Solar UV bursts

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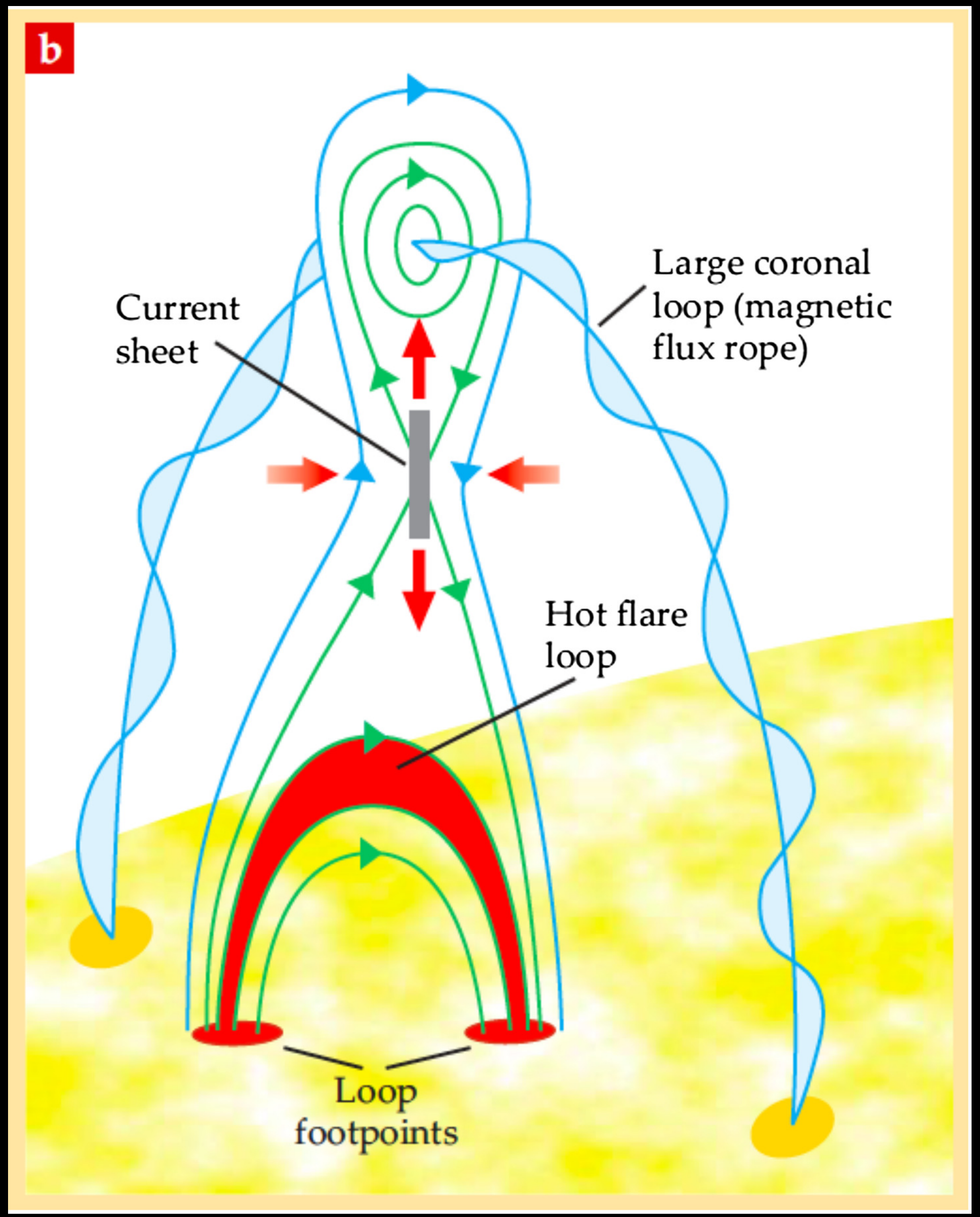
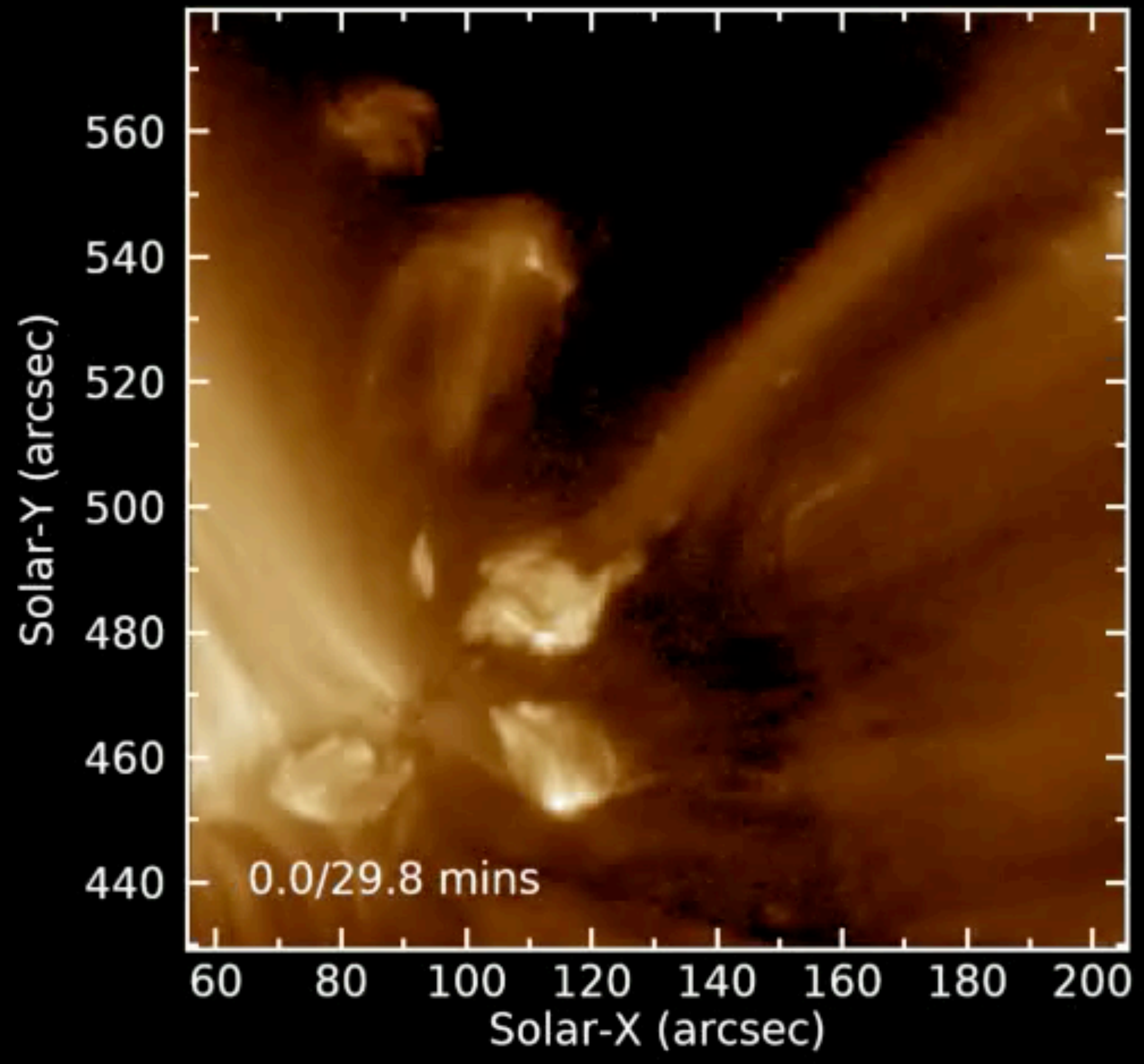
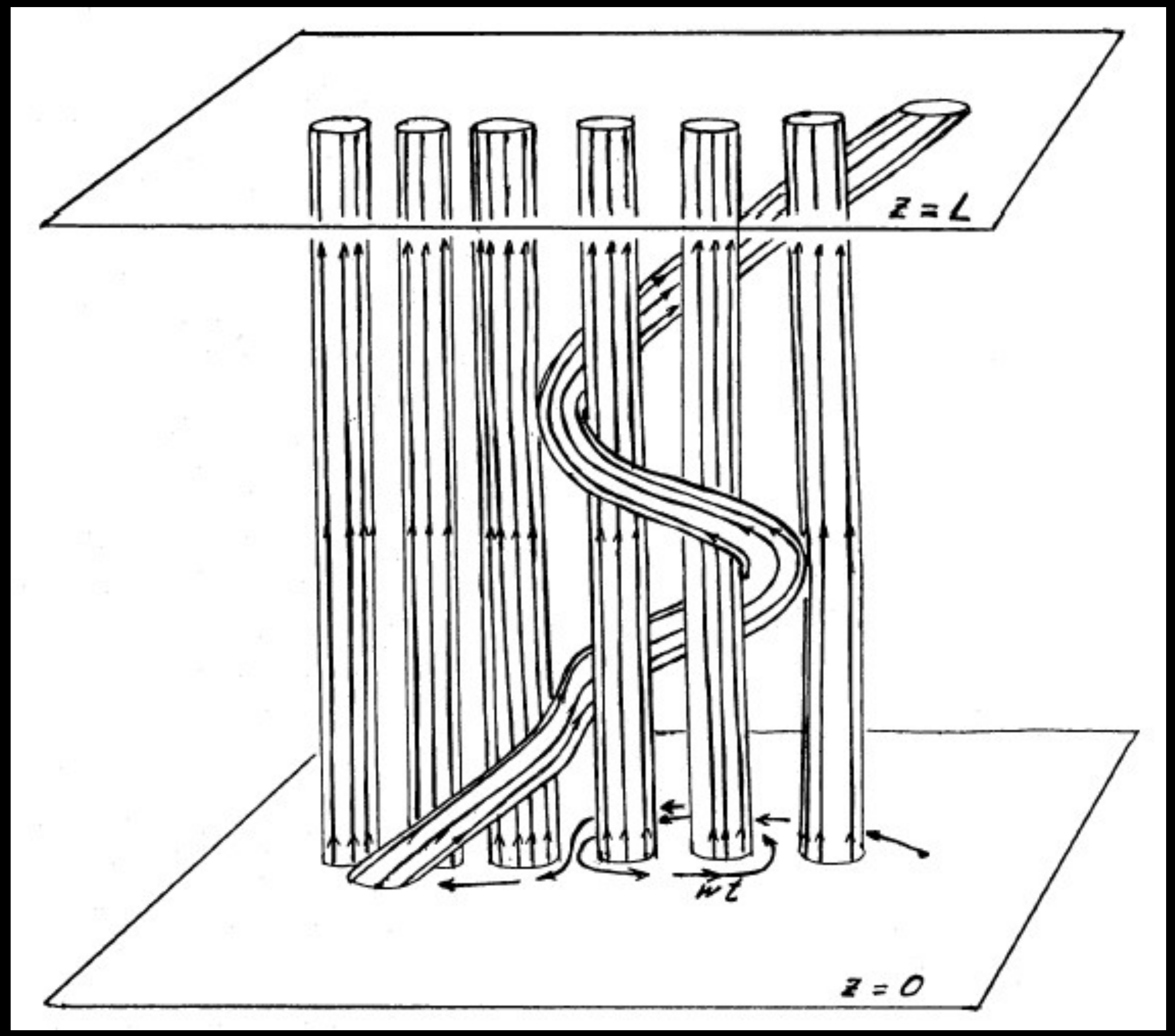
Reconnection scenarios



Solar eruptive events
[Holman, 2016, JGR]



Coronal jets



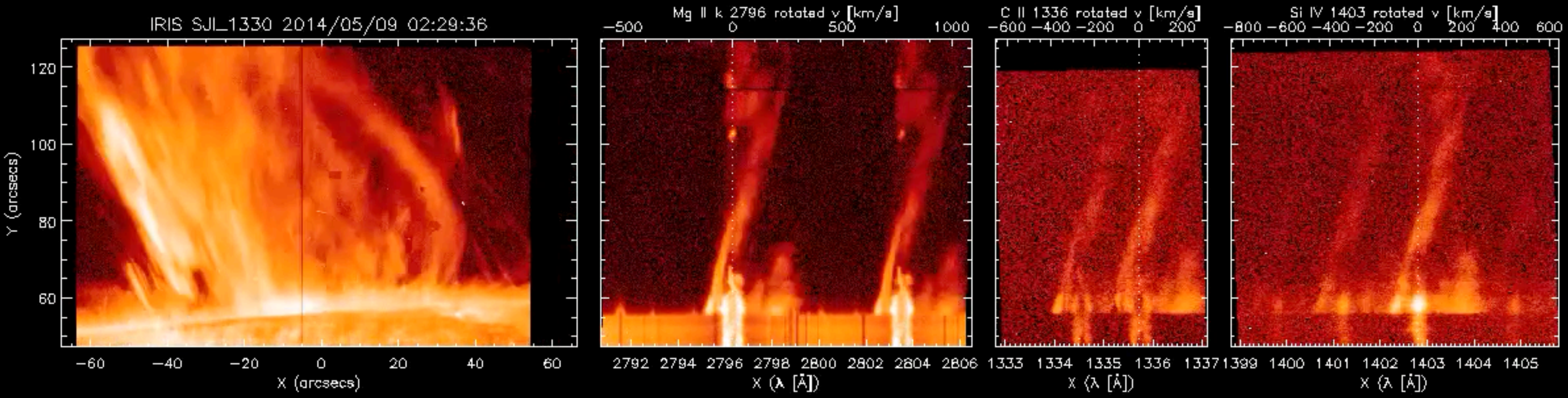
Nanoflares
[Parker, 1983, ApJ]

