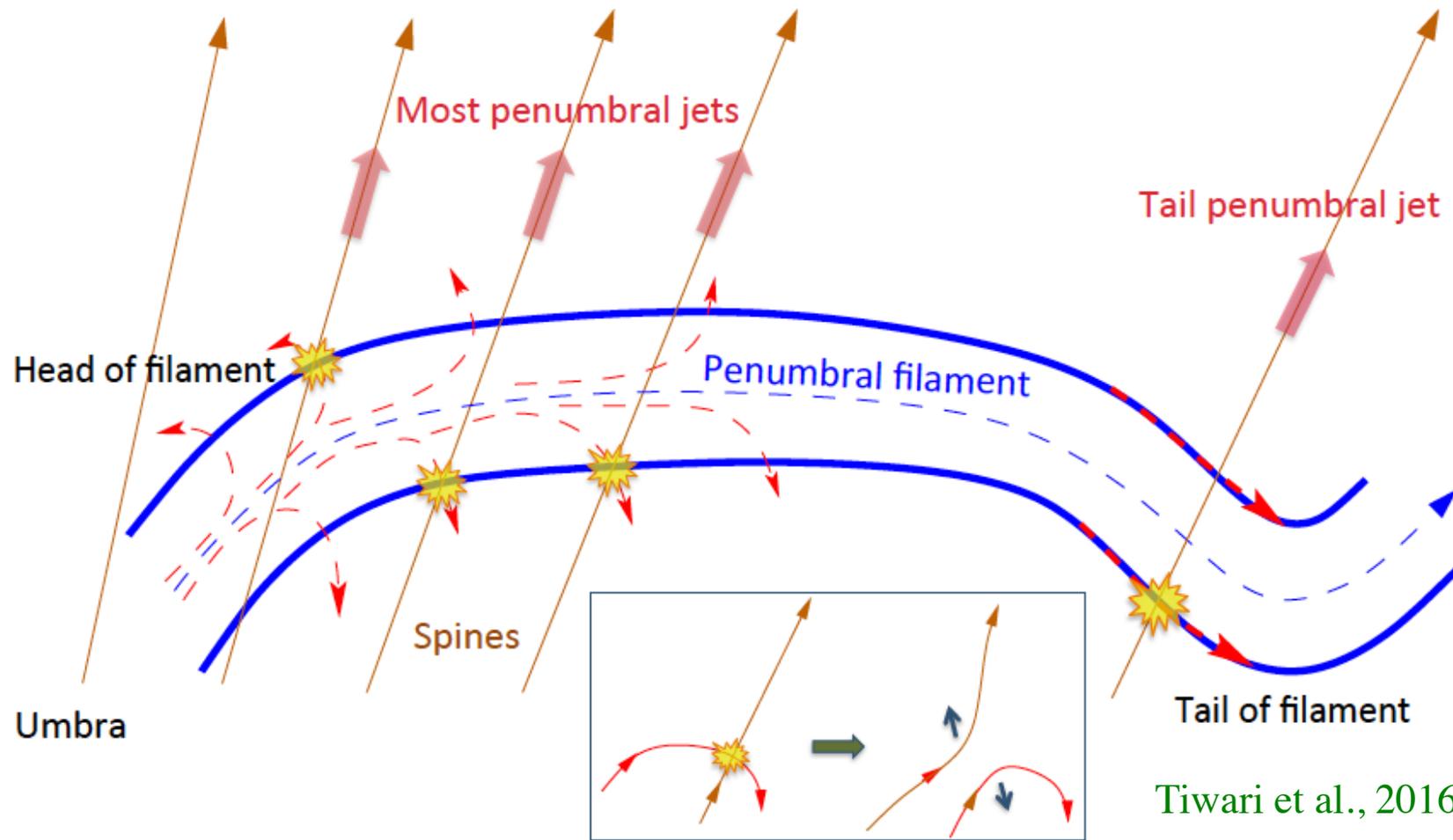
# Example of a large penumbral jet



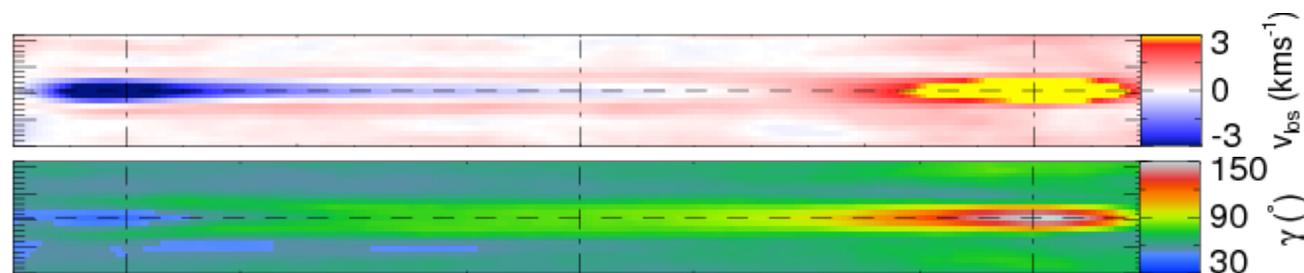
## Stokes-V images (equivalent to LOS magnetograms)



# Schematic diagram depicting the formation mechanism of penumbral jets

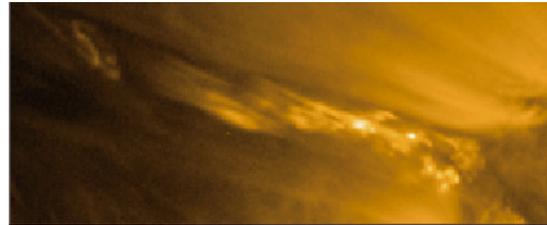
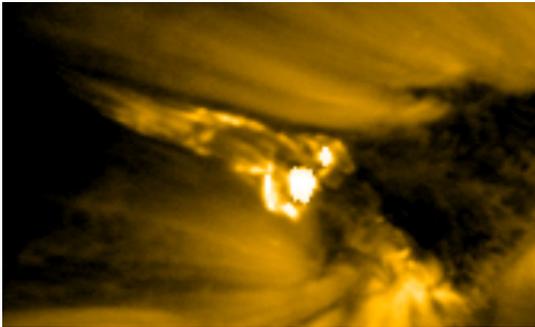


Tiwari et al., 2016, ApJ

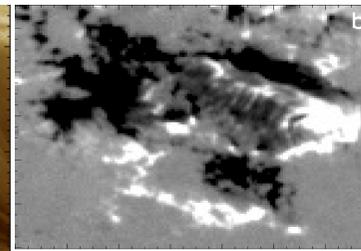
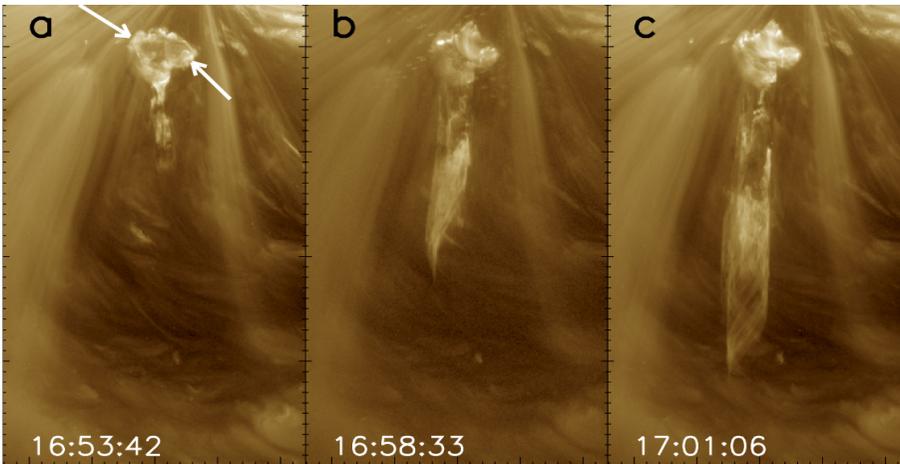
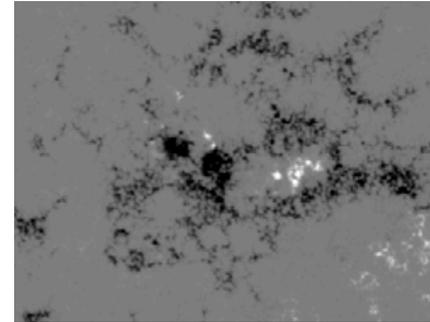


