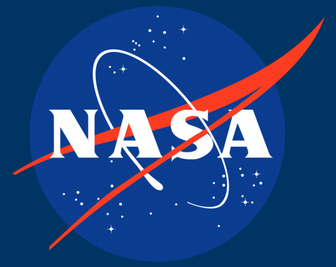
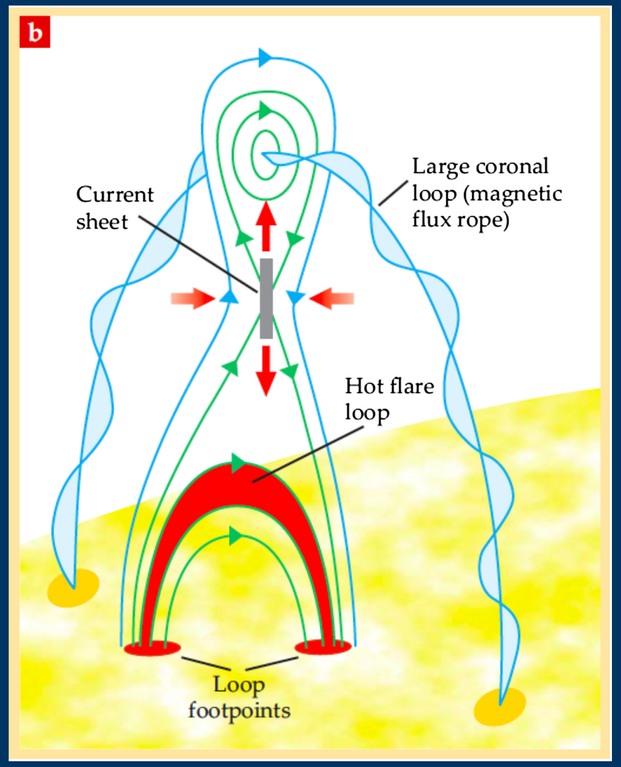
Magnetic reconnection in the low atmosphere: Ellerman bombs and UV bursts

Dr Peter Young
peter.r.young@nasa.gov

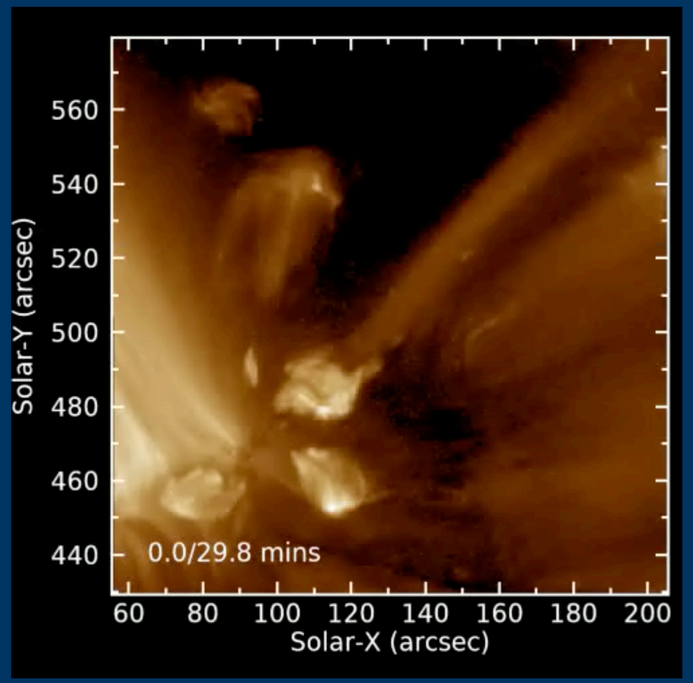
NASA Goddard Space Flight Center



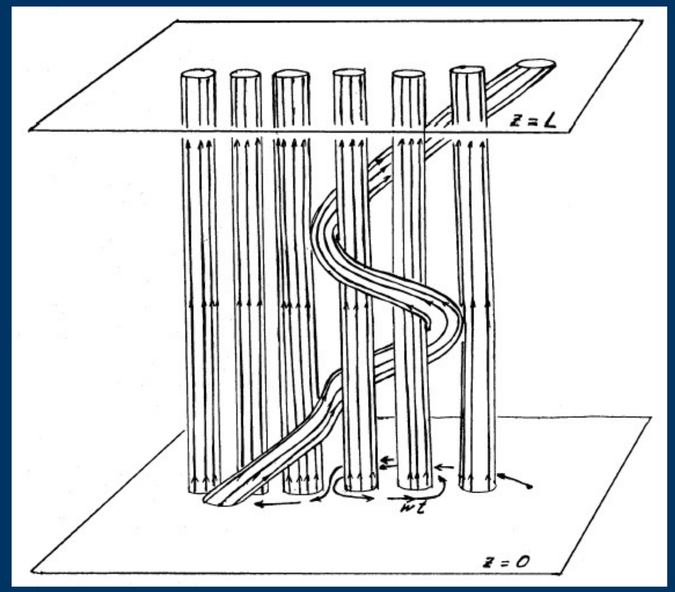
Reconnection scenarios



Solar eruptive events
[Holman, 2016, JGR]



