# Magnetic Setting and Transition-Region/Coronal Signatures of Sunspot Penumbral Jets

**Sanjiv K. Tiwari[1],**

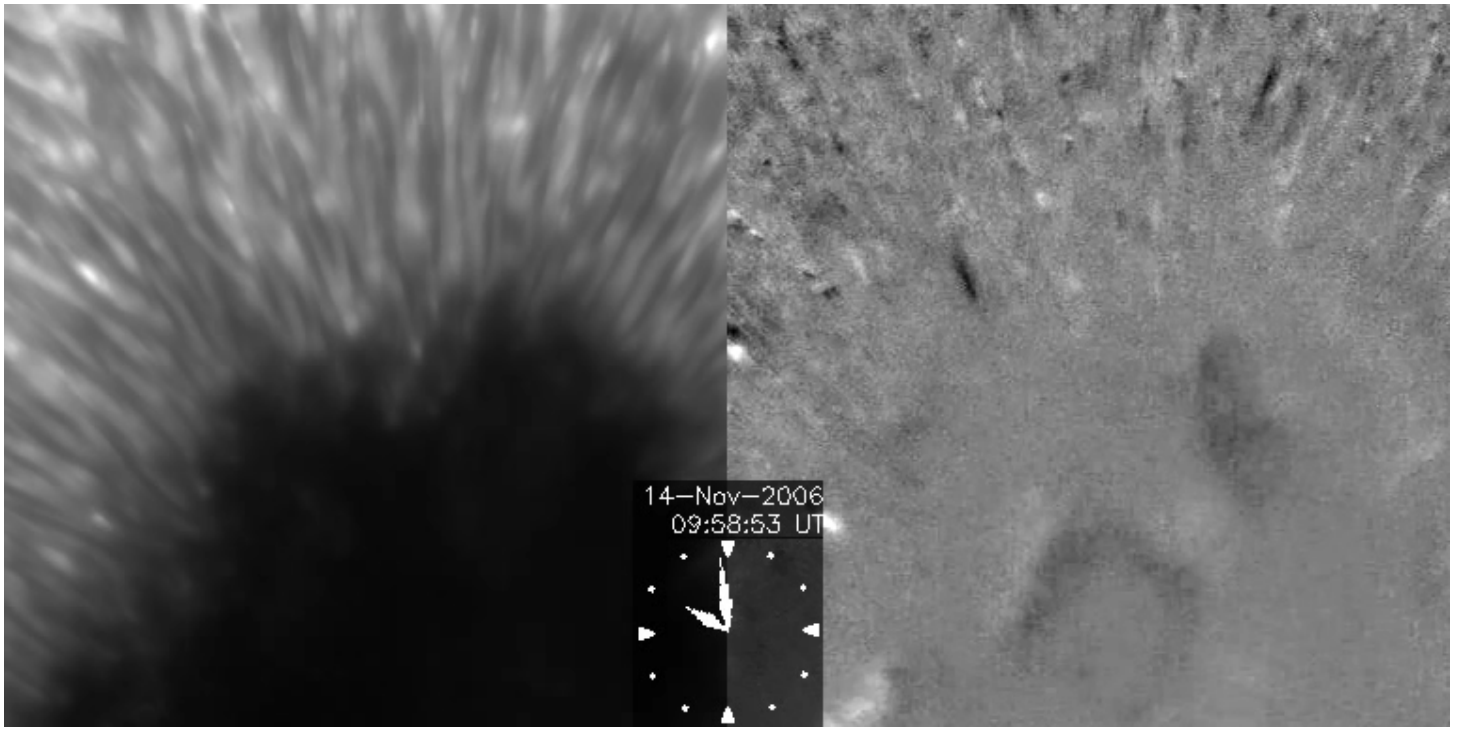
(R. L. Moore[1], A. R. Winebarger[1], S. E. Alpert[2])

NASA Marshall Space Flight Center, Huntsville, AL, USA
*Dept. of Physics and Astronomy, Rice University, Houston, TX, USA