Tiwari et al., 2013, A&A

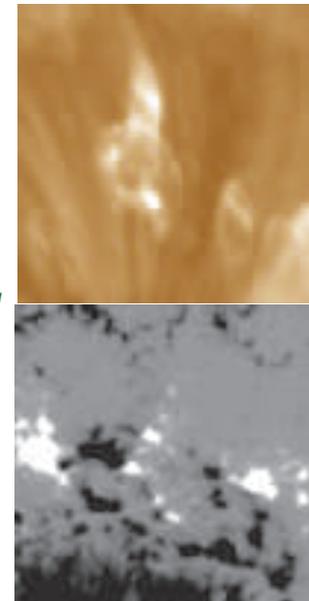
# Coronal Jets are Twisted and have Mixed-polarity Field



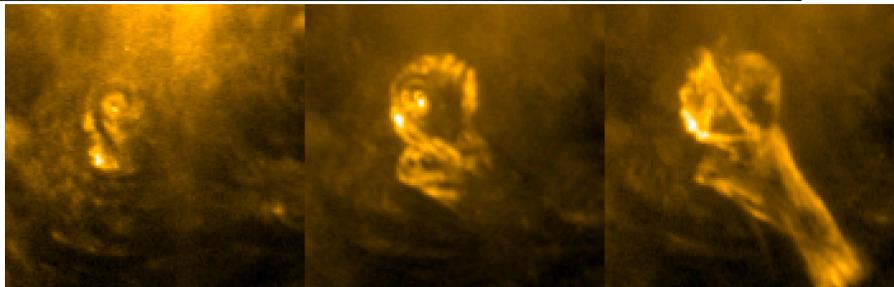
Schmieder et al. 2013, A&A



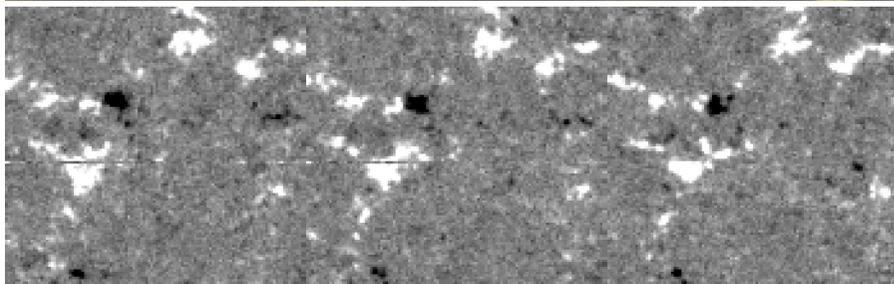
Panesar et al. 2016a, ApJL



Sterling et al. 2017, ApJ

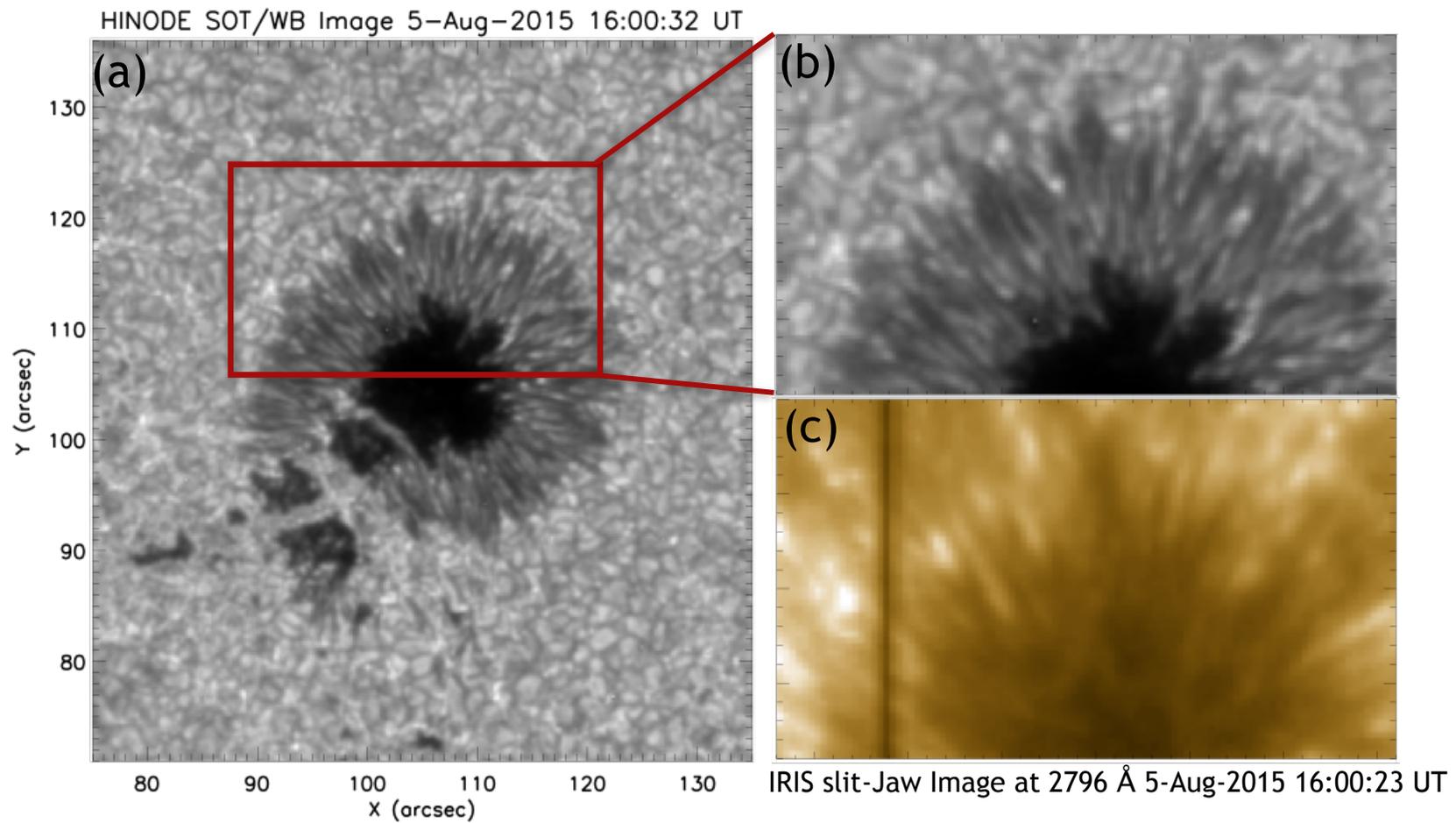


Panesar et al. 2016b, ApJL