Coronal jets

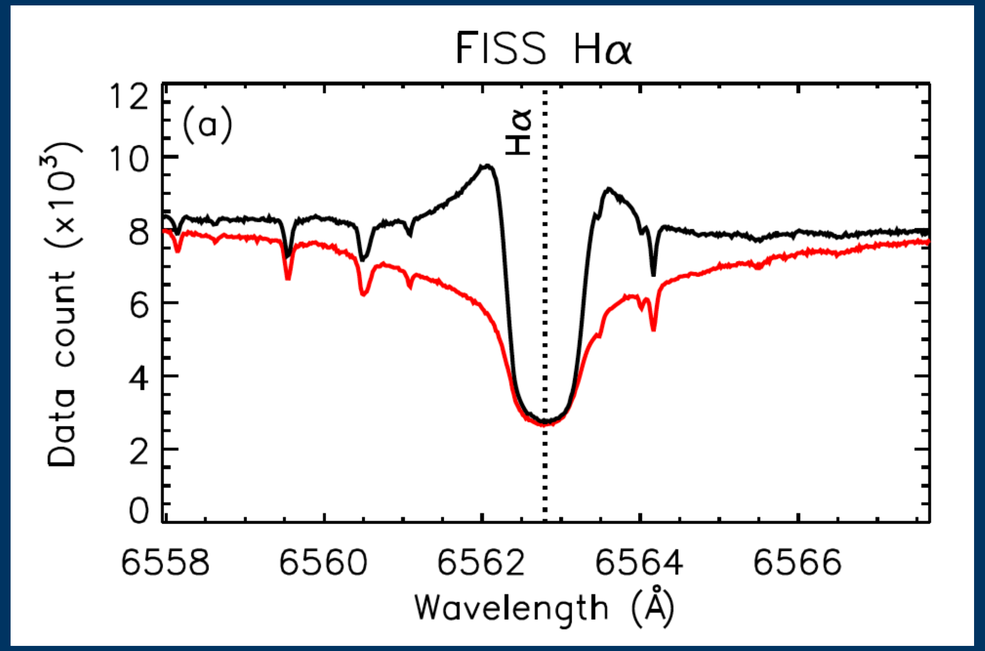


Nanoflares
[Parker, 1983, ApJ]

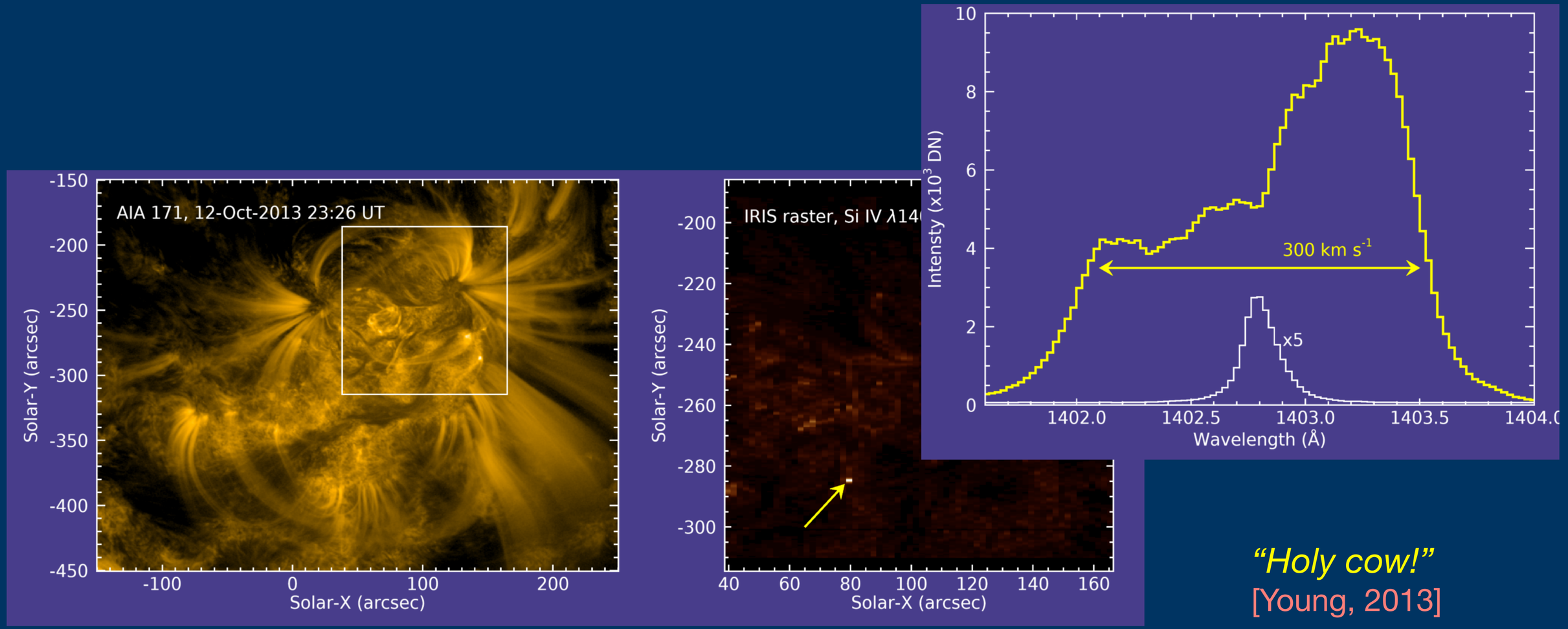
Ellerman bombs (EBs)