The IRIS satellite

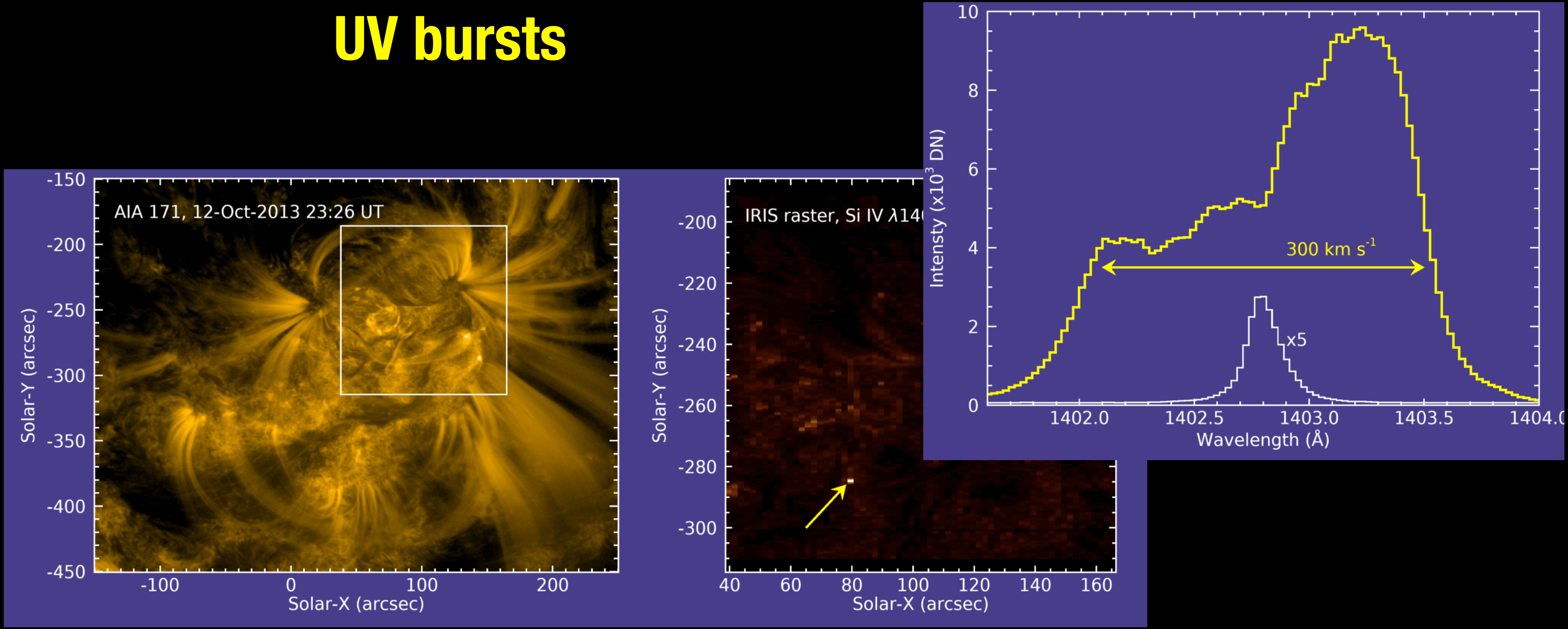
- NASA Small Explorer satellite, launched in 2013
- Ultraviolet imaging slit spectrometer
  - far-ultraviolet: 1332-1358 Å, 1389-1406 Å
  - near-ultraviolet: 2782-2834 Å
- High spatial resolution: 0.32 arcsec (230 km)
- Has a slitjaw camera for simultaneous imaging

For UV bursts:

- Si IV 1393.8 Å & 1402.8 Å
- Slitjaw 1400 Å filter
- Temperature: 80 kK (transition region)



UV bursts



AIA 171, 12-Oct-2013 23:26 UT
Solar-Y (arcsec)
Solar-X (arcsec)
-150
-200
-250
-300
-350
-400
-450
-100
0
100
200
IRIS raster, Si IV λ14
-200
-220
-240
-260
-280
-300
40
60
80
100
120
140
160
Intensty (x10³ DN)
Wavelength (Å)
300 km s⁻¹
x5
10
8
6
4
2
0
1402.0
1402.5
1403.0
1403.5
1404.0

Timeline

2013: IRIS launched (July)

2014: Peter et al. Science paper published (“hot explosions” or “bombs”)

2014: I received NASA HGI funding to study “compact energetic brightenings” for 3-year project

2015: Successful ISSI Team proposal to study “solar UV bursts”

2016: ISSI team met in January

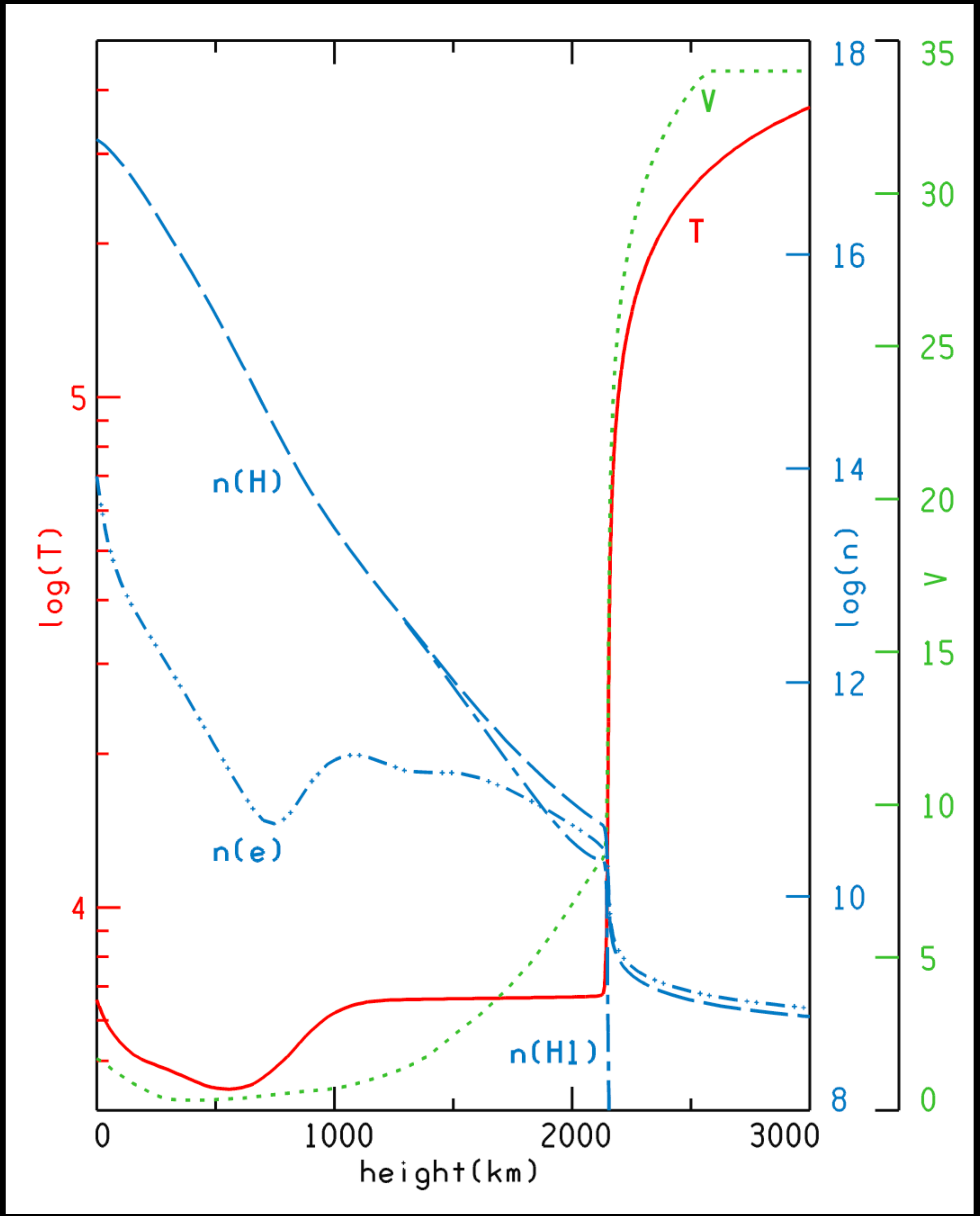
2017: ISSI team met in March

2018: Space Science Reviews article published

2018: I became a civil servant

Solar transition region

- Layer between the chromosphere (10^4 K) and the corona (10^6 K)
- Temperature rises sharply over 10's of km
- Small line-of-sight means lines very susceptible to plasma dynamics (Doppler shifts, line broadening)



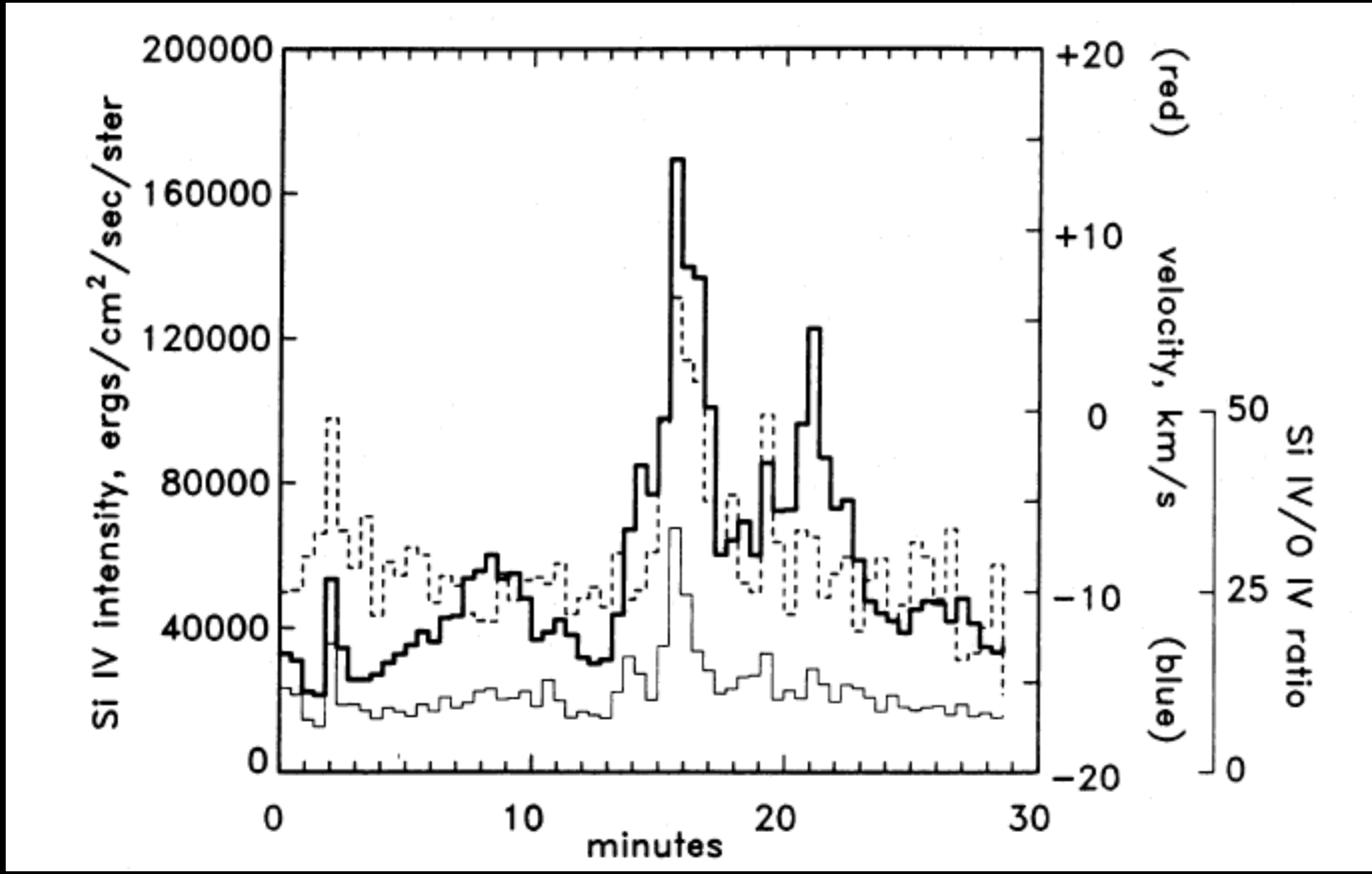
Naming

- **Bombs**: good name, but potential security risk!
- **Bursts**: used previously but too generic?
- **Explosive events**: different phenomena (QS, CH only)
- **Blinkers**: probably same phenomena, but out of fashion

Decided on “solar ultraviolet bursts”, or just “UV bursts”
- see Young et al. (2018) review for more details

