Rosseland Centre for Solar Physics

Ellerman Bombs and UV Bursts:

Reconnection at different atmospheric layers?

Viggo Hansteen, Ada Ortiz, Luc Rouppe van der Voort,
Bart De Pontieu, Paola Testa, Mats Carlsson, Tiago Pereira
Rosseland Centre for Solar Physics, Univ Oslo
IRIS 9 Conference, Göttingen, June 25-29 2018

Contributed Talk

3. Magnetic coupling and mass flux through the atmosphere

Ellerman bombs and UV bursts: reconnection at different atmospheric layers?

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The emergence of magnetic flux through the photosphere and into the outer solar atmosphere produces, amongst many other phenomena, the appearance of Ellerman bombs (EBs) in the photosphere. EBs are observed in the wings of H(alpha) and are highly likely to be due to reconnection in the photosphere, below the chromospheric canopy. But signs of the reconnection process are also observed in several other spectral lines, typical of the chromosphere or transition region. An example are the UV bursts observed in the transition region lines of Si IV. In this work we analyze high cadence coordinated observations between the 1-m Swedish Solar Telescope and the IRIS spacecraft in order to study the possible relationship between reconnection events at different layers in the atmosphere, and in particular, the timing history between them. High cadence, high resolution H-alpha images from the SST provide us with the positions, timings and trajectories of Ellerman bombs in an emerging flux region. Simultaneous co-aligned IRIS slit-jaw images at 1400 and 1330 A and detailed Si IV spectra from the fast spectrograph raster allow us to study the possible transition region counterparts of those photospheric Ellerman bombs. Our main goal is to study whether there is a temporal and spatial relationship between the appearance of an EB and the appearance of a UV burst.

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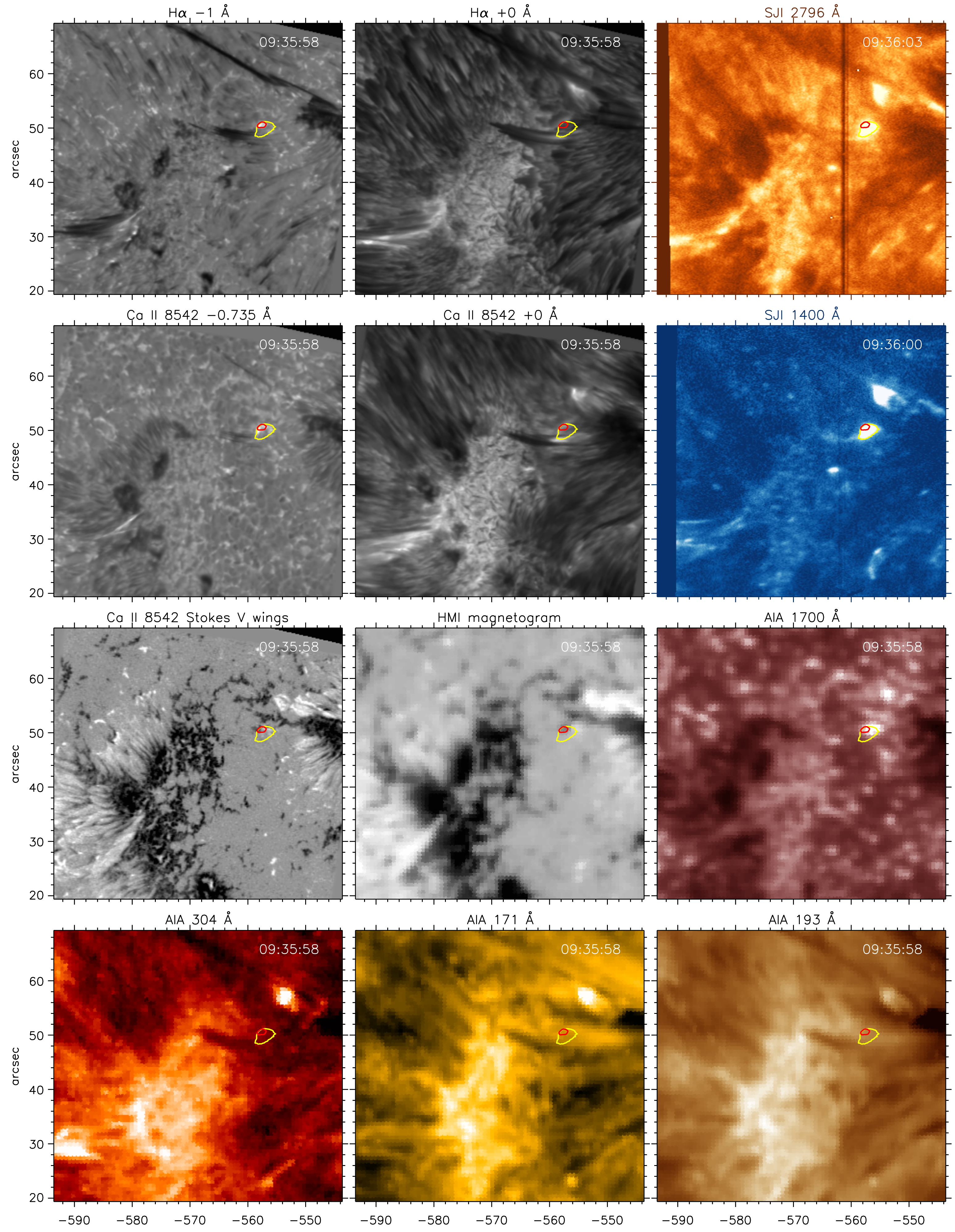
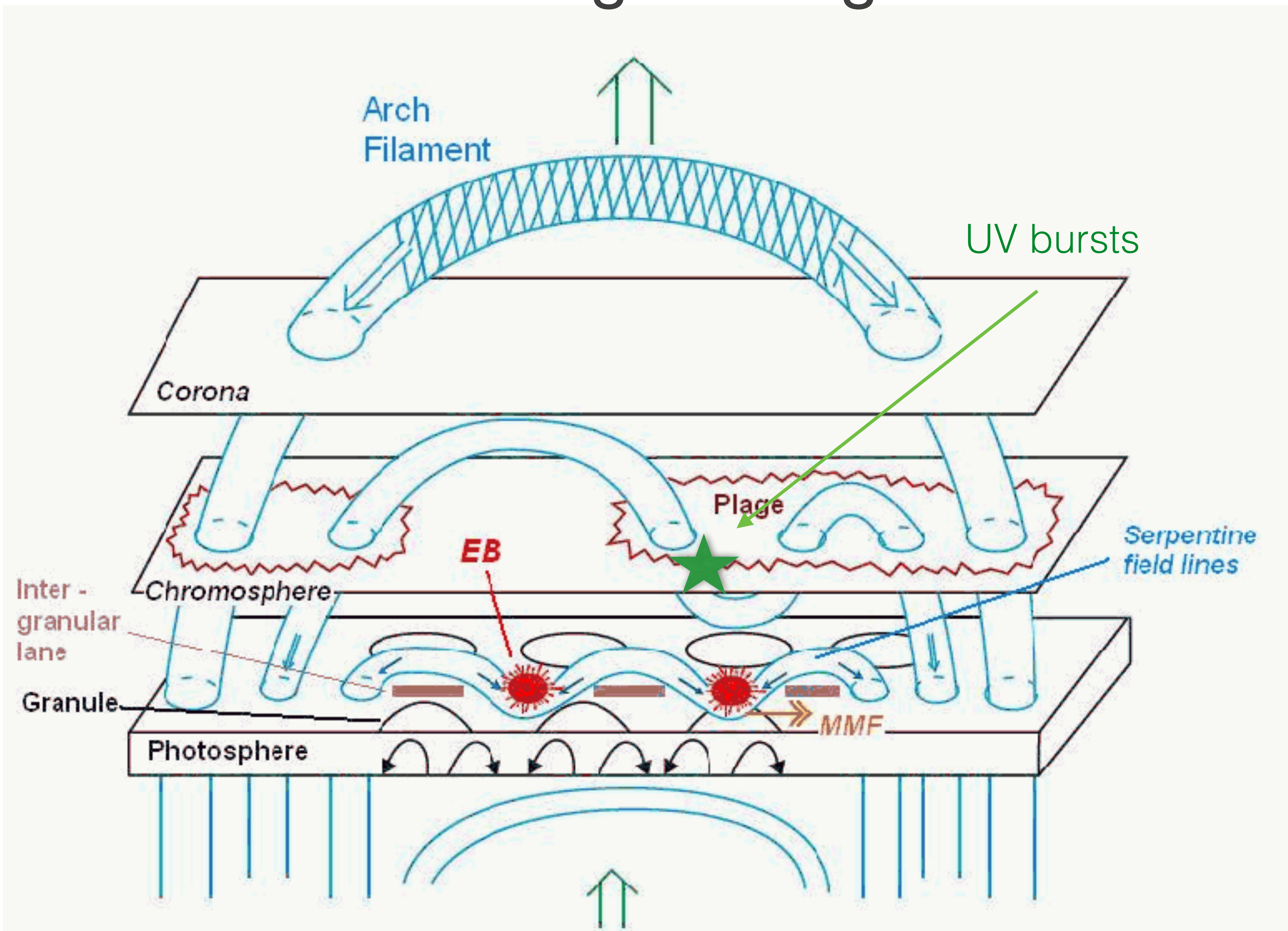
- site of opposite polarities
- EBs in Hα wing
- bright in Si IV, Mg II (k2), and AIA 1700
- dark in Hα and Ca II core (as well as Mg II core)
- also dark in He II 304, Fe IX 171 and Fe XII 193
- surge (of cold material) visible in many channels