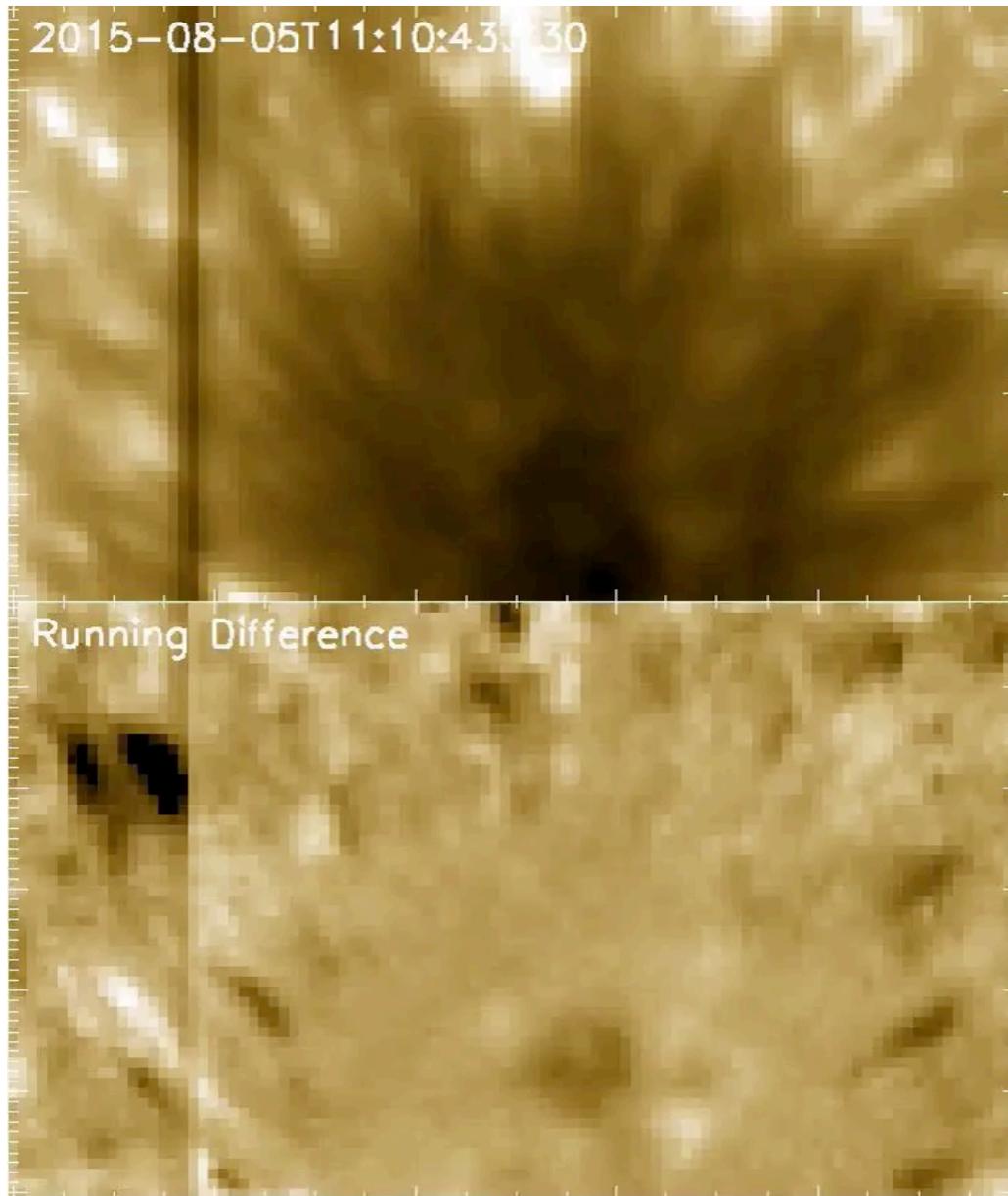


(e.g., Patsourakos et al. 2008; Pariat et al, 2012; Moore et al. 2013; 2015; Schmieder et al 2013; Sterling et al 2015, 2017; Cheung et al. 2015; Panesar et al 2016a, 2016b, 2018...)

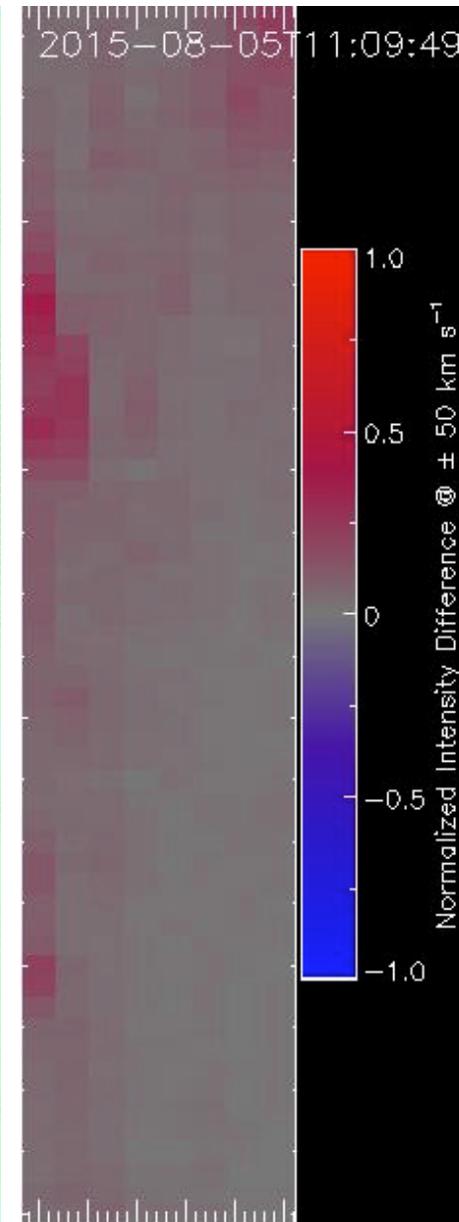
# IRIS and Hinode (SOT/FG) Observations of the leading sunspot of NOAA AR 12394