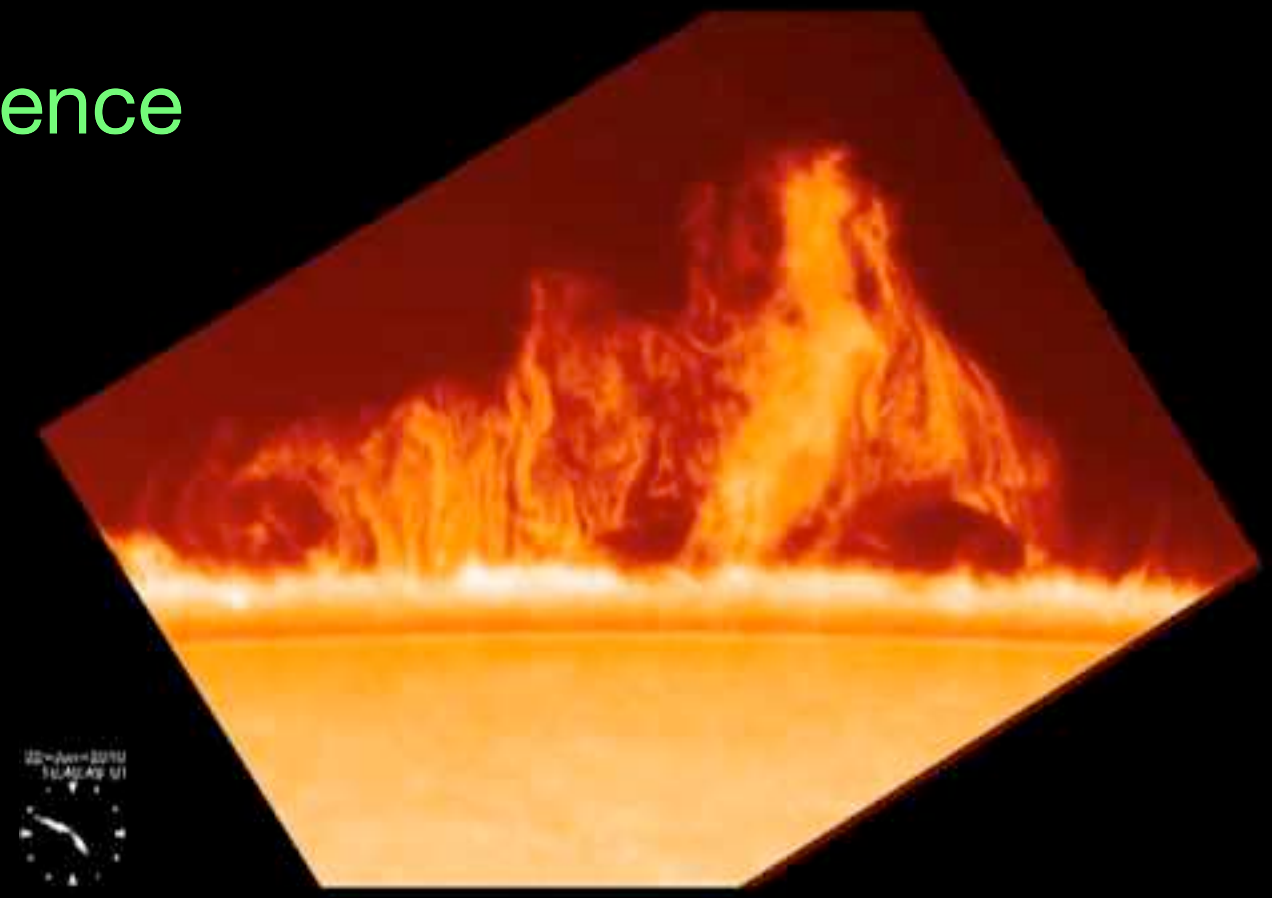
SMM/UVSP bursts

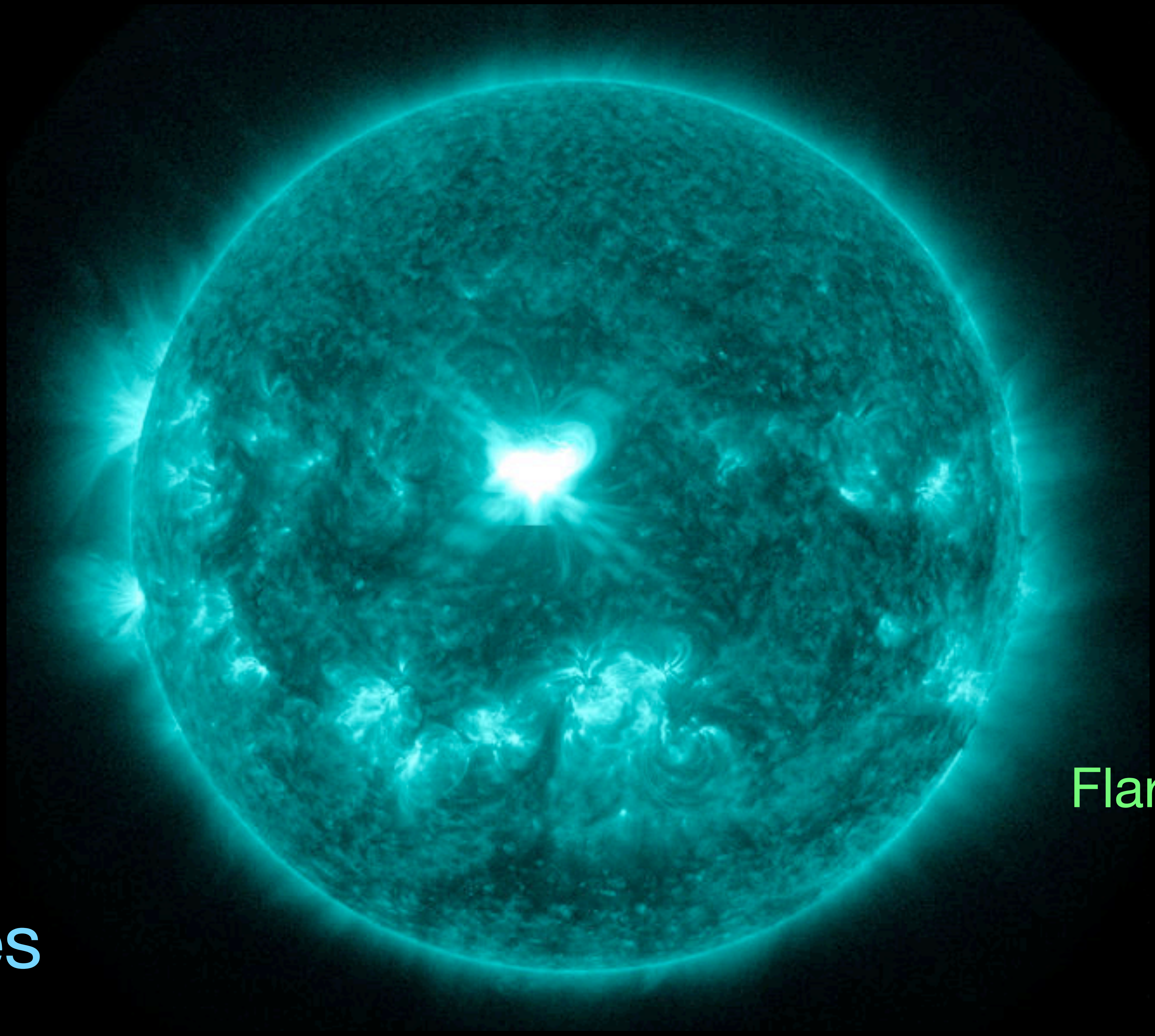
- Hayes & Shine (1987, ApJ) reported active region “bursts”
- I chose this name as I believed the events were the same as the IRIS ones



Defining UV bursts

Prominence

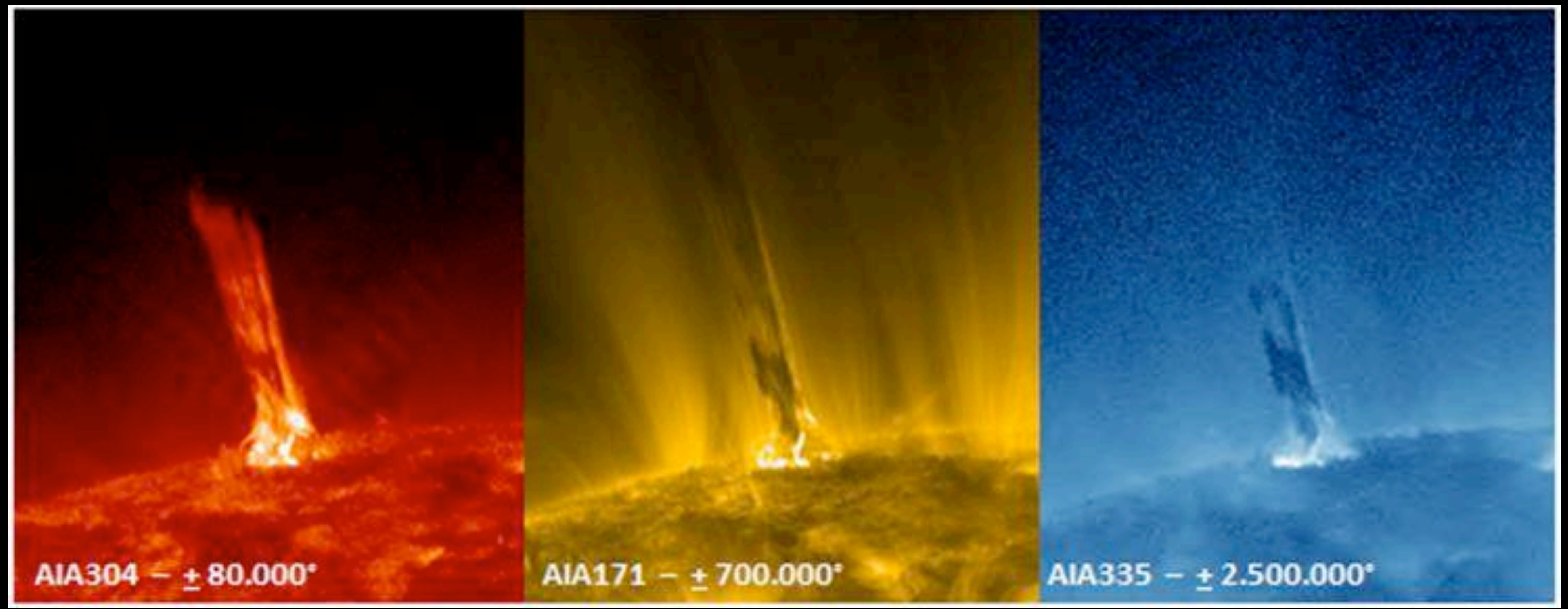


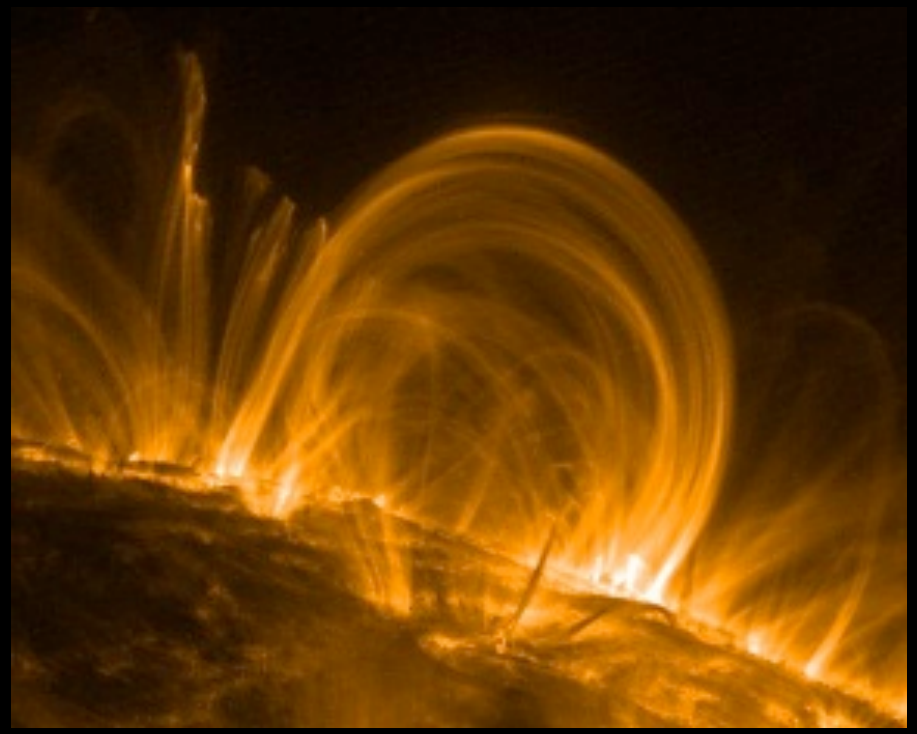


Flare

Most structures are defined through their images

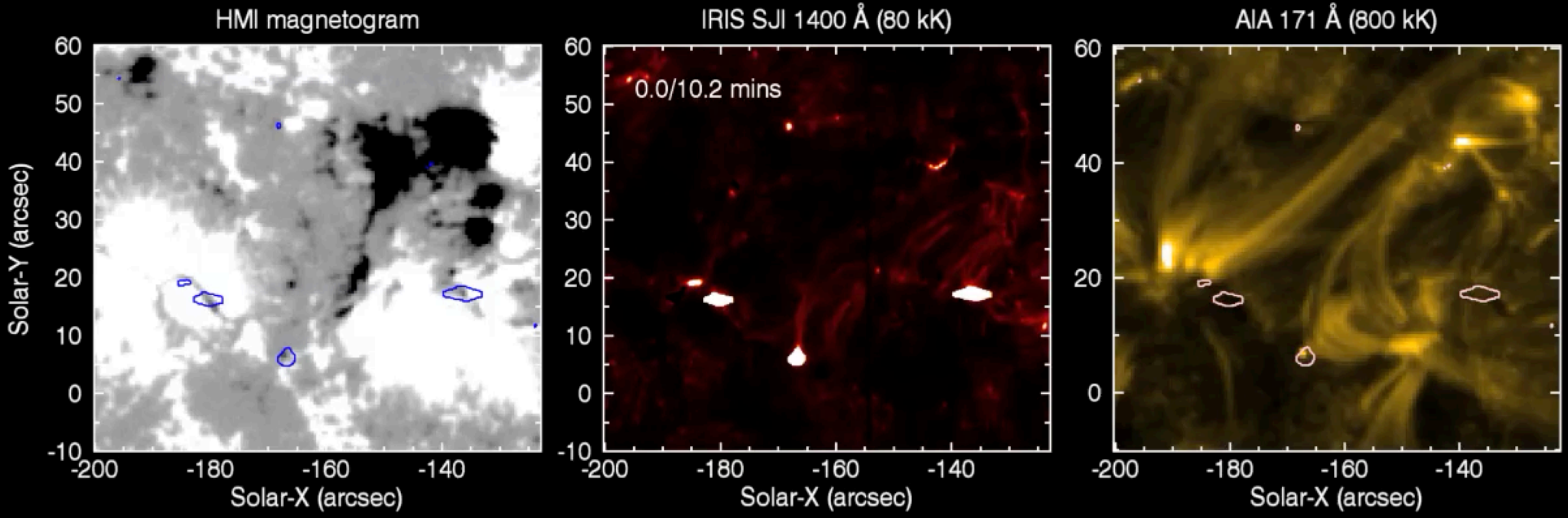
Jet





Loops

UV bursts in IRIS 1400 Å movies



Note:

- UV bursts generally overlie interacting, small-scale magnetic features (left panel)
- UV bursts generally have no signature in the AIA 171Å channel (right panel)

UV burst definition

Based on transition region image sequences (e.g., IRIS 1400Å):

1. Compactness: core brightening less than 2 arcsec
2. Duration: lifetimes 1-60 minutes, but flicker on timescales of 1 minute
3. Intensity: brighter than their surroundings by factor ≥ 20
4. Motion: small proper motions of < 10 km/s
5. Not related to flares

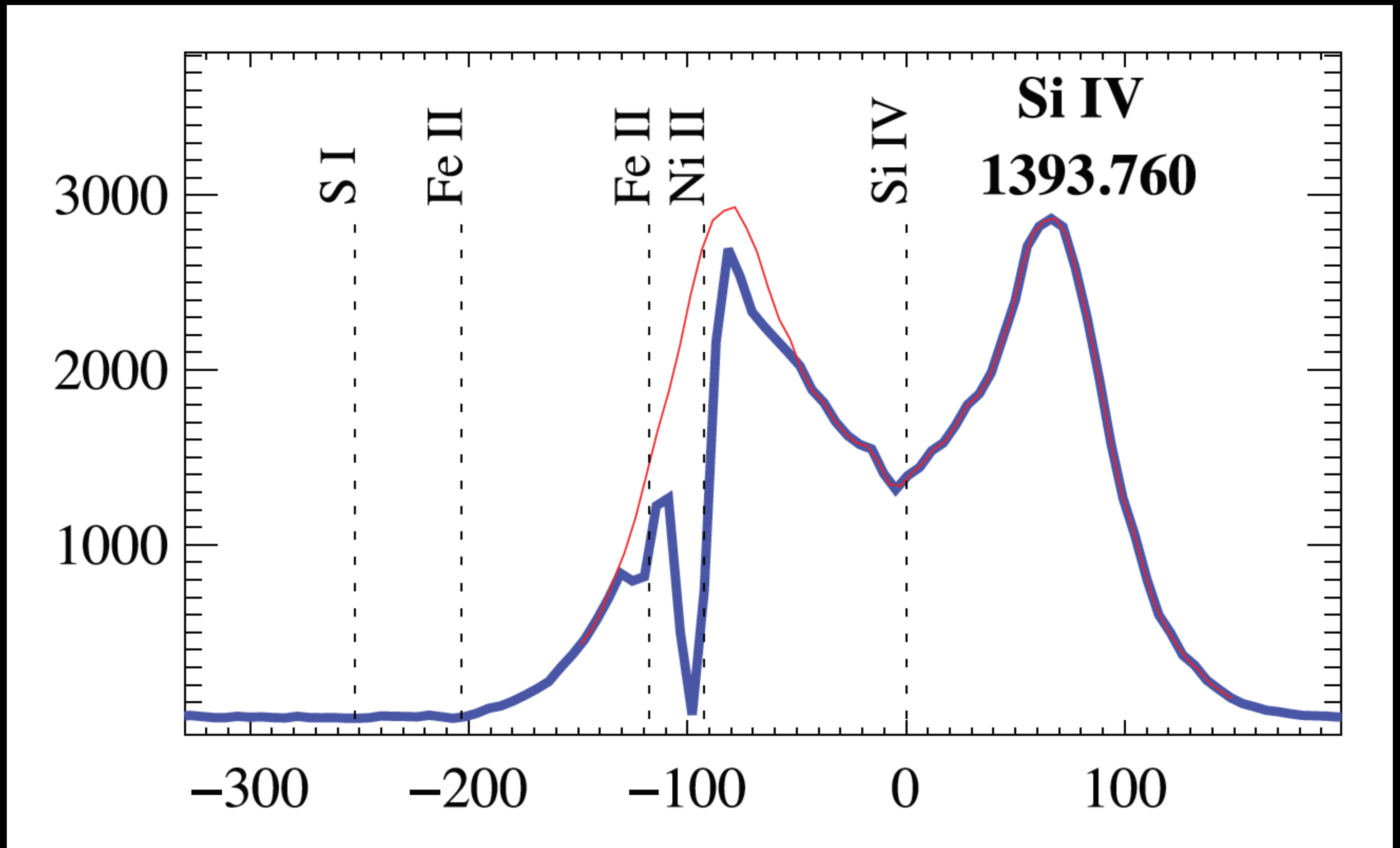
Young et al. (2018, Sp. Sci. Rev)

IRIS bombs

A subset (majority) of UV bursts have complex spectral line profiles

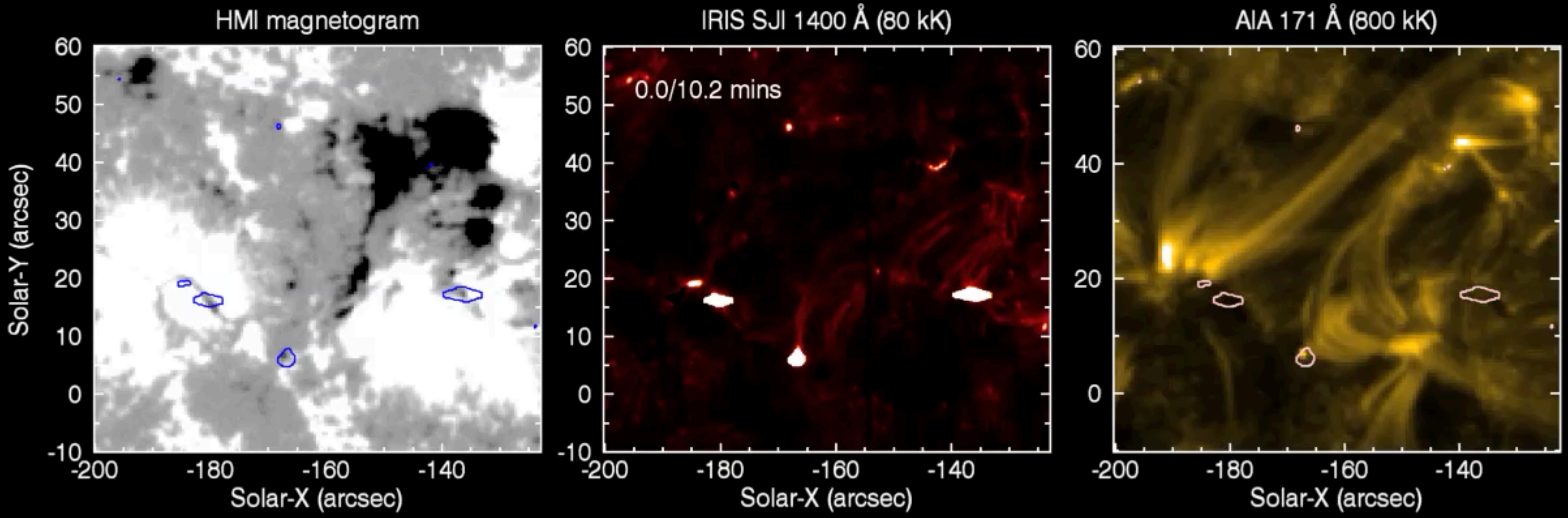
- these are the “IRIS bombs” of Peter et al. (2014, Science)

Use of the word “bomb” is discouraged, though!