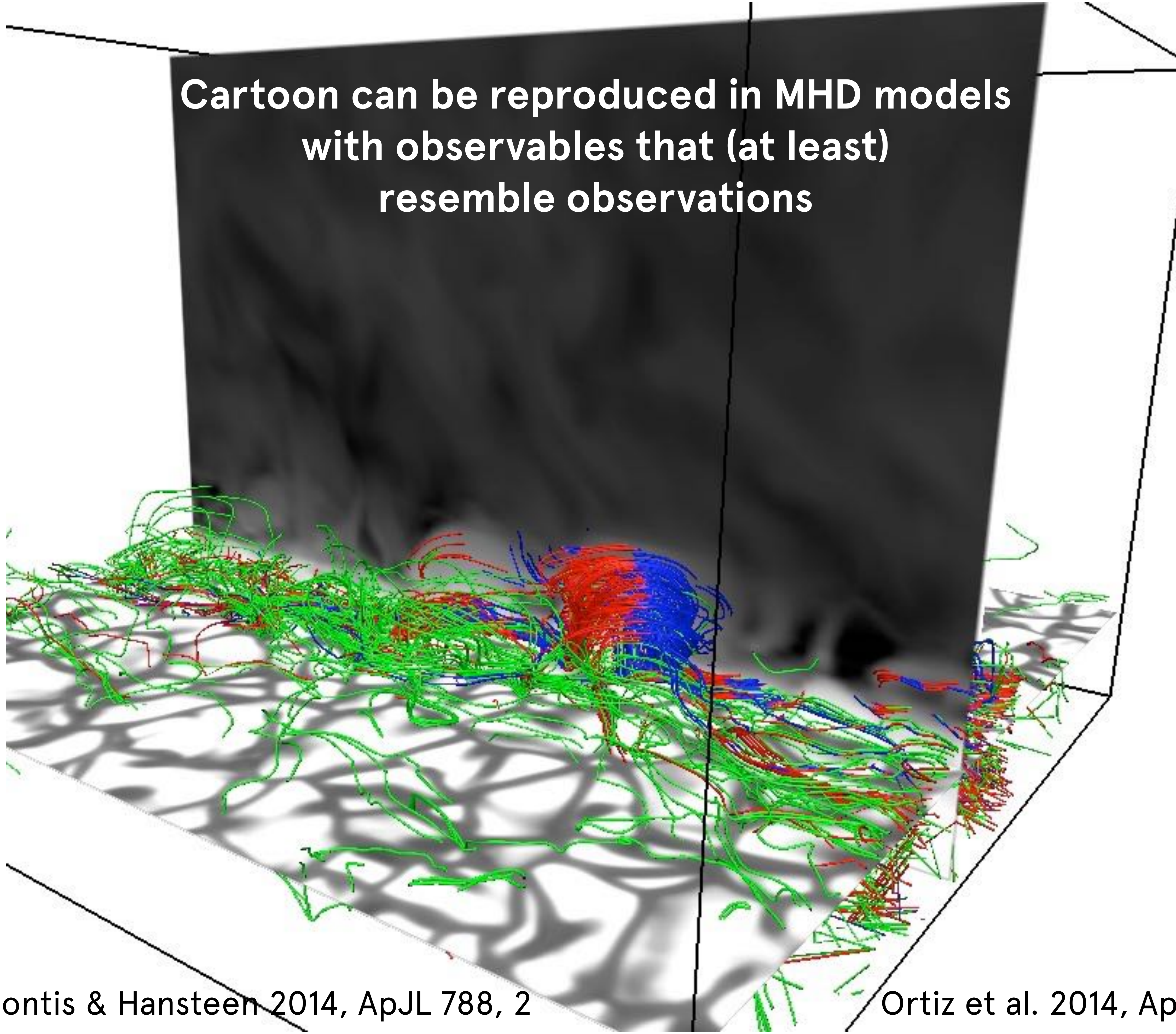


Sites of strong flux emergence, formation of coronal active region magnetic field



Schmieder & Pariat 2007 Scholarpedia 2(12):4335 (Shibata's cartoon, slightly modified)