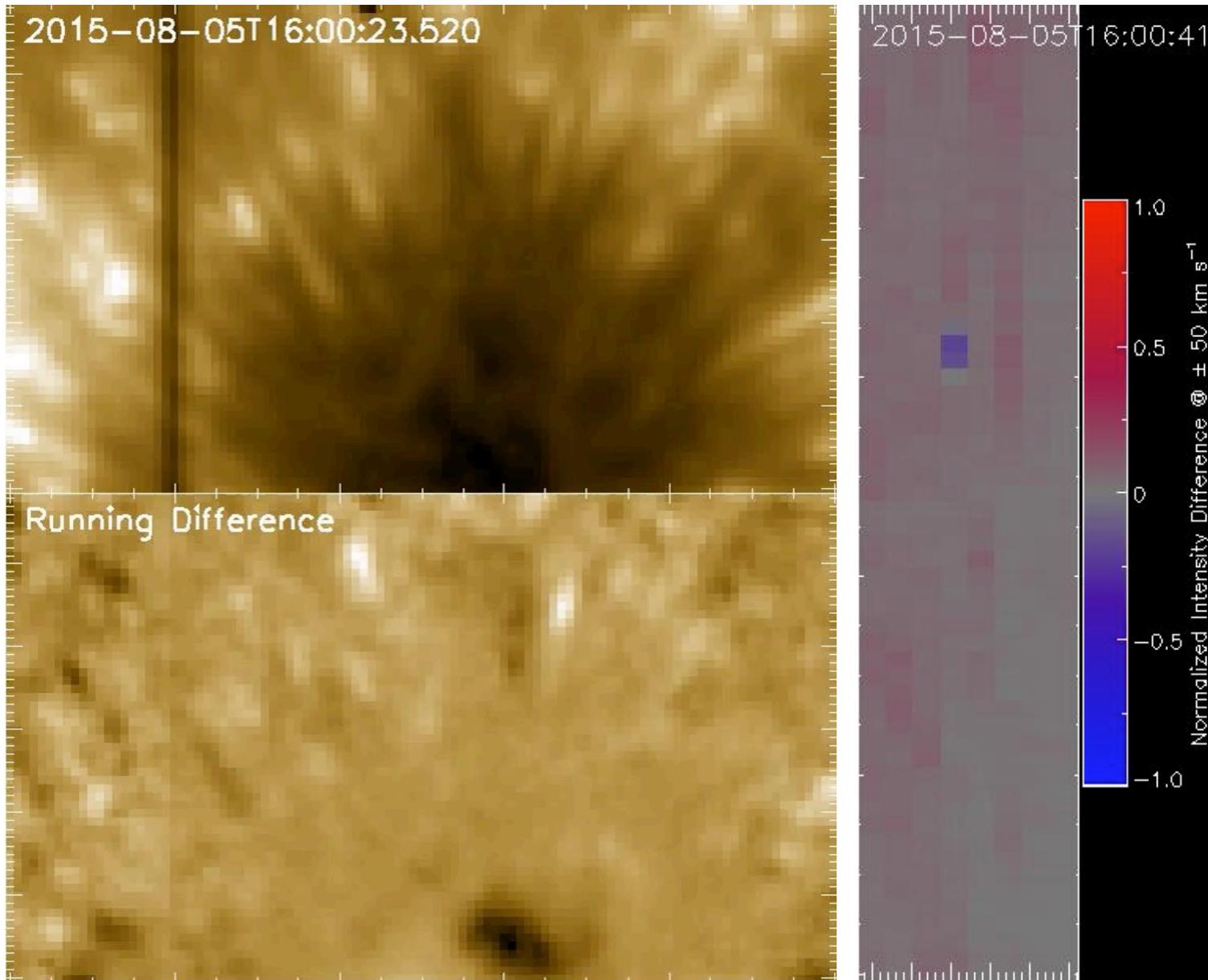
# Mg II k-line 2796 Å SJ movie



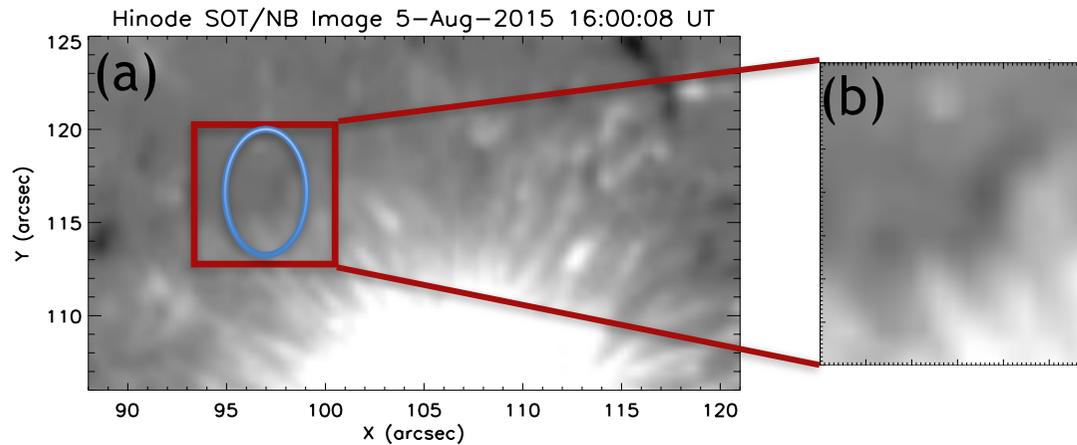
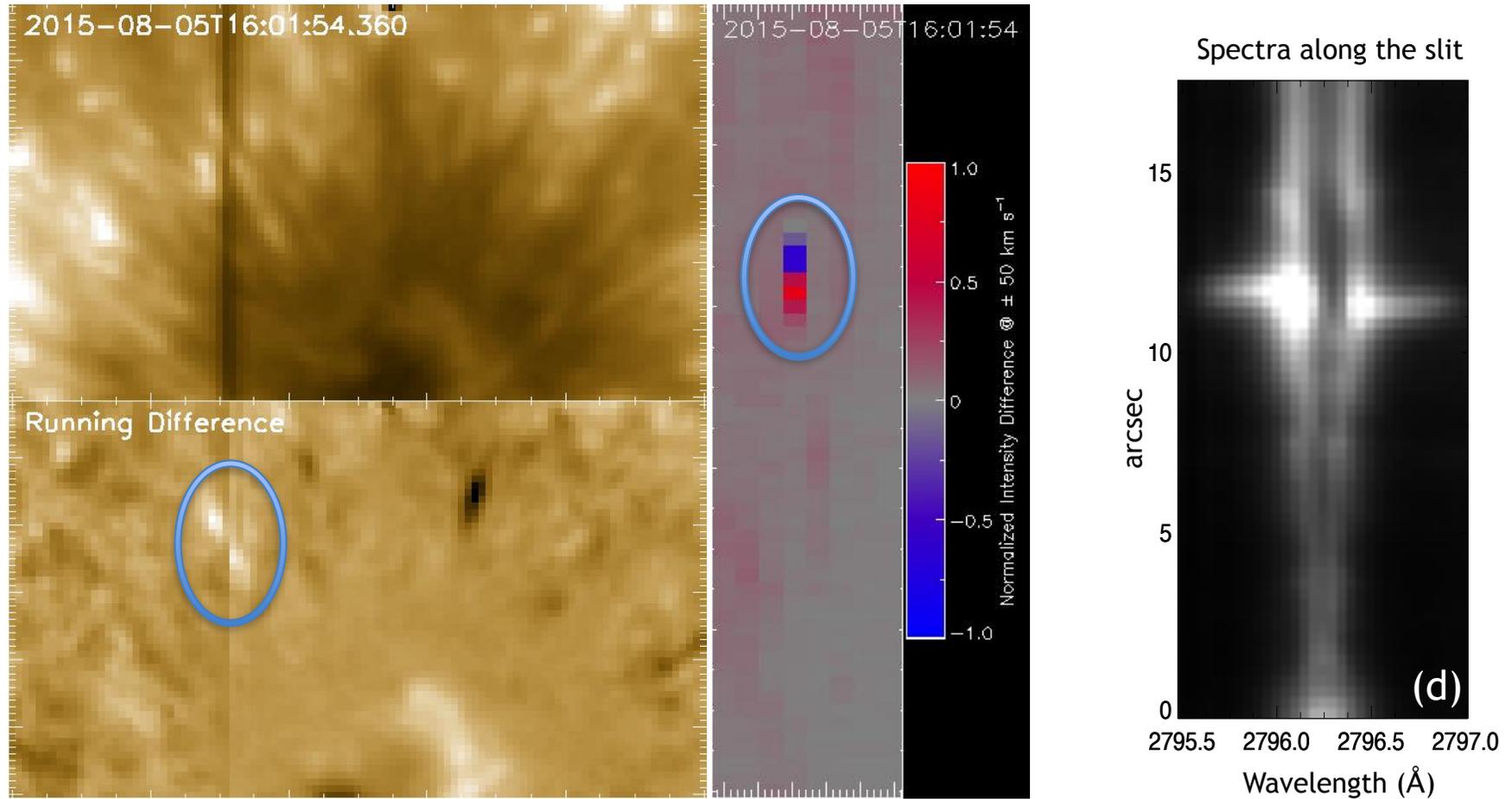
# Dopplergram movie