- Identified through enhanced wings of H-alpha
- Wings extend over several Å [> ±200 km/s]
- Size ≤ 2”
- Lifetimes 5-10 mins

“On the first occasion the appearance was so extraordinary that it seemed hardly real”
[Ellerman, 1917, ApJ]



Enhanced Hα wings
[J. Hong et al. (2017, ApJ)]

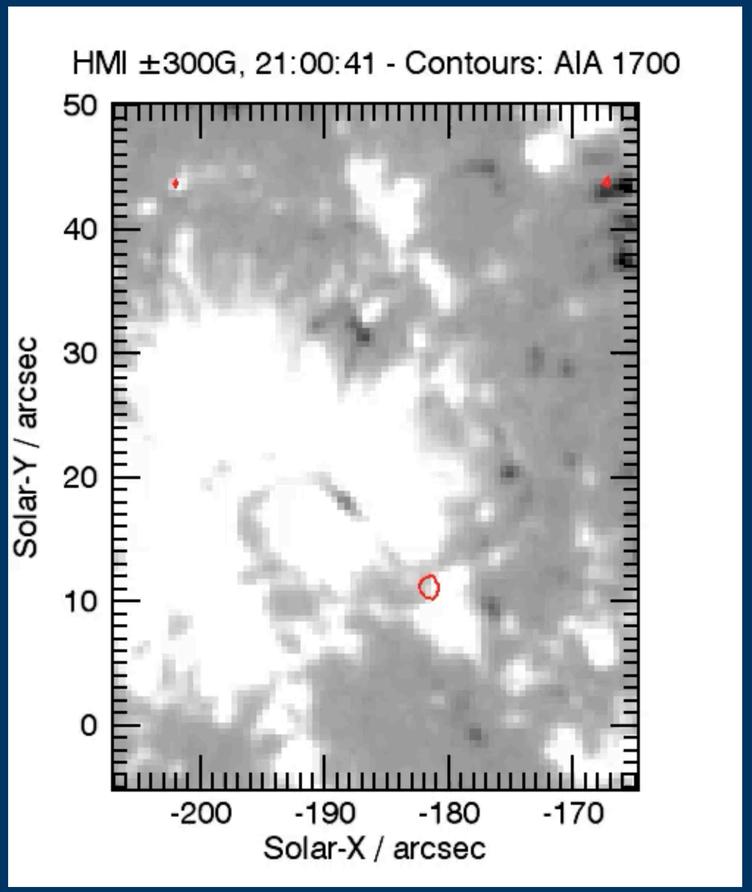


"Holy cow!"
[Young, 2013]

ISSI team named these events "Solar UV bursts"
[Young et al., 2018, Sp. Sci. Rev.]

EB - UV burst relationship

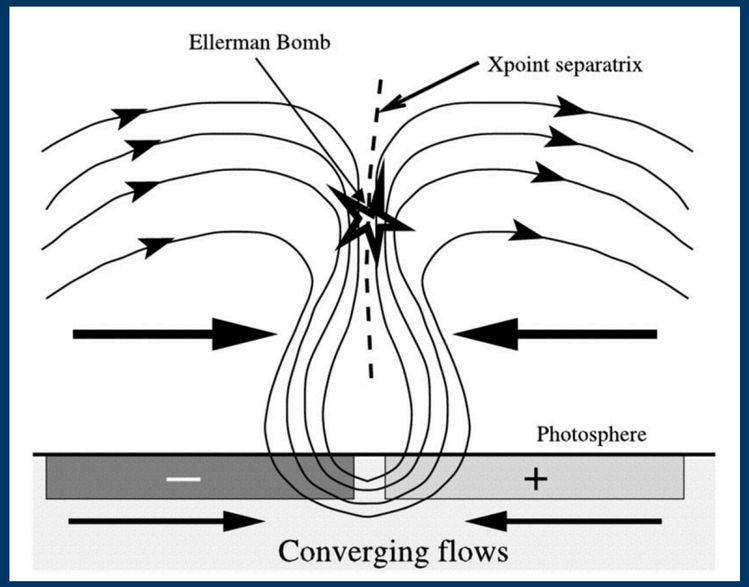
- They occur in similar locations
  - (1) MMFs, (2) emerging flux, (3) light bridges
- H. Tian et al. (2016, ApJ):
  - 10-20% of EBs have a UV burst signature
  - 30-60% of UV bursts have EB signature