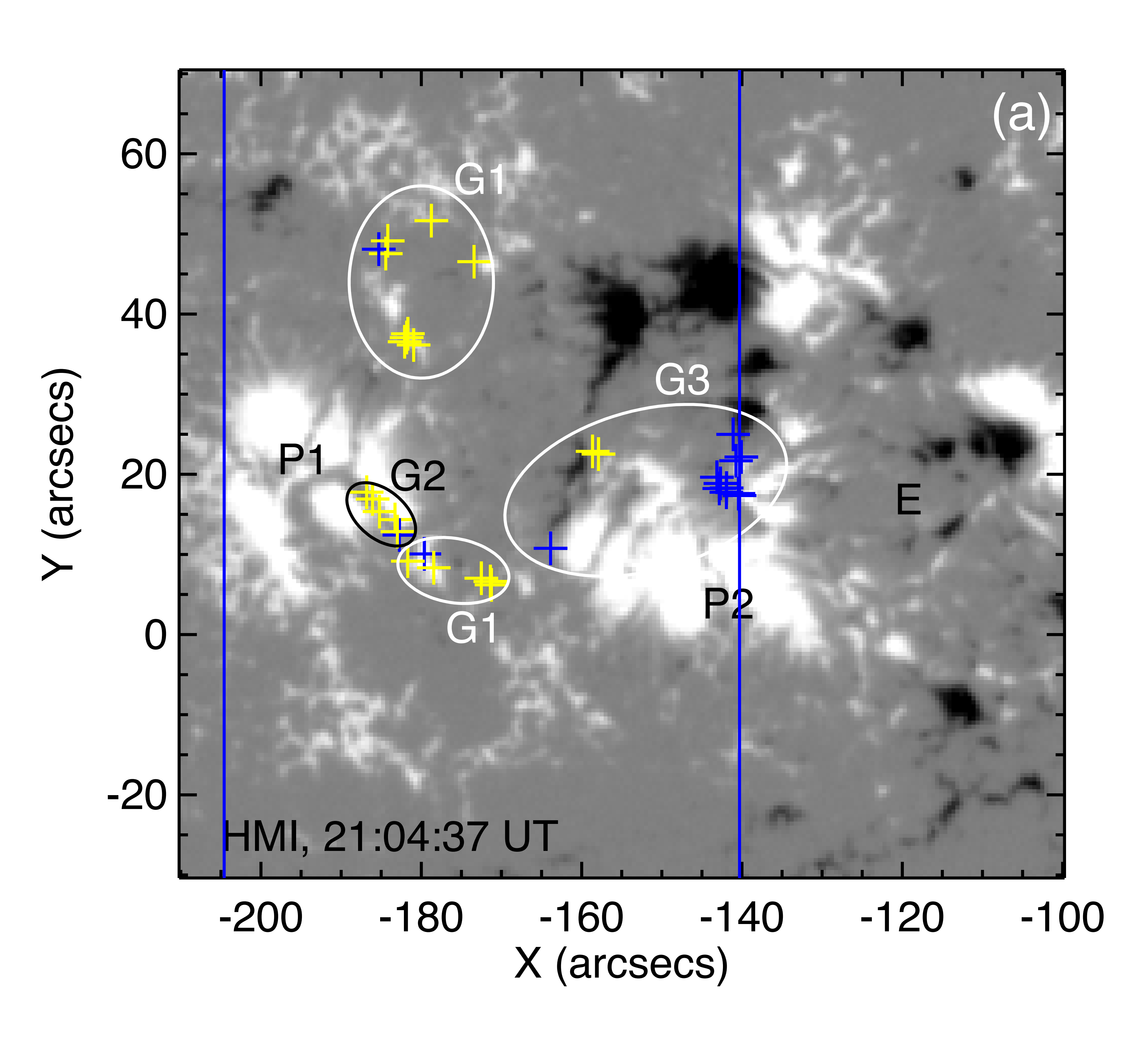


Properties of UV bursts

Data-set from 22-Oct-2013



Locations of UV bursts

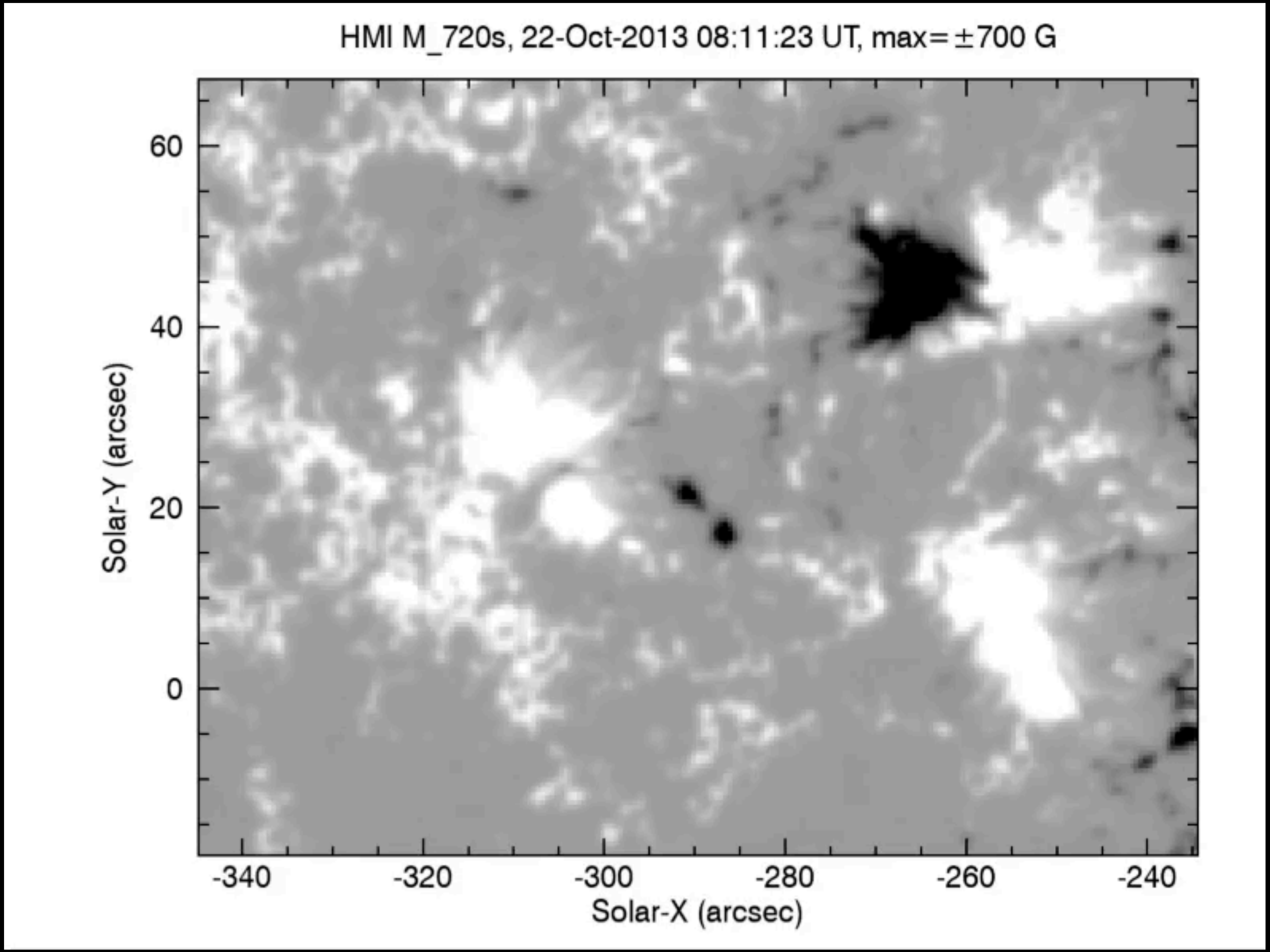


G1 - moving magnetic features (MMFs)

G2 - light bridge

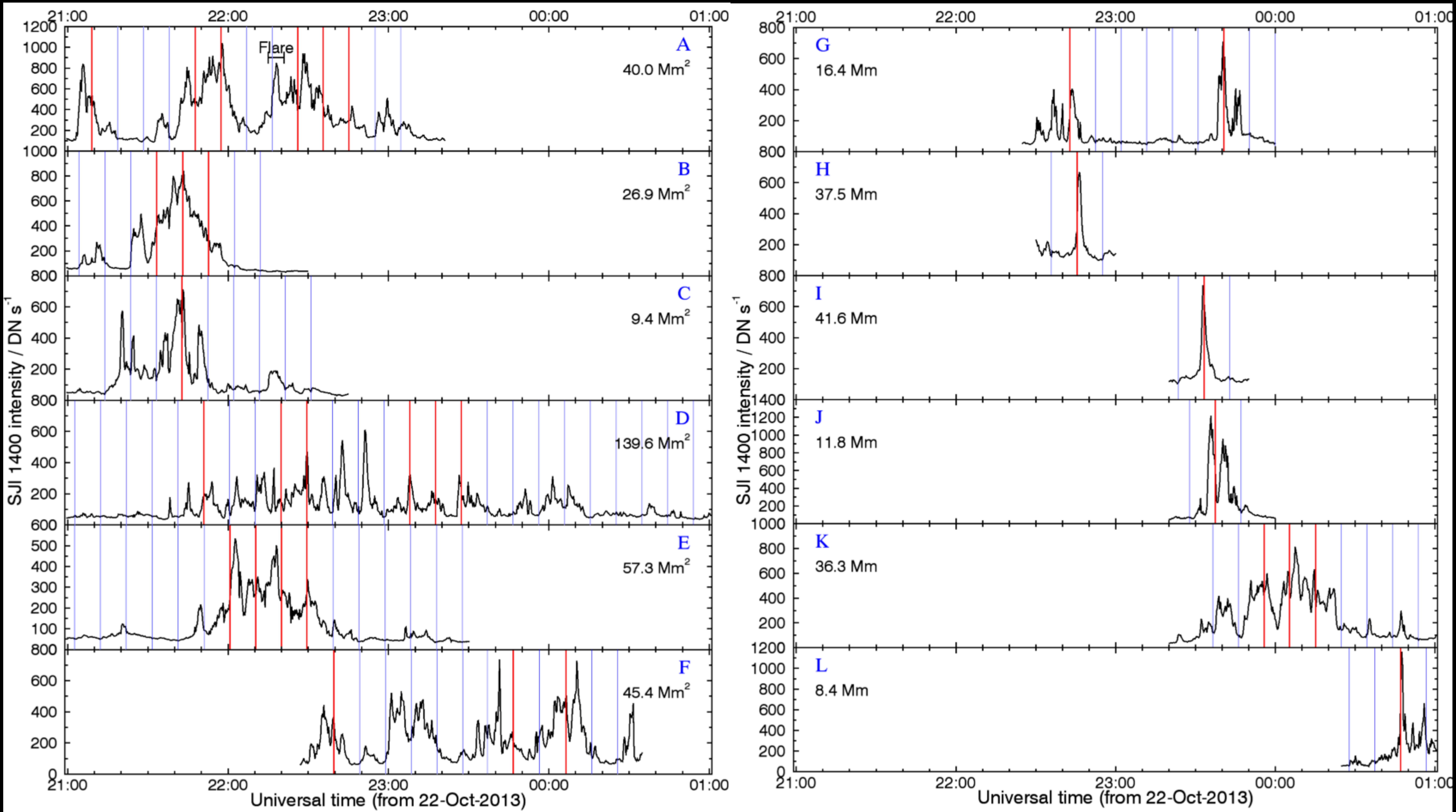
G3 - emerging or cancelling magnetic flux

Magnetic field evolution

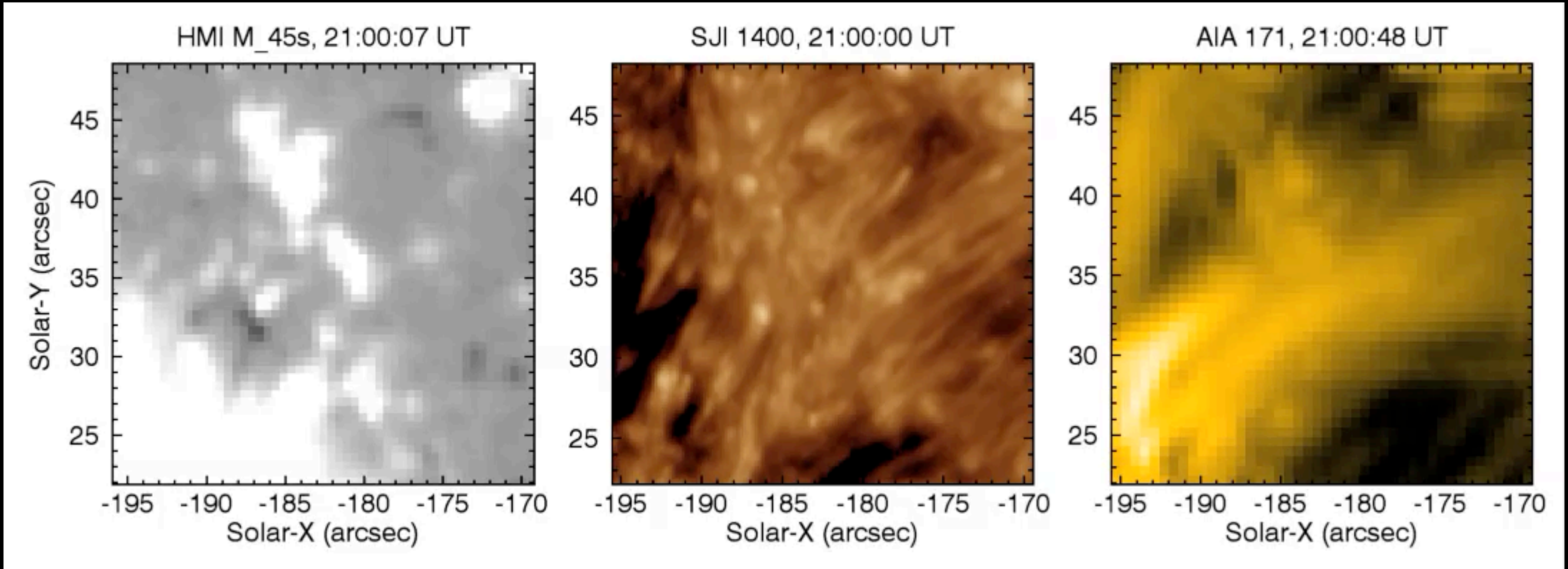


- Magnetic field movie (HMI) covers 18 hours (08:00 to 02:00)
- IRIS data covers 4 hours (21:00 to 01:00)
- UV burst locations marked with blue crosses