Marshall Space Flight Center

# Introduction:

Hinode (SOT/FG) Observations

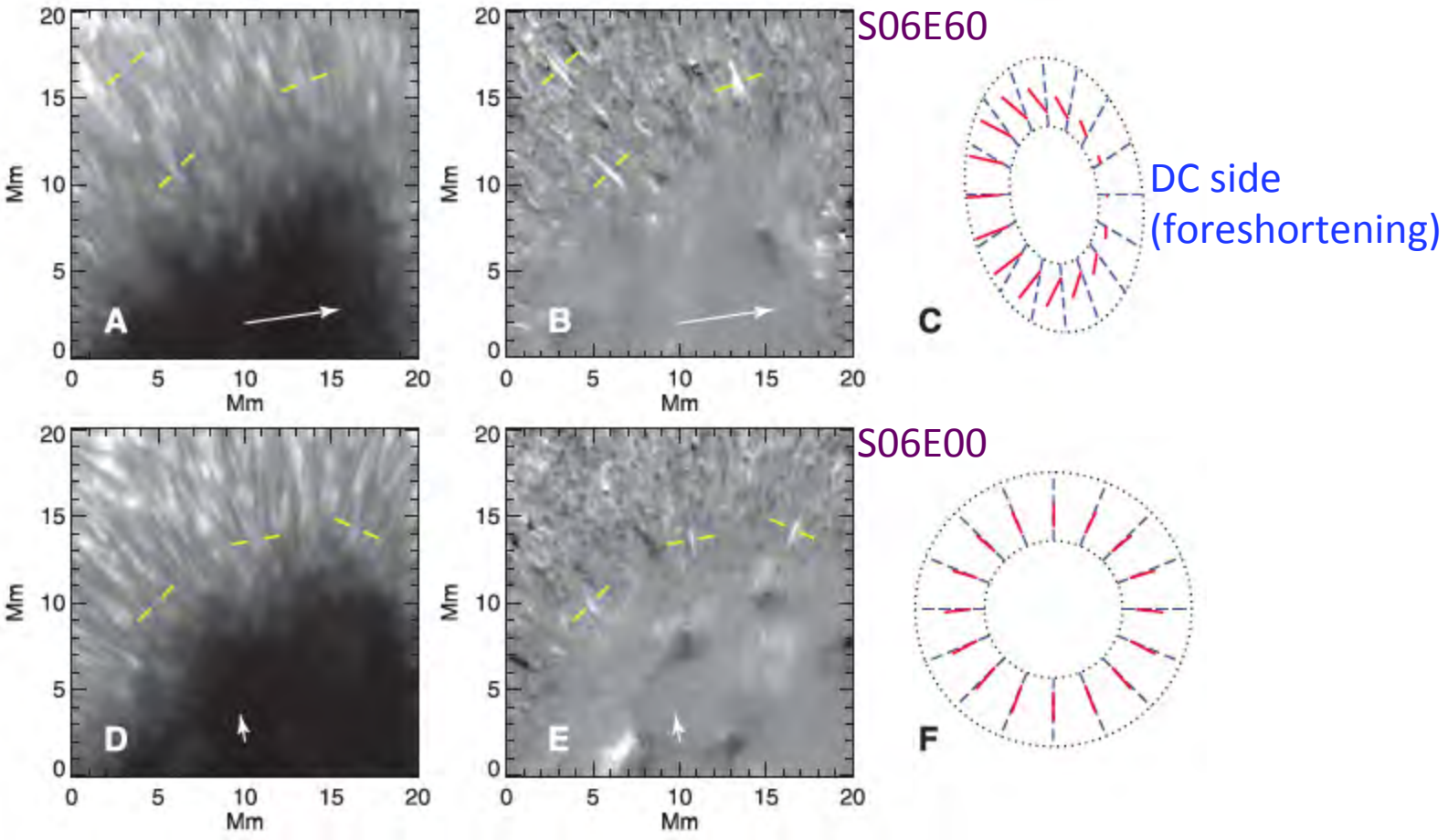



Katsukawa et al., 2007, Science

**Jet's characteristics**

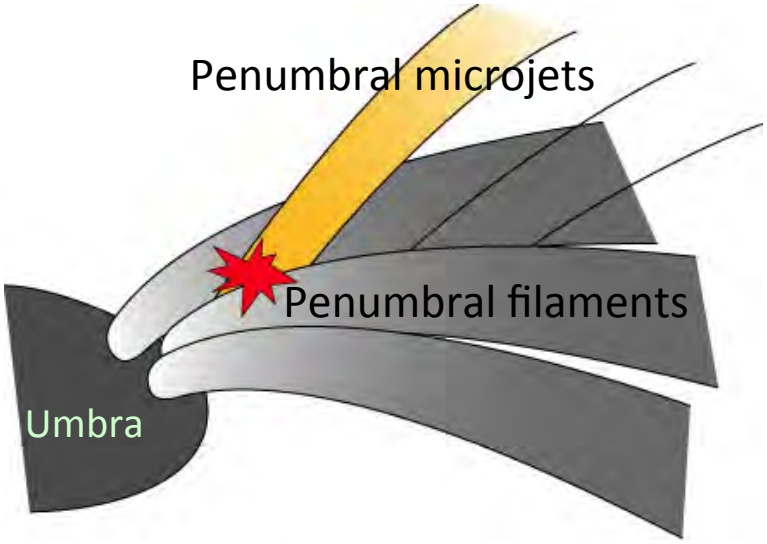
- Length 1000 – 4000 km
- Width 300 – 400 km
- Lifetime < 1 minute
- Apparent velocity 50-100 km/s
- Near Bright Dots (which are heads of penumbral filaments: Tiwari et al., 2013)

Visibility of these jets depends on the position of sunspots on the solar disk; difficult to see when close to disk center

