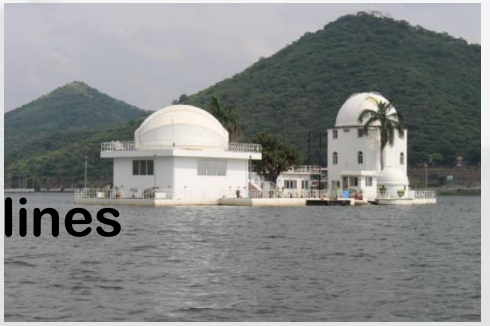
LECTURE – 2

SUNSPOT LIGHT BRIDGES – Upper Atmospheric Activity & Transients

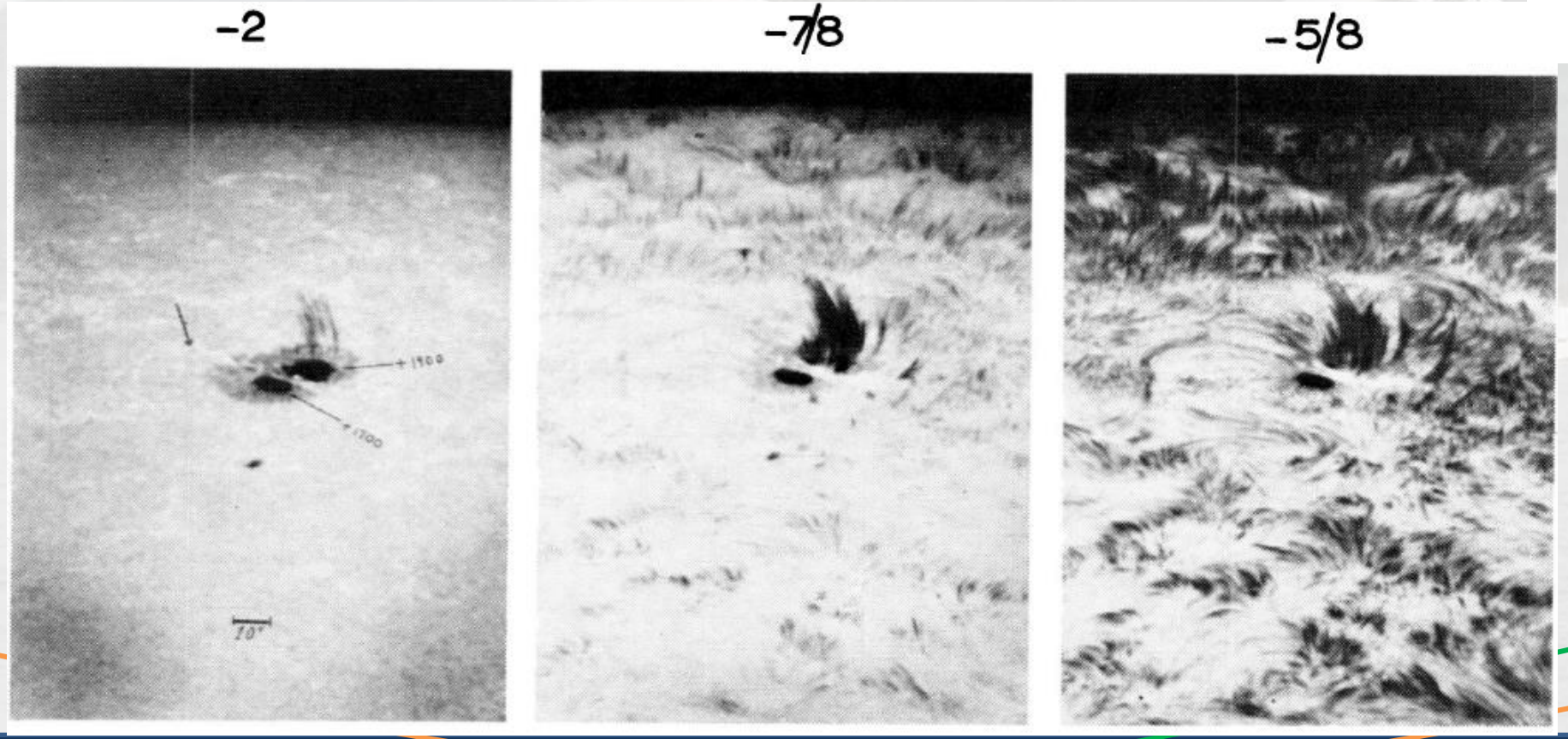
Rohan Eugene Louis

SURGES IN LBs



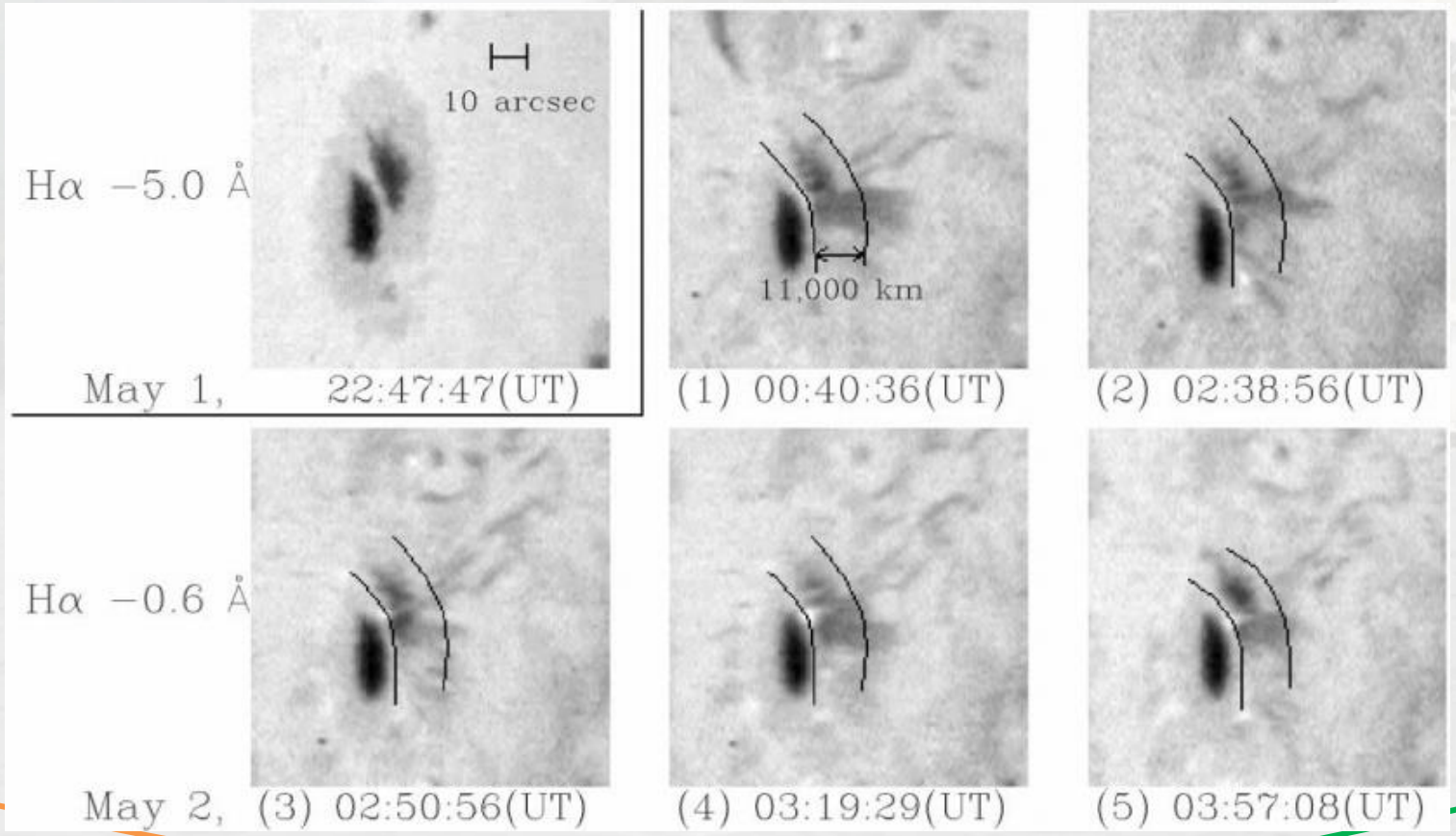
- Filamentary/Hair-like structures best seen in chromospheric lines
- Surges occur in regions associated with flux change
- Related to emergence of magnetic field

Roy 1973



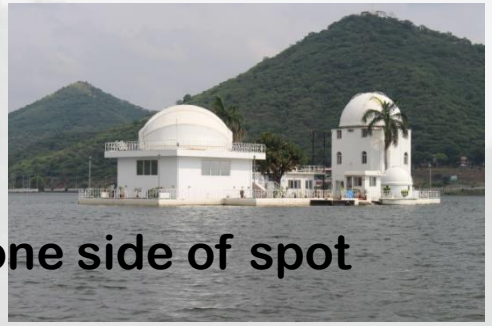
SURGES IN LBs

- Recurrent and intermittent surges, proj. speeds of 50 km/s
- Coincide with TRACE 171 Å brightenings

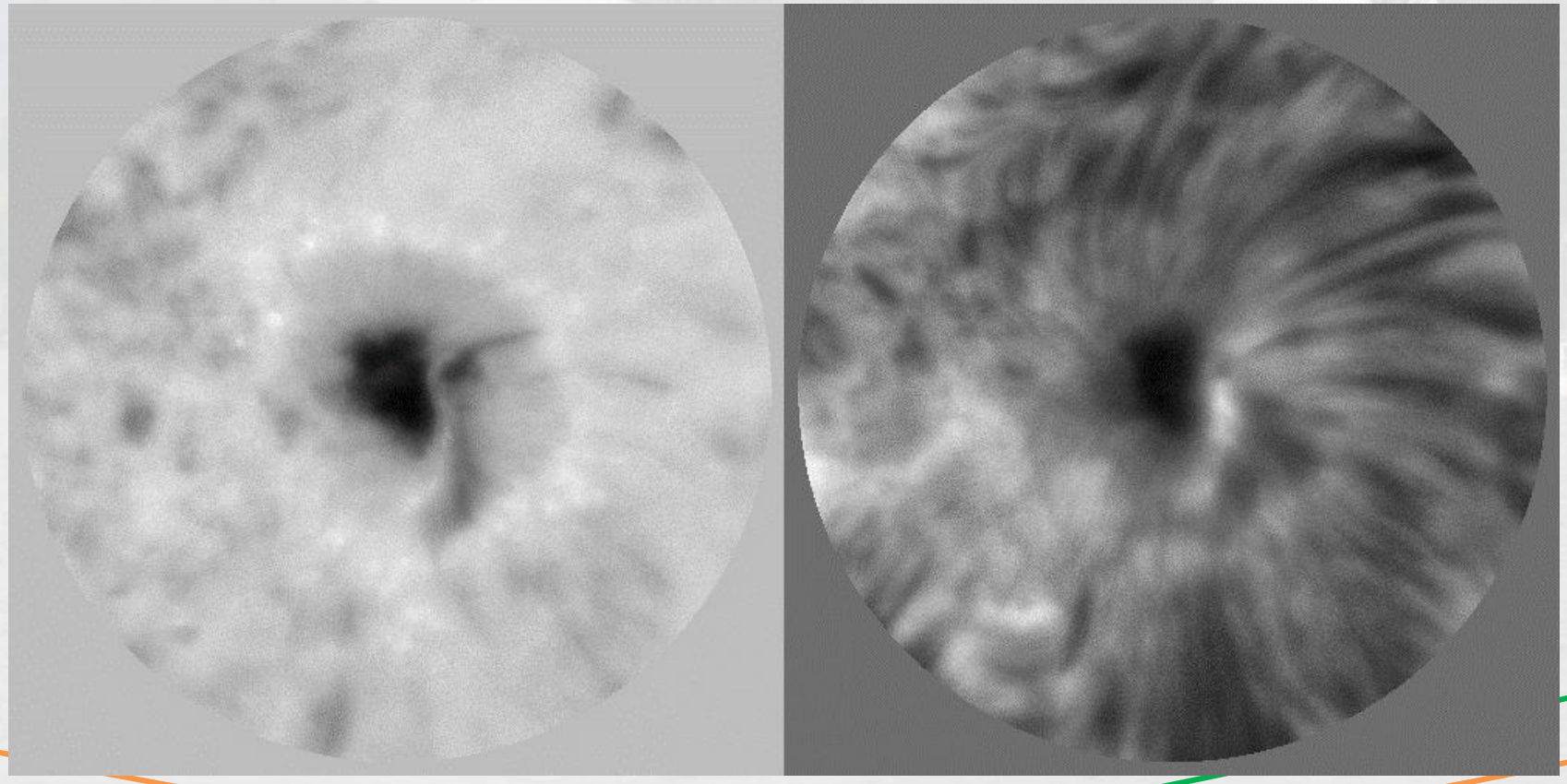


Asai et al. 2001

DYNAMICS OF SURGES

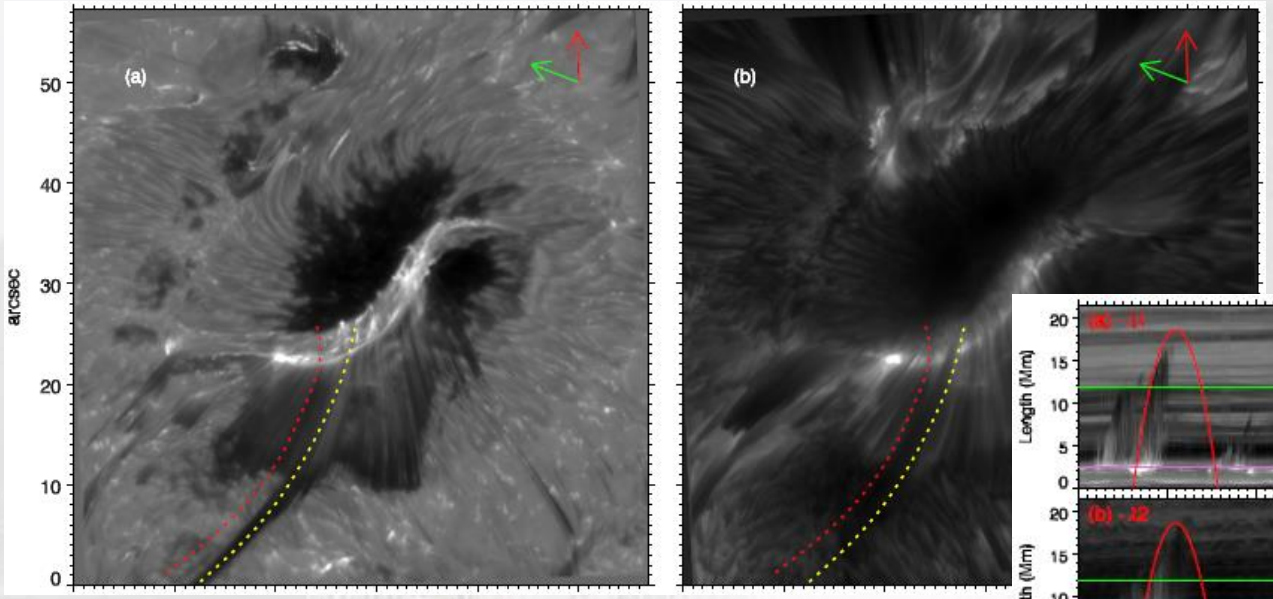


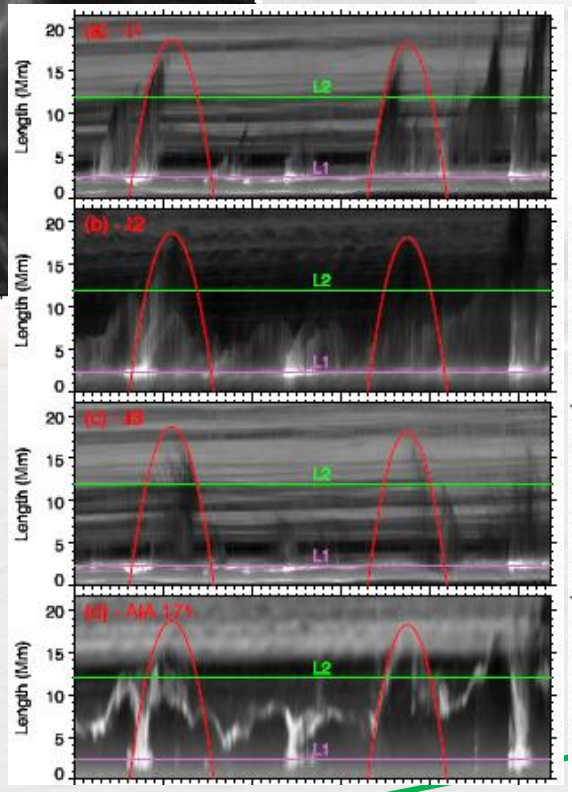
- Off-band chromospheric images show surges being launched to one side of spot
- Appear to move bodily from one end to other
- Rise and fall back to LB as they evolve