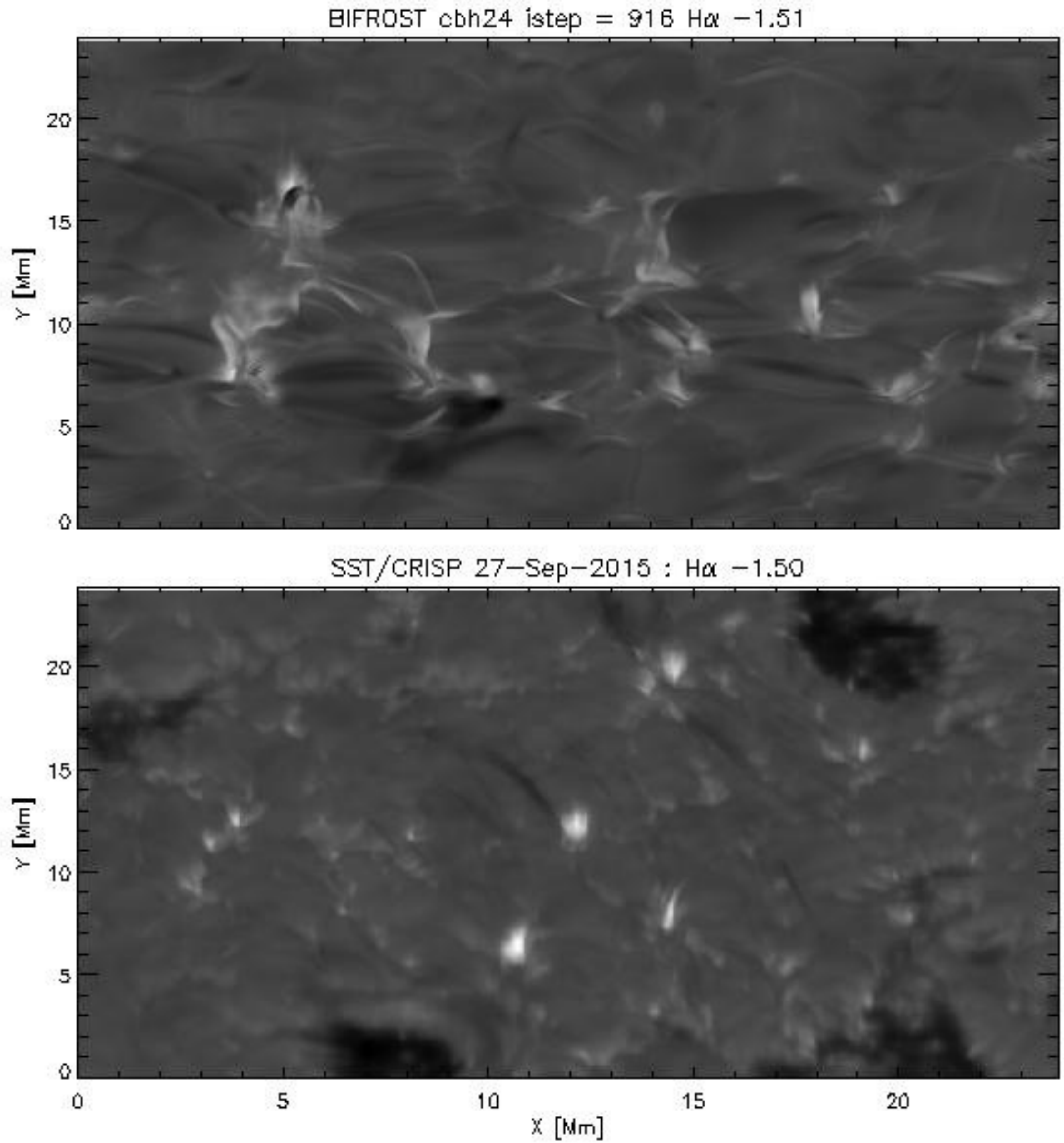
Cartoon can be reproduced in MHD models with observables that (at least) resemble observations