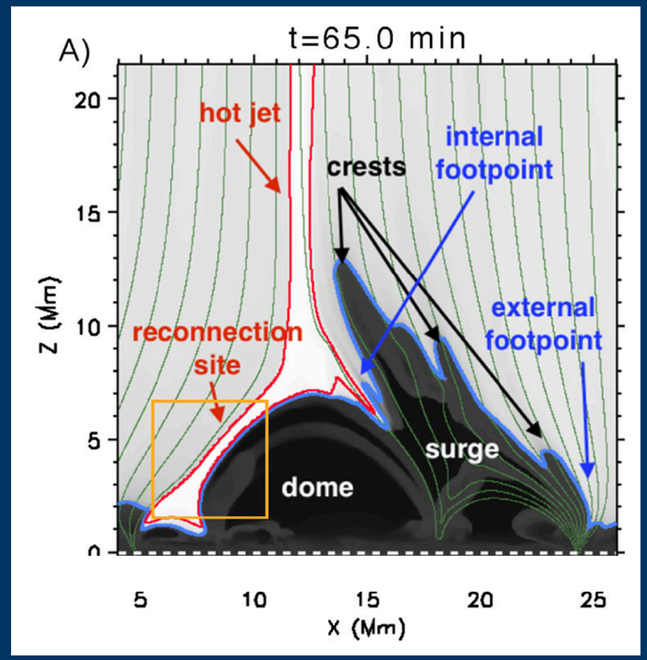
Notes:
- EBs can be identified in wings of Mg II (IRIS) [Grubecka et al. (2016, A&A)]
- Most EBs can be found in AIA 1700 Å images [Vissers et al. (2019, A&A)]

What type of reconnection?

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



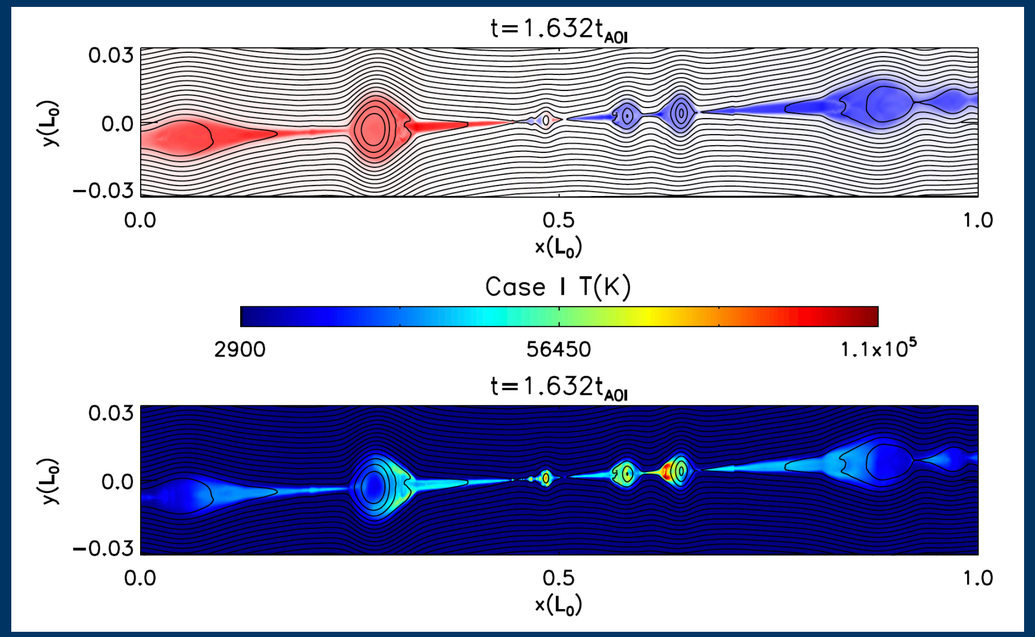
U-loop reconnection
[Georgoulis et al. (2002, ApJ)]