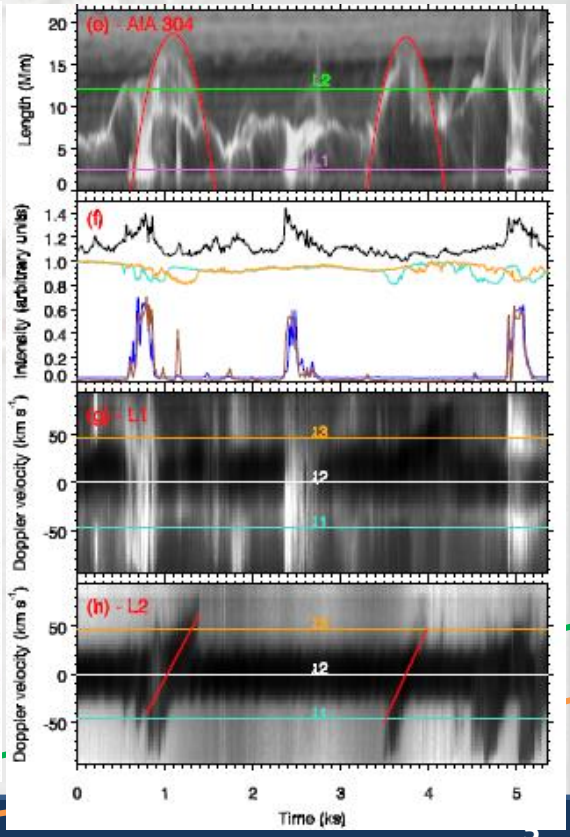


DYNAMICS OF SURGES

Robustini et al. (2016)

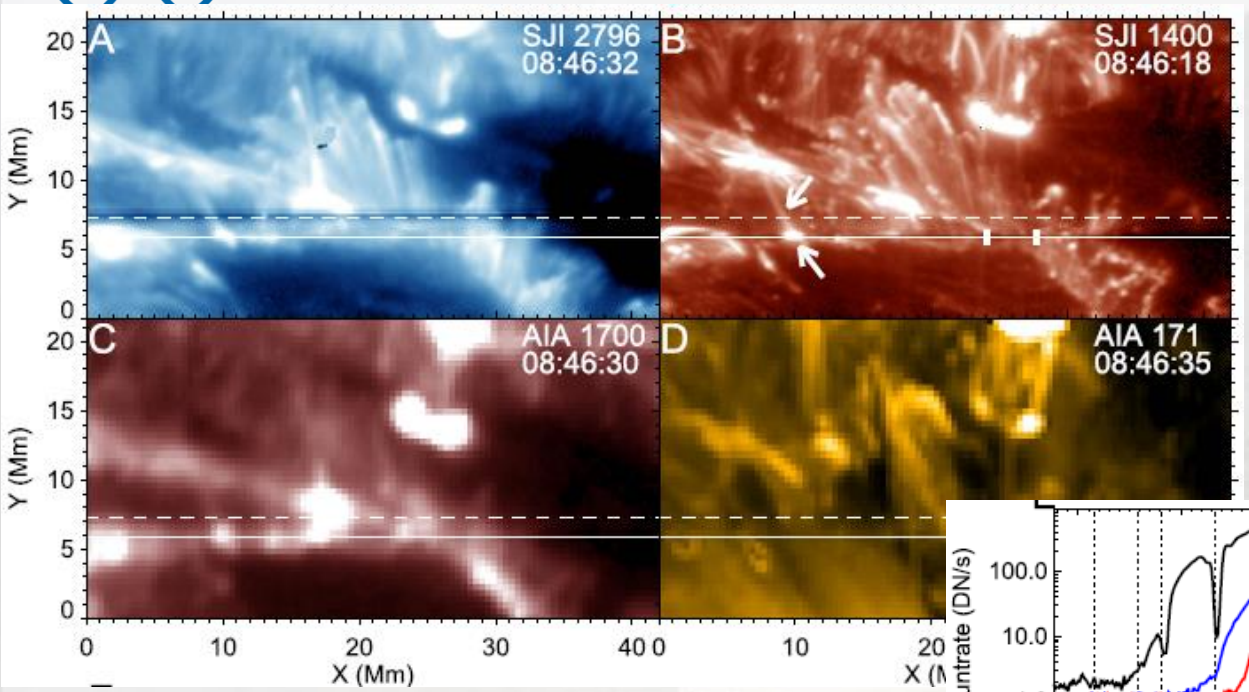




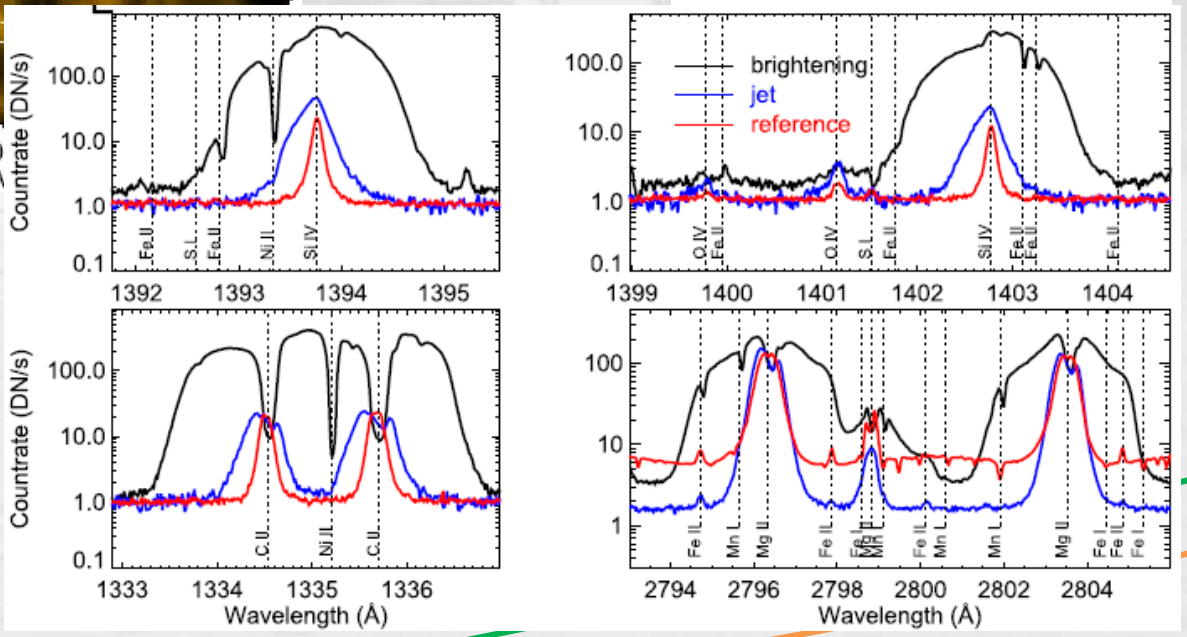


- Surges driven ballistically decelerate due to solar gravity
- Base of surges show impulsive brightenings
- AIA images show jet fronts to be brighter
- Heated to Transition Region temp.

DYNAMICS OF SURGES

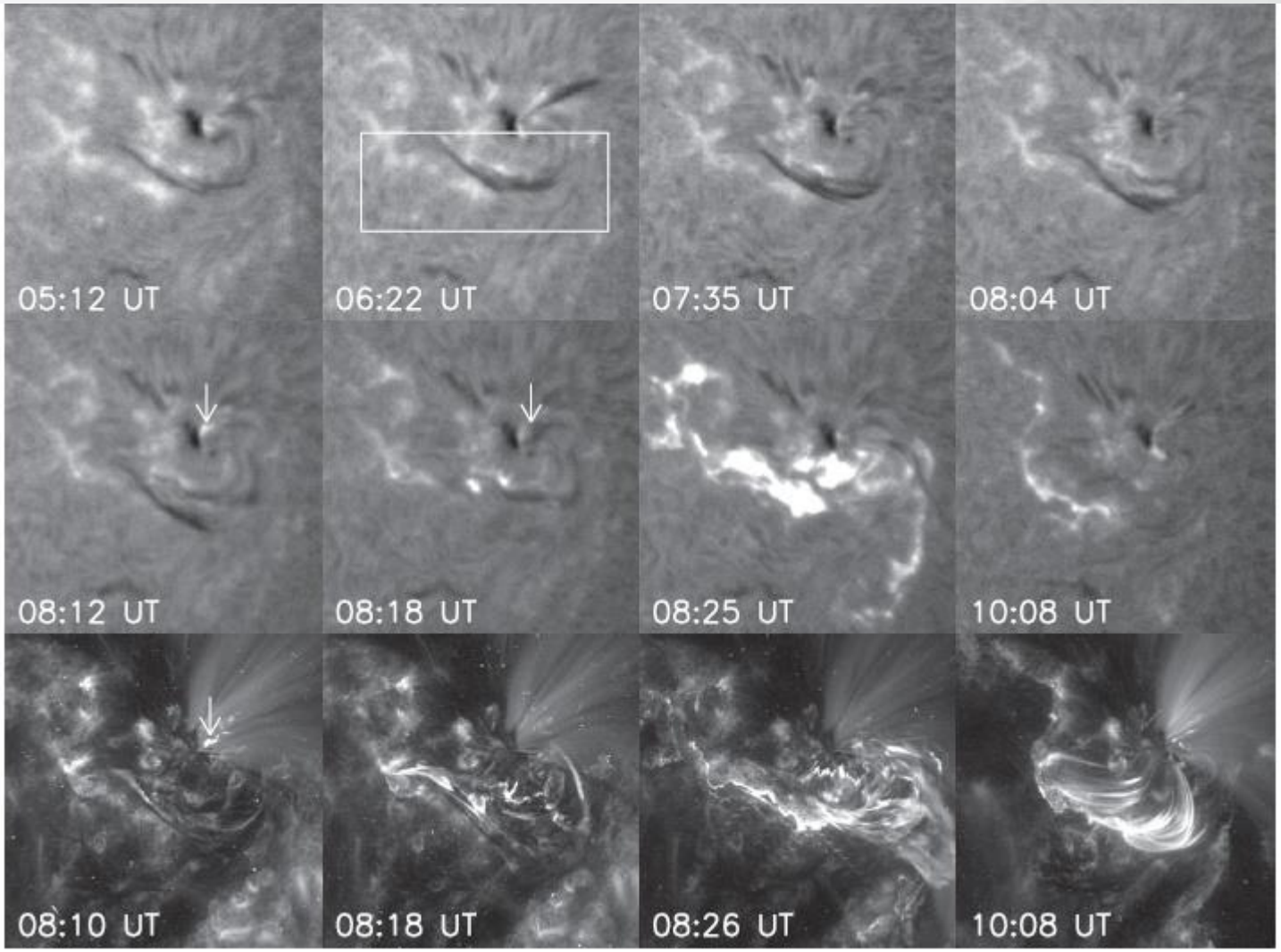


Tian et al. (2018)



- Jets heated to 70,000 K
- Broad, intense spectra, superposed with absorption lines
- Hot plasma resides below a cooler atmosphere
- Photospheric driver(s) that render phenomena homologous???