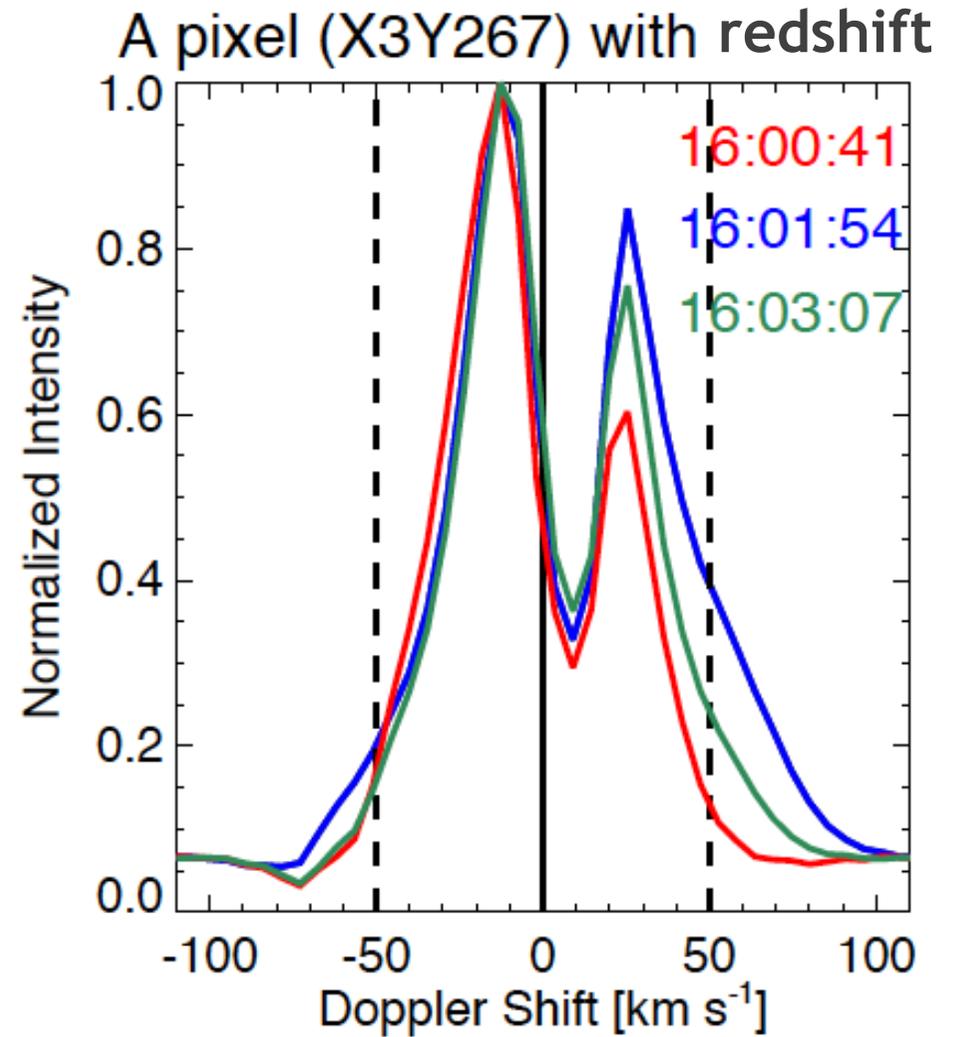
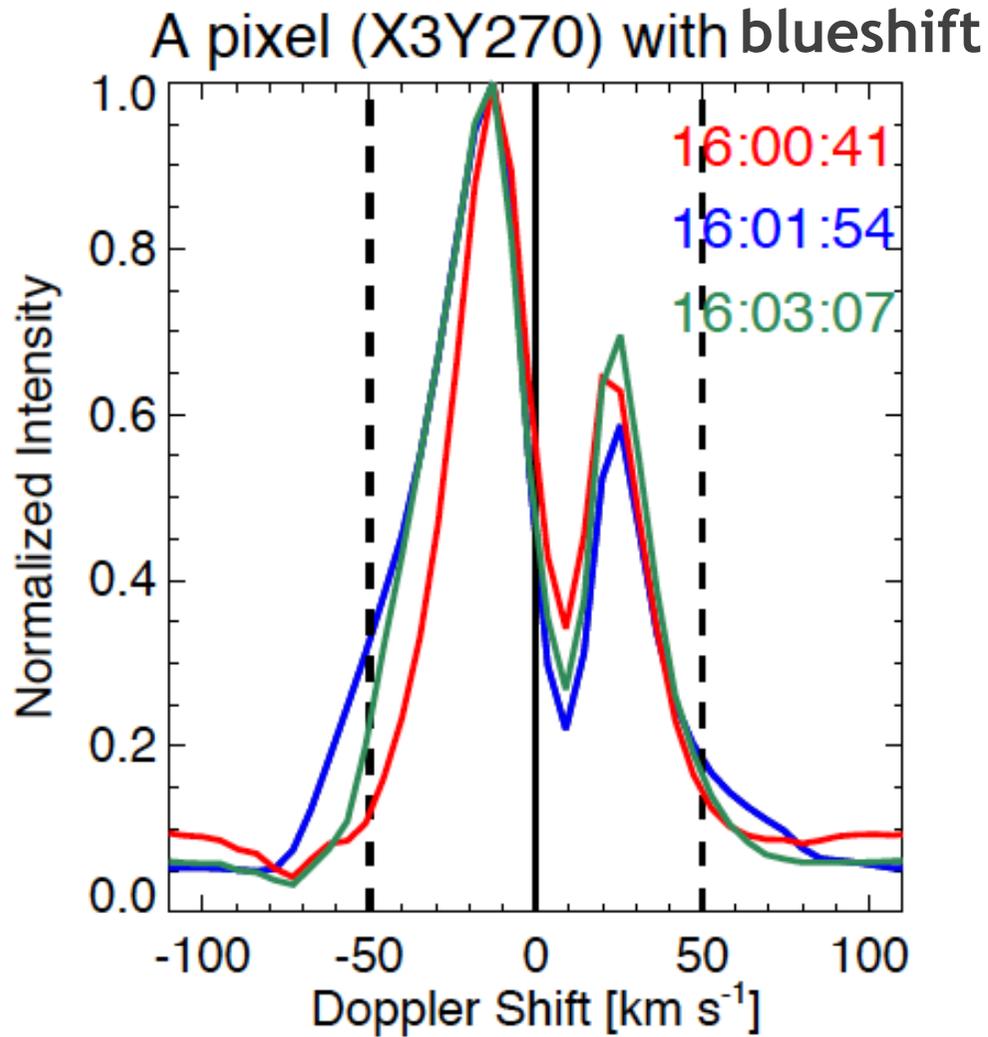
## Movies for the example jet