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

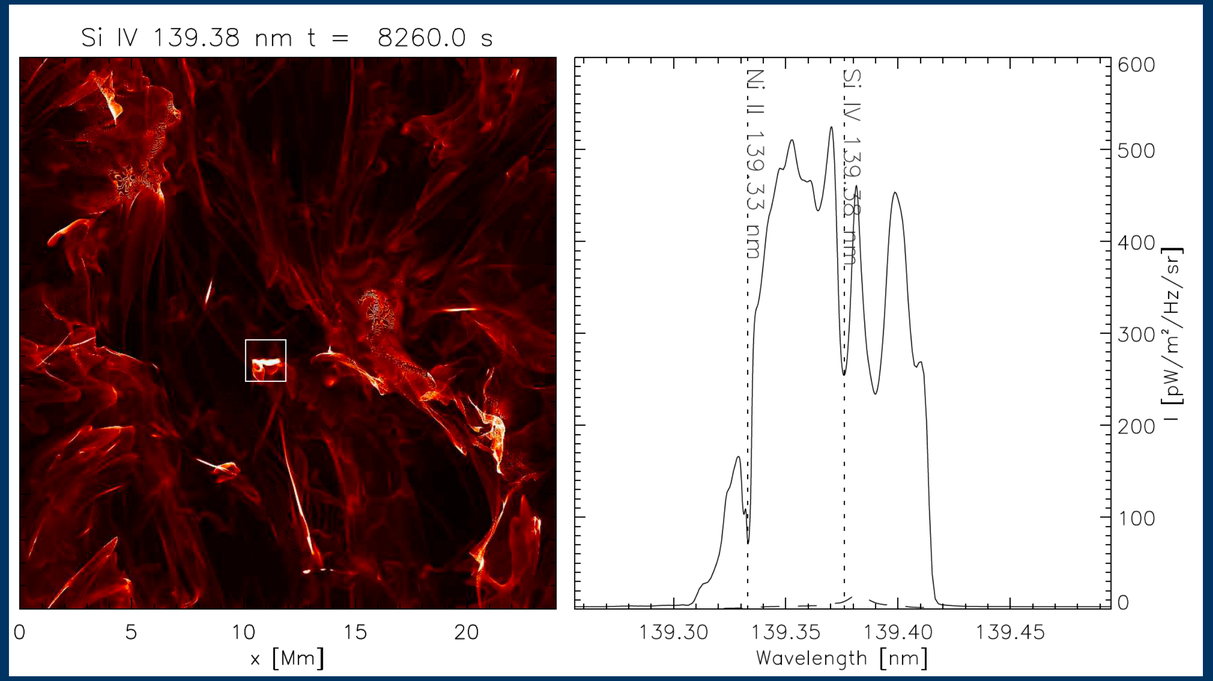
Modeling

Current sheets & plasmoids
[Lei Ni et al., 2015, 2016, 2018a,b,c]



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

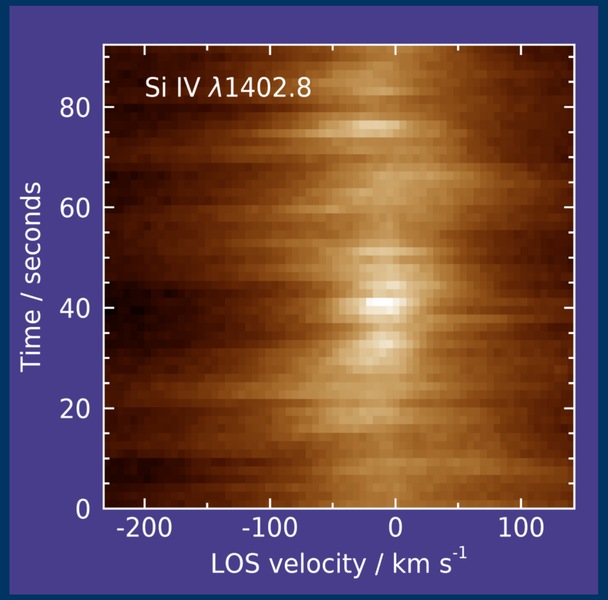
3D flux emergence
[Hansteen et al., 2017, 2019]

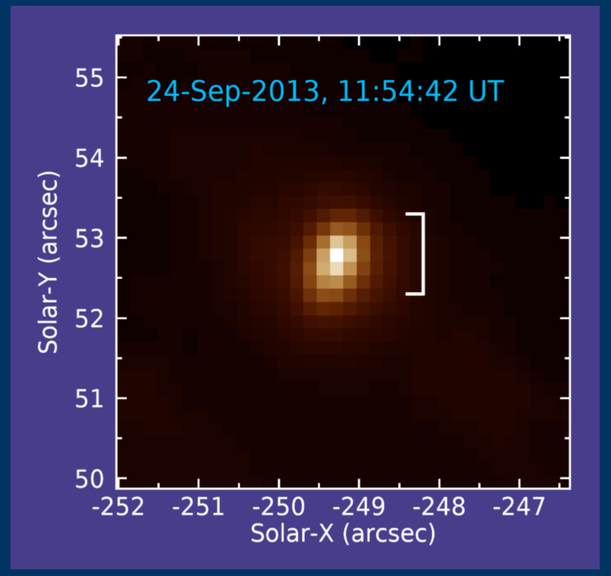


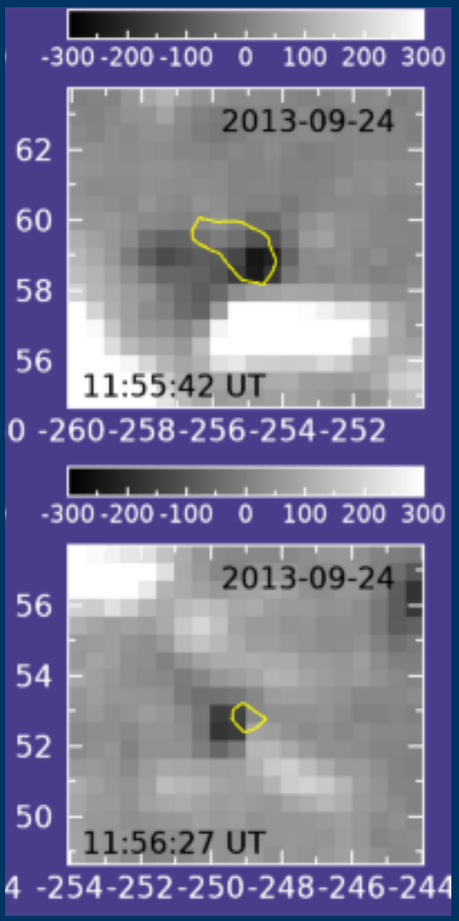
- Lower resolution (10’s of km)
- Fully 3D, can reproduce line profiles