Archontis & Hansteen 2014, ApJL 788, 2

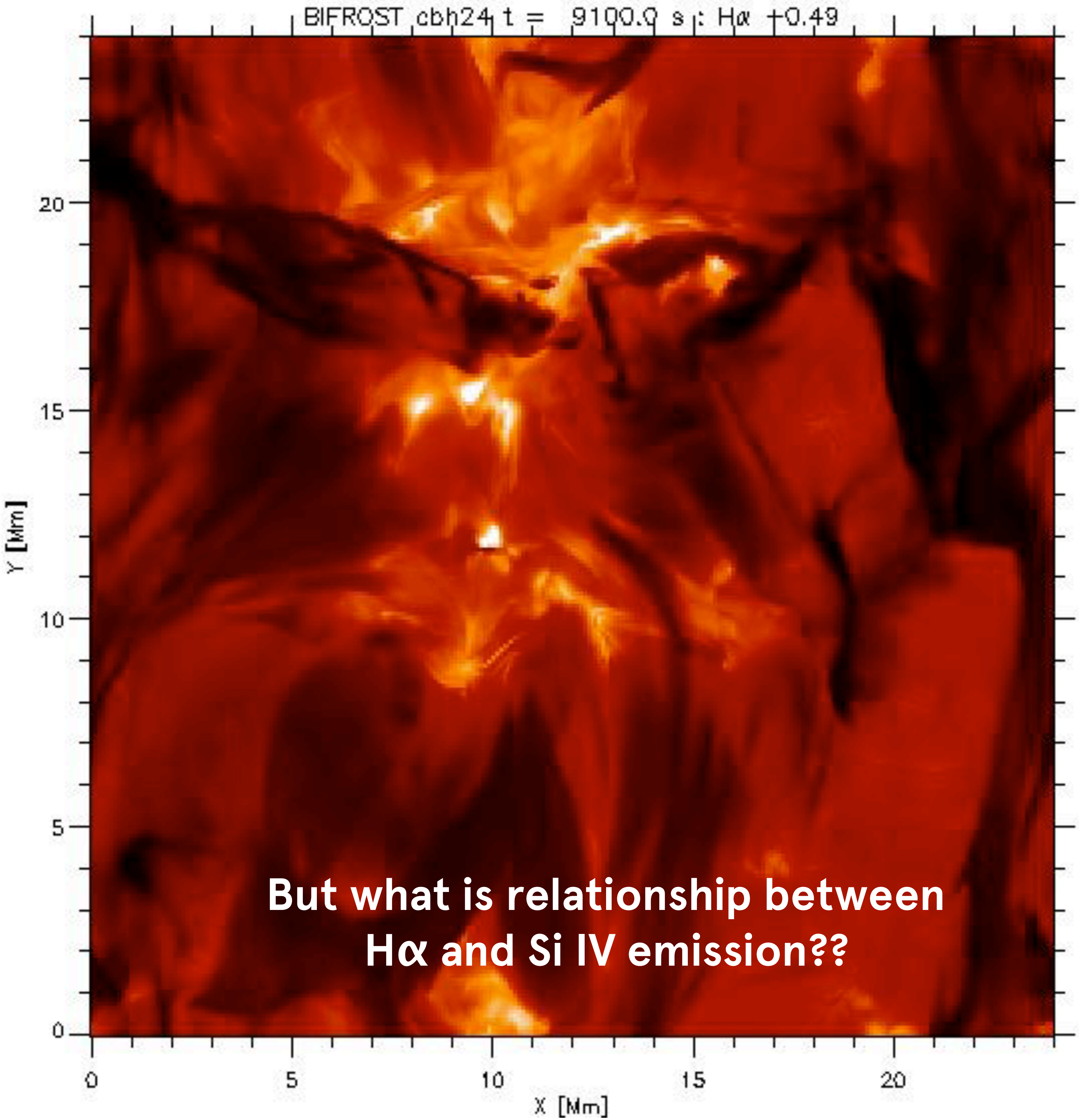
Ortiz et al. 2014, ApJ 781, 126

Hα wing
μ = 0.5



BIFROST cbh24 istep = 916 Hα −1.51
SST/CRISP 27−Sep−2015 : Hα −1.50
Y [Mm]
X [Mm]
0
5
10
15
20

Hα line
+0.5 Å
μ = 1
Formation
of fibrils



Observations: September 2016 coordinated SST - IRIS campaign

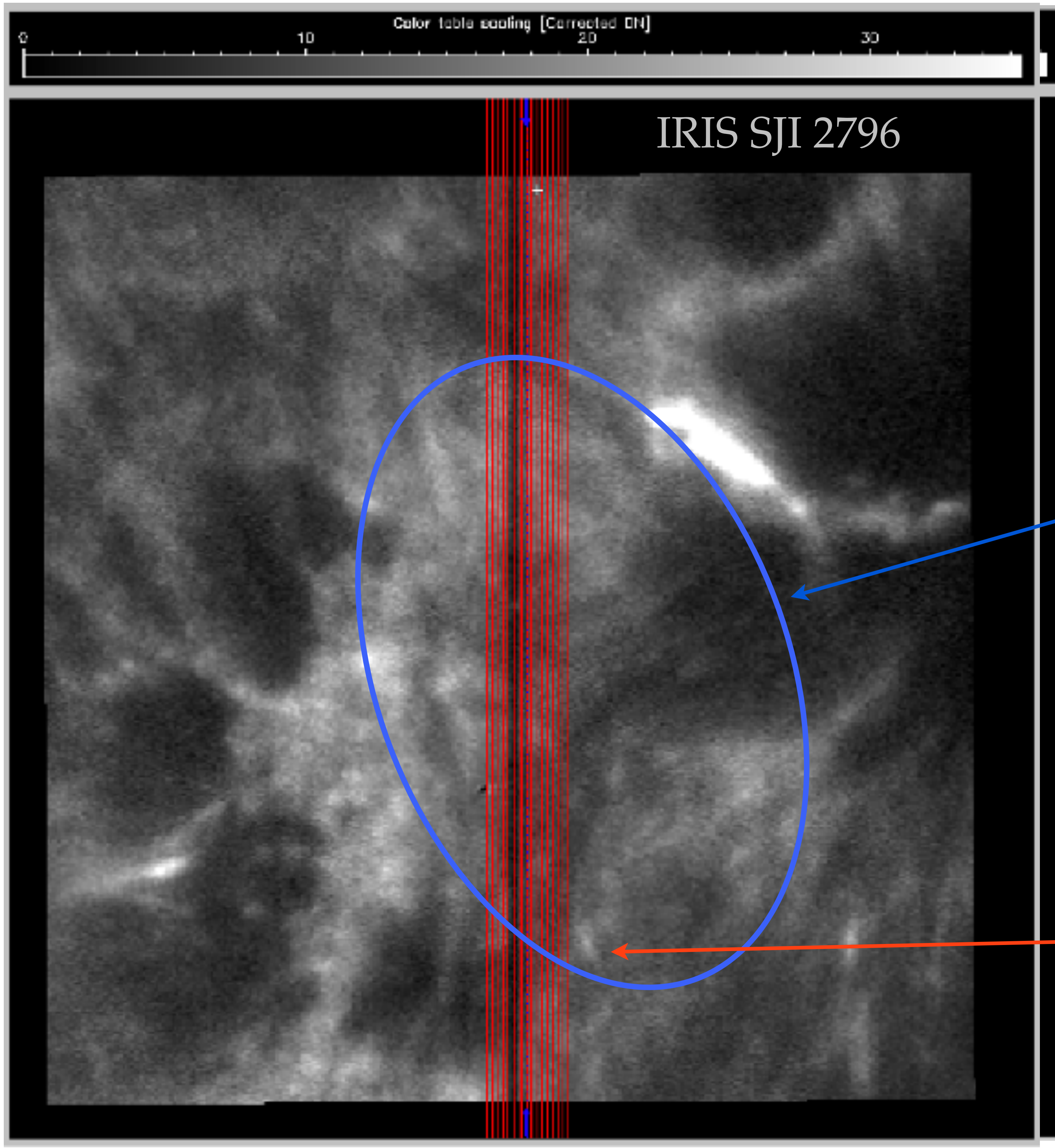
SST

- **CRISP** @ 1-m SST: 2-6 September 2016, AR 12585: flux emergence
- Scans of **6563 Å** and **Ca II 8542 Å**:
    - Hα: 15 wavelengths
    - Ca II 8542: 21 wavelengths w/spectropolarimetry
    - cadence: 20.2 s
    - sampling: 200 m Å for Halpha and 70 m Å for Ca IR
    - diffraction limited observations at high resolution: **0.14”** at 6300 Å

IRIS

- **IRIS**: 2-6 September 2016, AR 12585: medium dense 16-step raster
- Slit jaw images: **C II 1330** (TR), **Si IV 1400** (TR), **Mg II h/k 2796** (upper chrom.)
- FOV: 60” x 60” (SJI) & 5”x 60” (raster)
- cadence: 10 s (SJI) & 21 s (raster)
- Rasters in 3 spectral windows:
    - FUV 1: 1331.6 - 1358.4 Å (C II)
    - FUV 2: 1380.6 - 1406.6 Å (Si IV)
    - NUV: 2782.6 - 2833.9 Å (Mg II K & h)