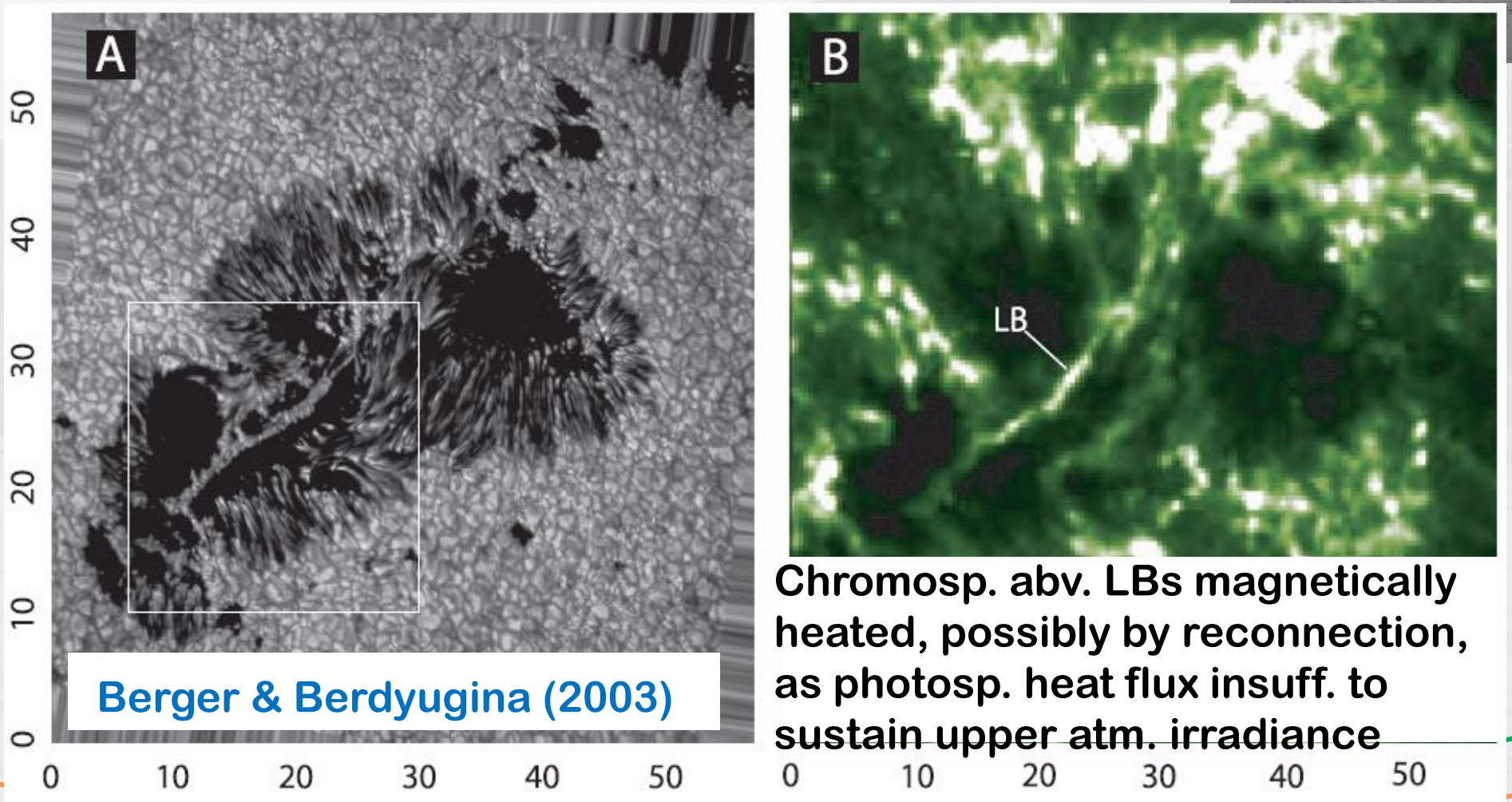
FILAMENT ERUPTION



- Eruption of AR filament triggered by recurrent surge activity over LB
- LB canopy possibly assoc. with global magnetic topology of AR

Guo et al. (2010)

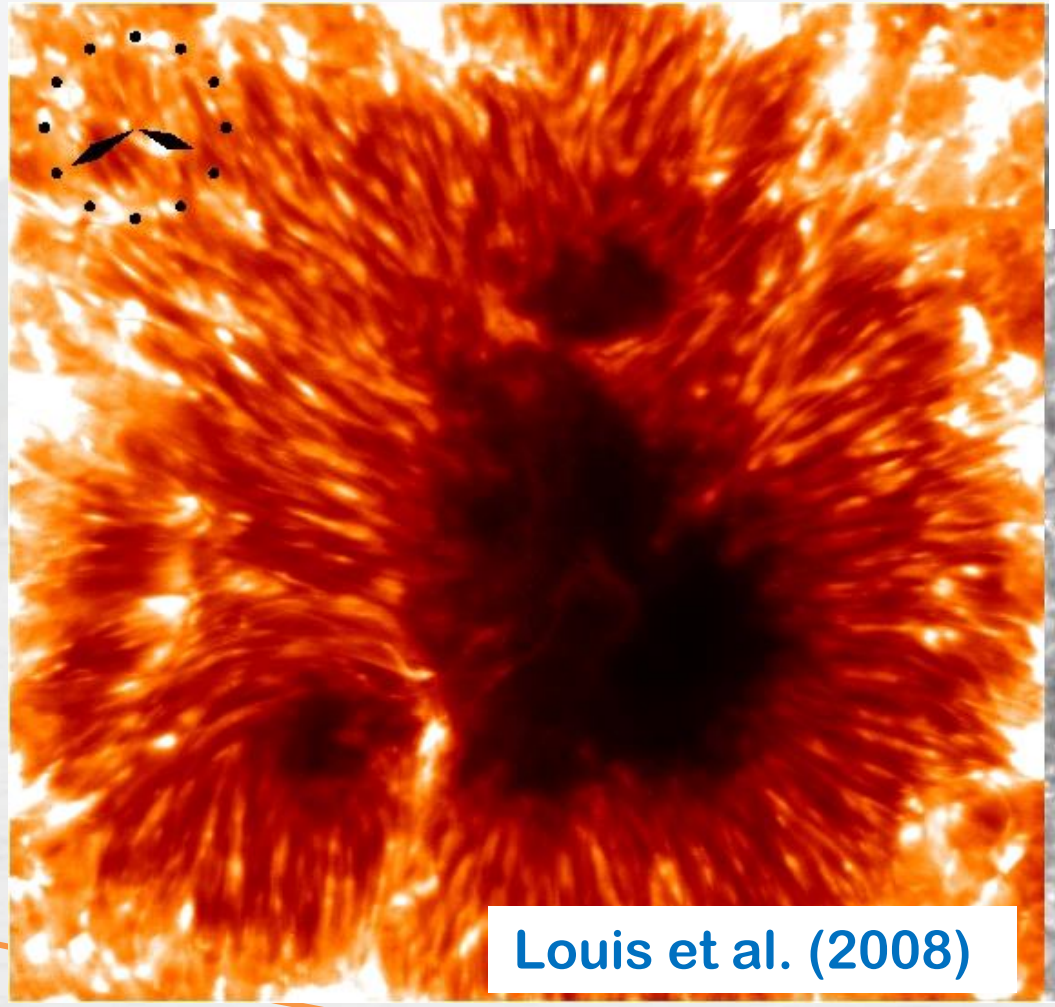
BRIGHTNESS ENHANCEMENTS & FLARE RIBBON OVER LB



Berger & Berdyugina (2003)

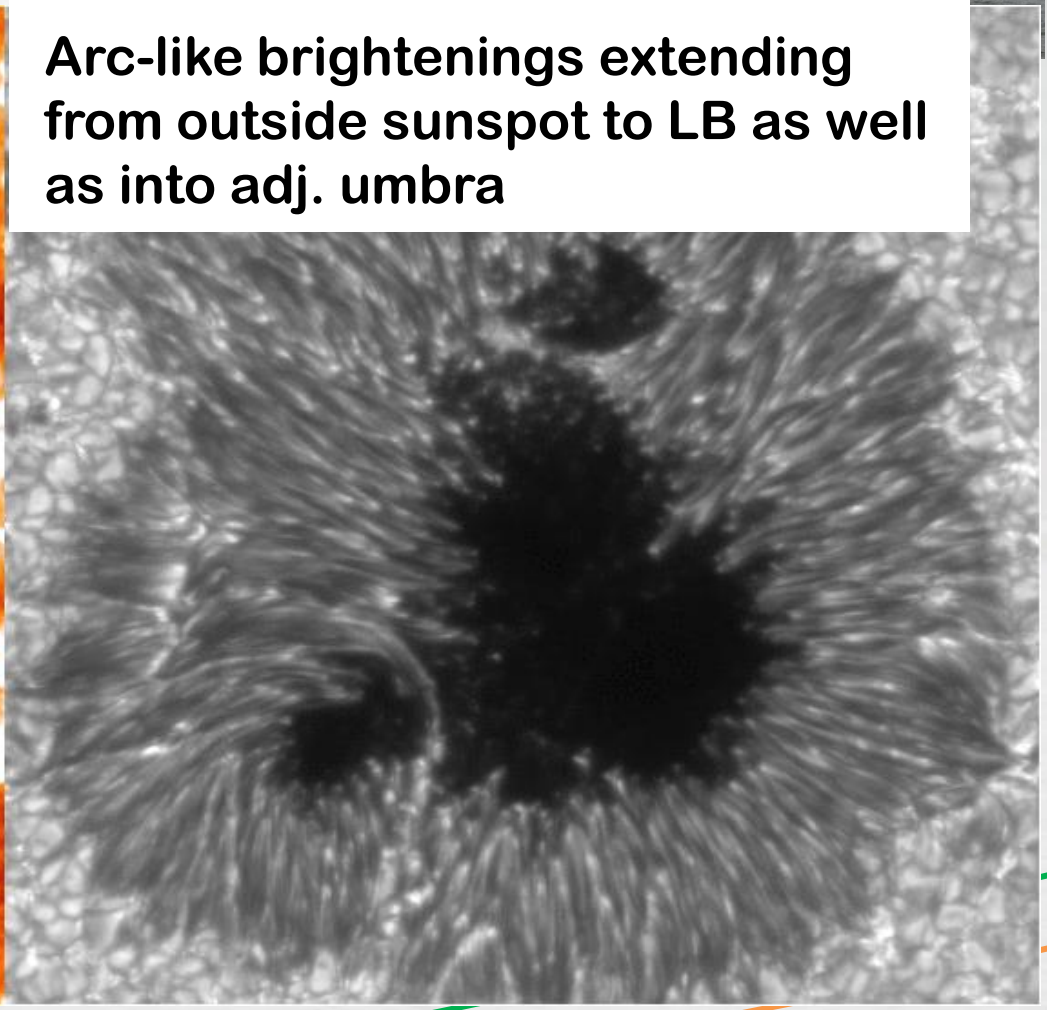
Chromosp. abv. LBs magnetically heated, possibly by reconnection, as photosp. heat flux insuff. to sustain upper atm. irradiance

BRIGHT CHROMOSPHEIRC THREADS

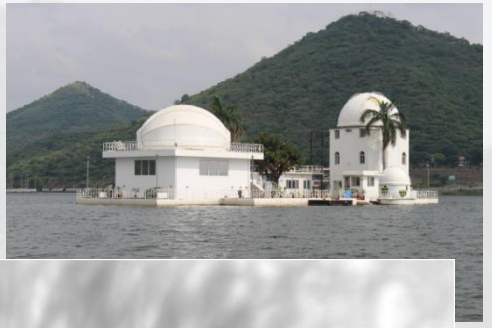


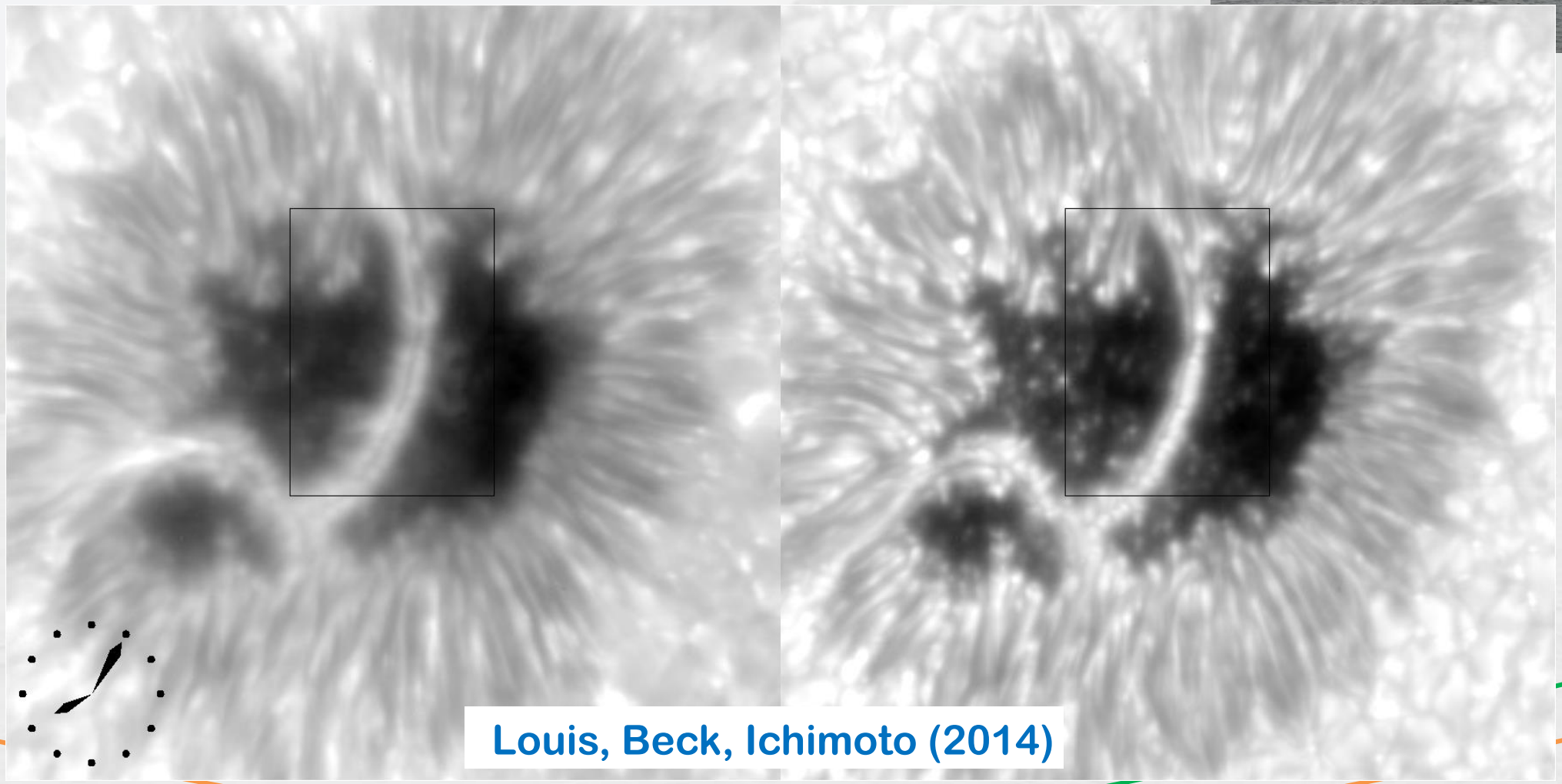
Louis et al. (2008)

Arc-like brightenings extending from outside sunspot to LB as well as into adj. umbra



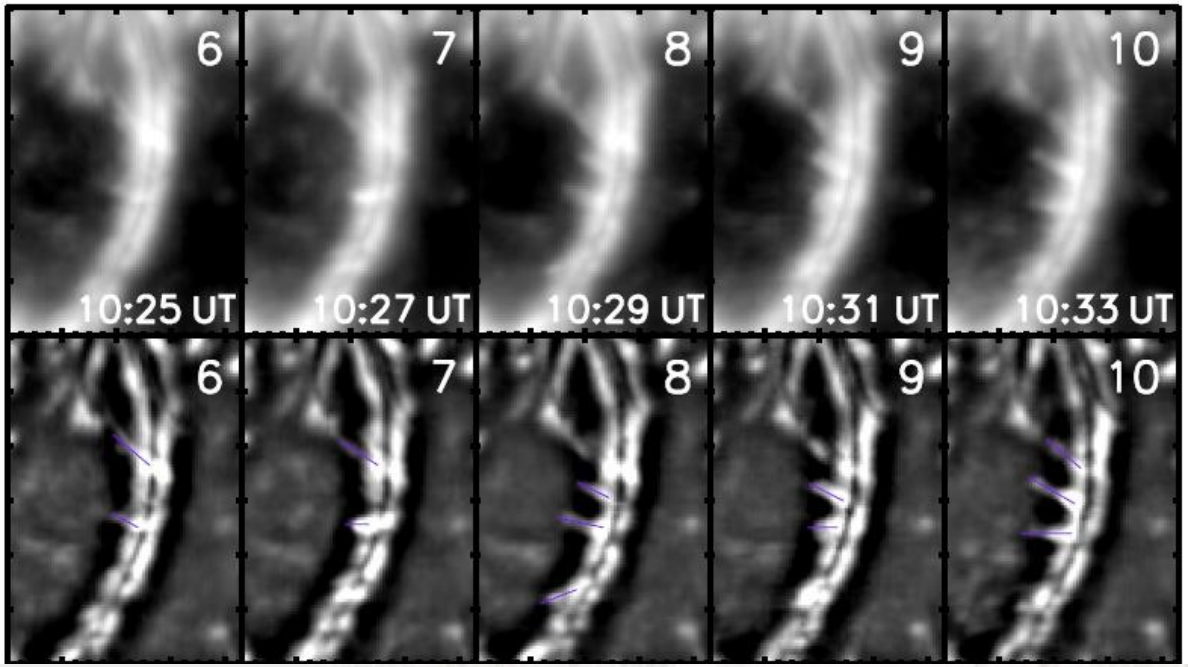
SMALL-SCALE JETS…More eg.