Advantages of the chromosphere & transition region

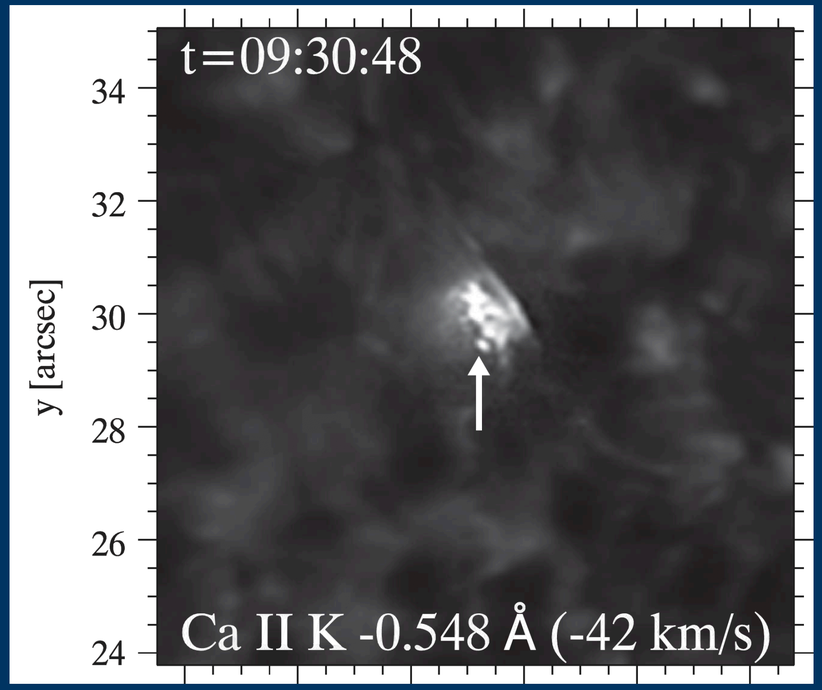
- Reconnection site is co-spatial with photospheric/chromospheric magnetic field
- Magnetic evolution is usually obvious (typically, cancellation)
- Highest spatial resolution (< 100 milli-arcsec)
- Can directly see the reconnection dynamics in line profiles (?)



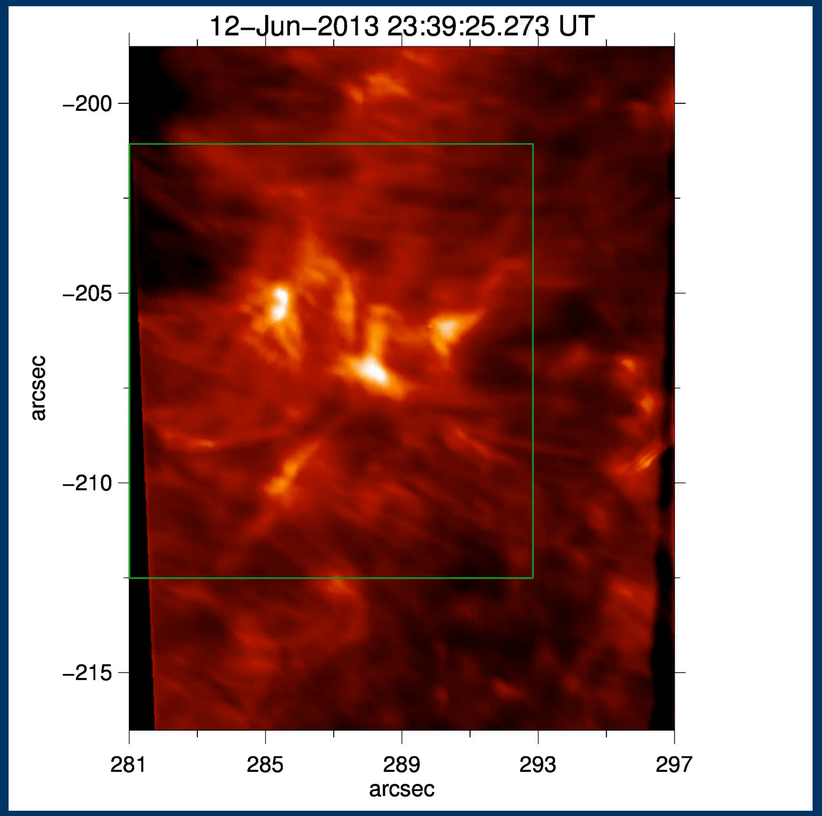




High spatial resolution



“Plasmoid” at 0.08” resolution observed with CHROMIS (Ca II K)
[Rouppe van der Voort et al., 2017, ApJL]