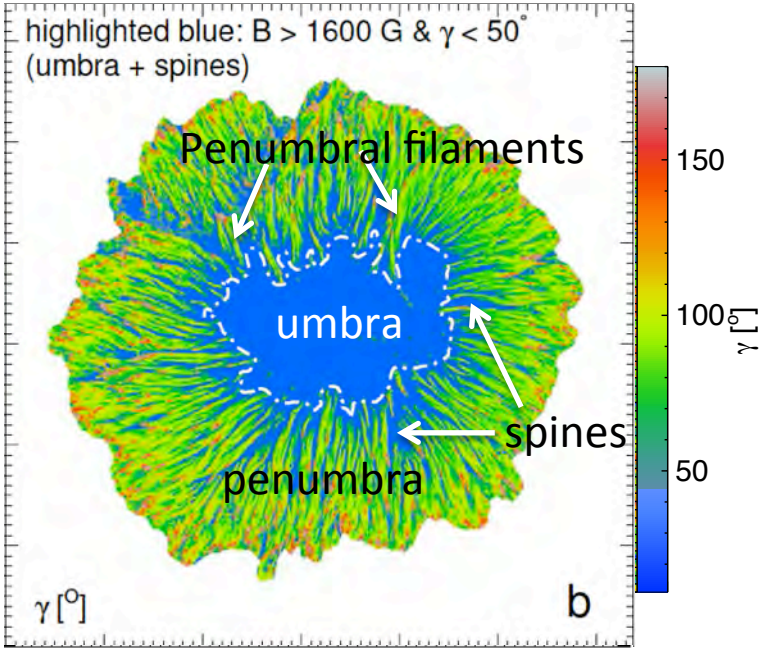



Katsukawa et al., 2007, Science

# Jet's origin: magnetic configuration

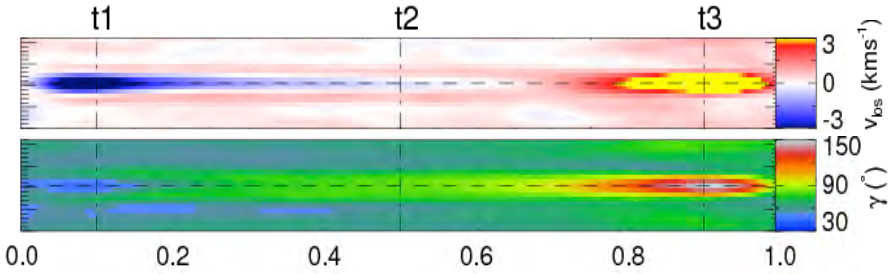



Katsukawa et al., 2007, *Science*

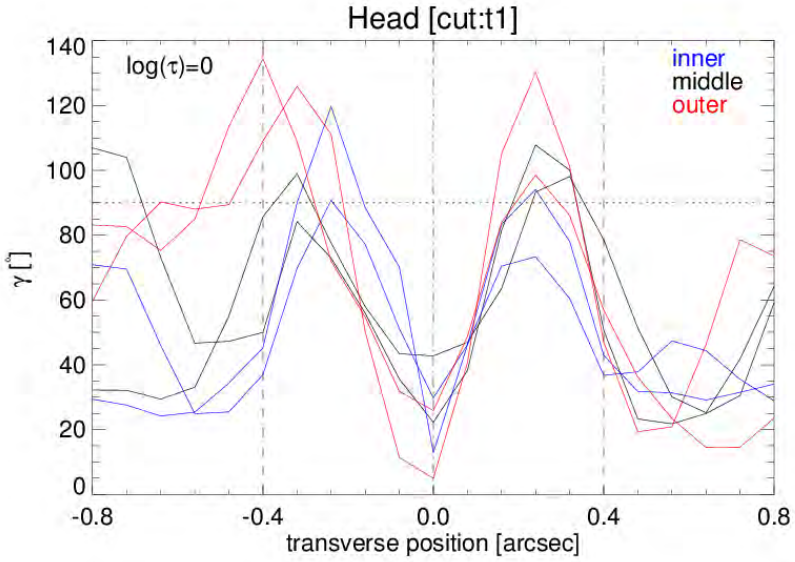



Tiwari et al., 2015, A&A

Standard penumbral filament

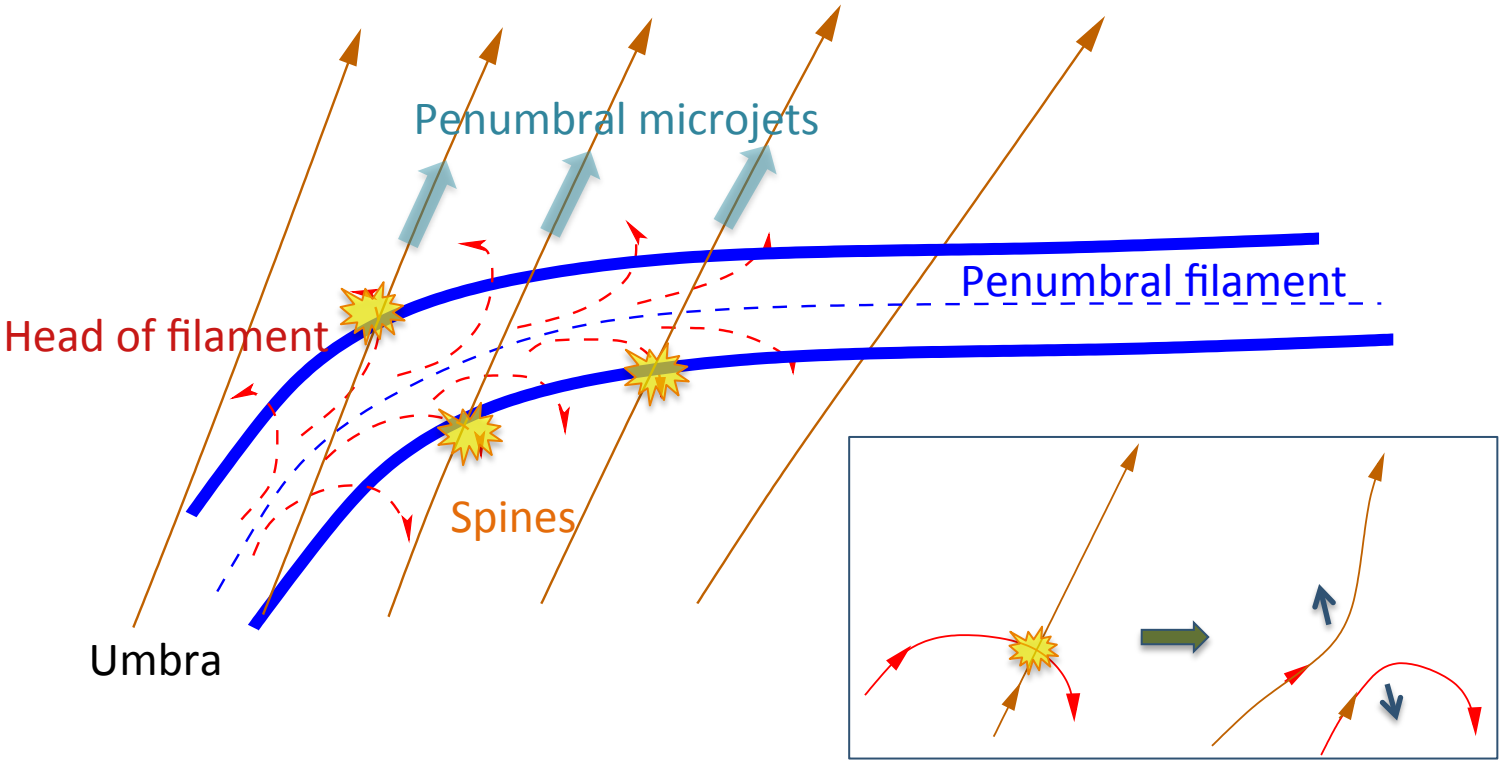



Tiwari et al., 2013, A&A




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




Tiwari et al., 2016, ApJ

## Transition-region/coronal signatures of microjets

Calculation of chromospheric thermal energy

$3/2\ nk_BTV \approx 2\times10^{16}$ J $\approx 2\times10^{23}$ erg;

$n = 10^{18}$ m$^{-3}$; $k_B \approx 1.38 \times 10^{-23}$ m$^2$ kg s$^{-2}$ K$^{-1}$ ;
$T \approx 10^4$ K; $V \approx 2000$ km $\times$ (300 km)$^2$

Of the order of that of a coronal nanoflare!

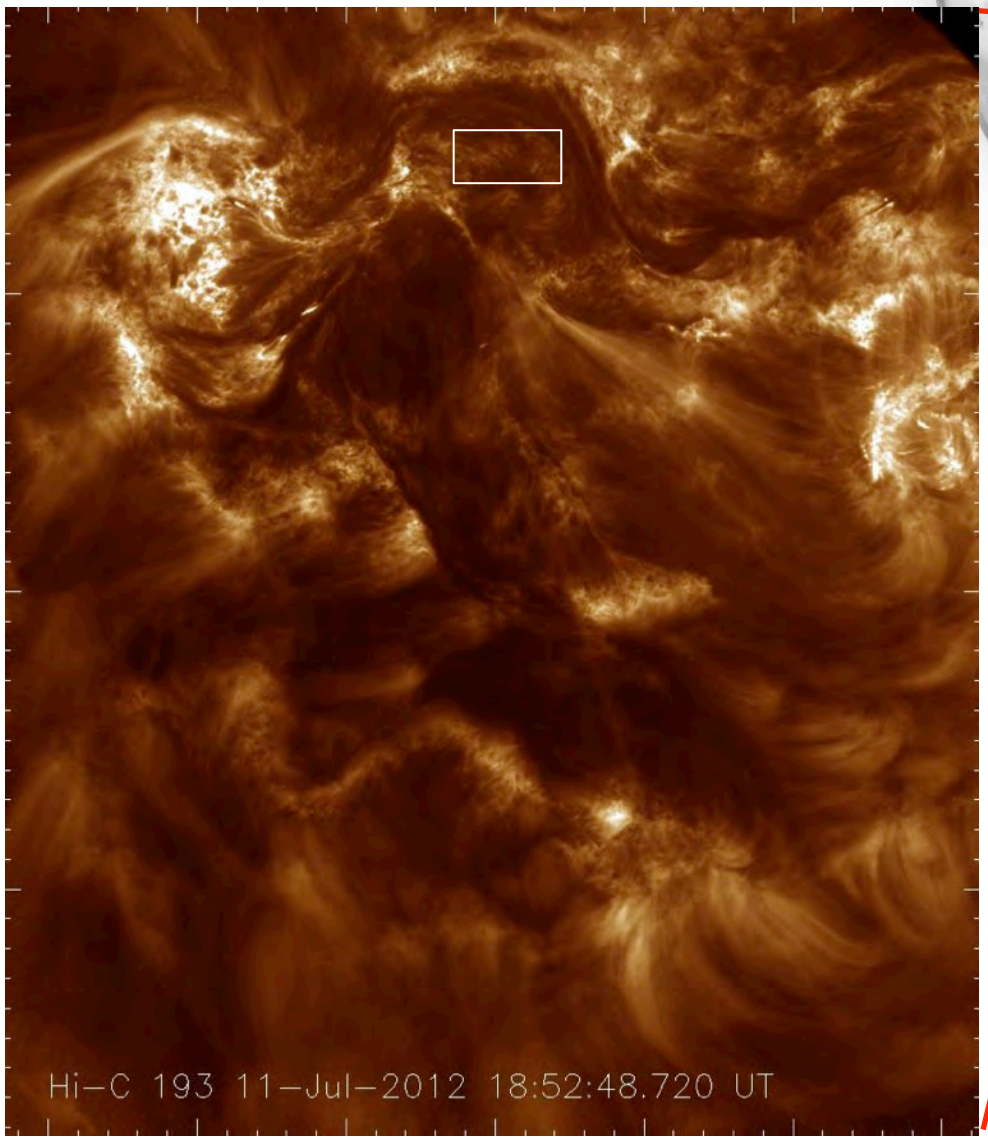
Telescope Resolution:

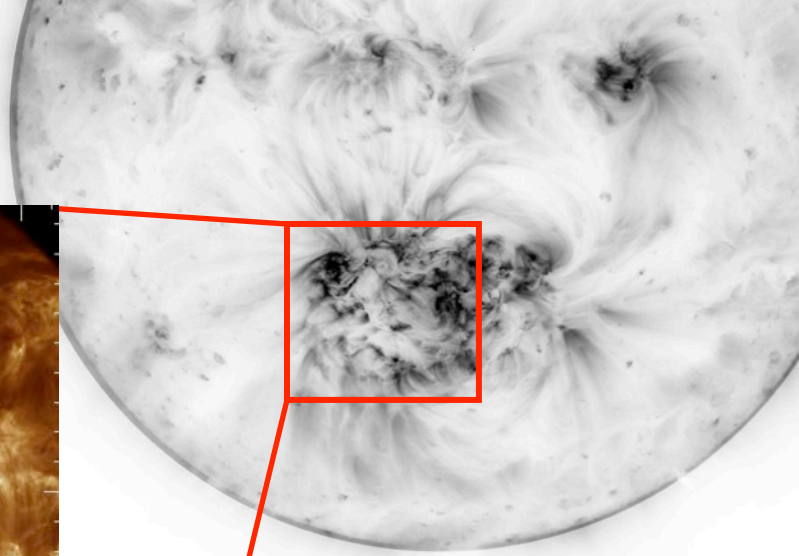
Hinode (SOT/FG): 0.2 arcsec ≈ 145 km

SDO (AIA) : 1.2 arcsec ≈ 890 km

Hi-C : 0.2 arcsec ≈ 145 km

# Hi-C Observations



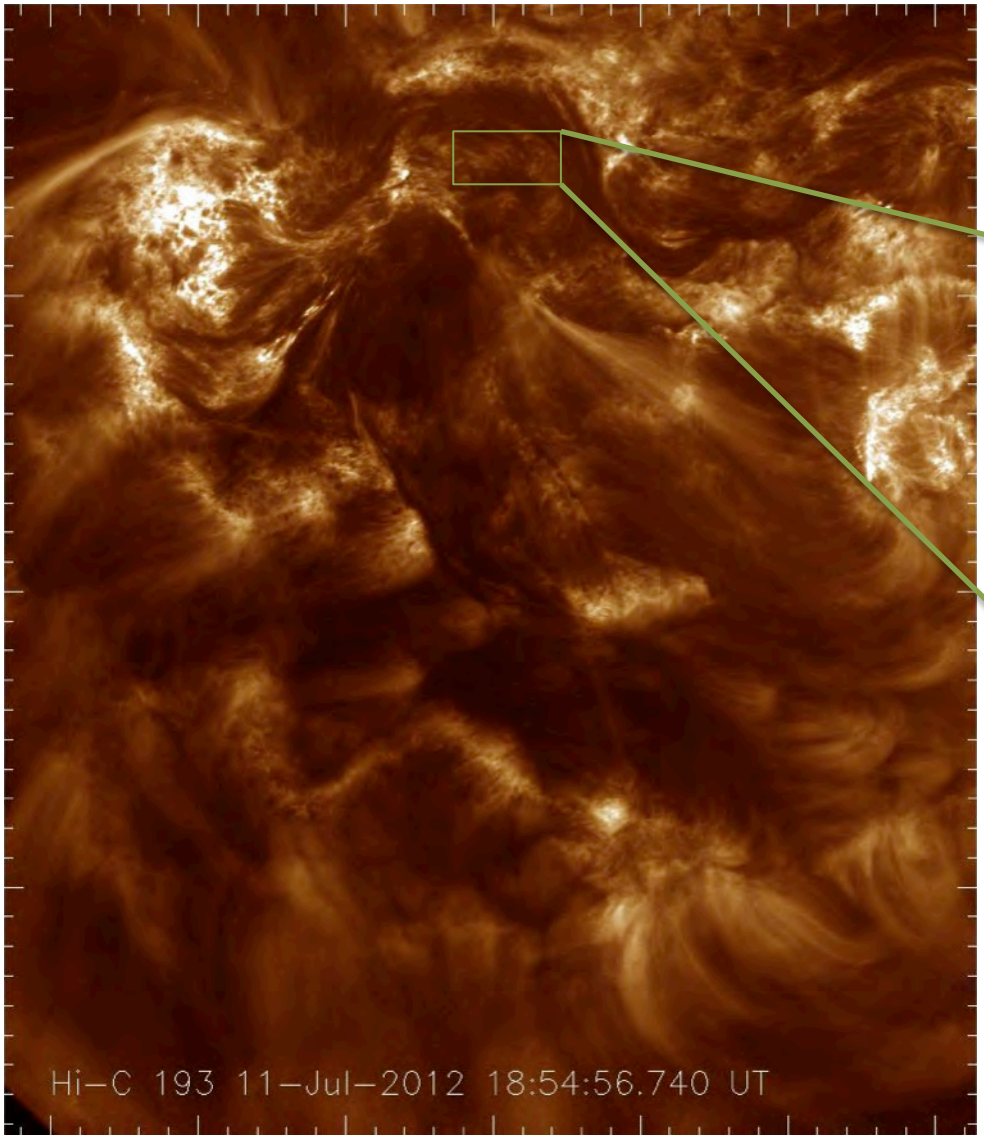



Hi-C: centered@193 Å; resolution 0.2 arcsec; cadence 5 s; ~6 min of AR 11520: Jul 11 2012, 18:51-18:57UT

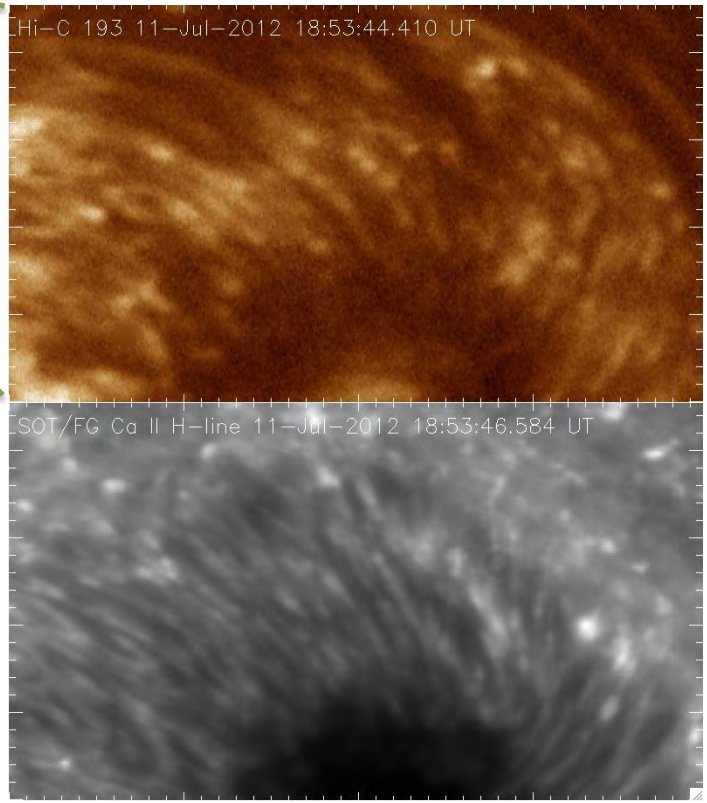
Cirtain, Golub, Winebarger et al. 2013, Nature;

Kobayashi, Cirtain, Winebarger et al, 2014, Sol. Phys.