Light curves



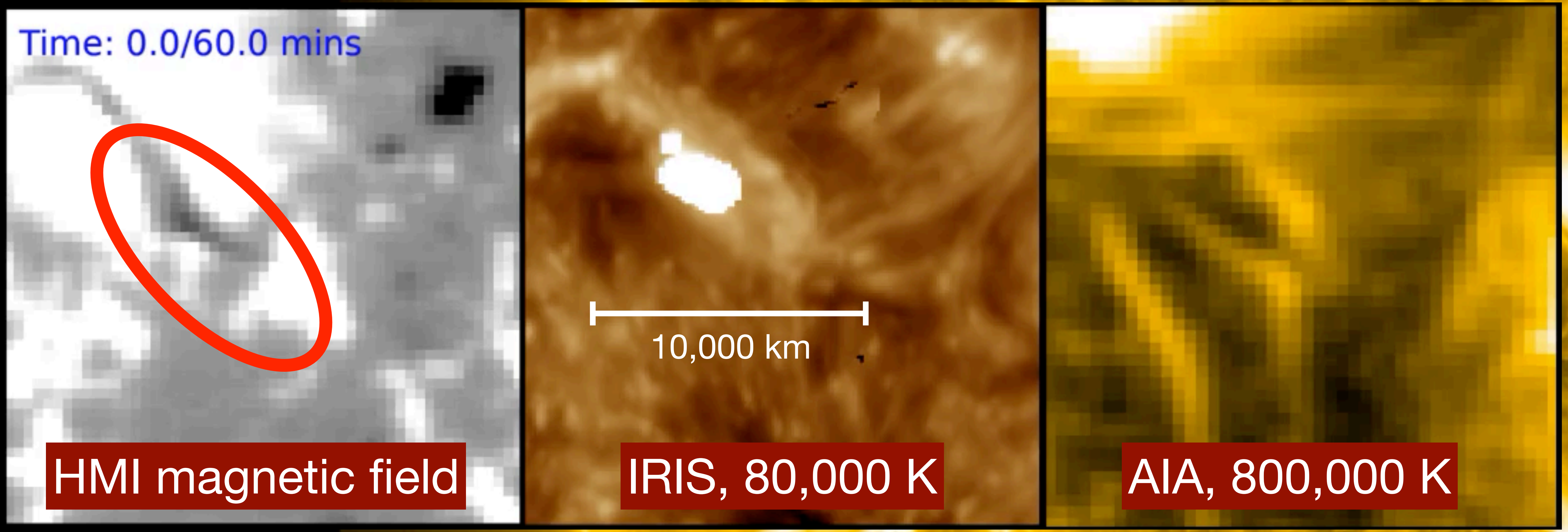
Moving magnetic feature (MMF) example



Plasma at 80 kK

Plasma at 0.8 MK

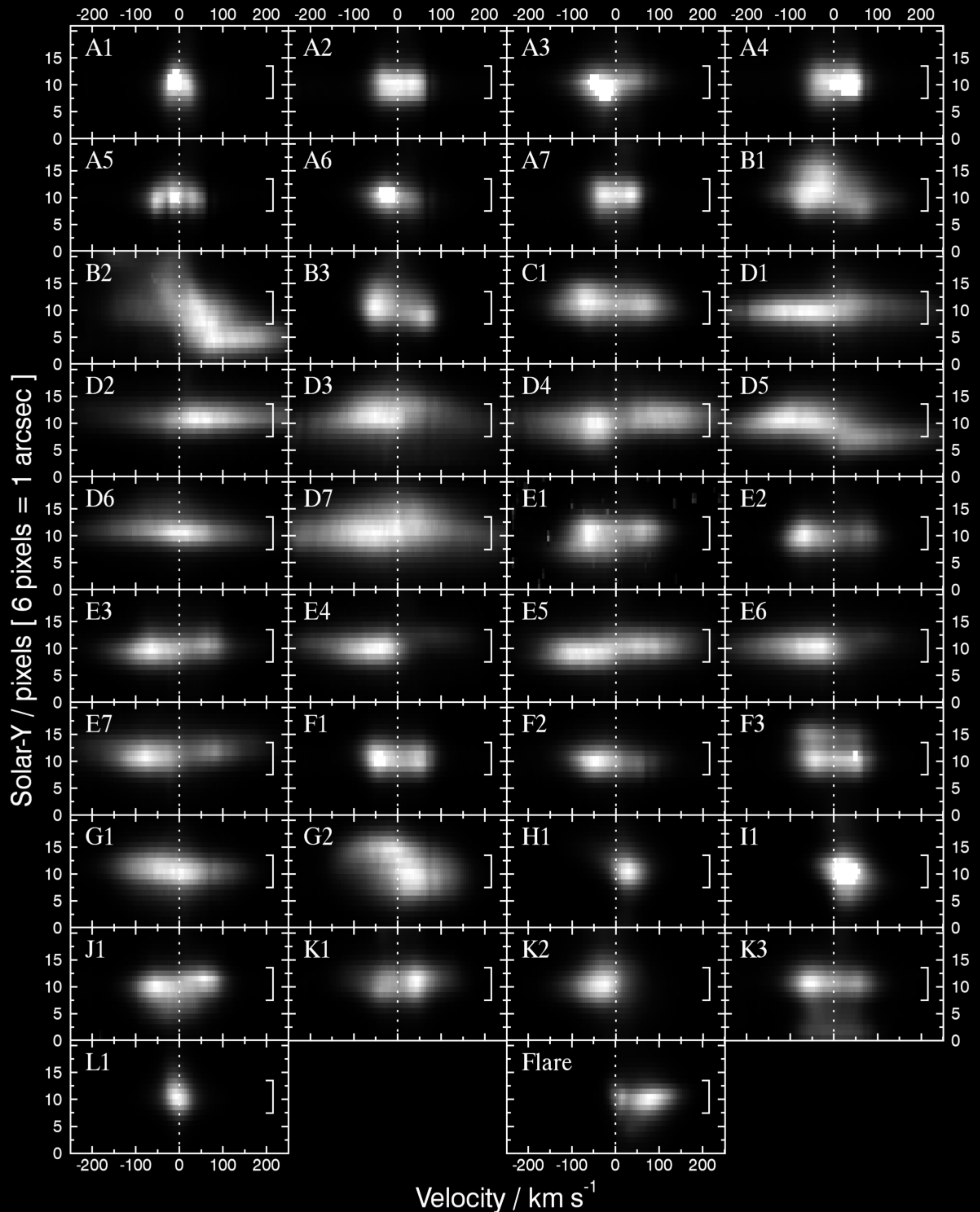
Light Bridge Example



HMI, AIA and IRIS movies show how fast (minutes) magnetic evolution drives explosive atmospheric activity at smallest scales (1000 km, 10 secs)

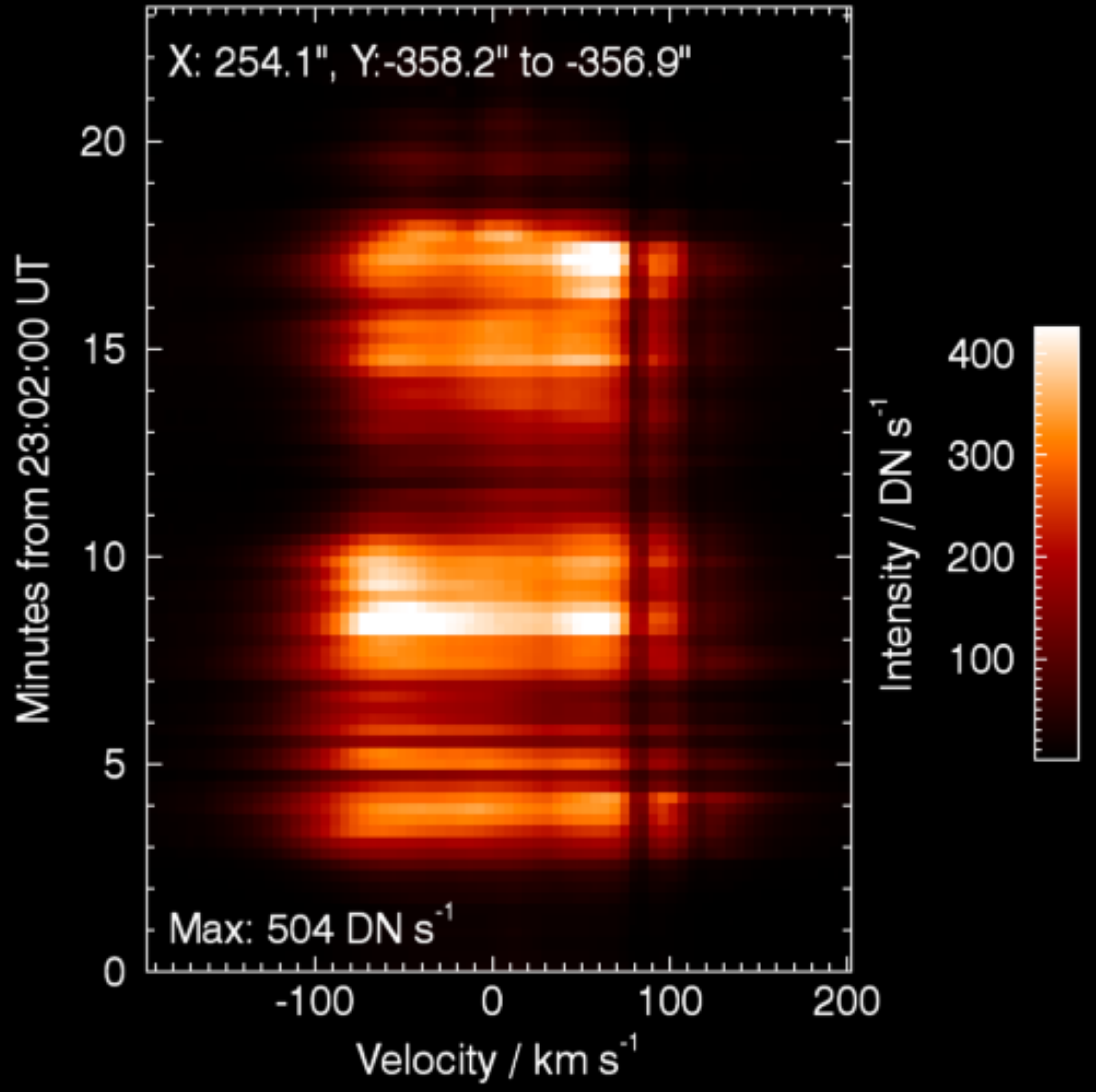
Si IV emission line profiles

- Bursts occur at 12 spatial locations (A-L)
- Observed in multiple raster scans (1, 2, 3, …)
- Wide variety of line profiles
- What physical process(es) cause these shapes?



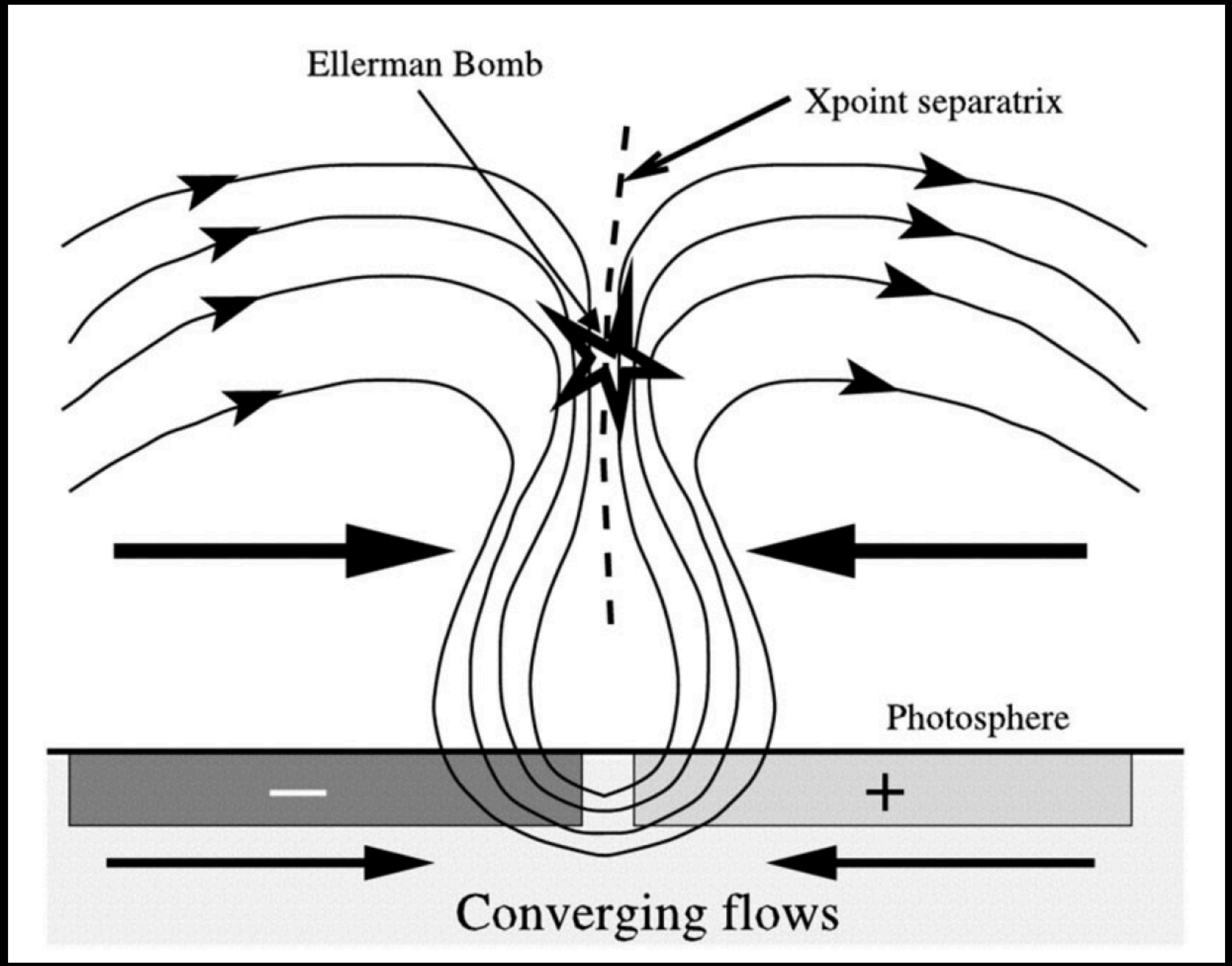
A “sit-and-stare” observation

- The intensity and shape vary significantly
- …but the overall width (≃ 200 km/s) remains about the same
- Also the cool absorption lines (at +80 and +115 km/s) remain present throughout

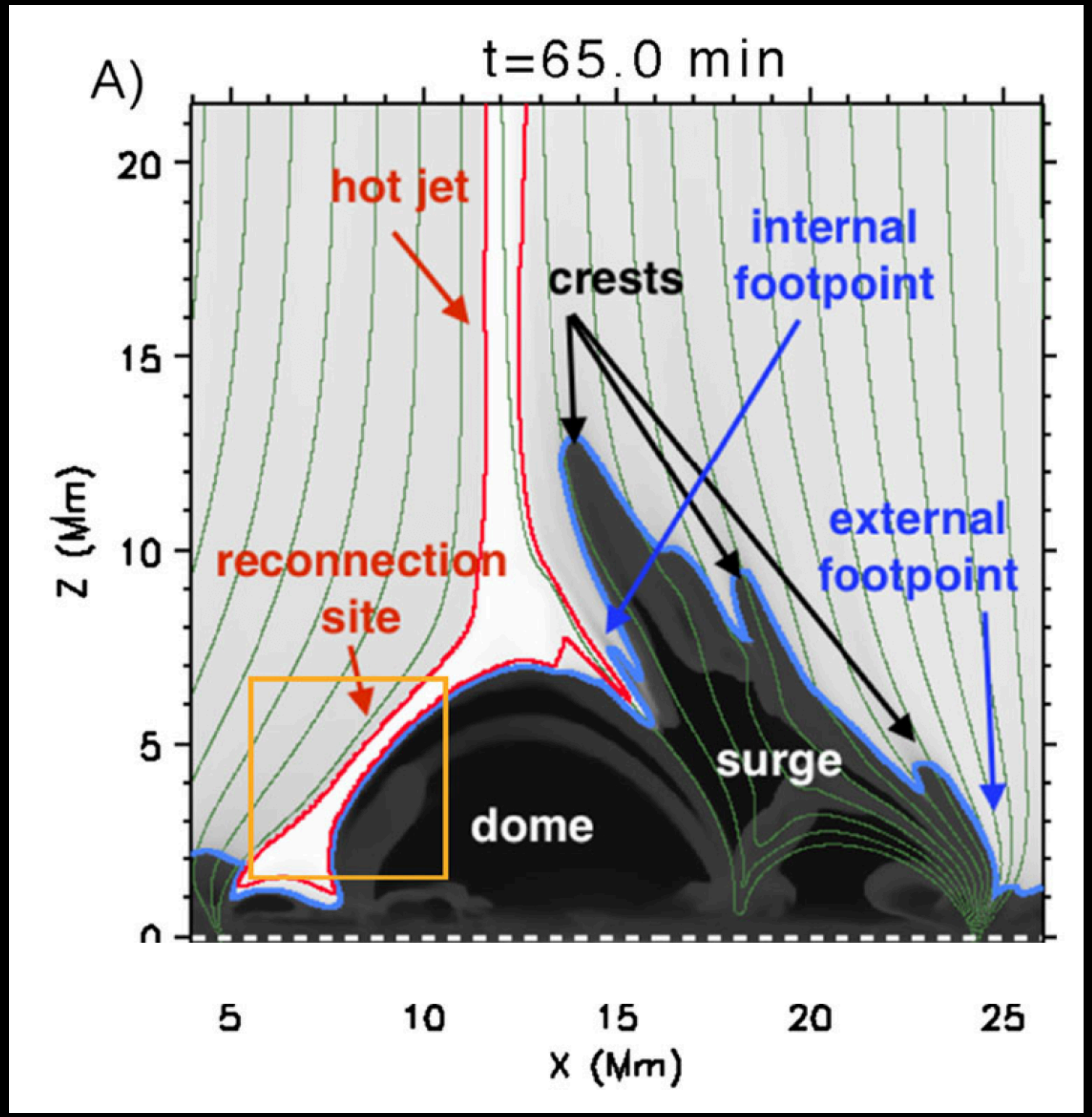


What type of reconnection?