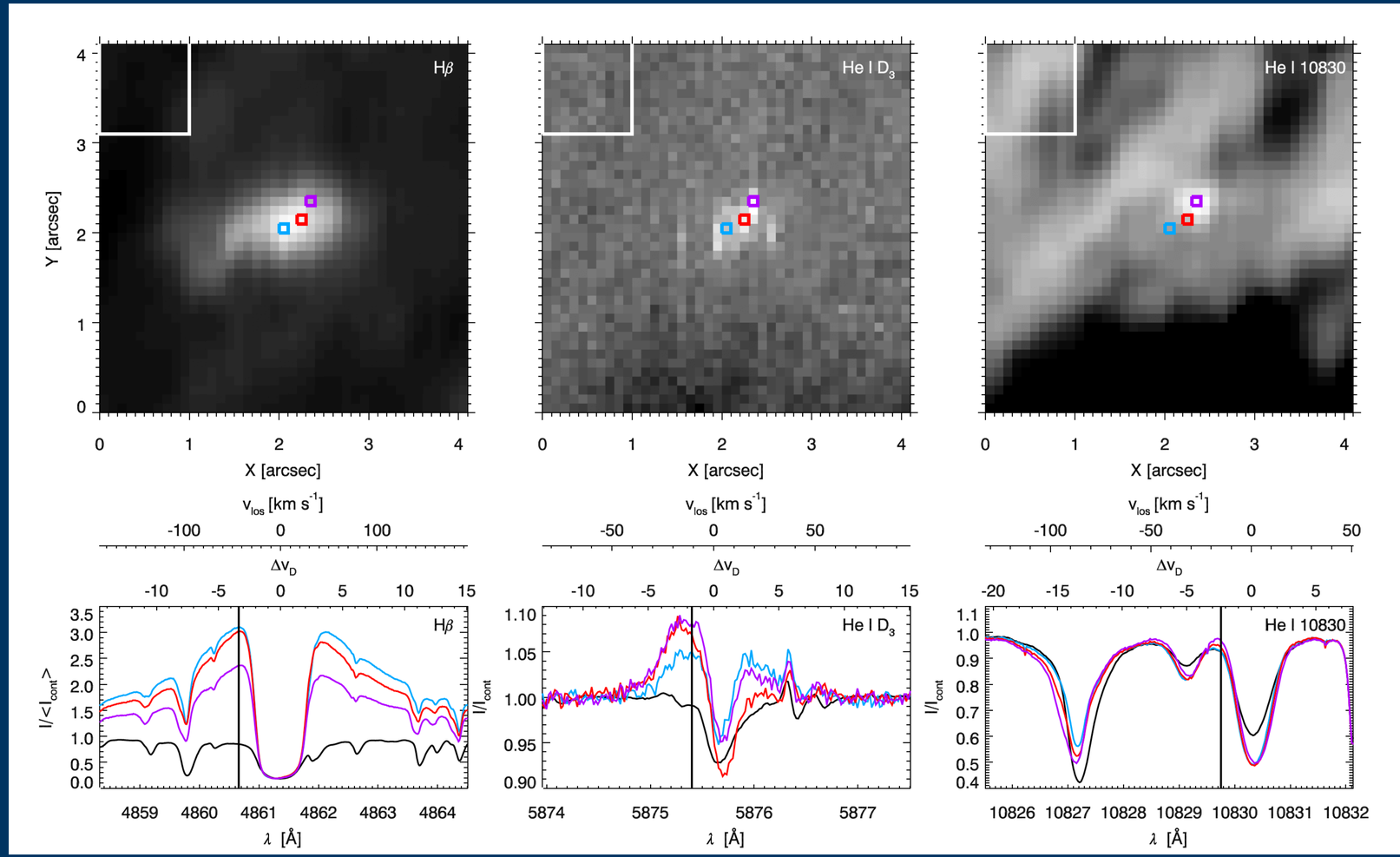


Burst evolution observed at 0.1” resolution with SUNRISE (Ca II H)
[Smitha et al., 2018, A&A]

Can UV bursts be seen by DKIST?

- UV bursts are seen at transition region temperatures
- Can they be seen at visible/ IR wavelengths?

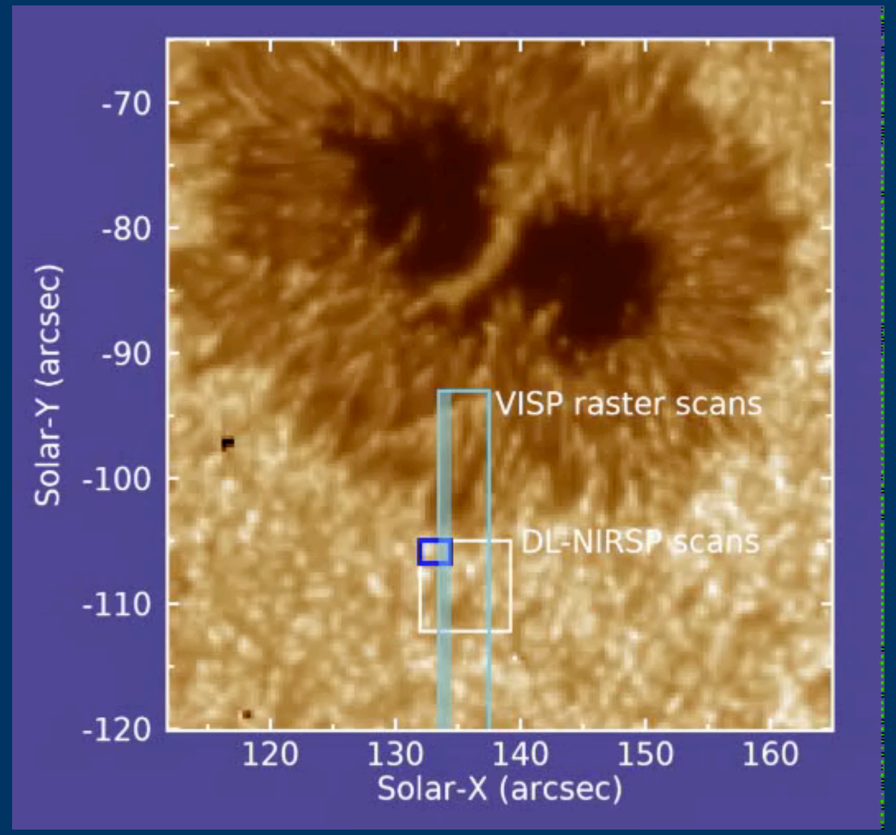
EBs with UV burst signatures show wing enhancements in He I D_3 (λ5876) and λ10830
[Libbrecht et al., 2017, A&A]