Hi-C 193 Å



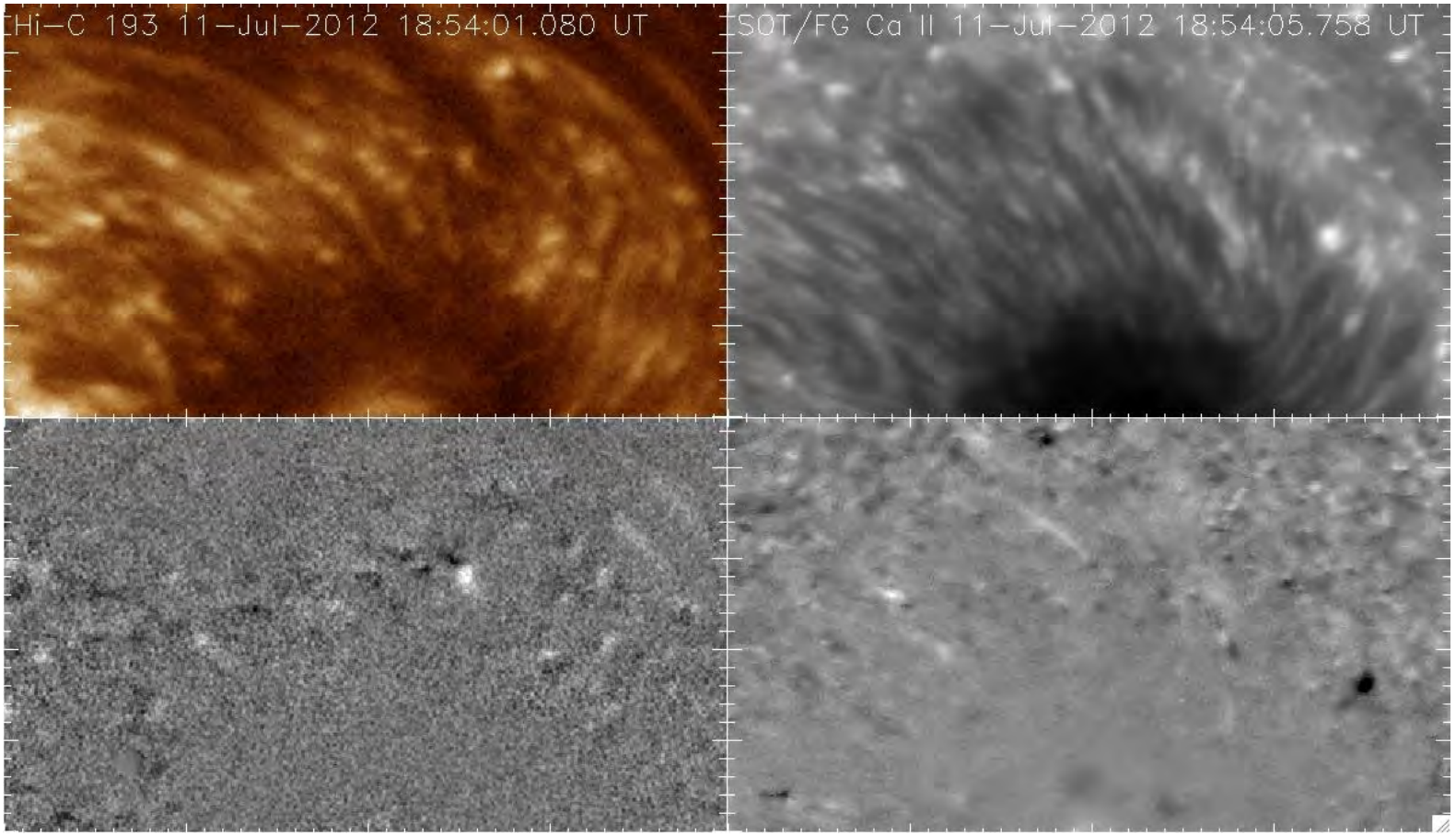

Penumbra; 18:53:44-18:55:30UT




Hinode/SOT/FG Ca II H-line

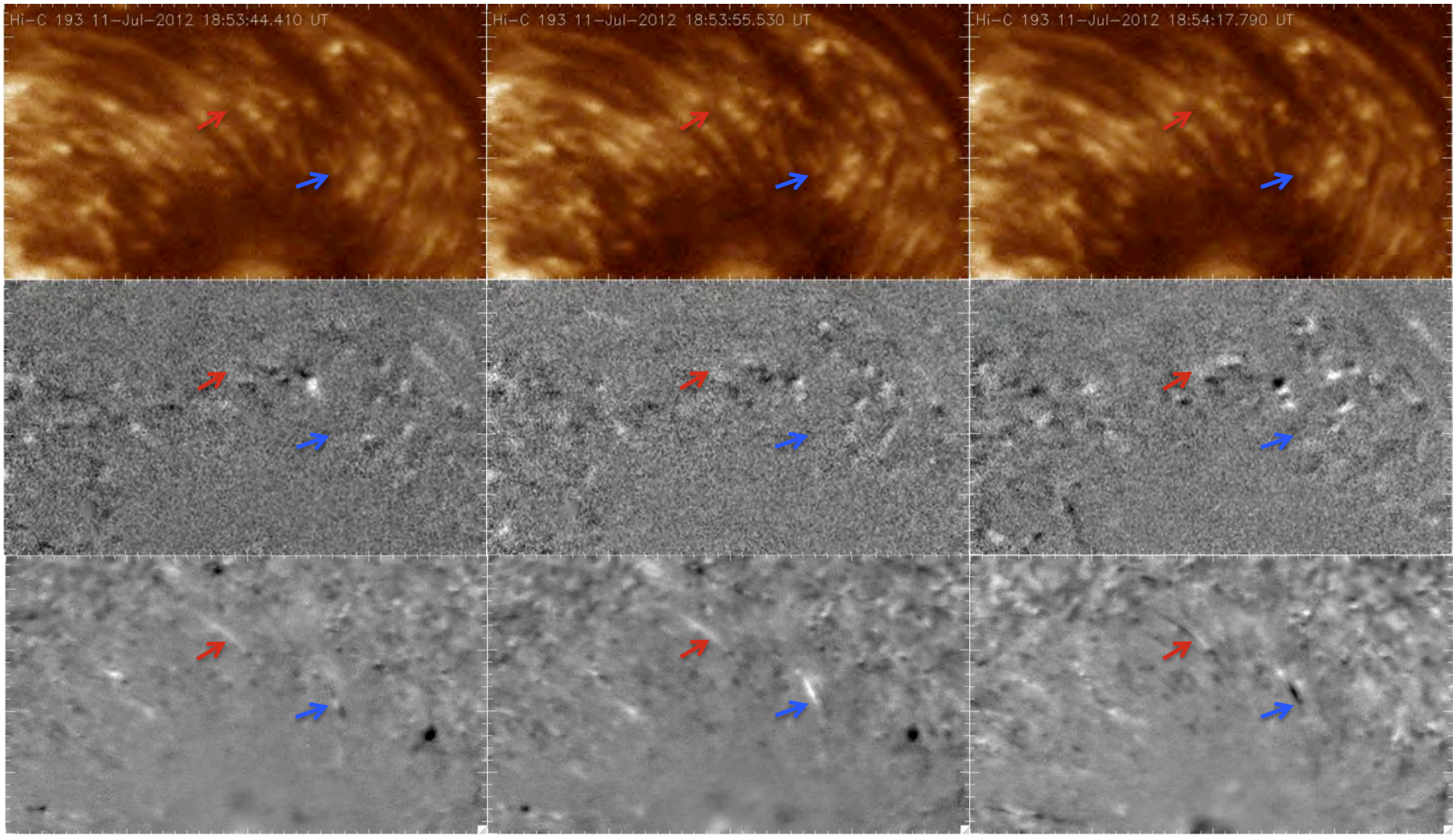
Hi-C 193 Å

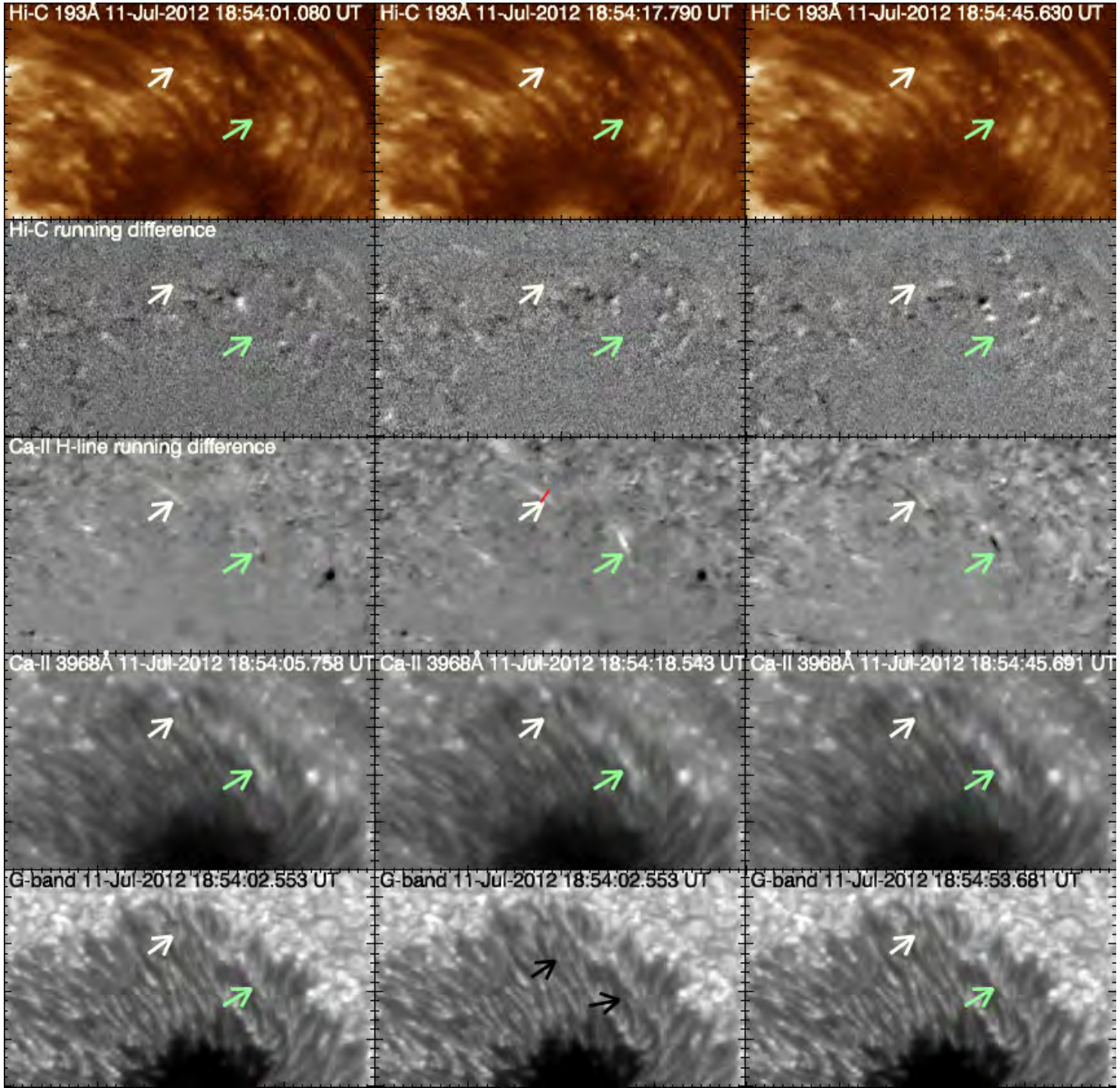
SOT/FG Ca II H-line



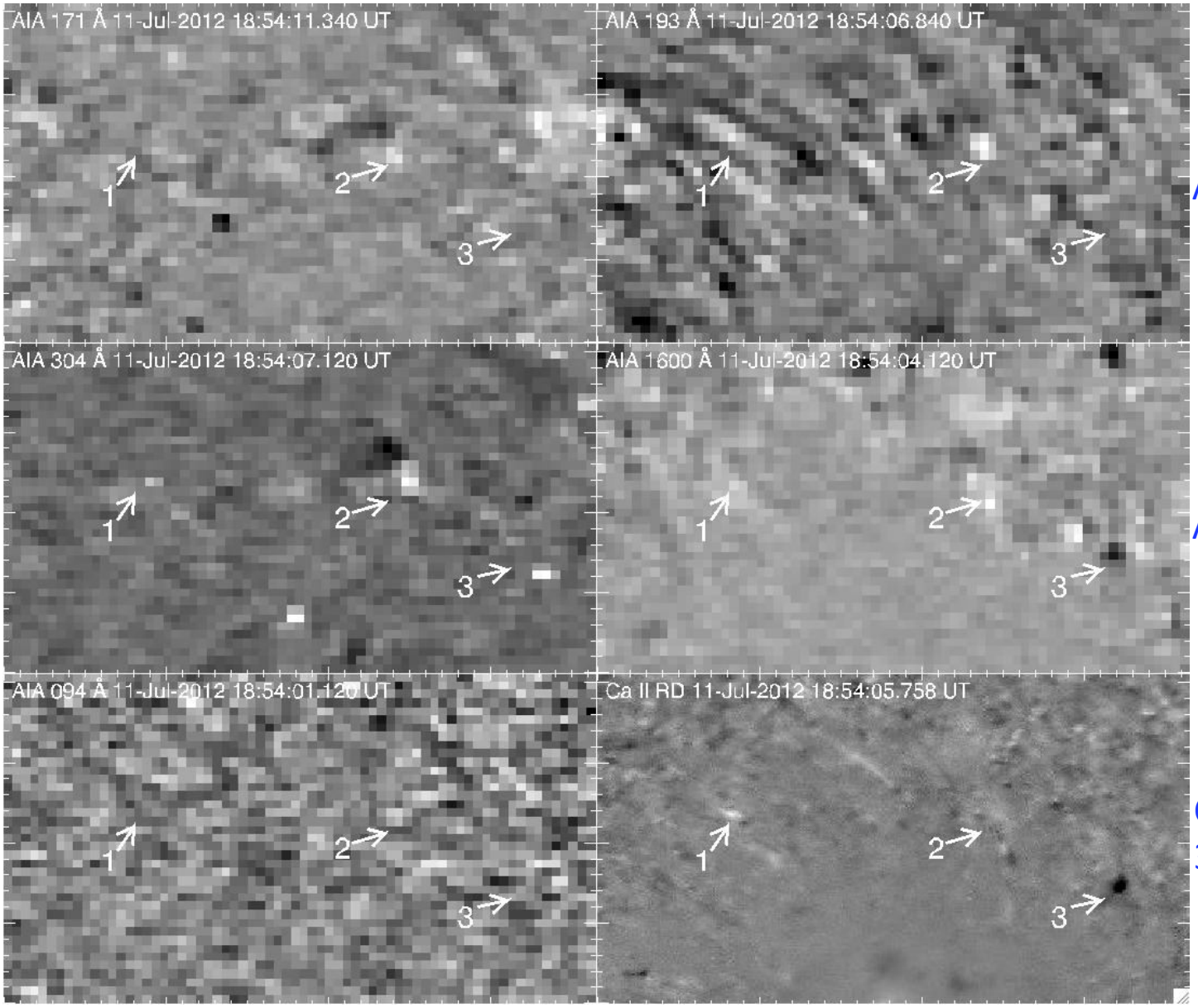

Lower frames are running differences

# Example jets




Hi-C 193Å 11-Jul-2012 18:54:01.080 UT
Hi-C 193Å 11-Jul-2012 18:54:17.790 UT
Hi-C 193Å 11-Jul-2012 18:54:45.630 UT
Hi-C running difference
Ca-II H-line running difference
Ca-II 3968Å 11-Jul-2012 18:54:05.758 UT
Ca-II 3968Å 11-Jul-2012 18:54:18.543 UT
Ca-II 3968Å 11-Jul-2012 18:54:45.691 UT
G-band 11-Jul-2012 18:54:02.553 UT
G-band 11-Jul-2012 18:54:02.553 UT
G-band 11-Jul-2012 18:54:53.681 UT