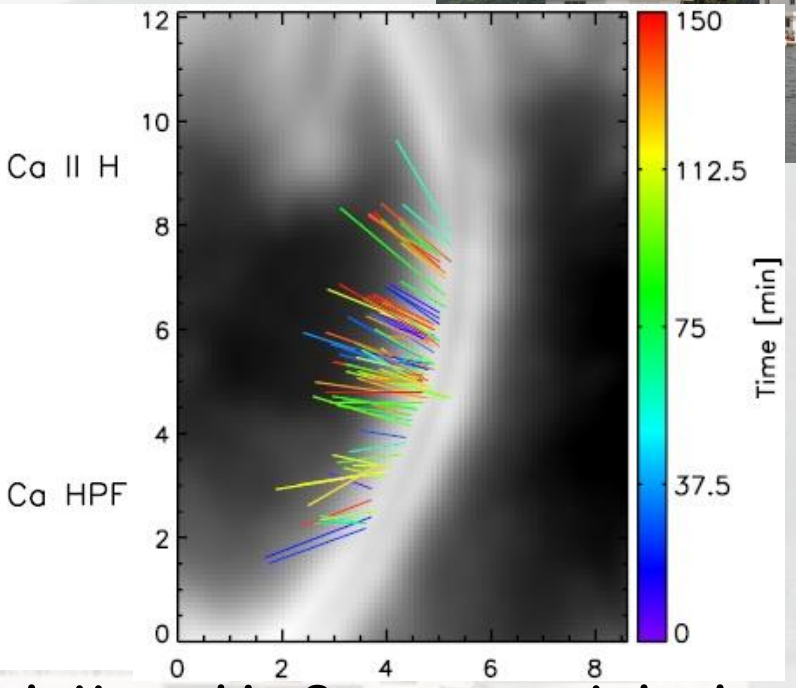


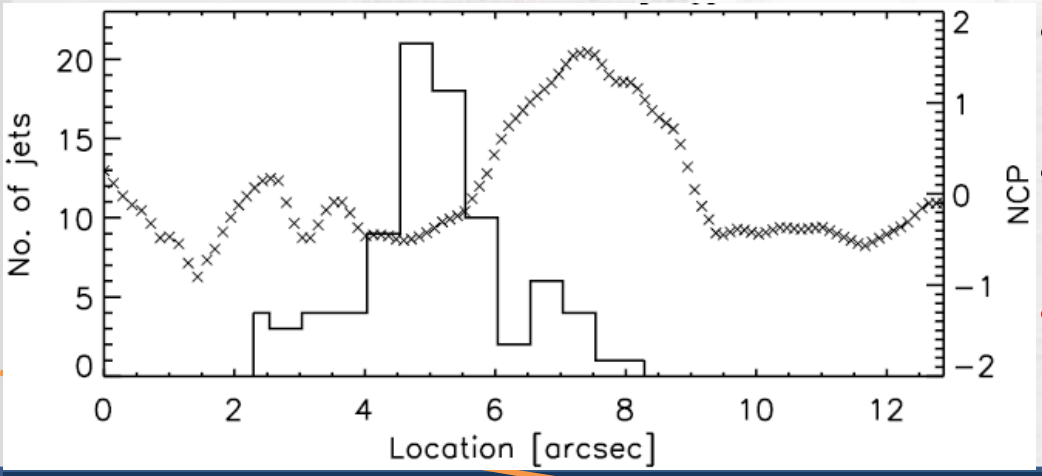


Louis, Beck, Ichimoto (2014)

SMALL-SCALE JETS





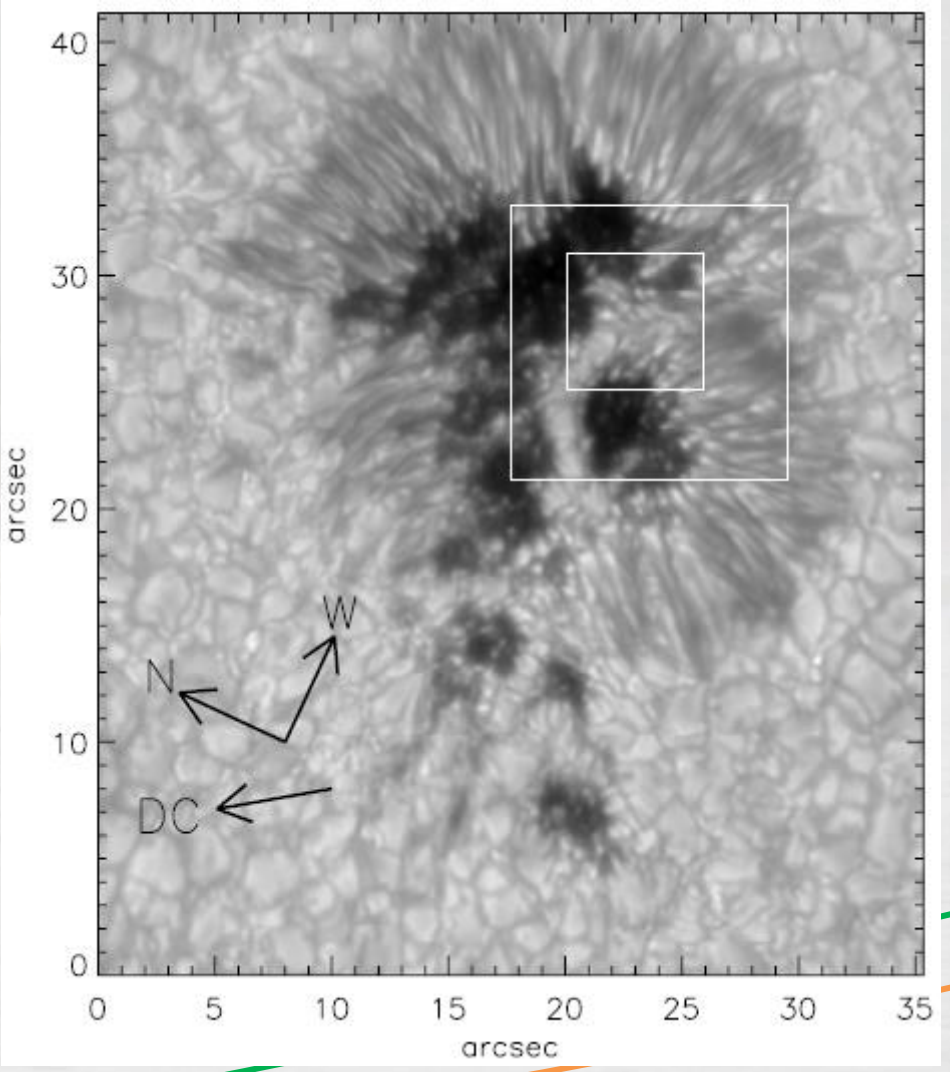


- Jets cluttered in 2arcsec patch close to area of enhanced NCP
- Offset from photo. chromo.height diff. with viewing angle
- Images do not reveal real pic., need for spectro-polarimetry in photo., chromos. with high spatial & temporal res.

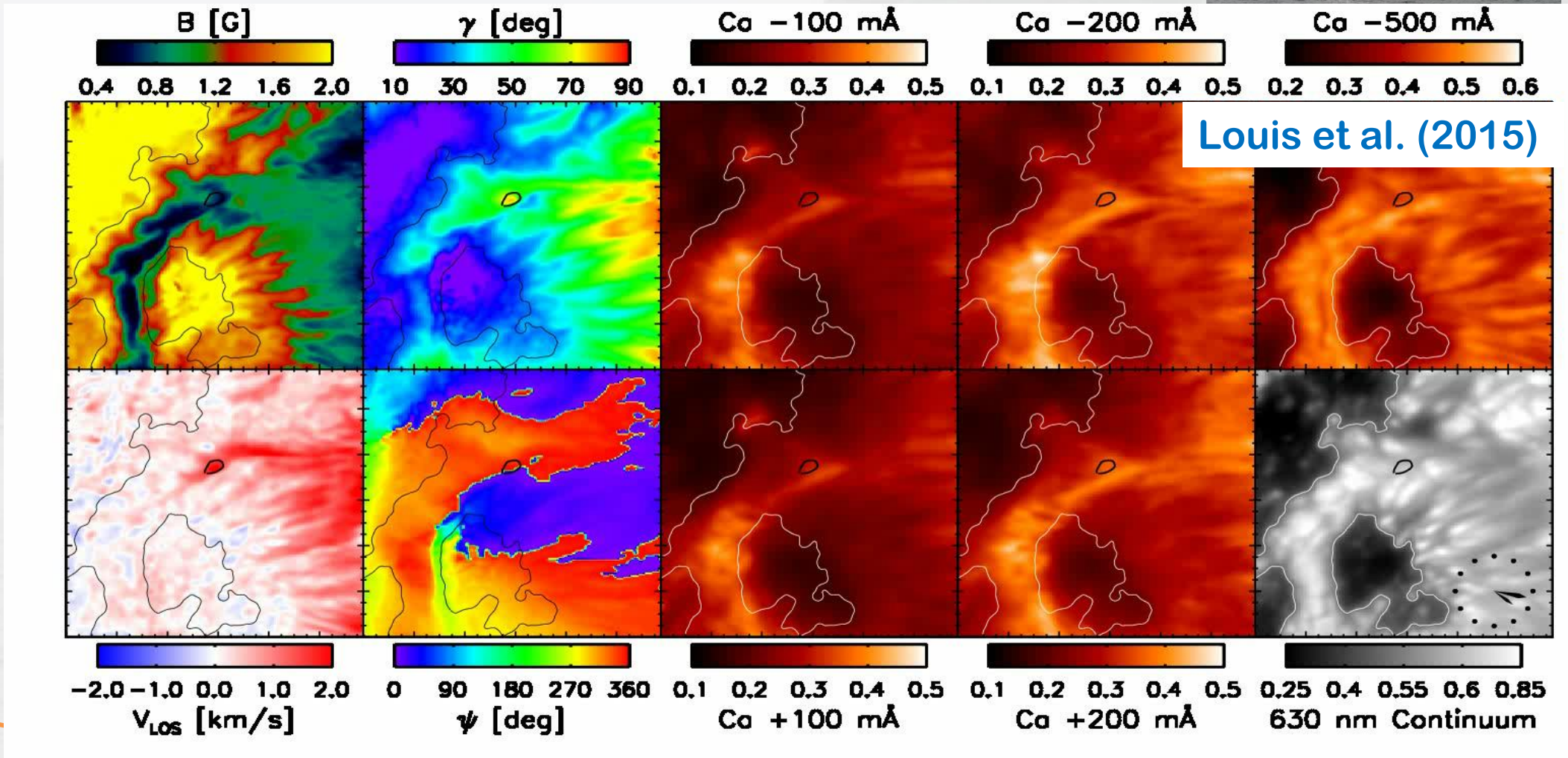
EXPL. PHOTOS. – CHROM. RELATION

- High-res SST/CRISP obs.
- Narrow band images in Fe I 630 nm, Ca II 854 nm
- Sunspot in AR 11024
- 2009 July 5, Θ = 33°

- 1k x 1k images, 0.059"/pixel
- 31 wavelength points Fe lines
- Sampling 4.8 pm
- 17 wavelength points Ca line
- Sampling 10.0 pm



SMALL-SCALE EMERGENCE

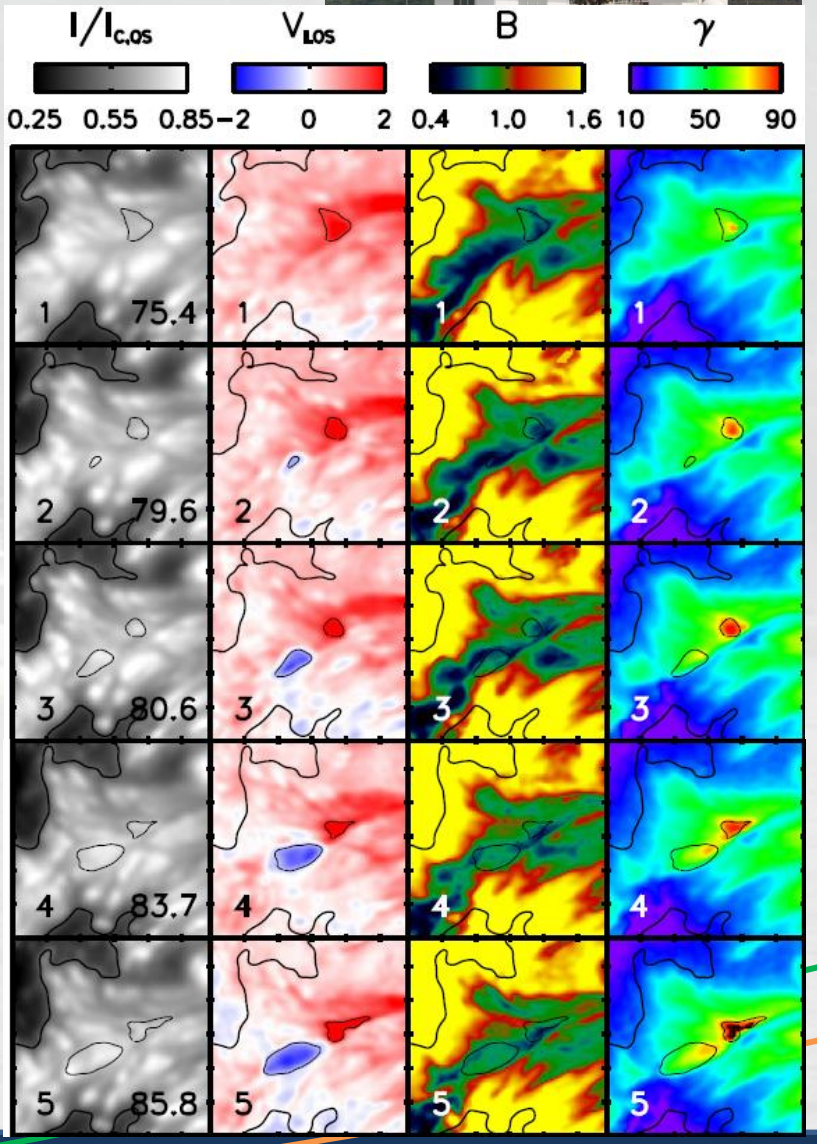


EVOLUTION OF BLUE-SHIFTS

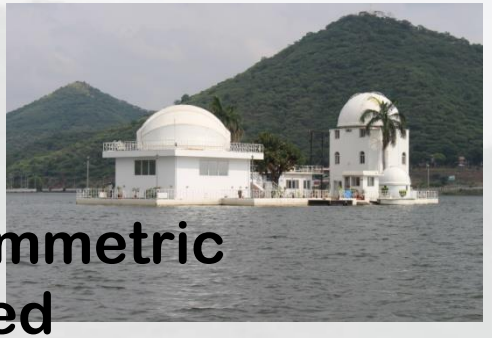
- Blueshifts of 2 km/s next to strongly redshifted patch
- BSP coincides elongated granule