Occurs at heights of ~ few Mm (temperature minimum region)



U-loop reconnection
[Georgoulis et al. (2002, ApJ)]



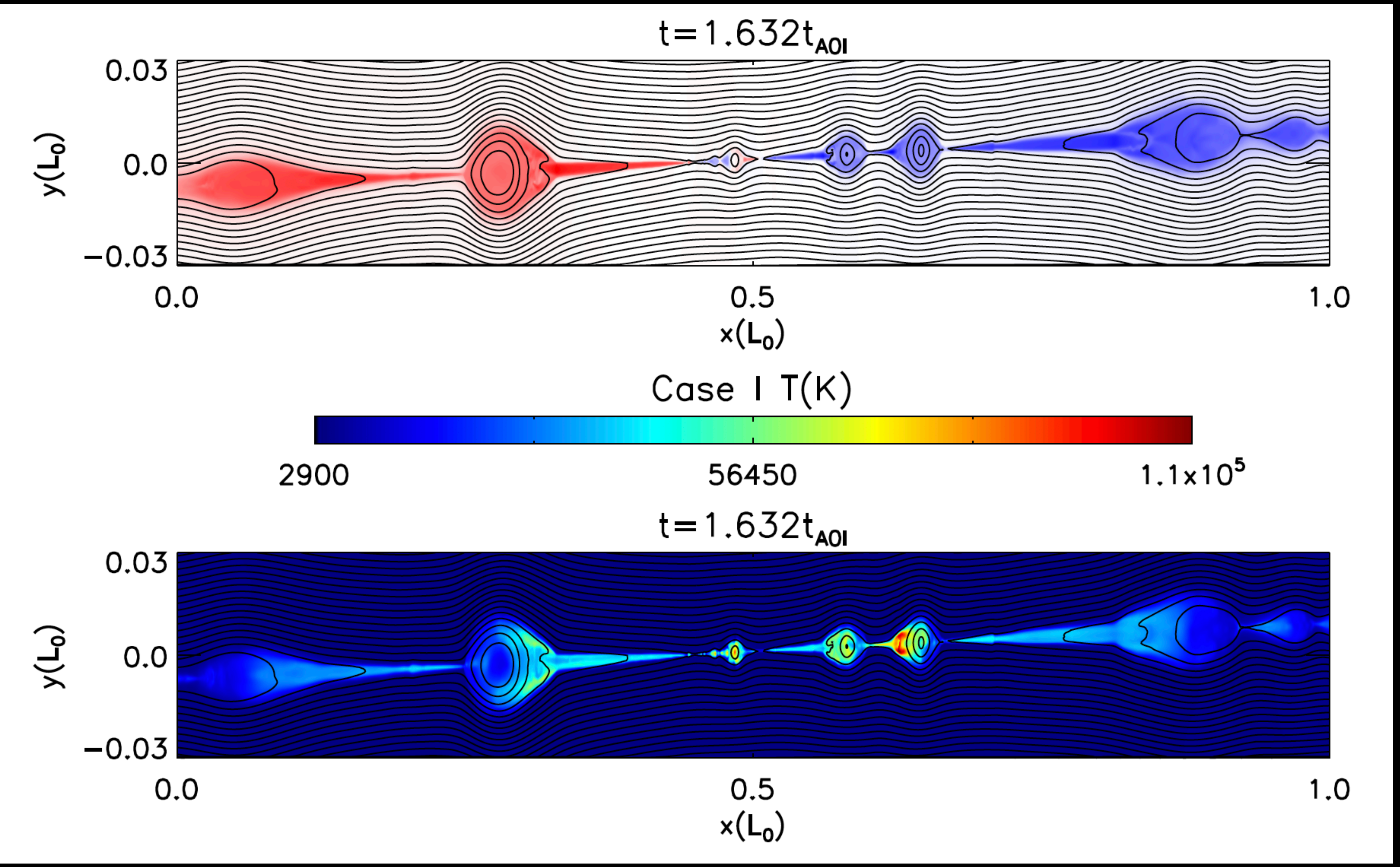
Jet/surge reconnection
[Nóbrega-Siverio et al. (2017, ApJ)]

Magnetic geometry may affect coronal signature

Modeling

Current sheets & plasmoids

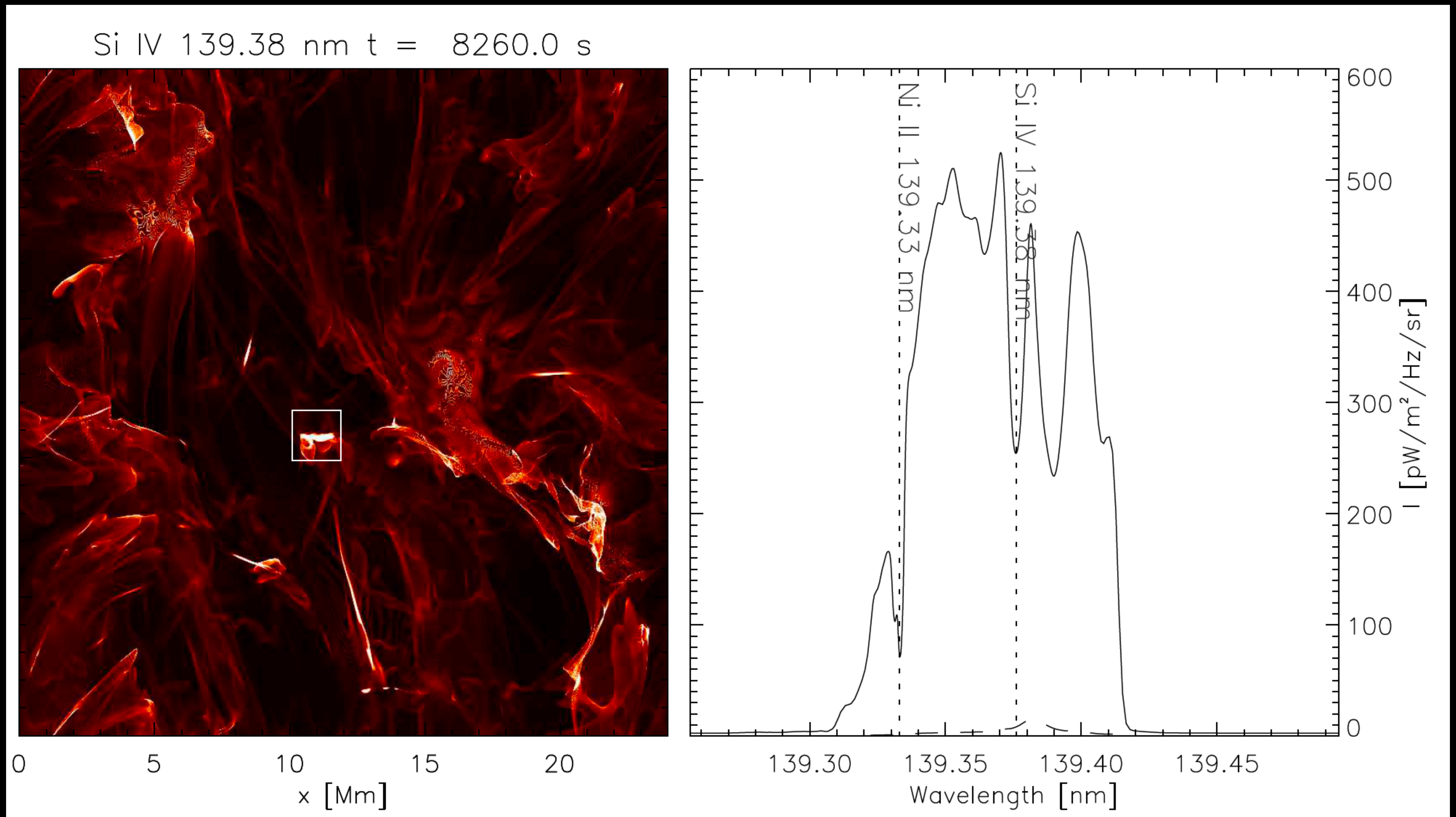
[Lei Ni et al., 2015, 2016, 2018a,b,c, 2021]



- High resolution (meters)
- Can model details of plasmoid heating and dynamics

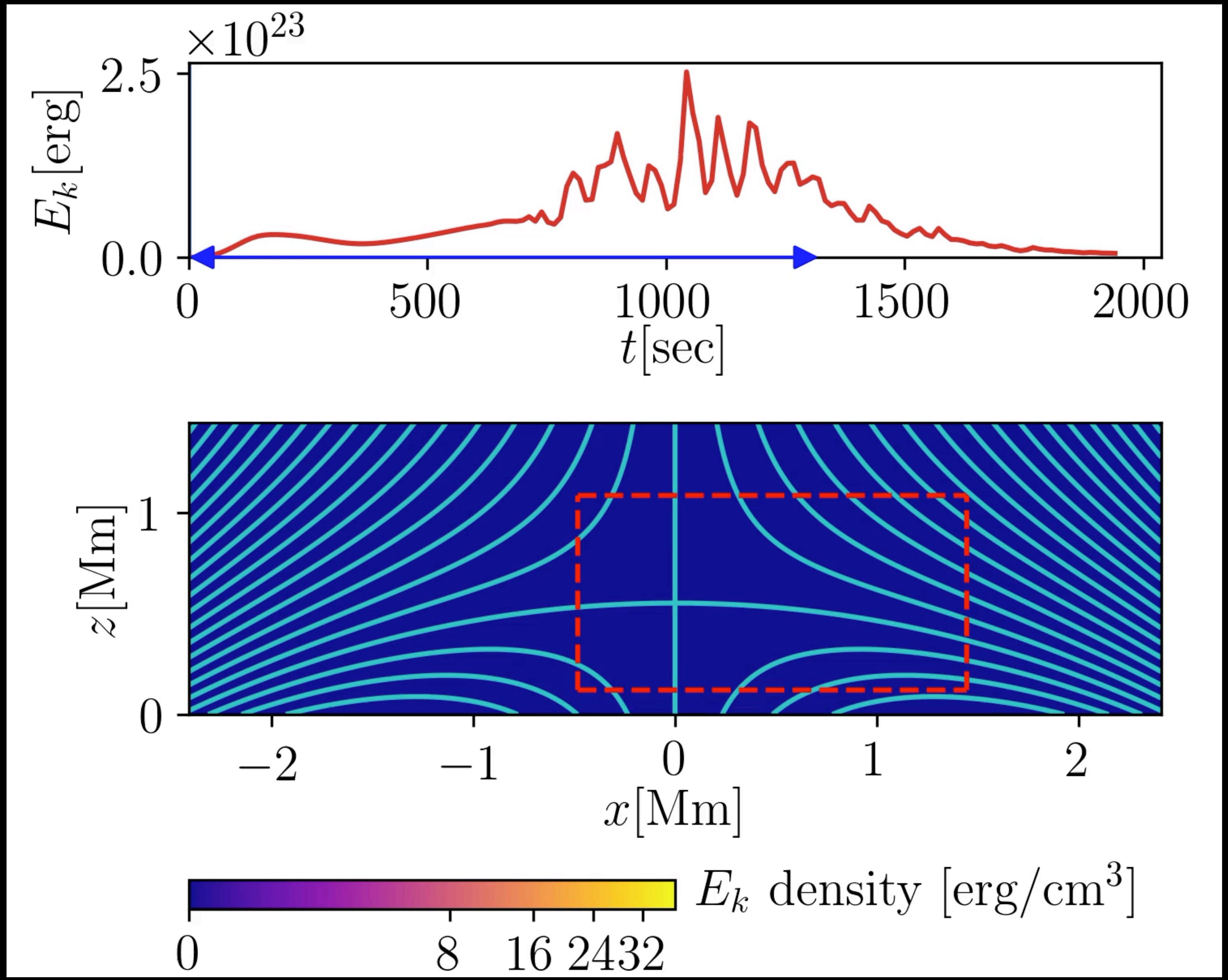
3D flux emergence

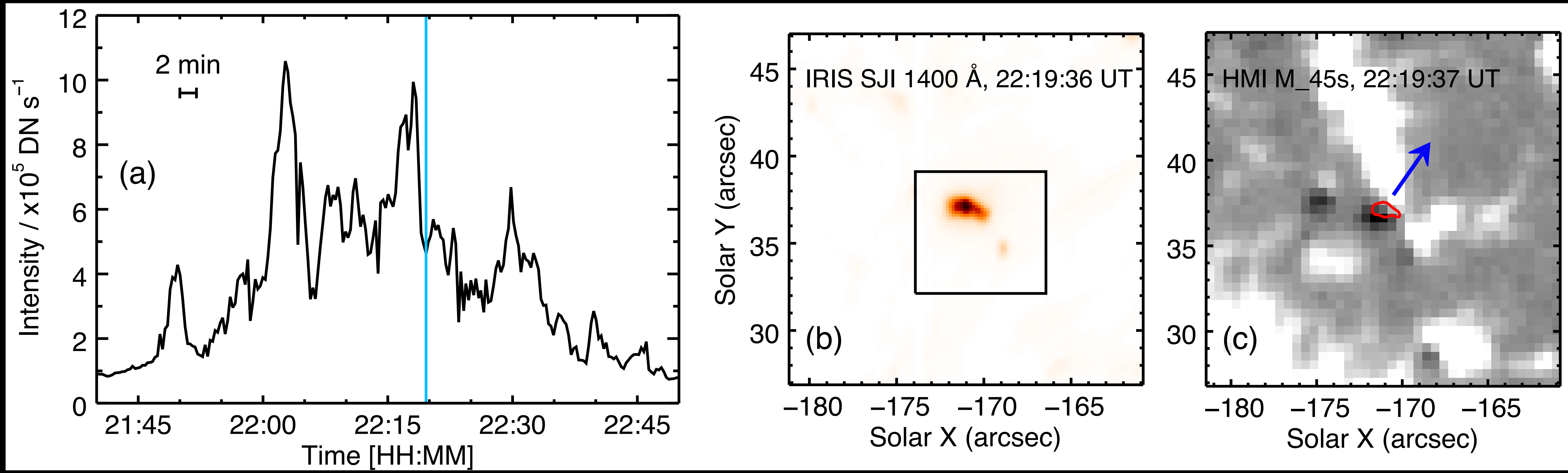
[Hansteen et al., 2017, 2019]