FOV for 3rd September 2016

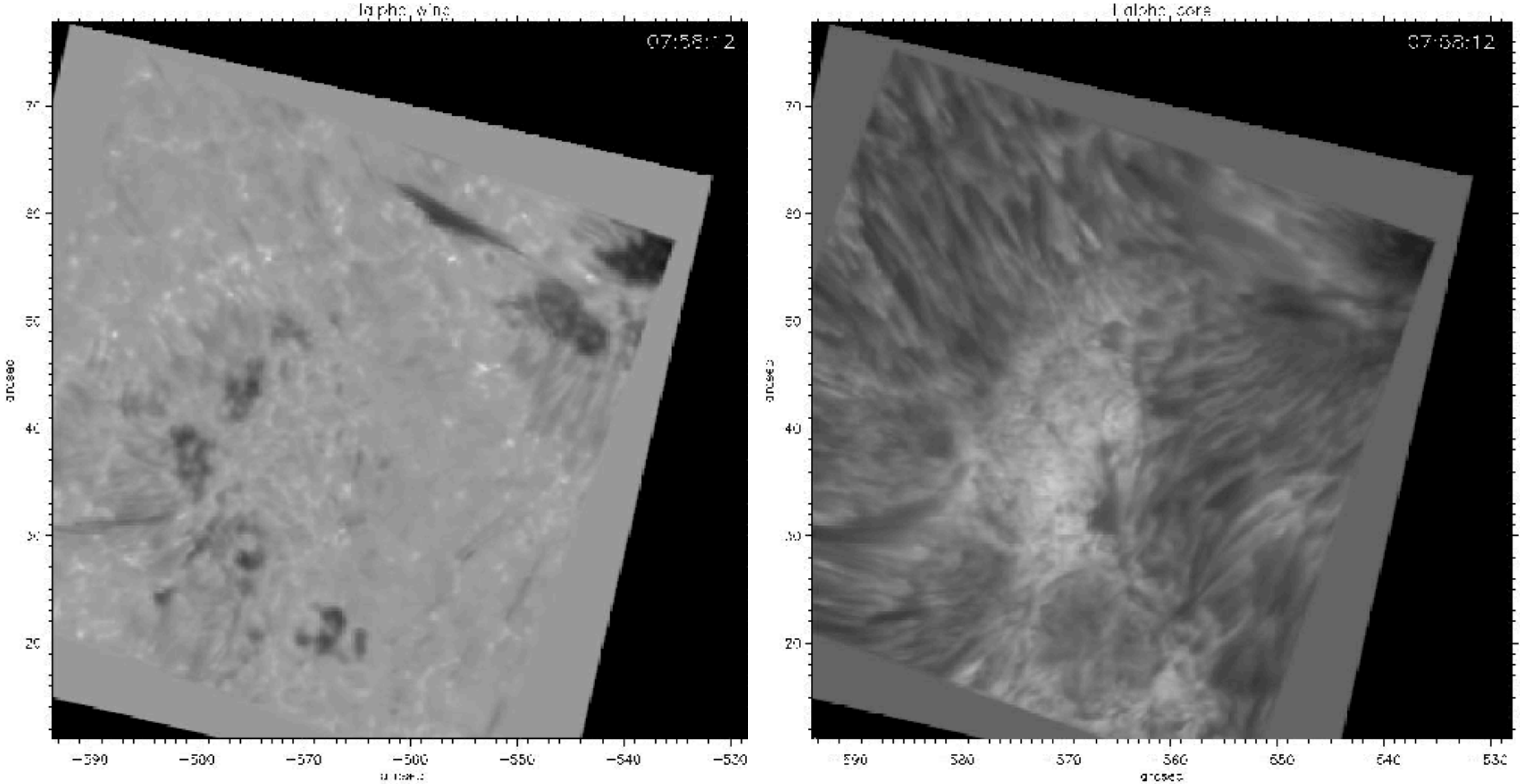


Flux emergence region

IRIS slit positions

3rd September 2016:
roughly 2 hours from 7:58 UT

spatial displacement between EB and UV burst

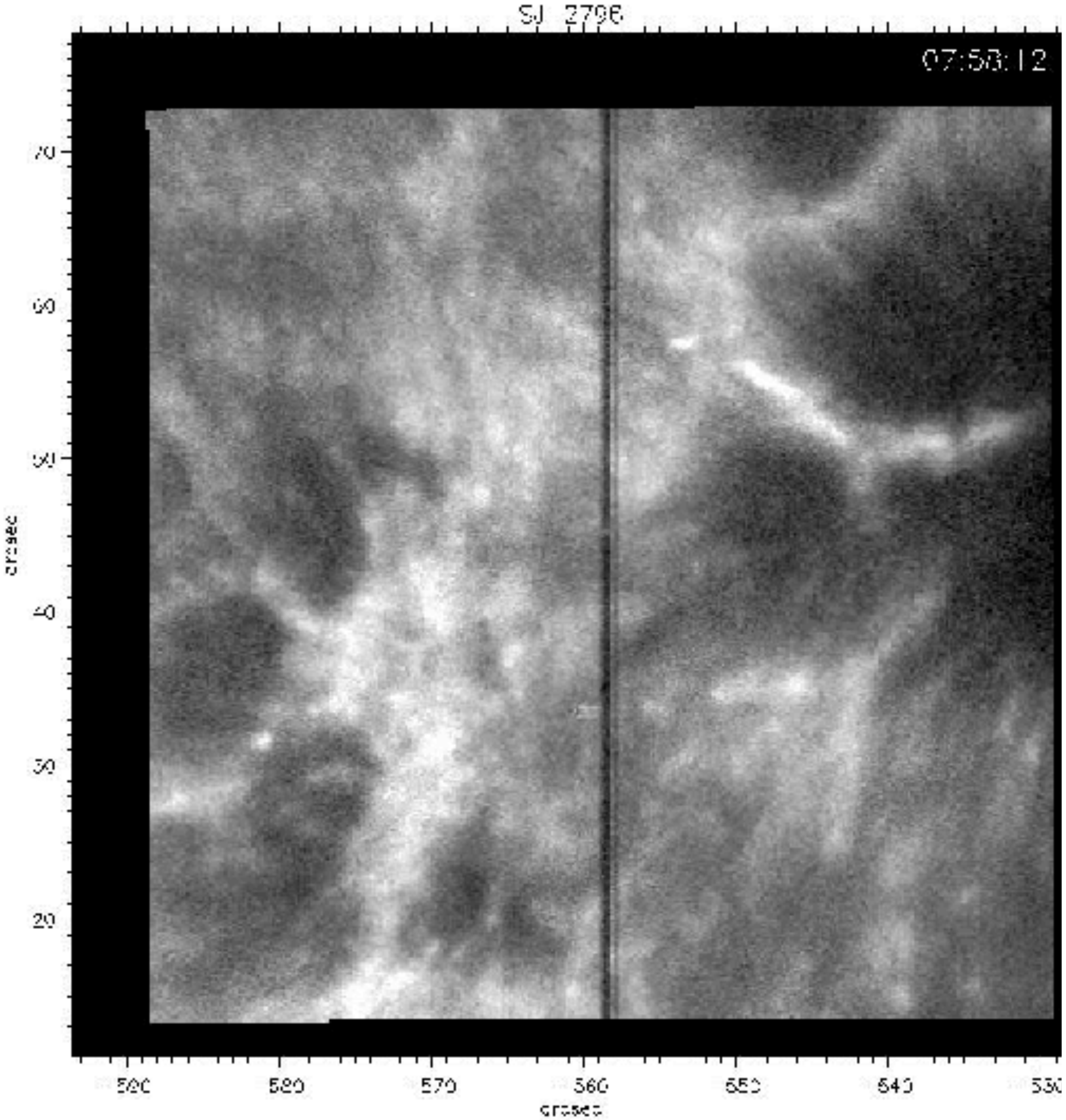


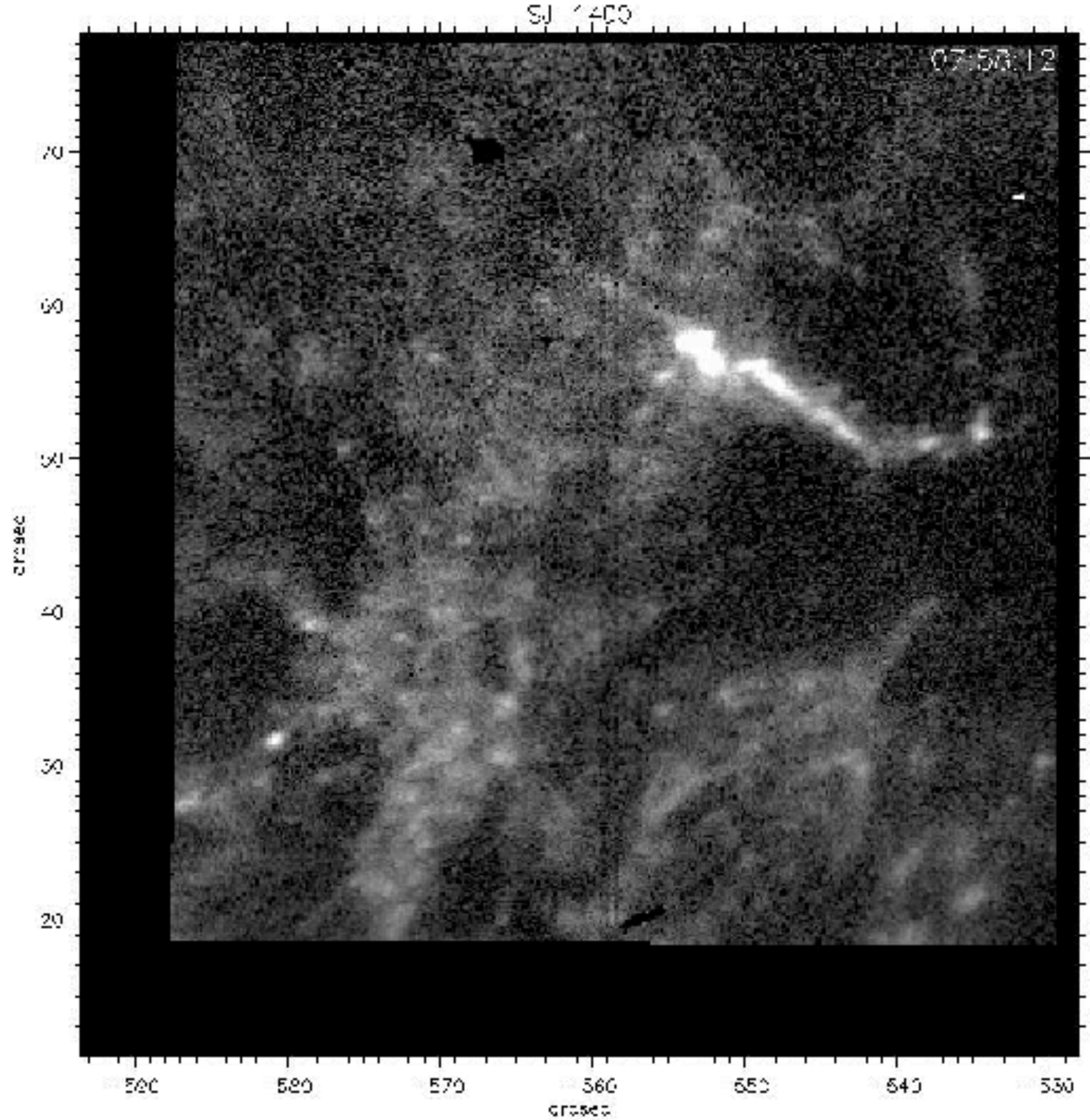
EB box tracking