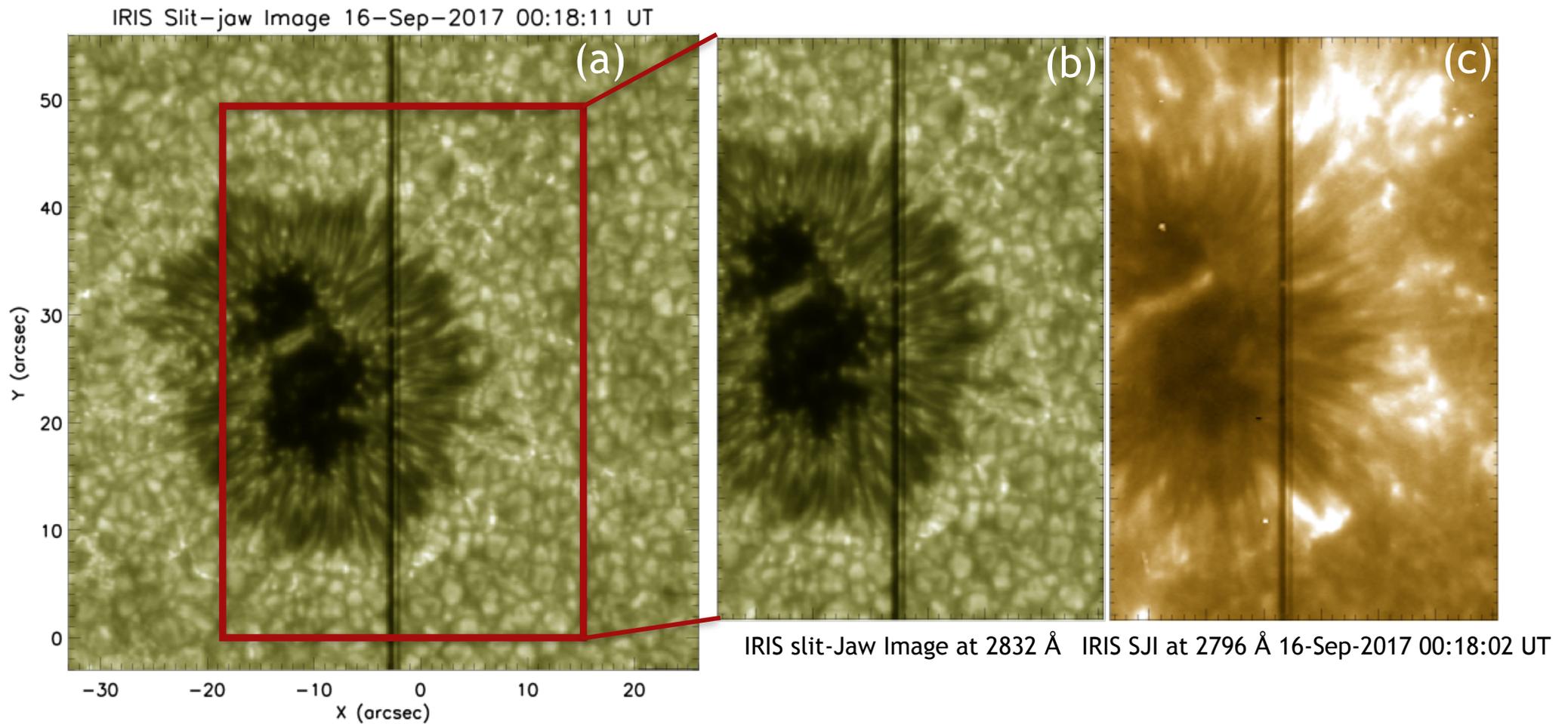
# A frame from the movie (an example jet)

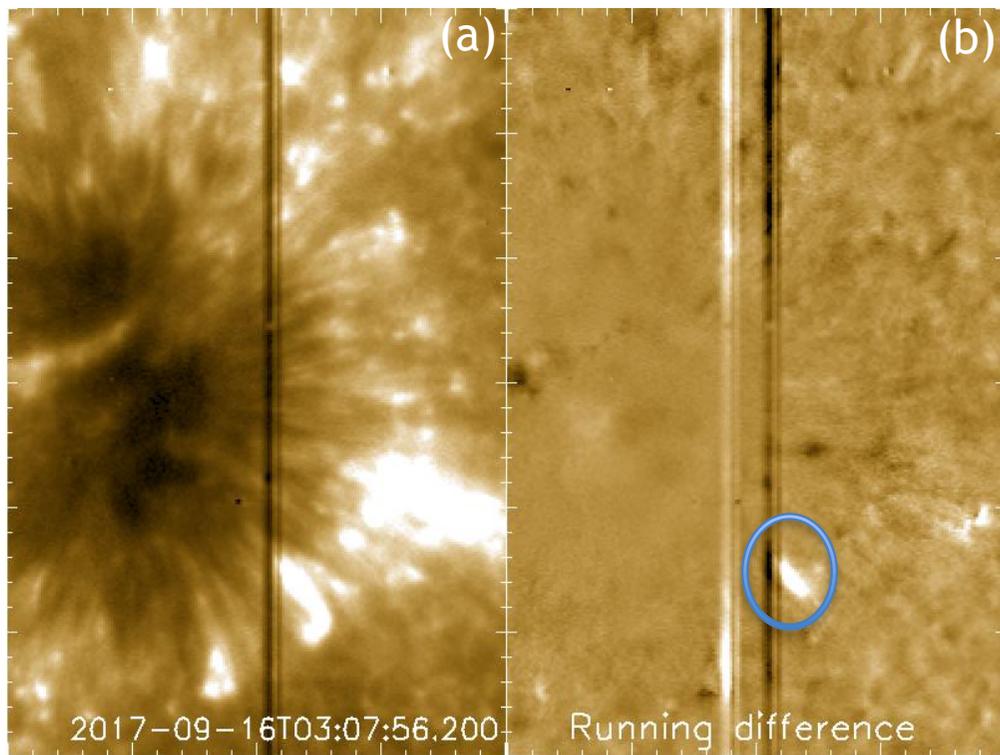


# Mg II k 2796 line profiles for the example jet



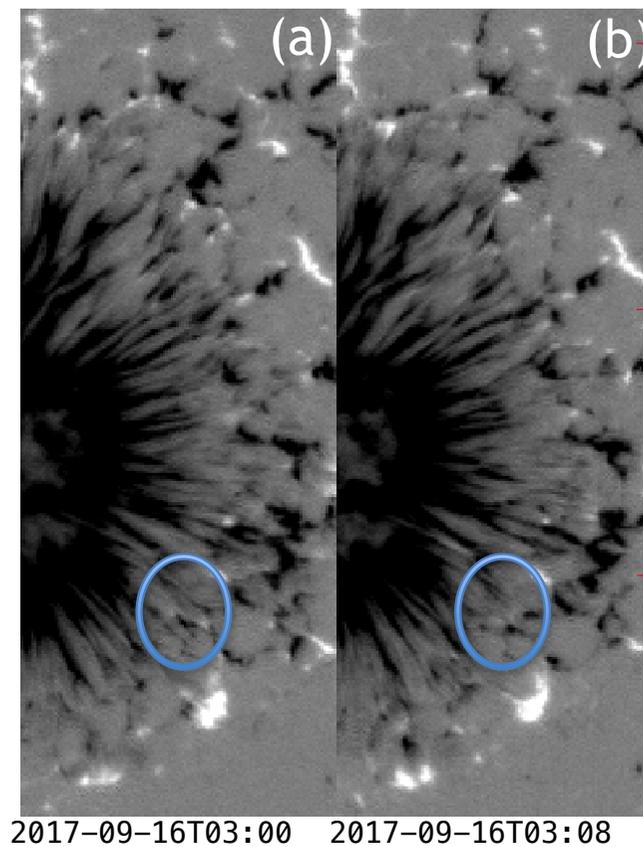
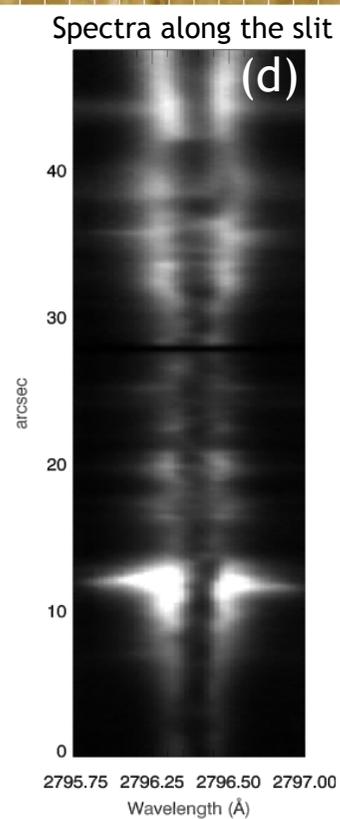
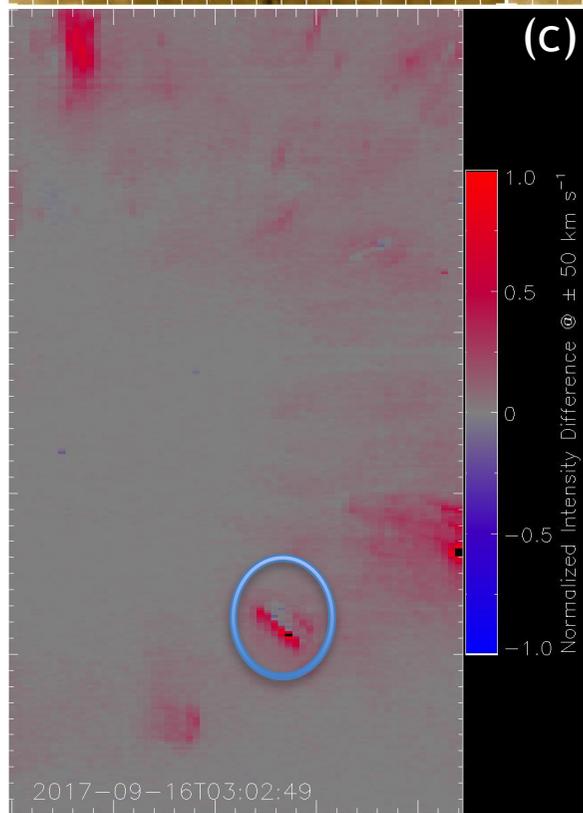
# IRIS and Hinode (SOT/SP) Observations of the leading sunspot of NOAA AR 12680