- B increases ≈ 400 G, inclination increases by 25˚ nearly horizontal
- BSP & RSP have opposite polarity
- Both patches remain close to one another, T ≈ 25 min

- Chromospheric brightenings over both patches 17 min after BSP
- Brightenings persist till end of sequence

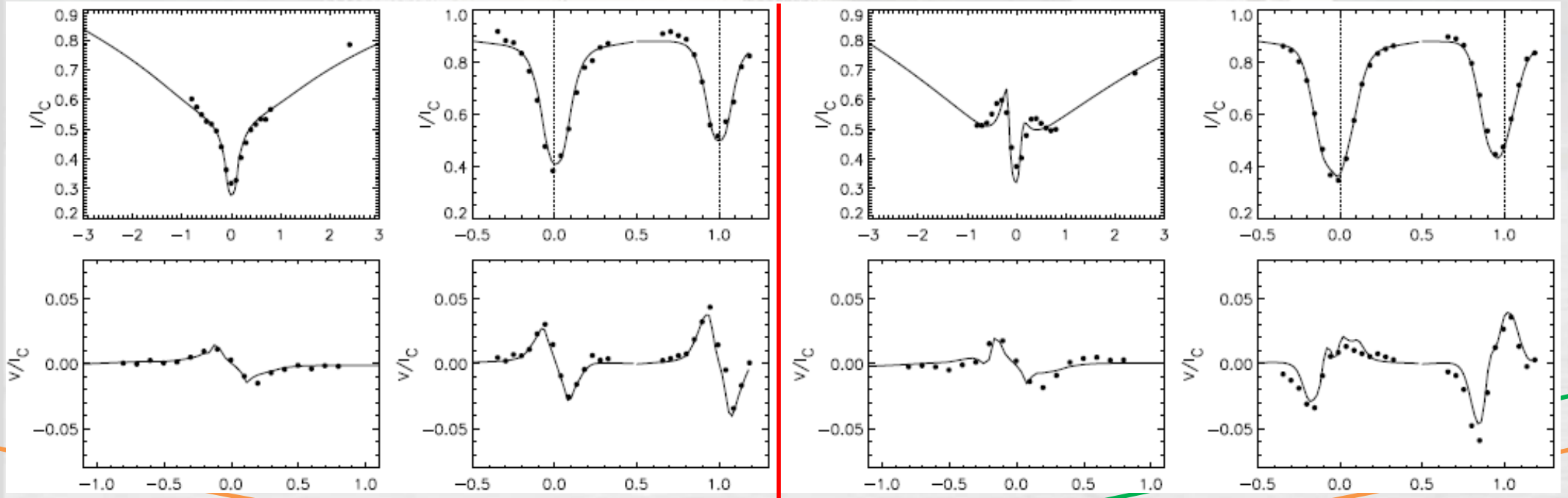


SPECTRAL SIGNATURES

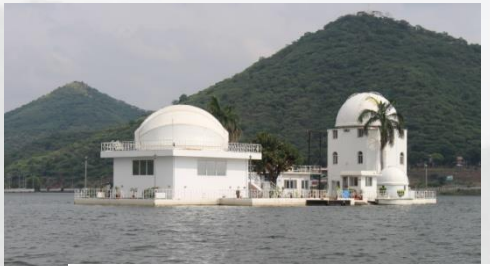


- Brightening in LB over the two patches due to asymmetric emission in line wing of Ca, Stokes V remains unchanged
- Fe lines Doppler shifted and Stokes V highly asymmetric with reversal in sign

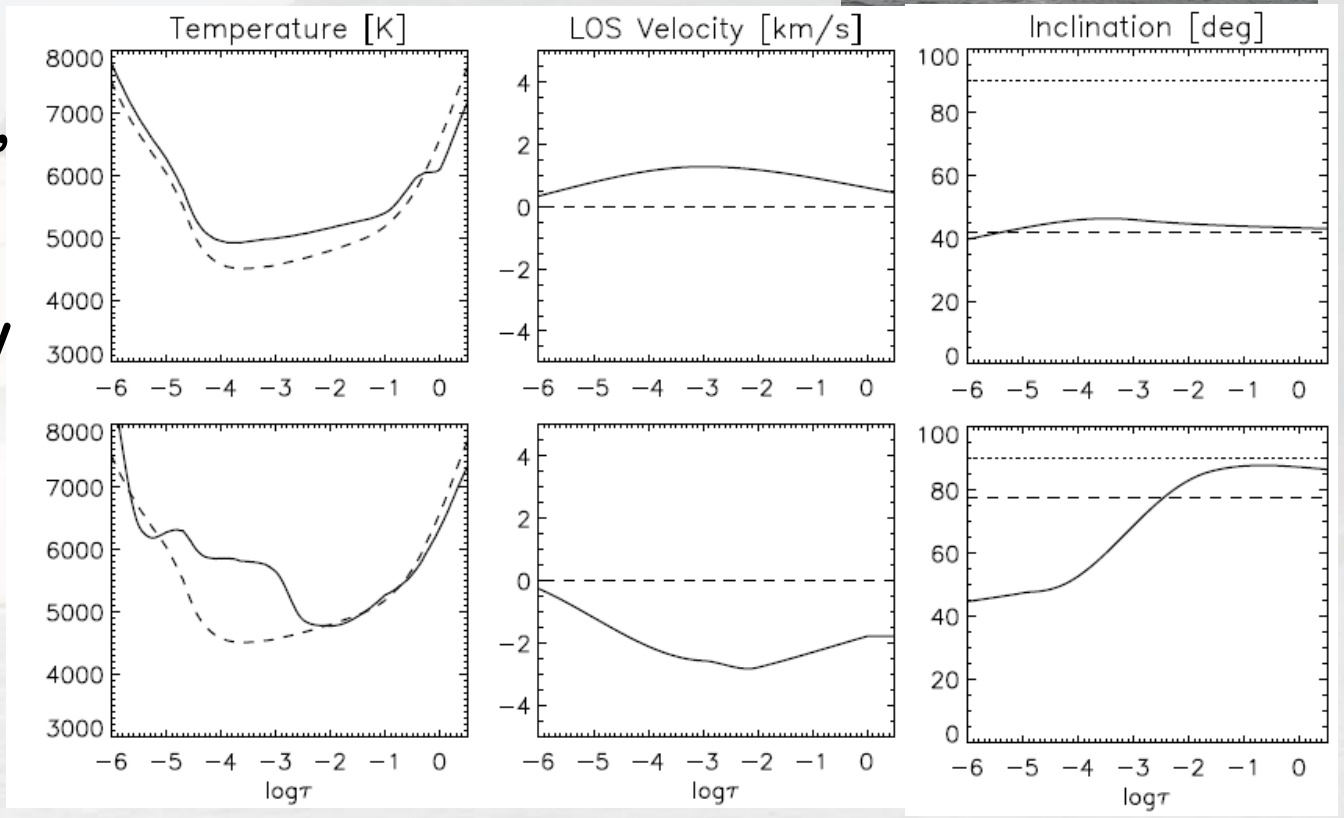
BEFORE **AFTER**



ATMOSPHERIC CONDITIONS

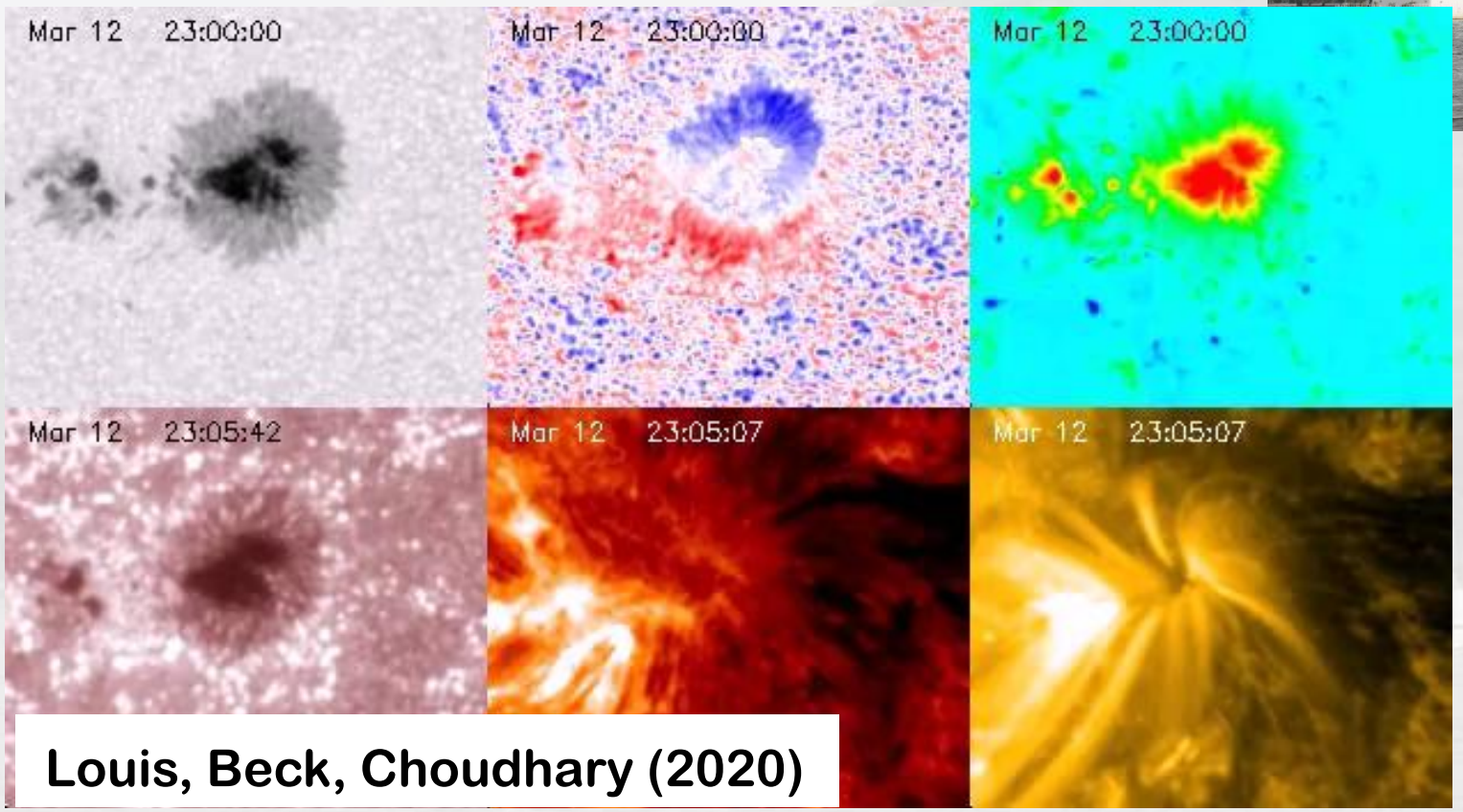


- Enhancement in T : 750 K
- Blueshifts of 2.5 km/s, initially redshifted
- No motions beyond -5.5
- Inclination changes only in photosphere



- Emergence of a flat Ω-loop bi-polar geometry, develops a siphon flow as it rises
- Line wing emission due to interaction with overlying sunspot field

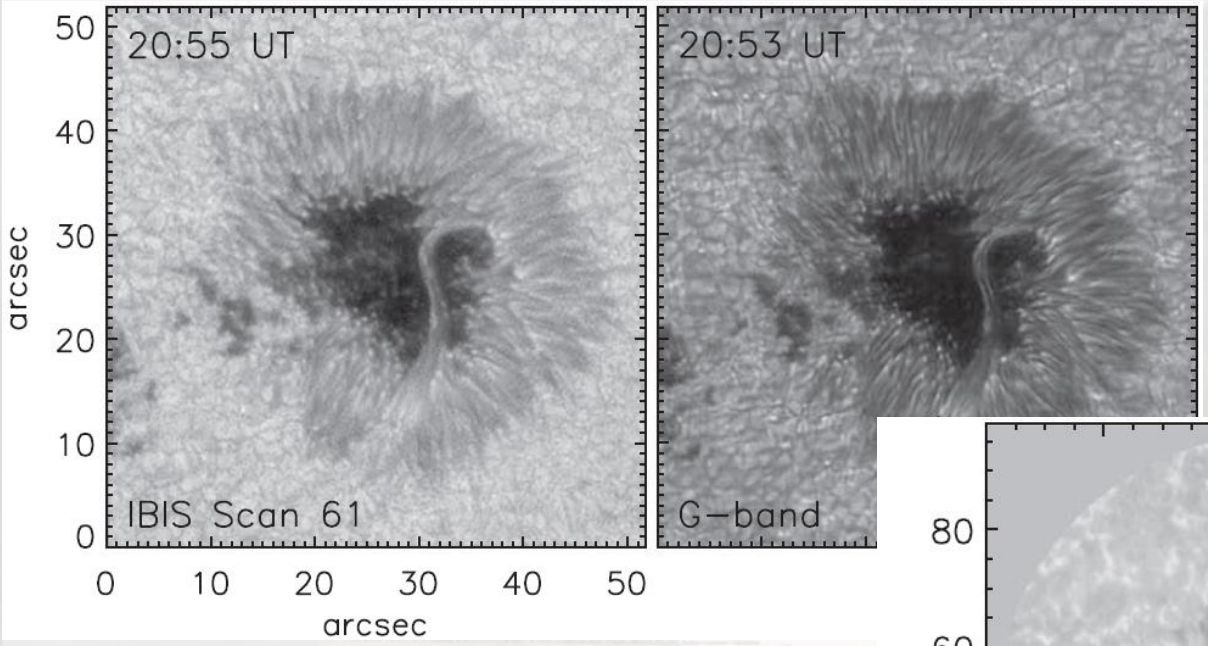
FORMATION OF ATYPICAL LB



Louis, Beck, Choudhary (2020)