UV burst box tracking

3rd September 2016

spatial displacement between EB and UV burst





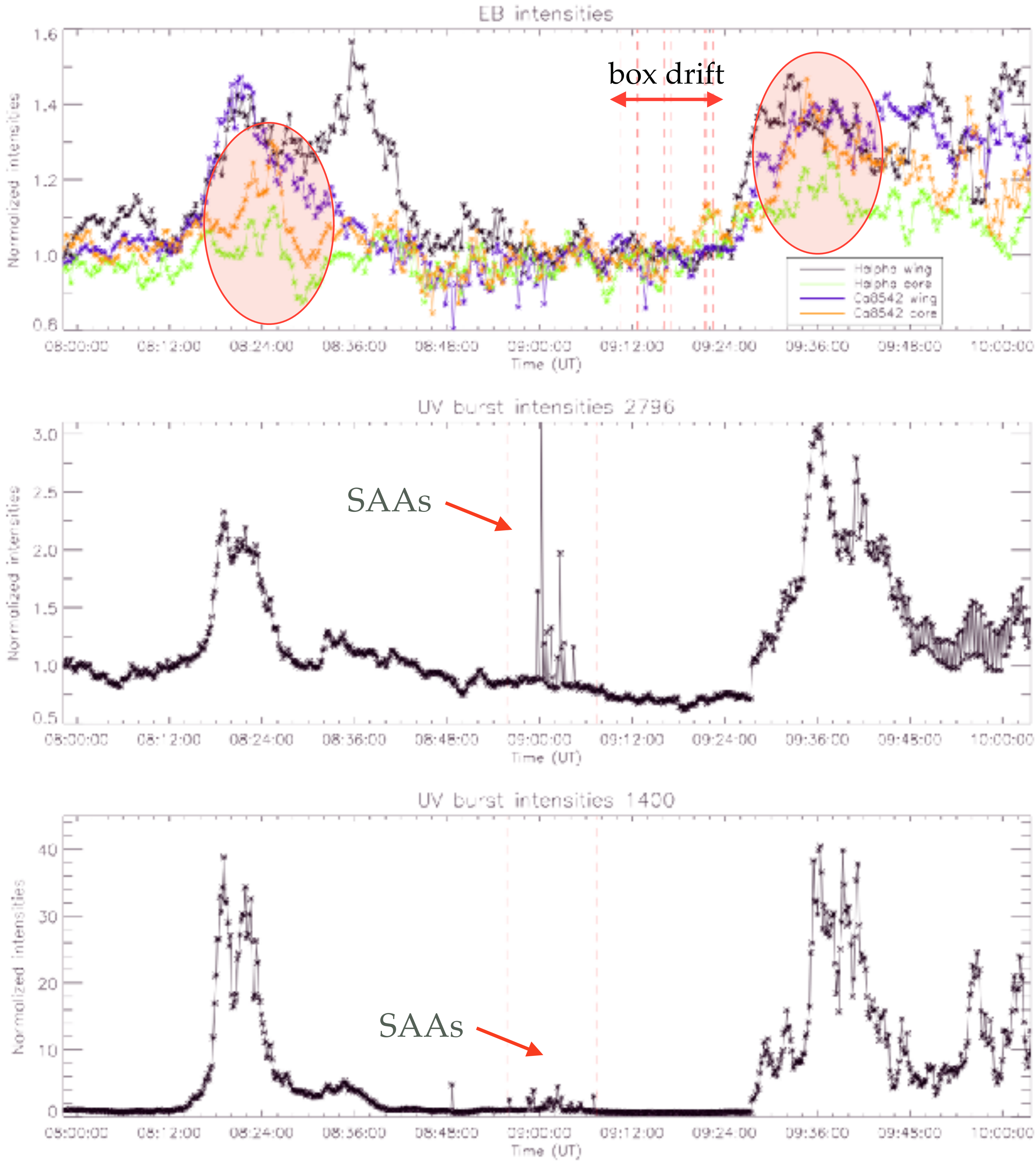
EB box tracking

UV burst box tracking

3rd September 2016

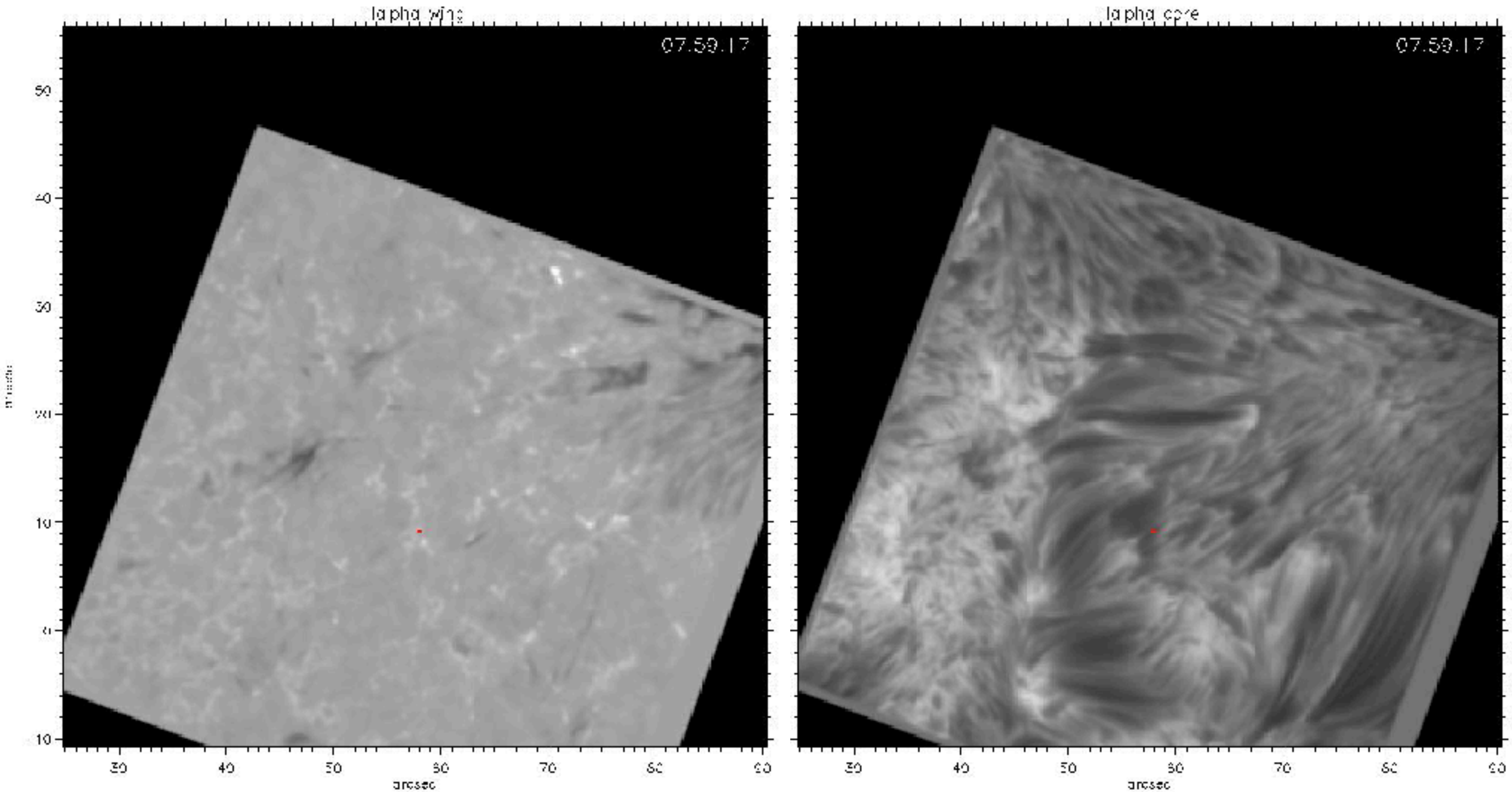
- 2 brightenings during observing sequence
- Hα wing and Ca wing have very similar behaviour
- Hα core and Ca core show some **brightenings** that coincide with bright feet of Hα surge at: 08:25 and 09:34-09:40 UT
- EB lits up more **gradually**, UV burst has a **very steep** increase
- UV lits up **slightly later** than the EB:
  - almost **simultaneously** in 1st brightening
  - **2 min** later in 2nd brightening