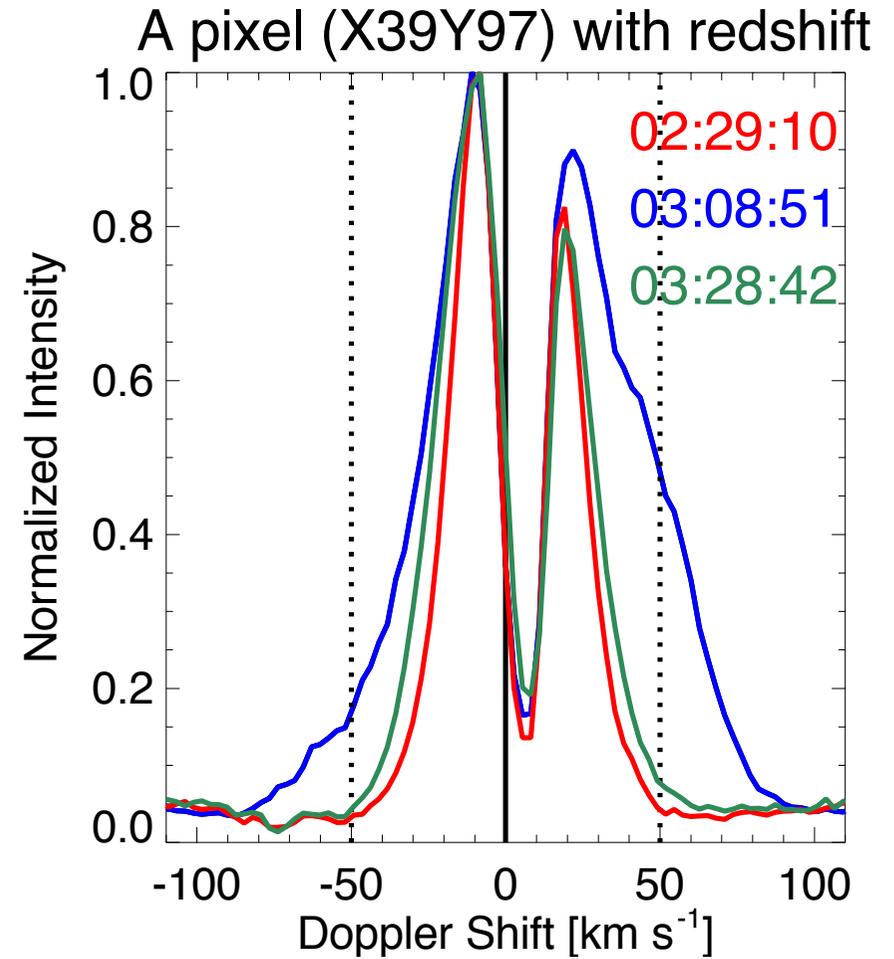
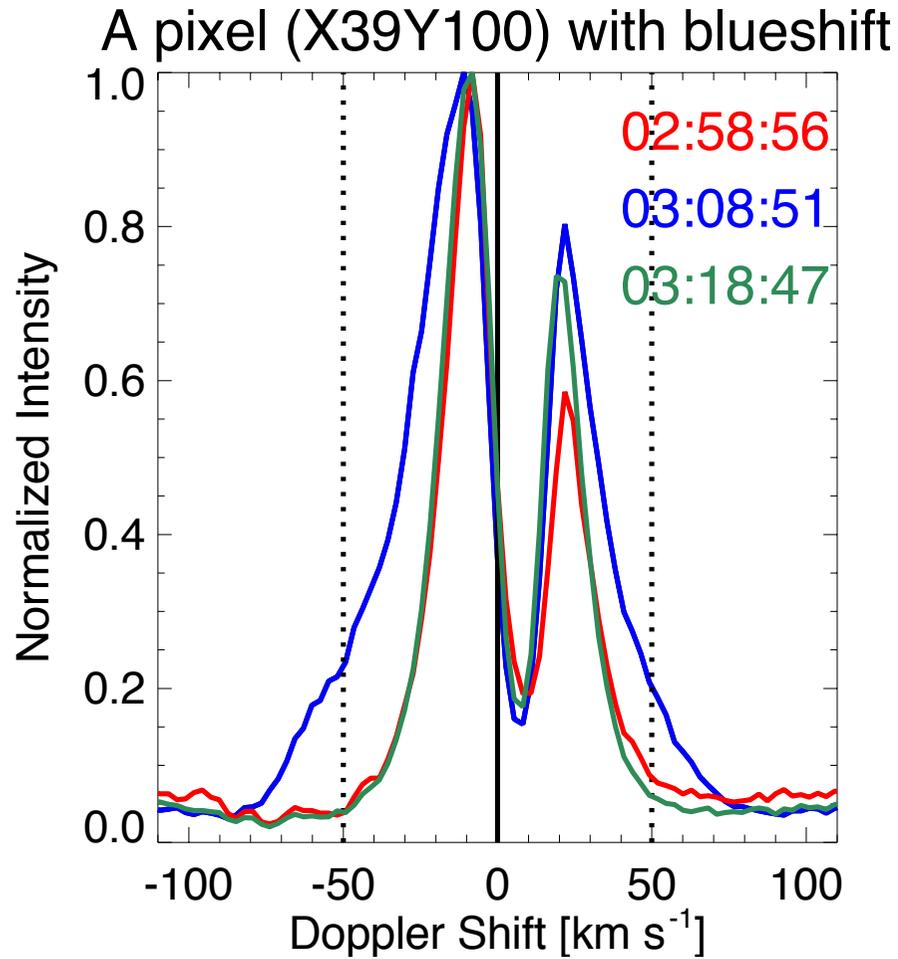