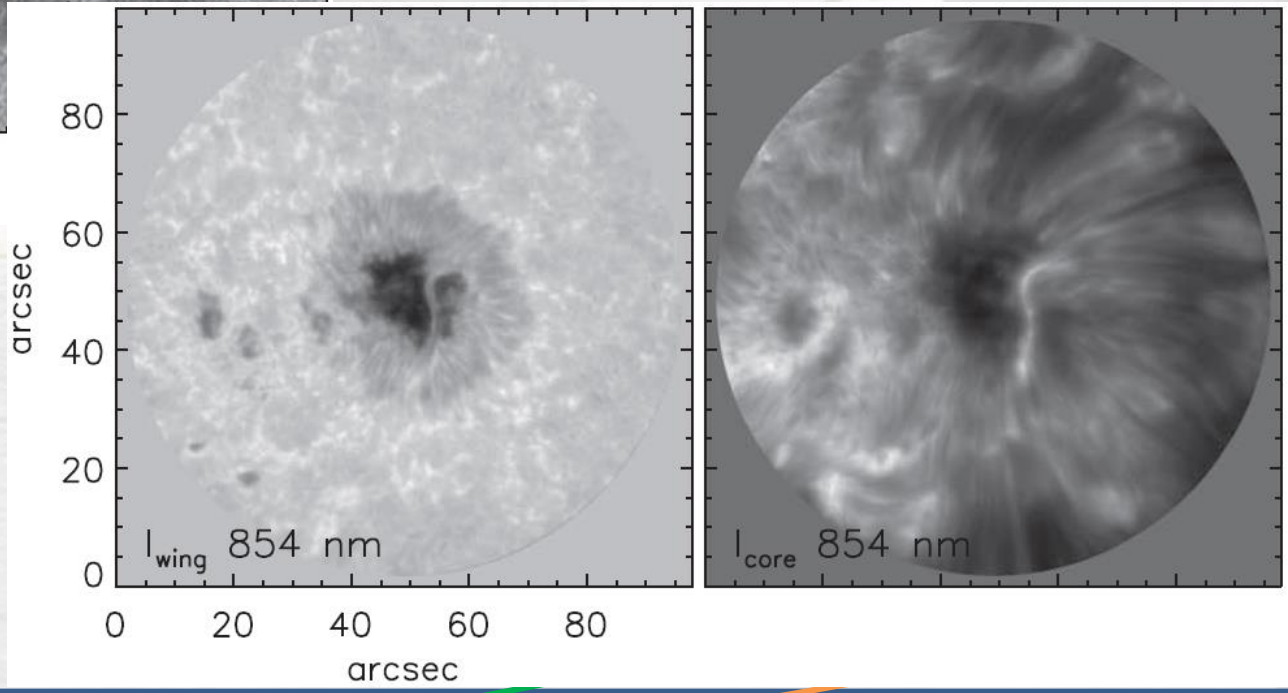
- LB results from emergence of magnetic flux, with pore appears about 17 hrs earlier
- Pore opp. Polarity, red-shifted, recedes from parent sunspot 0.4 km/s
- Nearly horizontal structure, B~ 1.2 kG, long-lived photospheric blueshifts ~ 0.85 km/s
- Surges seen in Chromo. & TR 13 min later

LB MORPHOLOGY – HIGH RES.

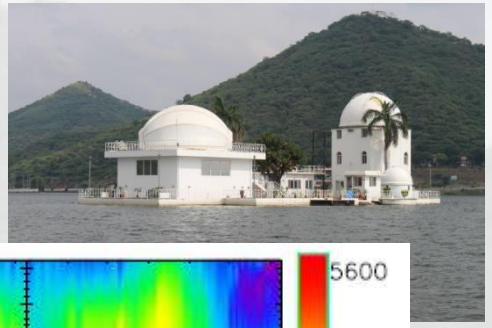


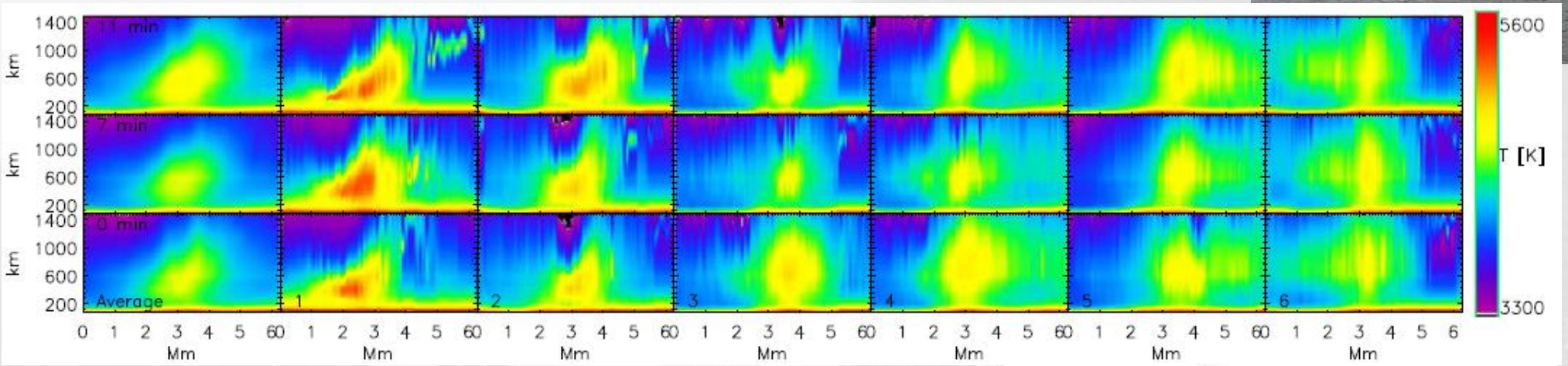
- Bright Grains at southern end of LB
- Northern end is S-shaped
- No dark lanes perpendicular to axis

- LB stands out in chromosphere
- Enhanced intensity than any other region in sunspot

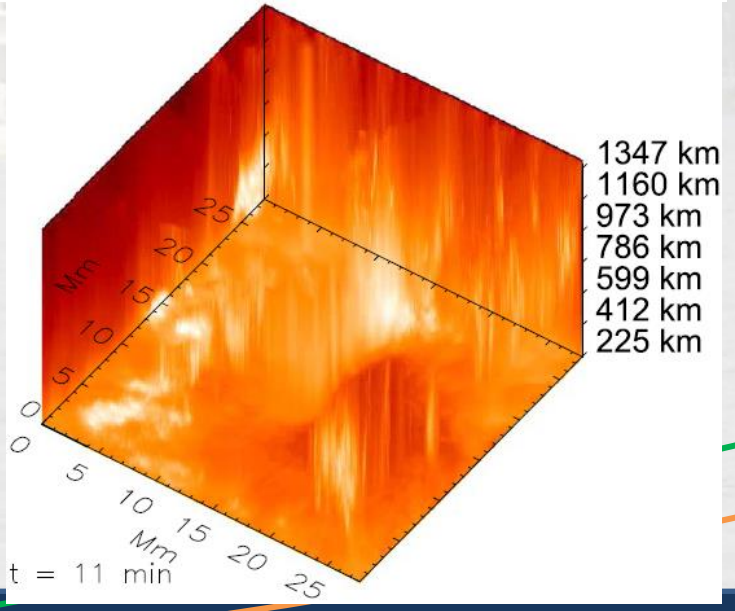


TEMP. STRATIFICATION – CAISAR

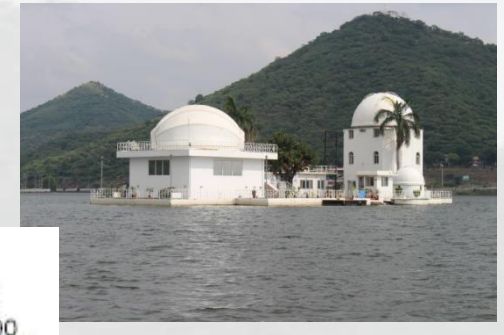


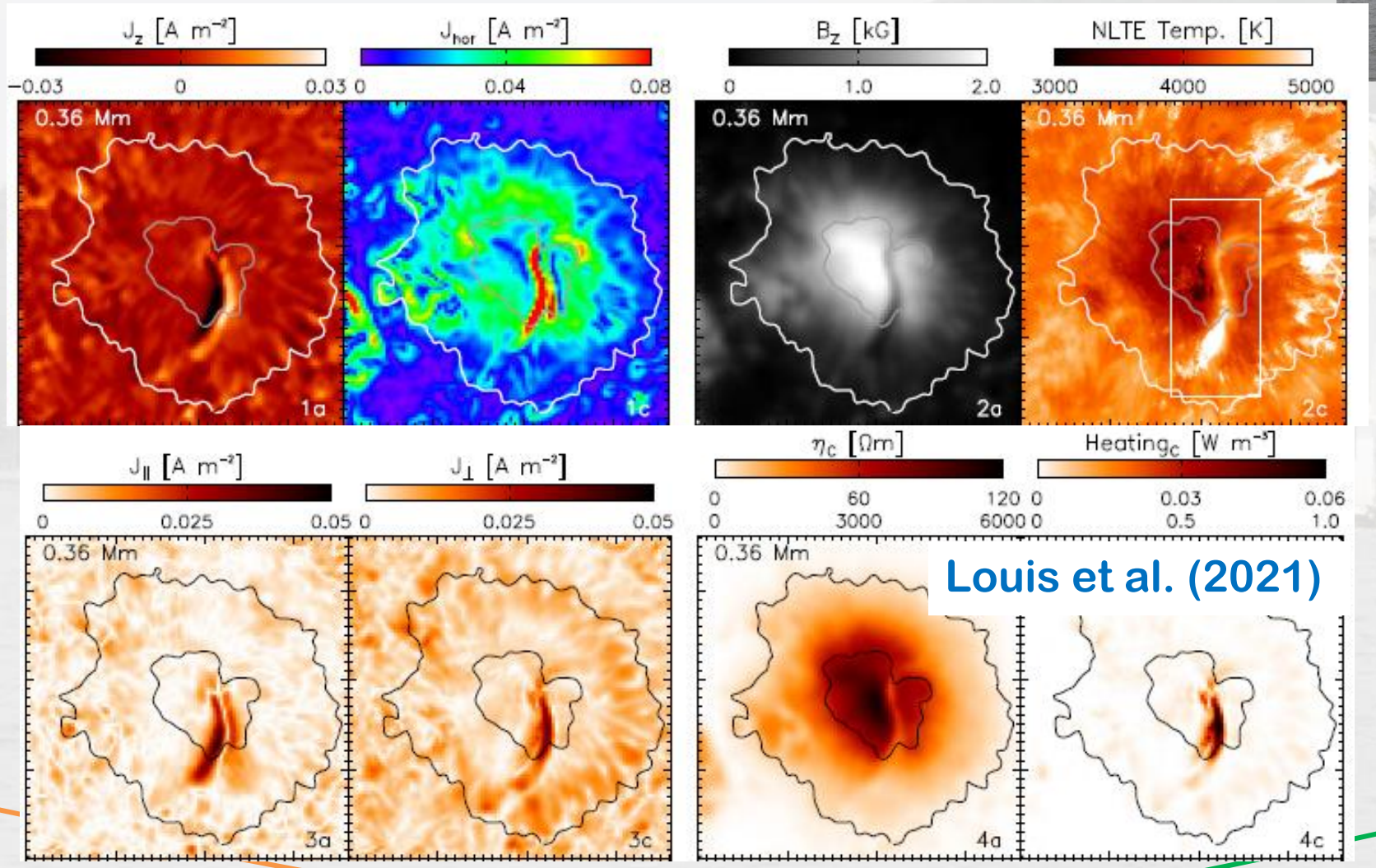


- **LTE SPECTRAL ARCHIVE** Beck et al. (2015)
- Complex Temp. distribution
- Parts of LB disconnected from Photosphere
- Boundary enclosing LB changes spatially and temporally
- T_{LB} ~1100K and 650 K hotter T_{umb} southern to northern end
- Temp. enhancement lower (higher) southern (northern)



HEATING BY STRONG ELECTRIC CURRENTS

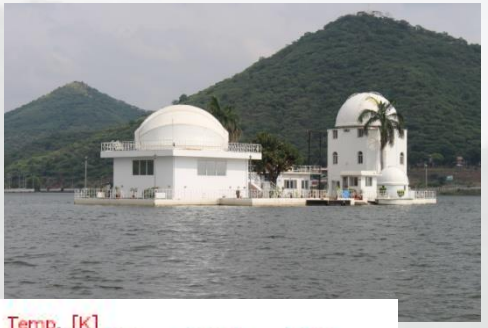


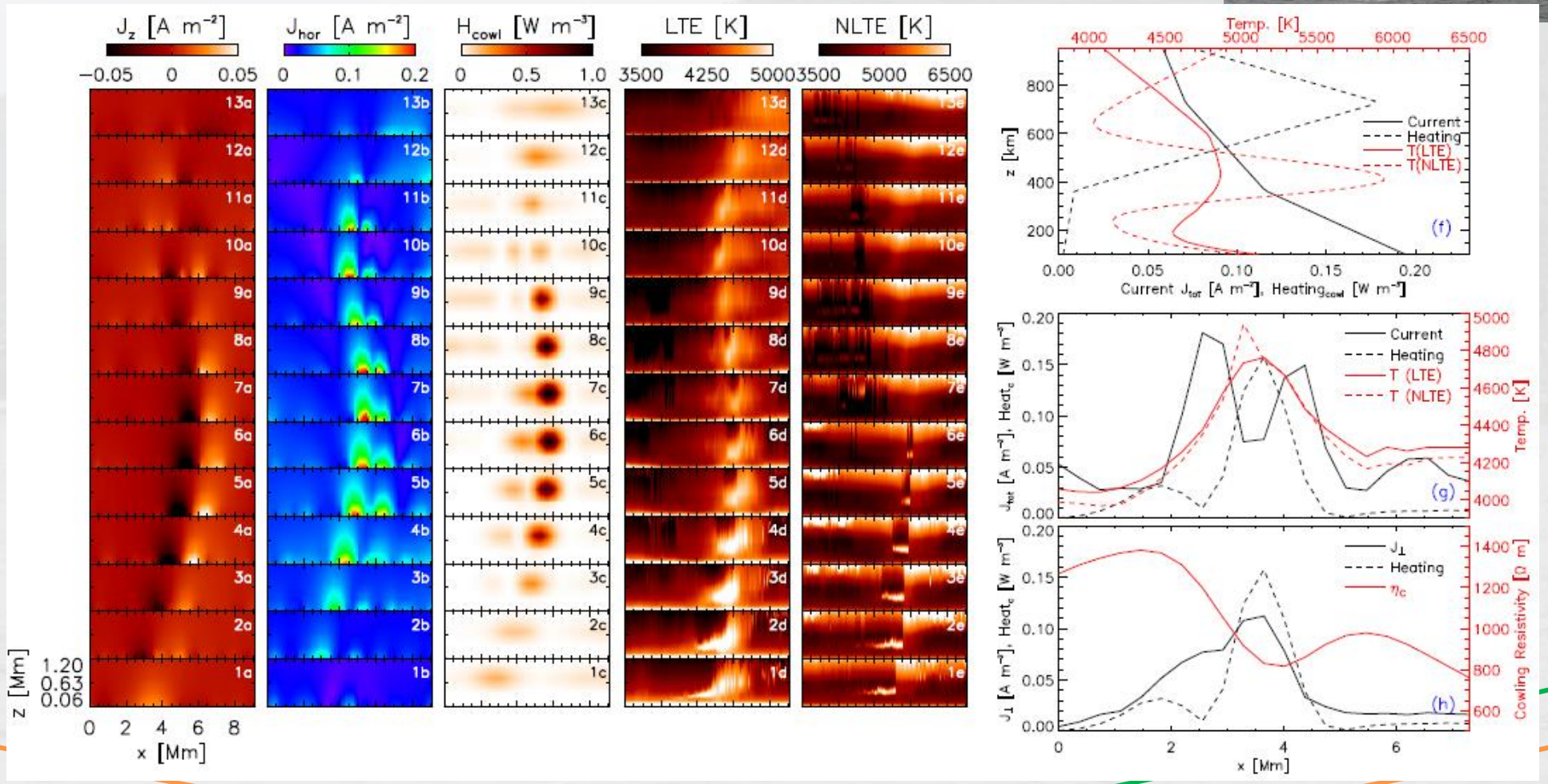


Louis et al. (2021)