Observing strategies

- Experience from SST/CRISP:
  - cadence ≃ 10 seconds
  - maximum spatial resolution
- VTF is ideal, but single-etalon restriction limits wavelength
- VISP has fast raster mode (100 steps in 3 sec)
  - Wavelength windows are 7-14 Å -> ideal for studying extended EB wings
- DL-NIRSP must do small 2D scans

EBs often associated with MMFs from sunspots



VTF: single-etalon means wavelength scans of ± 0.5 Å; EB wings typically at ± 1.0 Å

Comparison of Use Case observing modes

	VISP	VTF	DL-NIRSP
UC-19 (Katsukawa)	Mg I 5183, Fe I 5250	Hα 6563, Fe I 6302	Ca II 8542, He I 10830, Fe I 15650
UC-78 (De Pontieu)	Mg I 5172, Fe I 5250	Hα 6563	Ca II 8542, He I 10830, Fe I 15650
UC-108 (Young)	Hβ 4861, Mg I 5183, Hα 6563	—	Ca II 8542, He I 10830, Fe I 15650
UC-134 (Vissers)	Hβ 4861, Mg I 5183, Hα 6563	—	Ca II 8542, He I 10830, Fe I 15650
UC-150 (J. Lee)	—	Ca II 8542 / Hα 6563	—/Ca II 8542, He I 10830, Fe I 15650

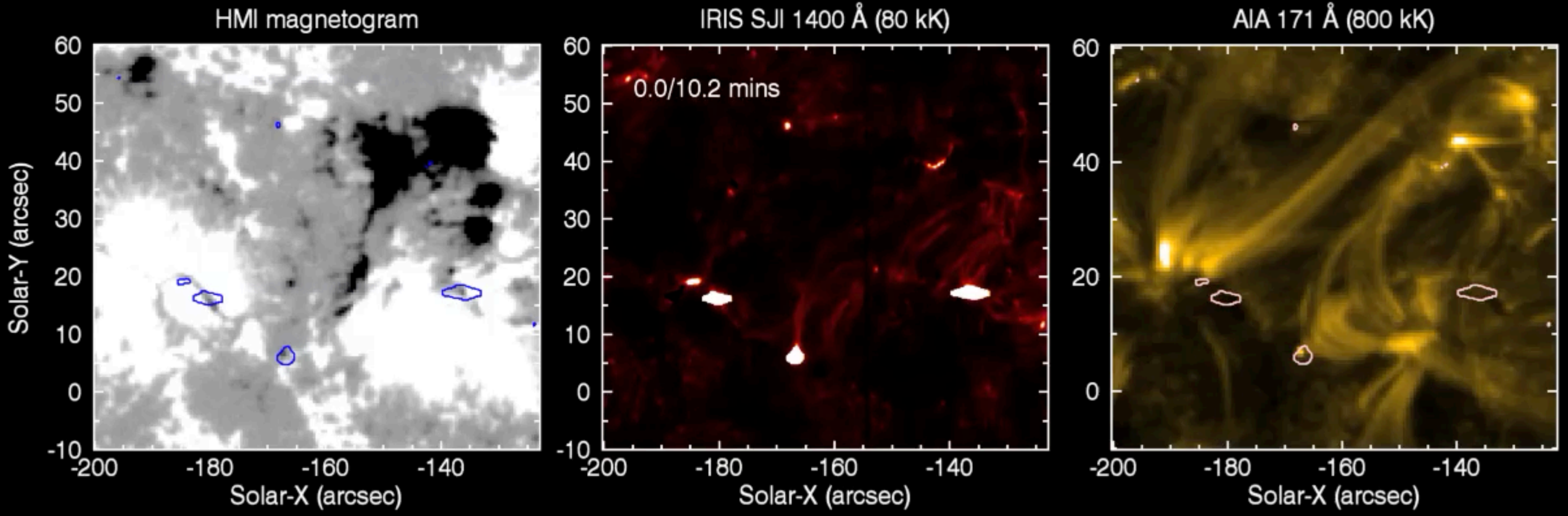
Summary

- Ellerman bombs provide excellent test of DKIST's spatial and temporal capability
- IRIS coordination required for UV burst connection [but He lines may be useful]

- EBs and UV bursts are important case study for modeling reconnection
  - no activities currently taking place in US, though!

Talk available at https://pyoung.org/talks

EXTRA SLIDES


HMI magnetogram
IRIS SJI 1400 Å (80 kK)
AIA 171 Å (800 kK)
0.0/10.2 mins
Solar-Y (arcsec)
Solar-X (arcsec)
Solar-X (arcsec)
Solar-X (arcsec)
60
50
40
30
20
10
0
-10
-200
-180
-160
-140