# 1 hour Ca II H line and AIA running difference movies




AIA171

AIA193

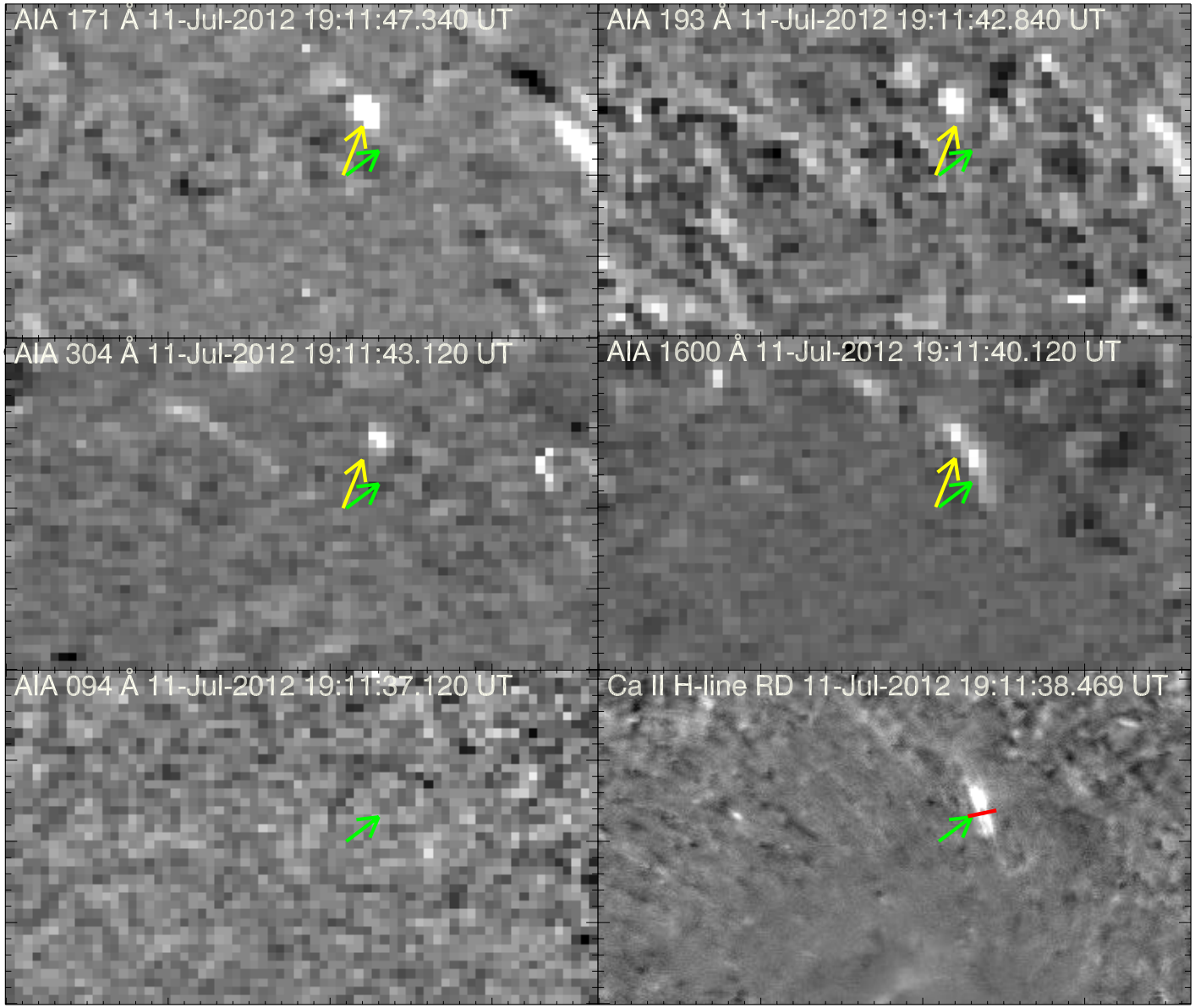
AIA304

AIA1600

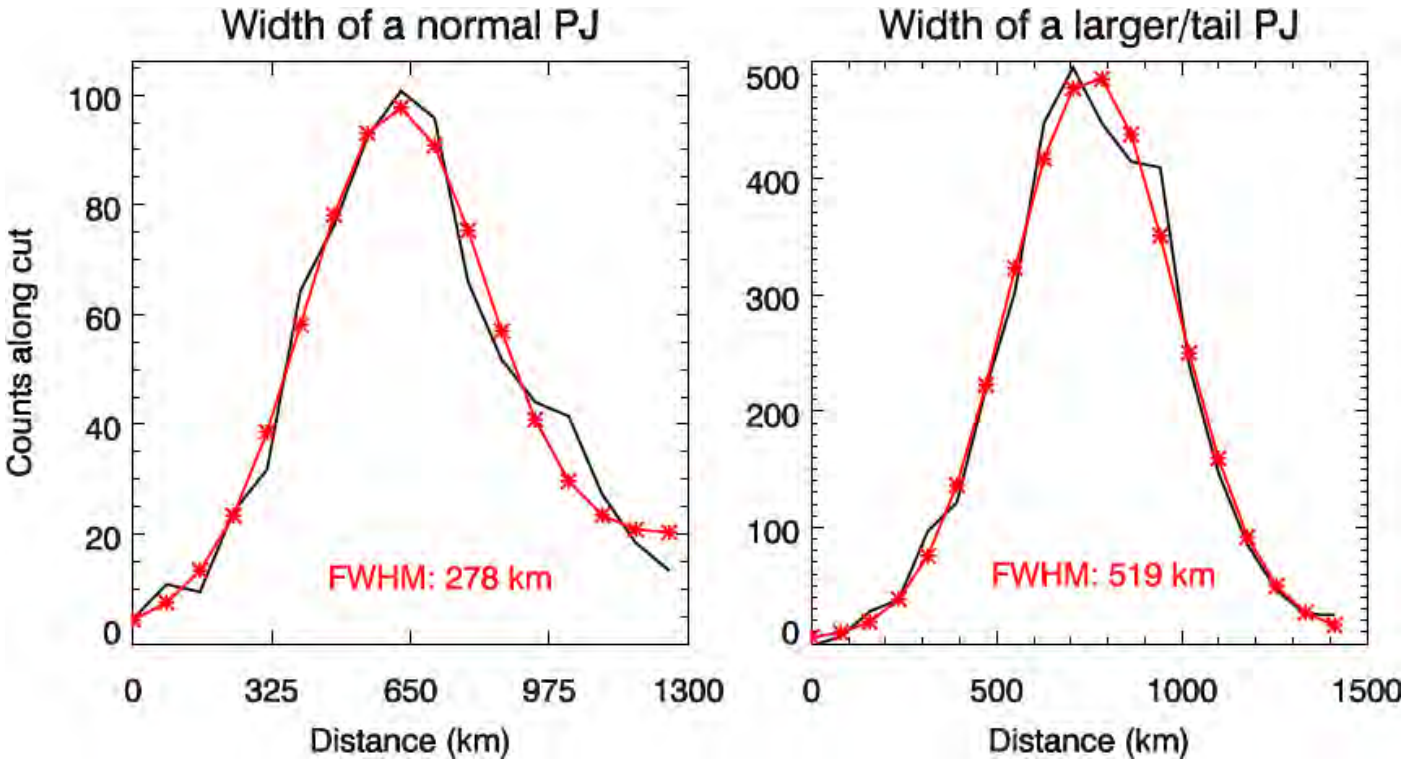
AIA 94

CaII H-line 3968

# Example of a larger jet

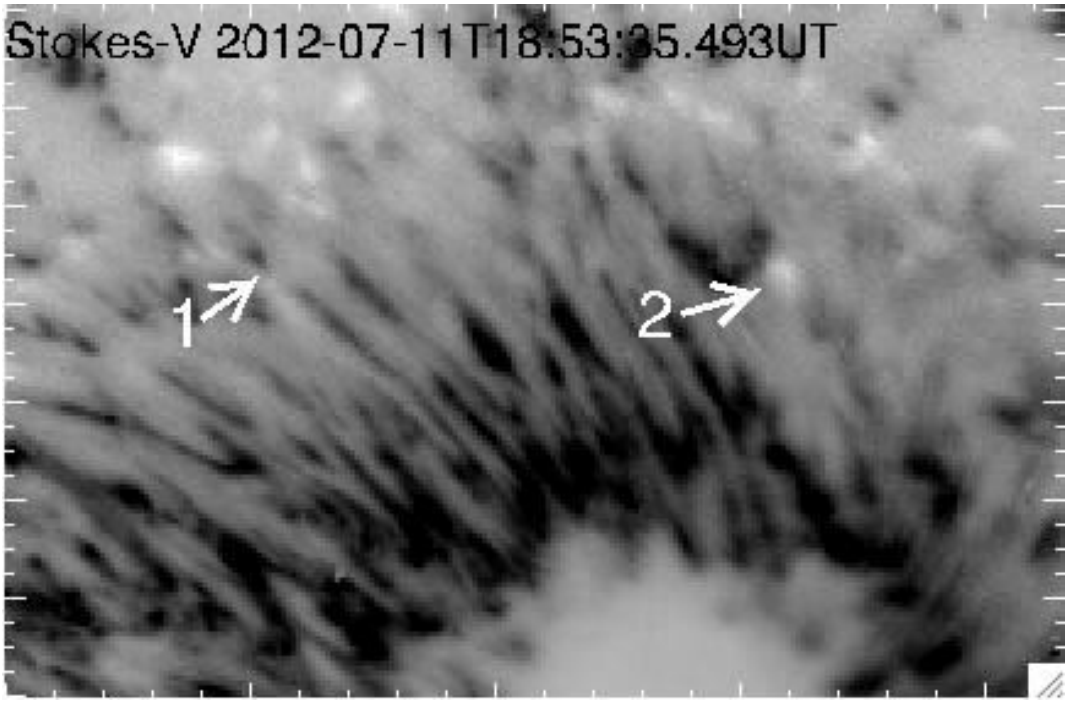


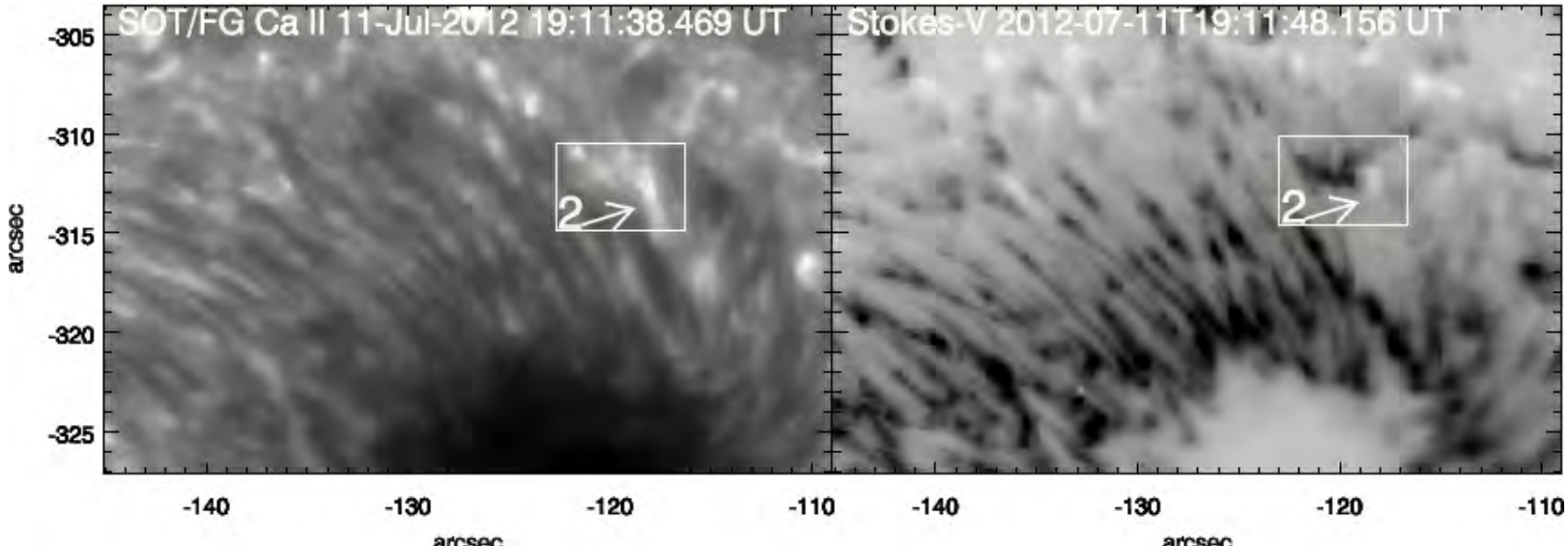
Widths of a normal jet and a larger jet using a Gaussian function fitting



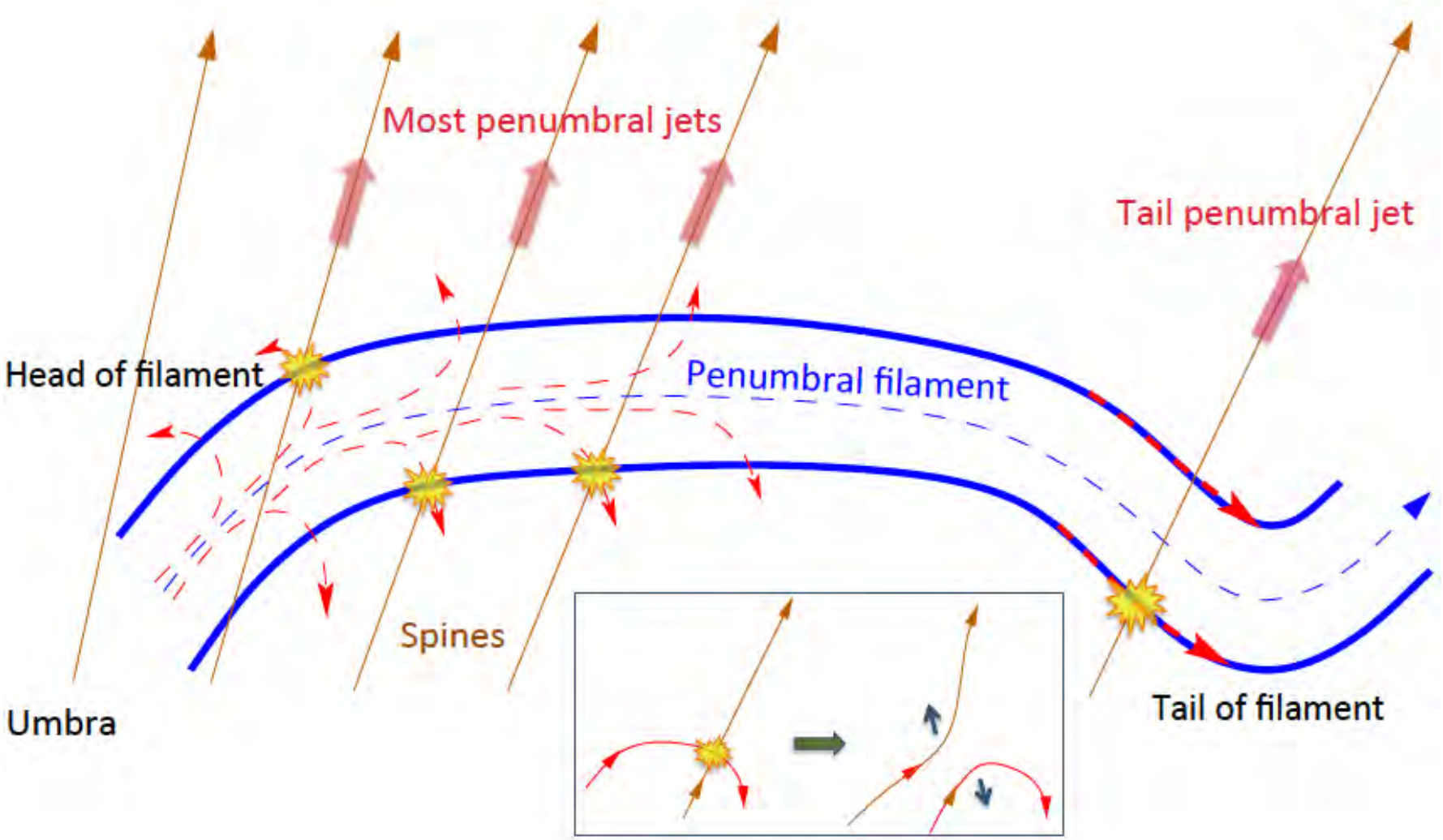

- Width of the widest jet: 600 km
- Speed of fastest jet found: 250 km/s
- Length: 420 km (subject to projection)

Stokes-V images (equivalent to LOS magnetograms)



## Cartoon diagram depicting the formation mechanism of penumbral jets



# Summary

- Penumbral microjets form a la Katsukawa et al., 2007 but by reconnection of oppositely directed field (Tiwari et al. 2016)
- Normal microjets show hardly any TR/coronal signature
- Larger jets, which flash repeatedly, show TR signatures; opposite polarity field patches are observed underneath those locations
- Need more TR/coronal observations at a resolution similar to that of Hi-C or better to verify these results.

***Thanks!***