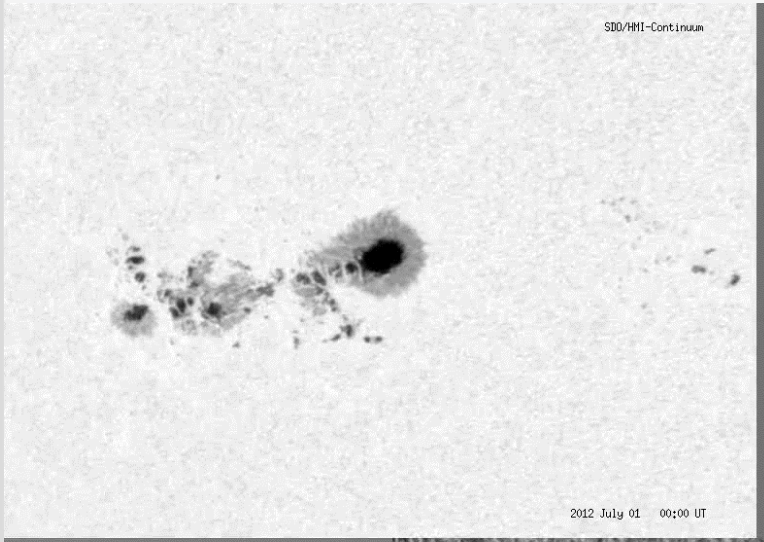
- Currents strongest in LB
- FE of nearly horizontal magnetic structure in sunspot
- Temp. excess in LB due to Ohmic dissipation
- Direct evidence of current-driven heating

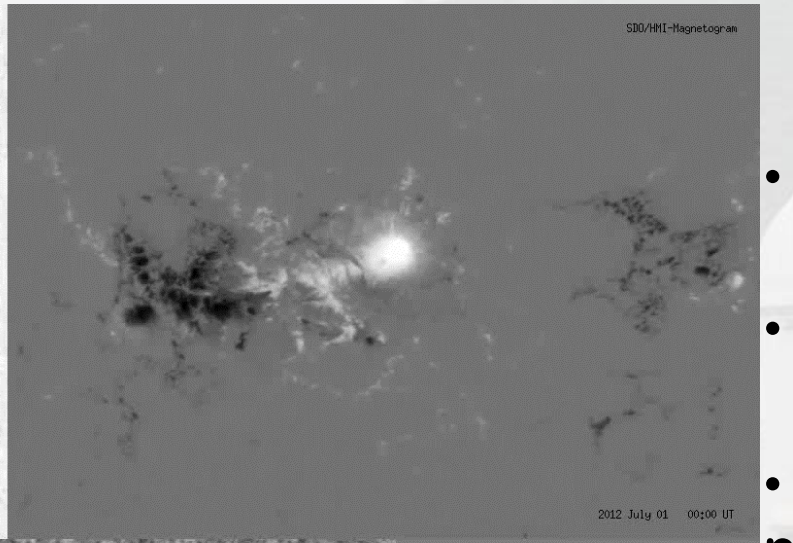
HEATING BY STRONG ELECTRIC CURRENTS

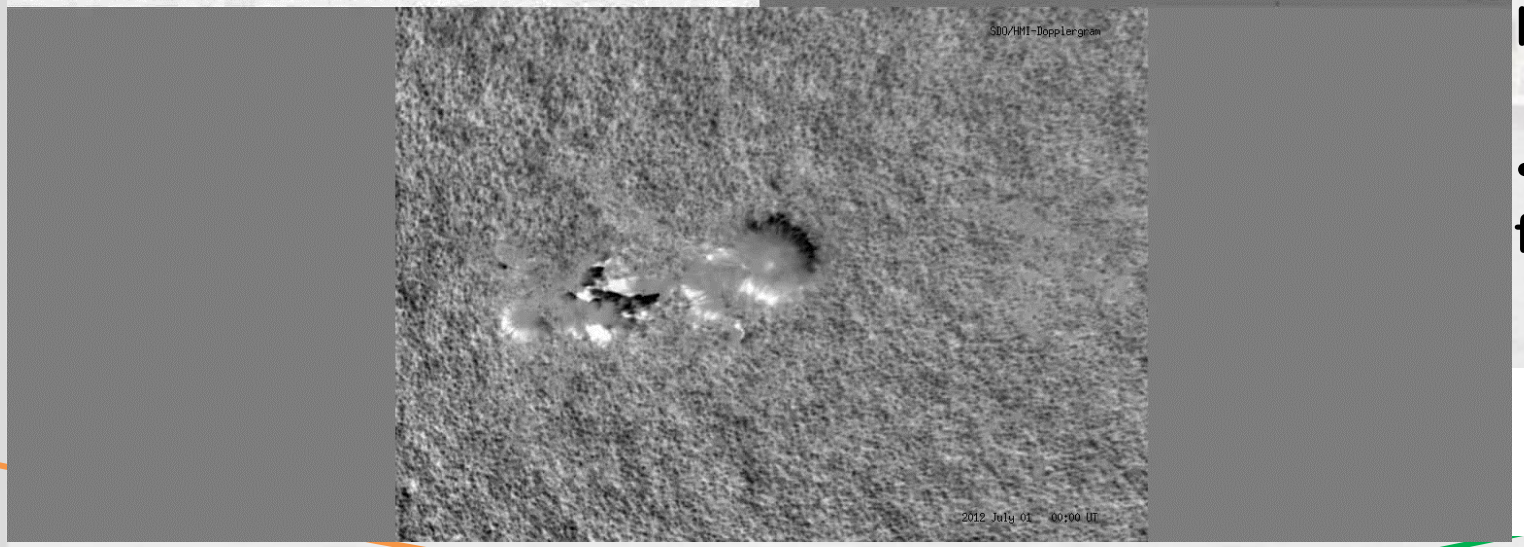




SPLITTING OF SUNSPOT





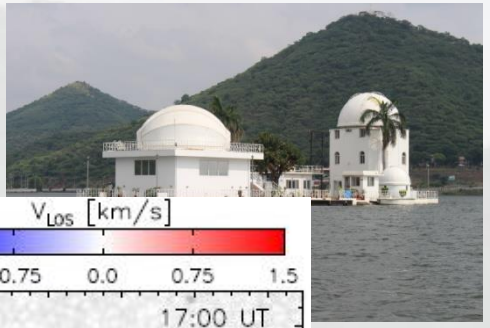


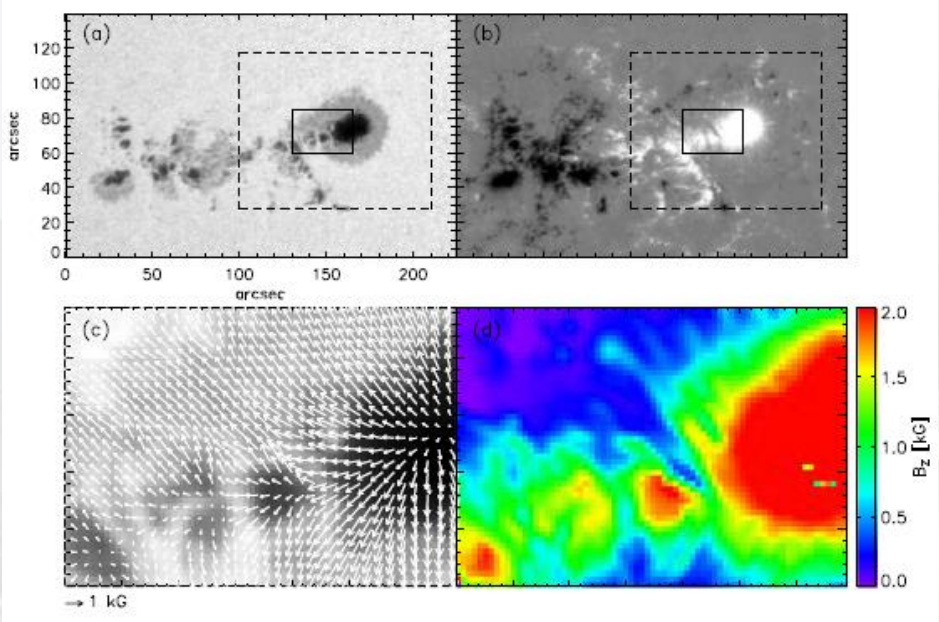
- S19 E28 on 2012 July 1
- Semi-complex βγ
- Leading sunspot of positive polarity
- Produced several flares

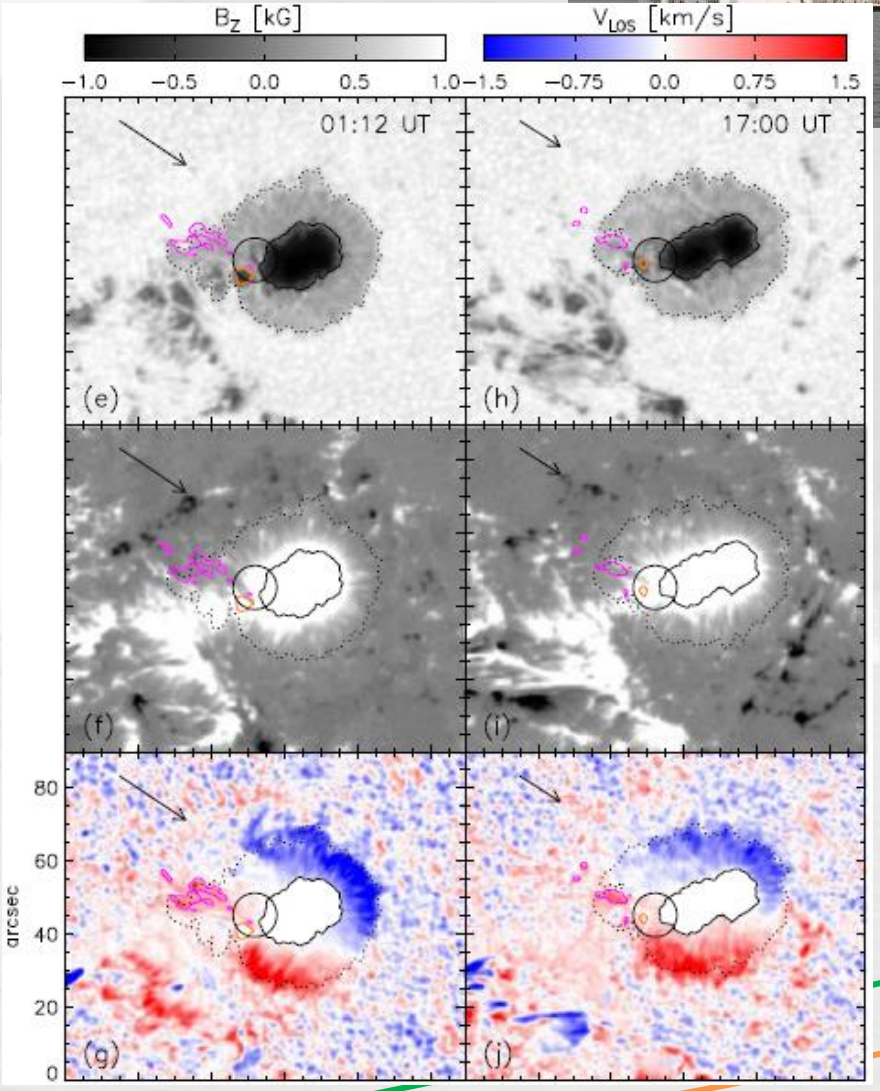
Louis et al. (2014)

Louis et al. (2015)

LS PRIOR TO SPLITTING

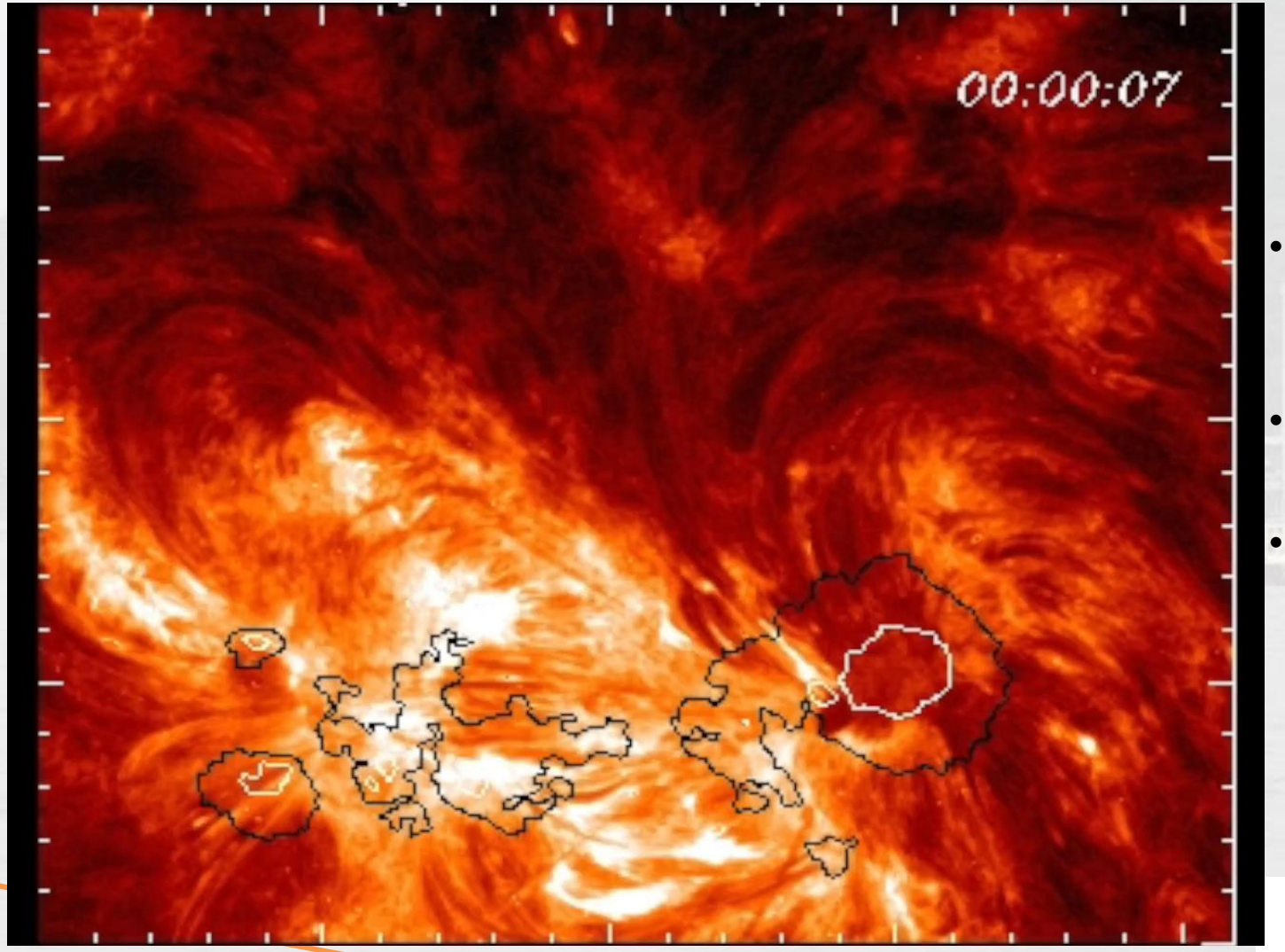






- Splitting of LS major driver for eruptive flare
- Flux emergence, flux cancellation aid in destabilization of coronal magnetic field