- Lower resolution (10's of km)
- Fully 3D, can reproduce line profiles

Plasmoid-mediated reconnection (Peter et al. 2019)



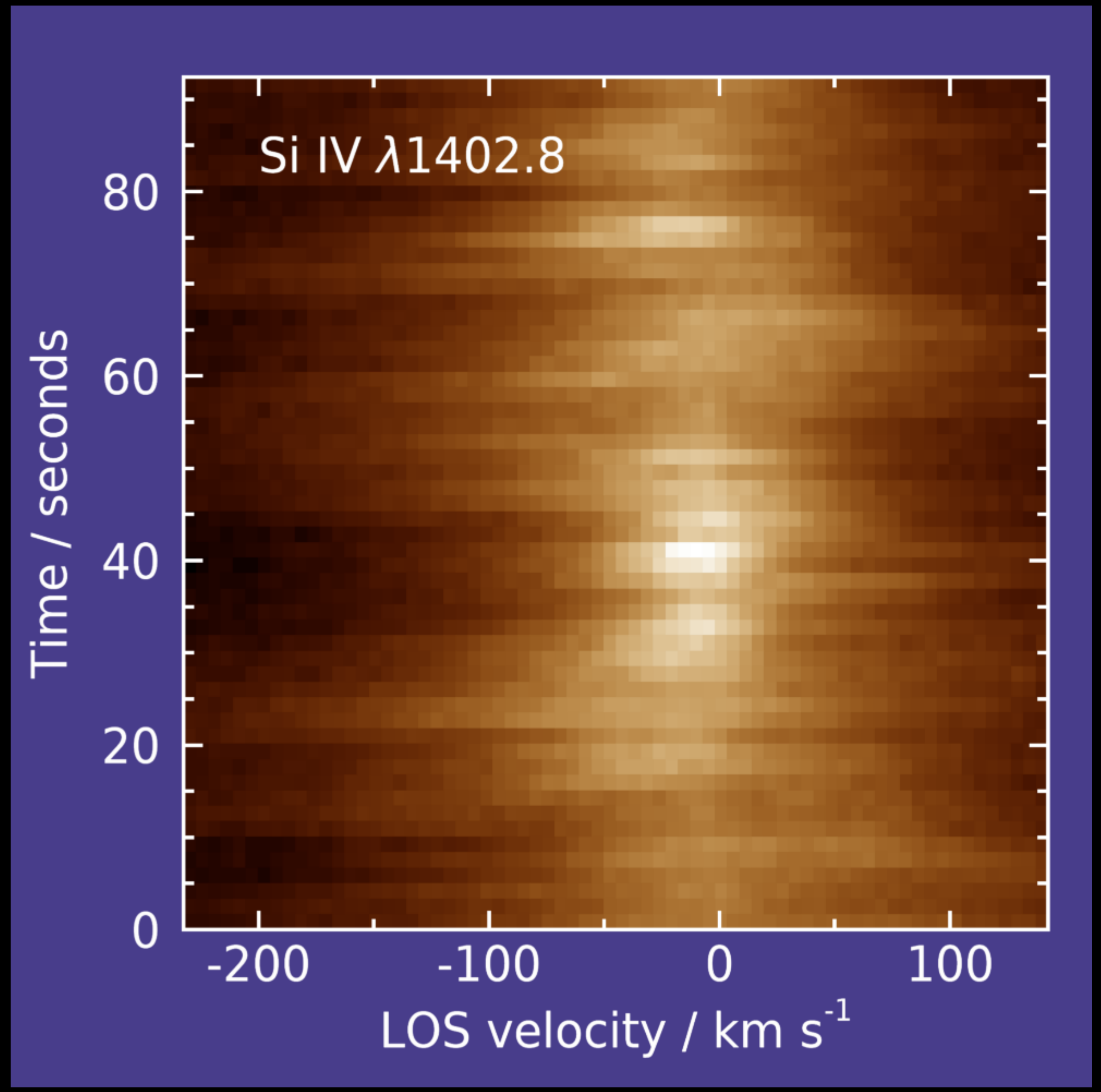


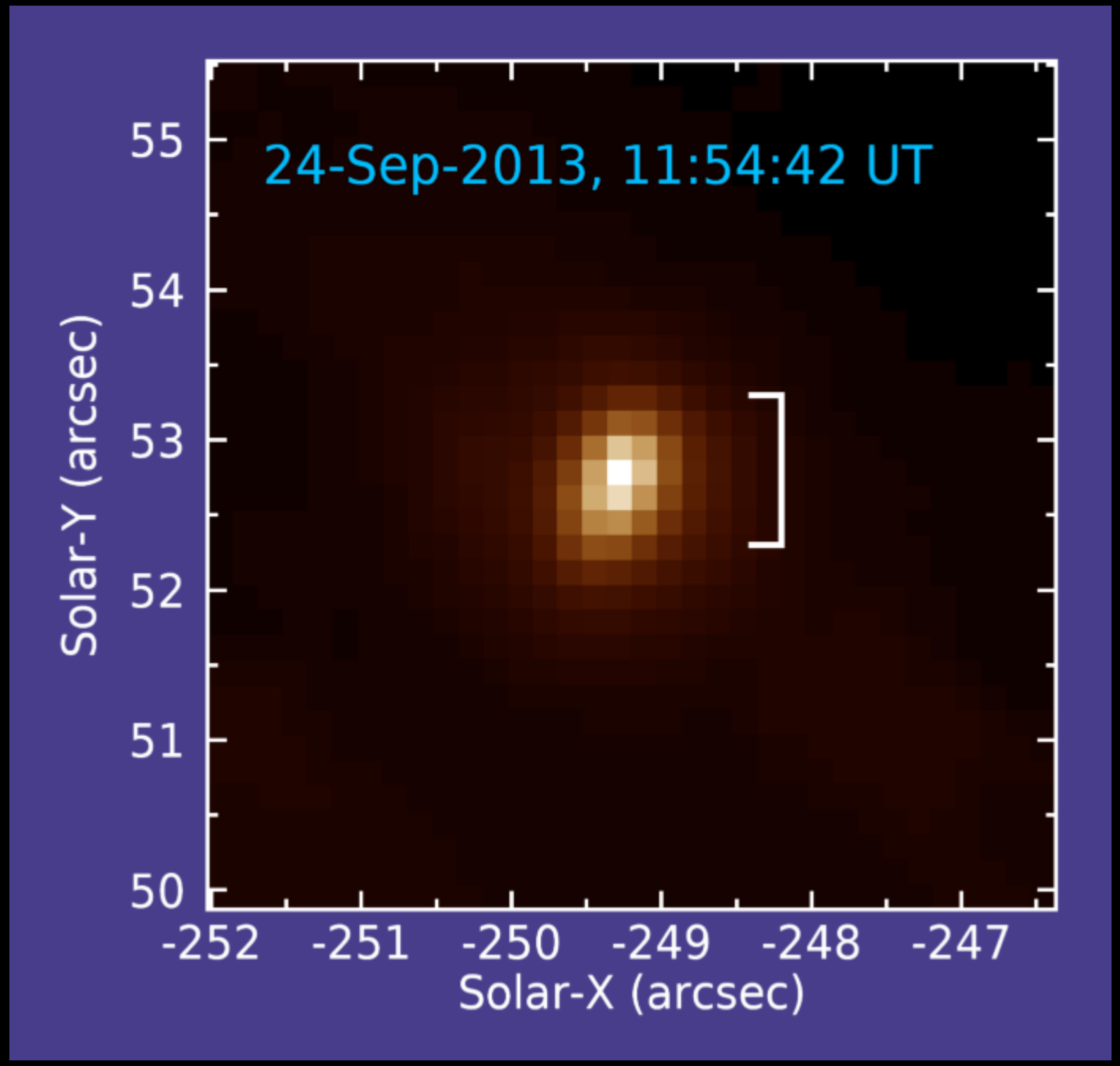
Example IRIS light curve from moving magnetic feature UV burst

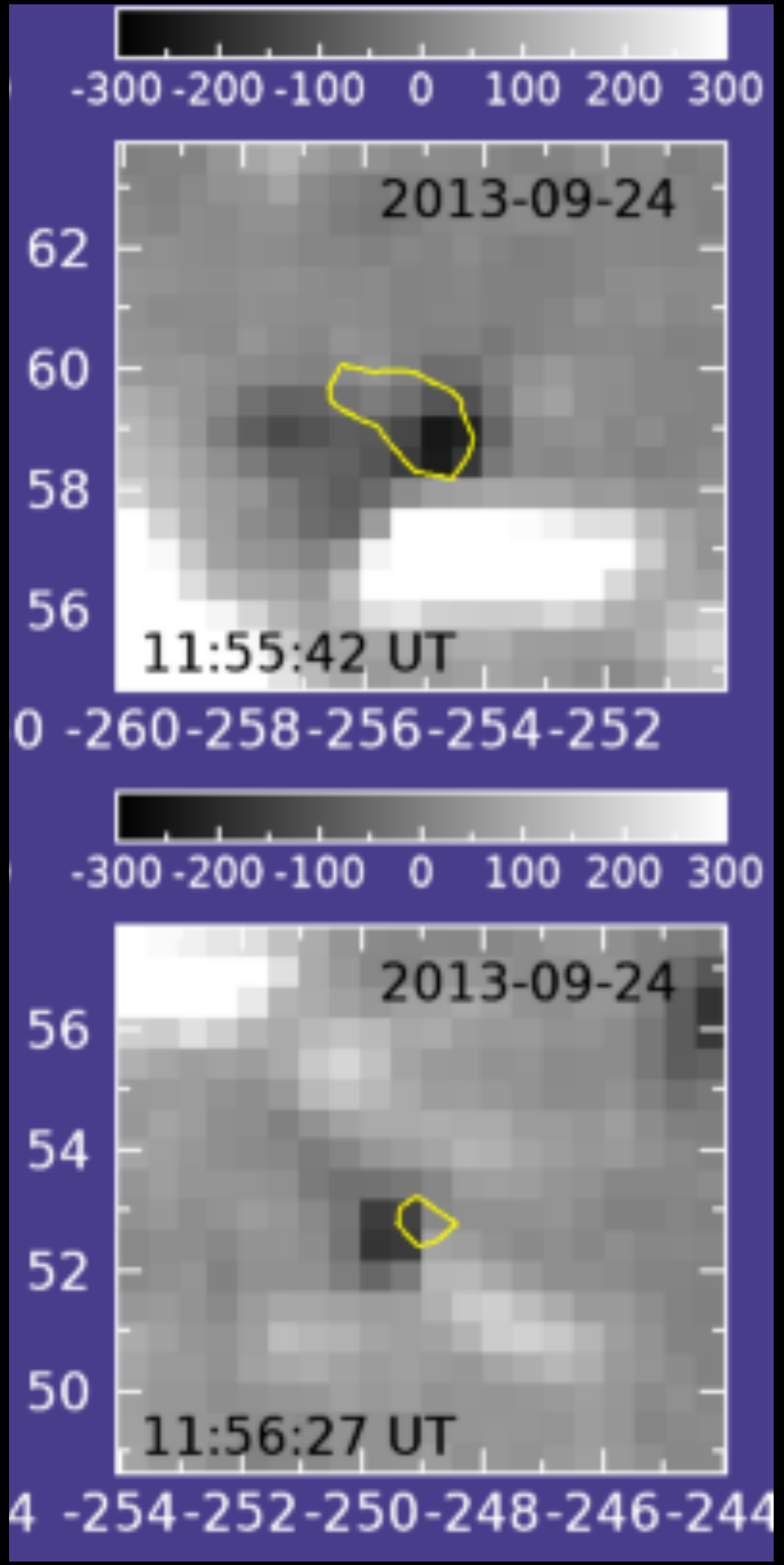
- Simulation of moving magnetic feature UV burst
- 2.5D resistive MHD
- See “flickering” in kinetic energy related to plasmoids

Advantages of transition region for reconnection studies

- Reconnection site is co-spatial with photospheric/chromospheric magnetic field
- Magnetic evolution is usually obvious (typically, cancellation)
- Highest spatial resolution (0.3 arcsec)
- Can directly see the reconnection dynamics in line profiles (?)







Summary

- UV bursts are an important case study for magnetic reconnection
- Modeling suggests complex Si IV line profiles can be reproduced
- DKIST will give much-improved magnetic field measurements
- DKIST will also allow Ellerman bomb connection to be studied
- EUVST will reveal temperature structure of UV bursts

Decadal Survey thoughts

UV bursts show benefit of:

- High resolution spectra at high spatial resolution
- Stable, high resolution, high-cadence magnetograms
- Transition region imaging

Decadal survey mission concepts:

- “4π” or polar missions likely would not prioritize high-resolution, high-cadence data
- Imaging spectrometers would be a low priority