**An example jet  
from the 2<sup>nd</sup> sunspot**

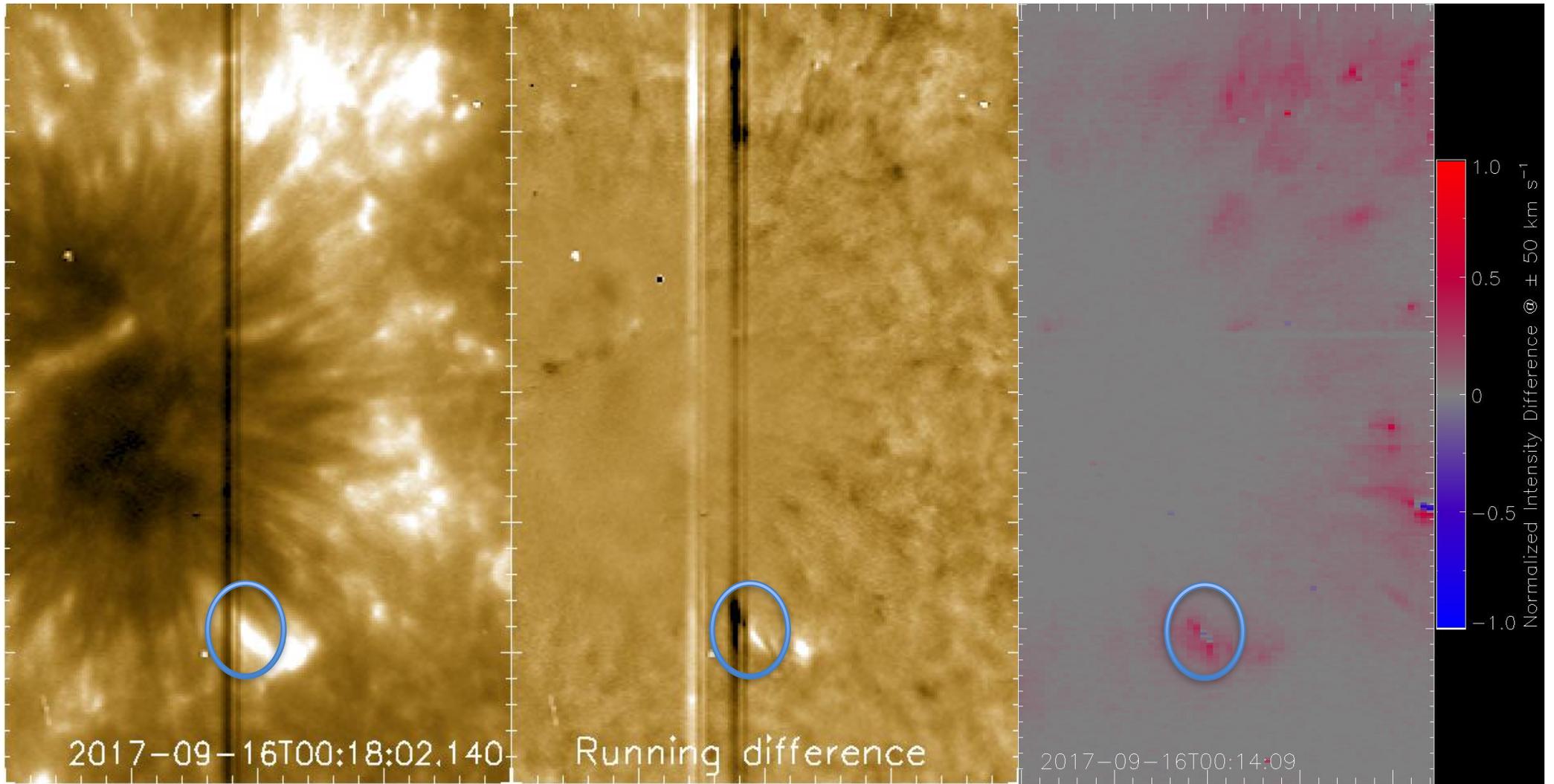
Hinode SOT/SP Stokes-V:  
equivalent to LOS magnetogram



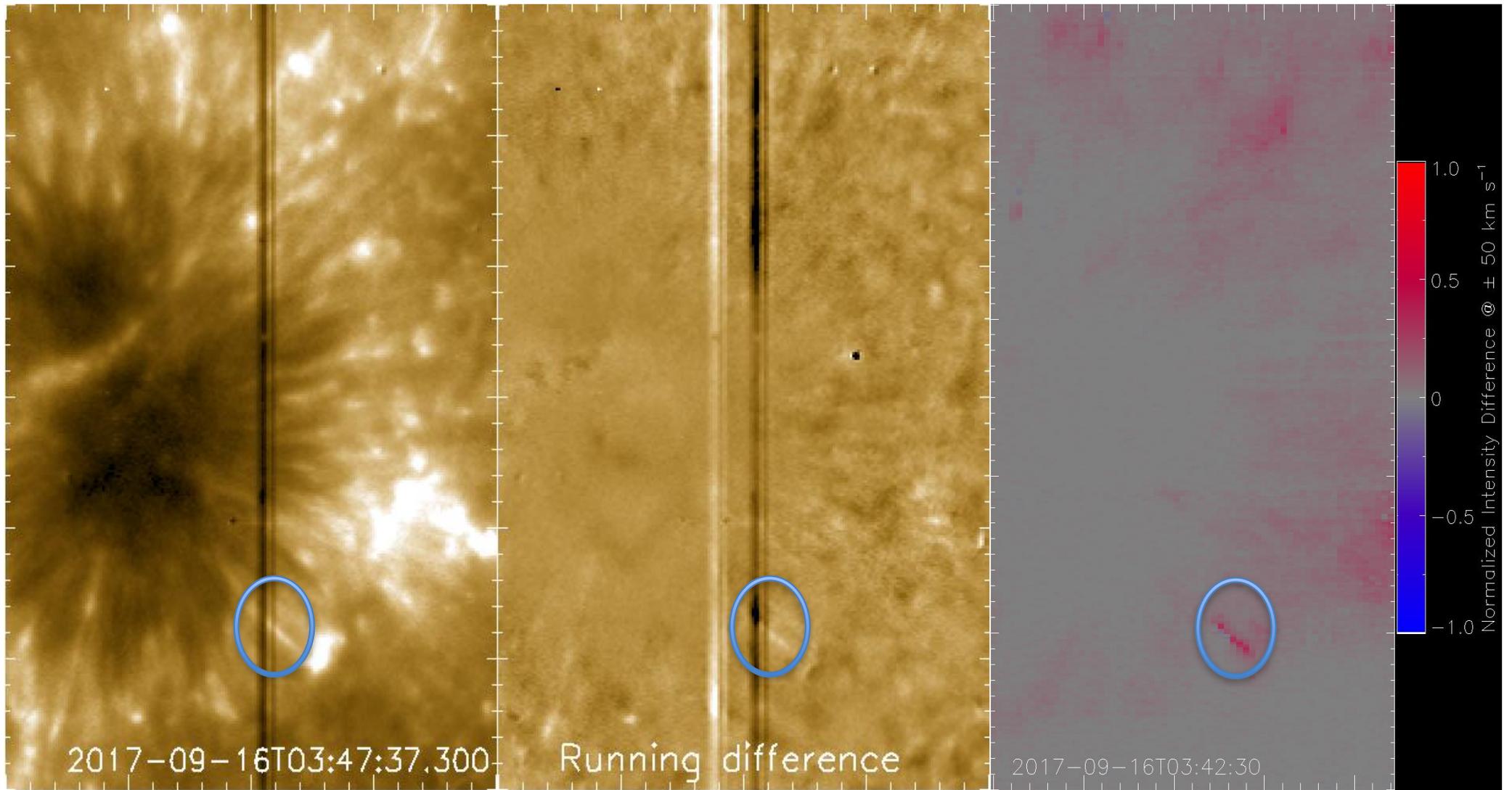
# Mg II k 2796 line profiles for the example jet



## Another example jet



## Another example jet



# Summary

- Large penumbral jets often repeatedly occur at the same locations; show direct transition-region signatures; no 94 Å coronal signatures are detected.
- Opposite polarity field patches are found at the base of large penumbral jets; they apparently form at tails of penumbral filaments (Tiwari et al. 2016).
- We found evidence of twisting in large penumbral jets.
- Because they have mixed-polarity field at the base and they spin, penumbral jets might form the same way as other coronal jets (in CHs, QRs, ARs) do!

Thanks!