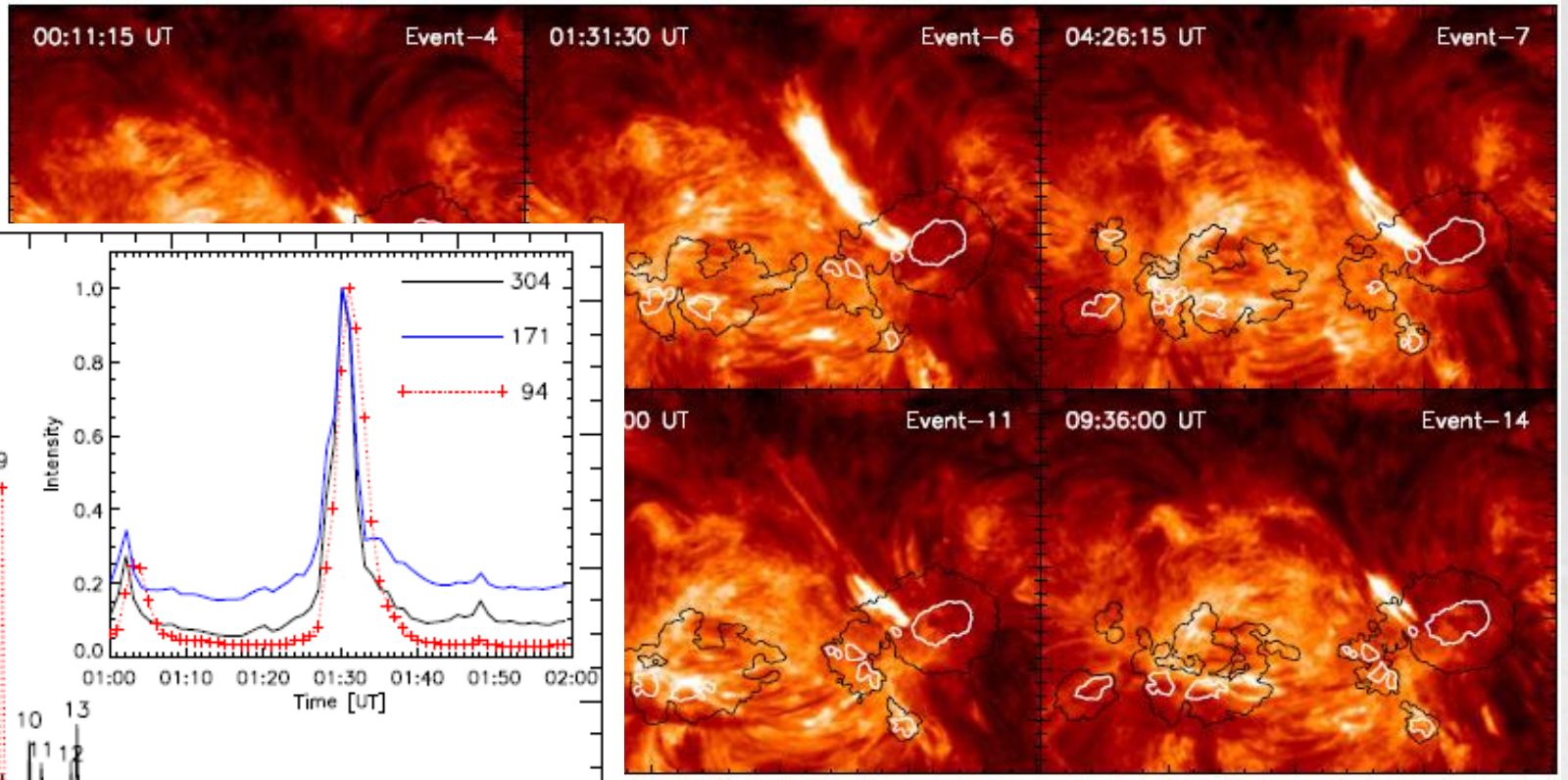
HOMOLOGOUS FLARING ACTIVITY

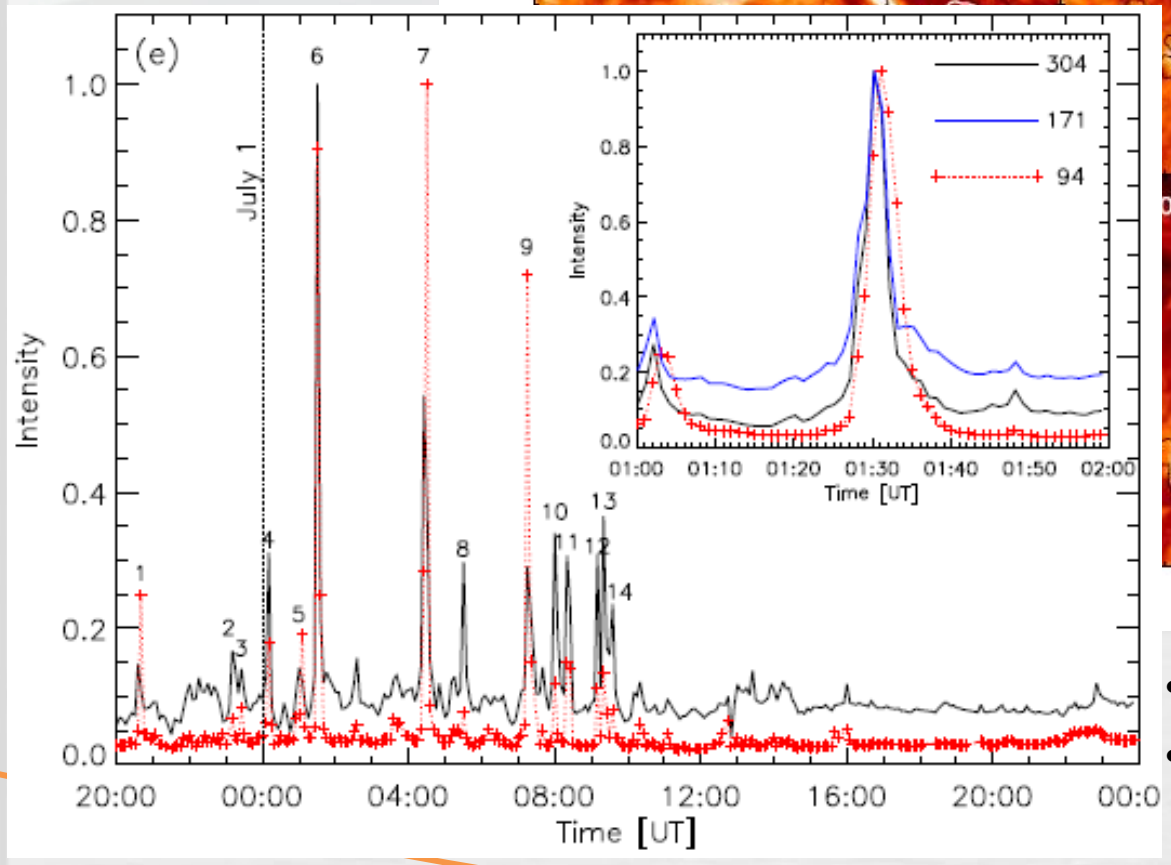


- Flaring activity over small LB in LS
- Collimated jets
- B6.4 flare at 01:30 UT

Louis & Thalmann (2021)

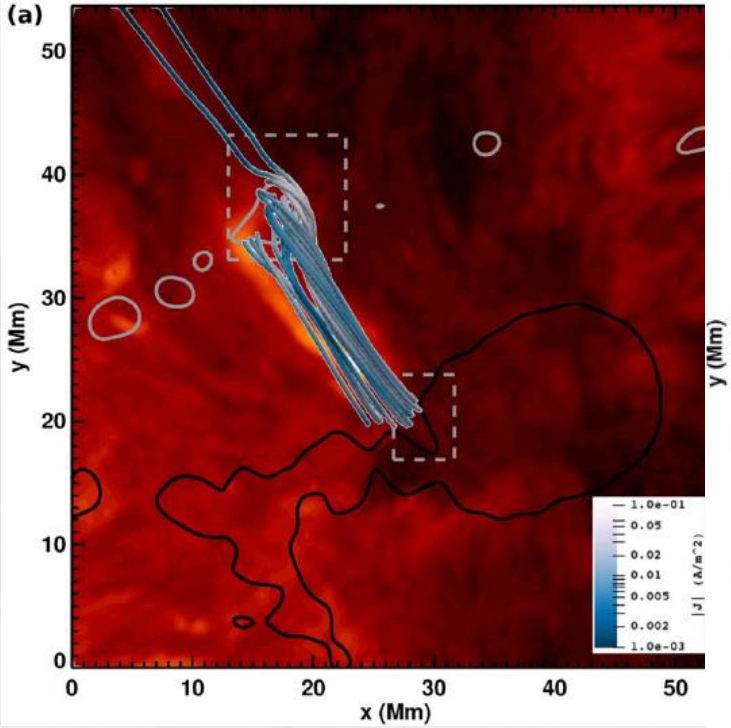
HOMOLOGOUS FLARING ACTIVITY

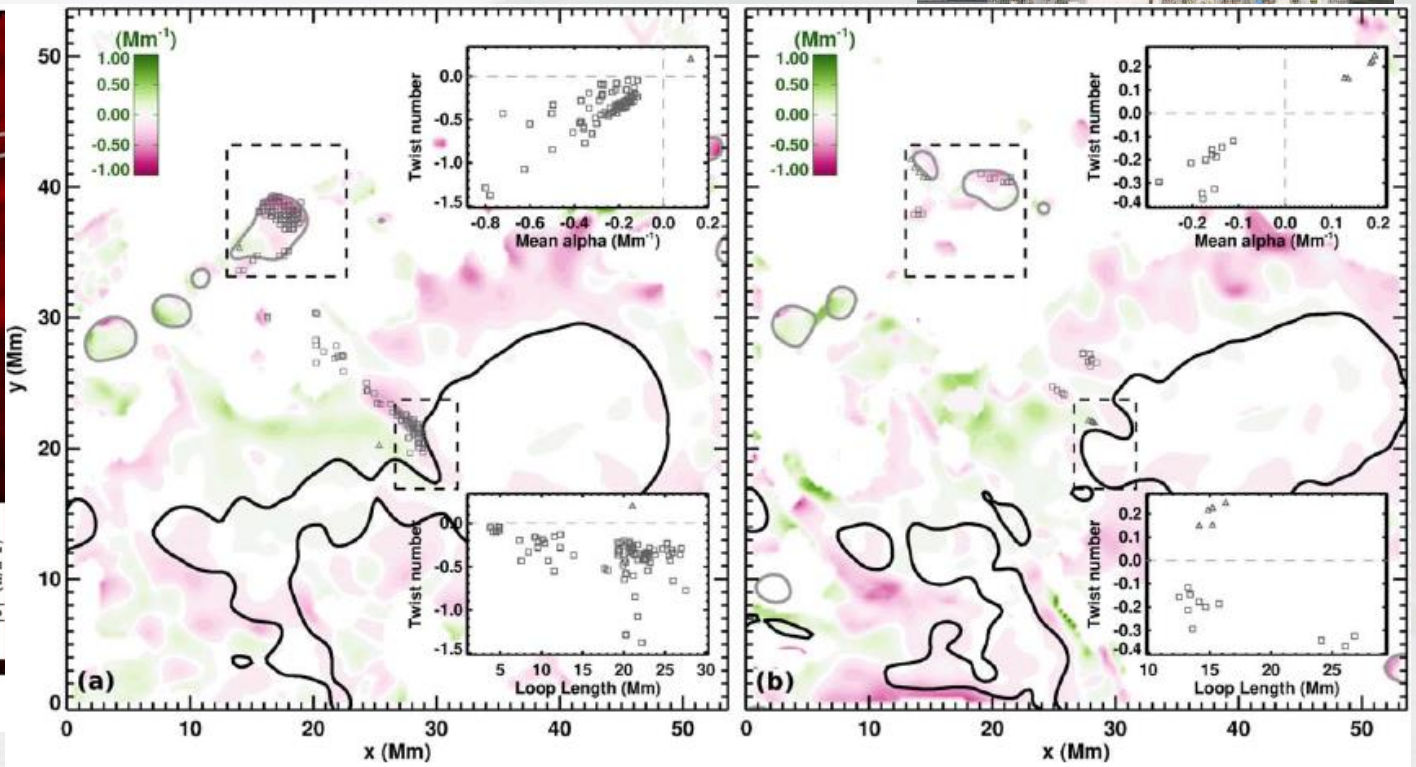


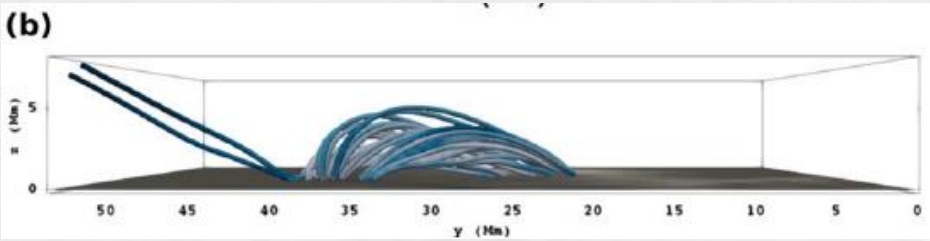


- Nearly 1 jet/hr
- Flaring activity stops after 13:00 UT

CORONAL MAGNETIC FIELD







- Low-lying flux rope connecting LB to opp. polarity magnetic patch in sunspot moat
- Reconnection with sunspot field driven by rapid proper motion
- Flaring renders loss of twist

SUMMARY

- Wide variety of dynamic phenomena in chromo. TR & corona above LBs
- LBs ideal sites for flux emergence, small- and large spatial scale
- Surges, jets, brightness enhancements, flares
- Lower chromospheric heating
- Flux emergence key factor for transporting energy to higher layers

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