Clear relationship between EB and UV burst as they happen almost simultaneously



6th September 2016:
20 minutes from 7:59 UT

spatial coincidence between EB and UV burst

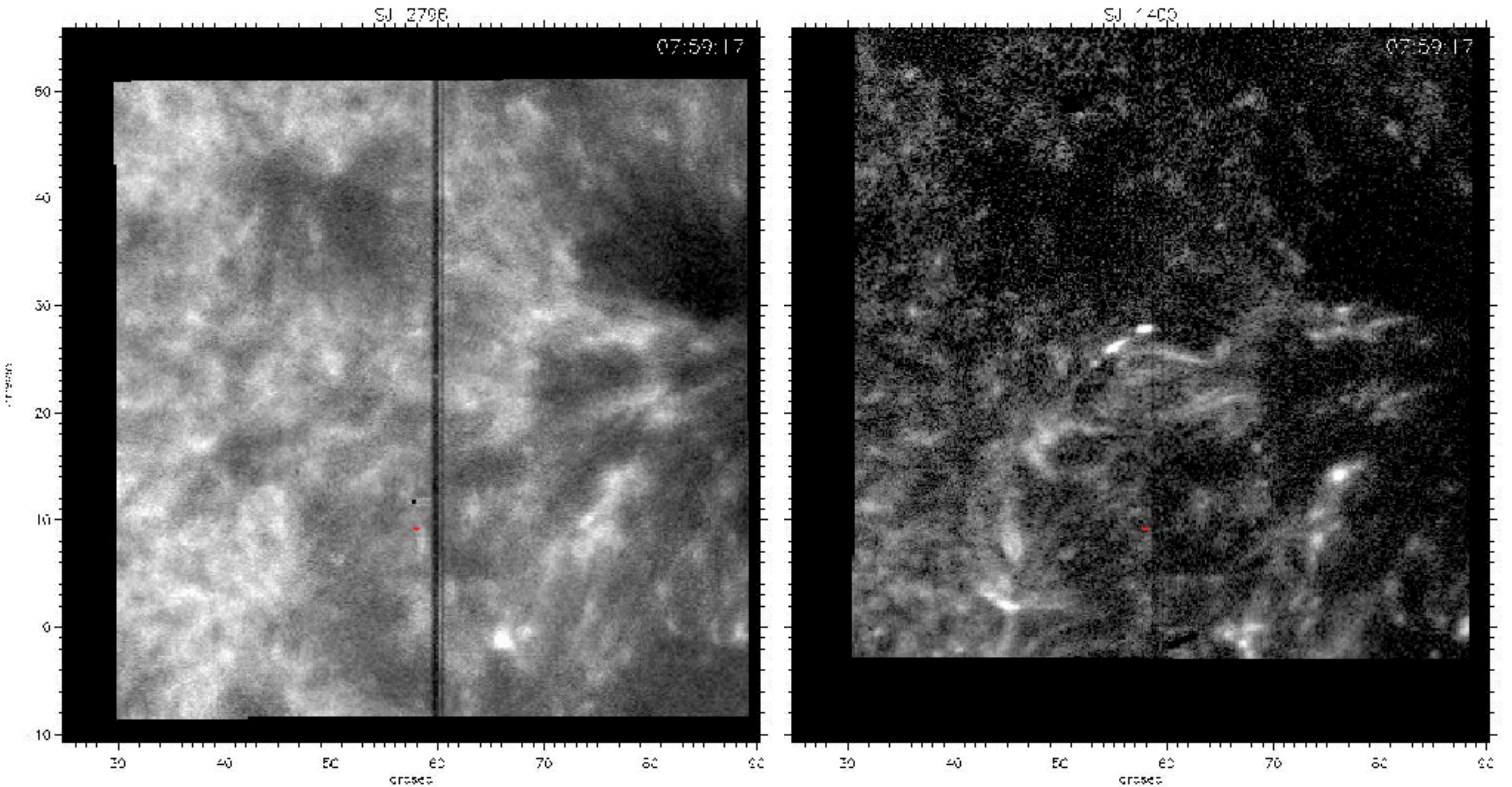


EB box tracking

UV burst box tracking

6th September 2016

spatial coincidence between EB and UV burst



EB box tracking

UV burst box tracking

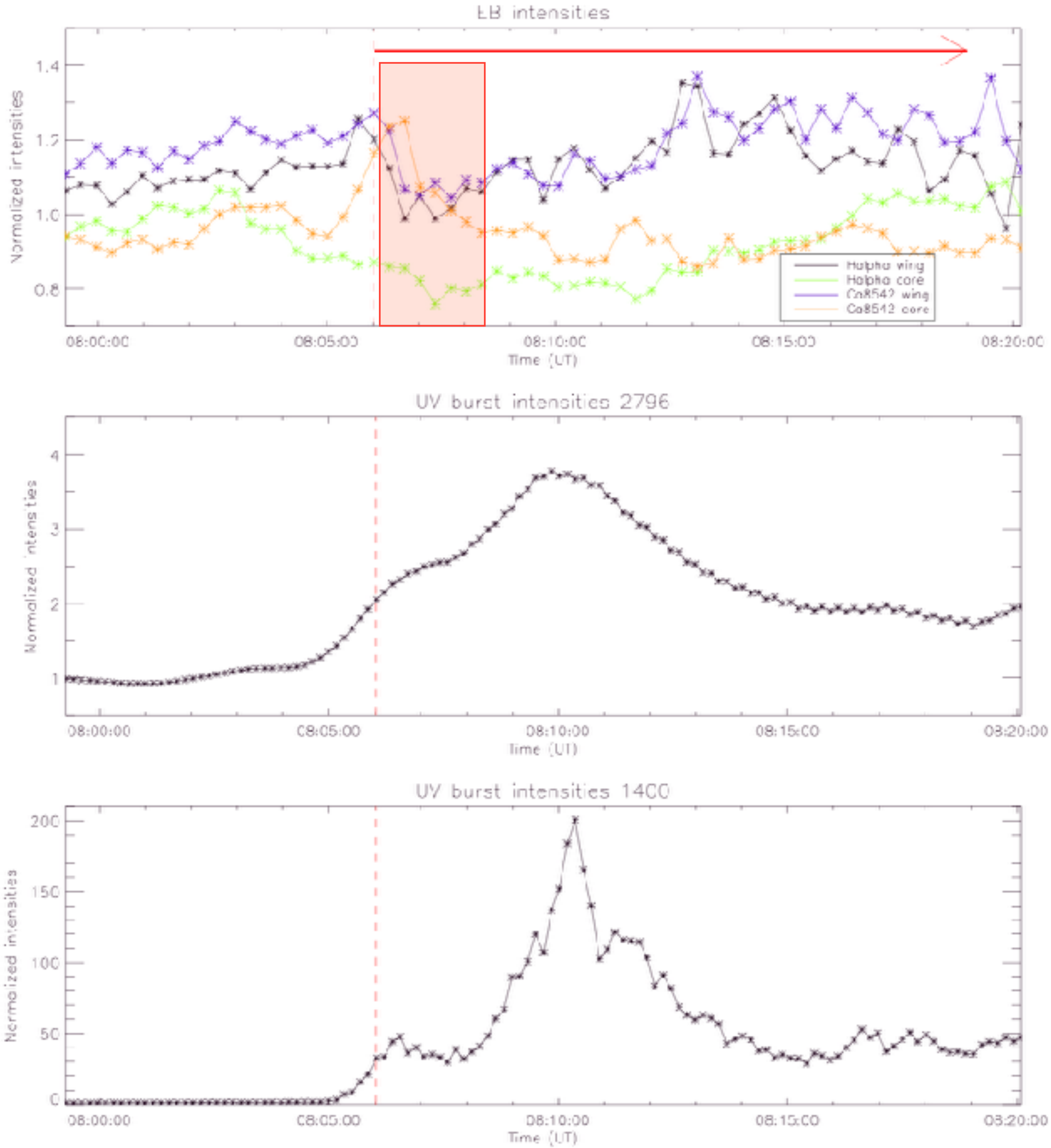
6th September 2016

- Hα surge starts at 08:06:02 UT, lasting until the end of the observing sequence. Totally hides the EB for 1 min.

Unclear relationship between EB and UV burst: spatial coincidence but temporal?

- Again UV burst shows steep increase of intensity. EB shows almost flat temporal variation.

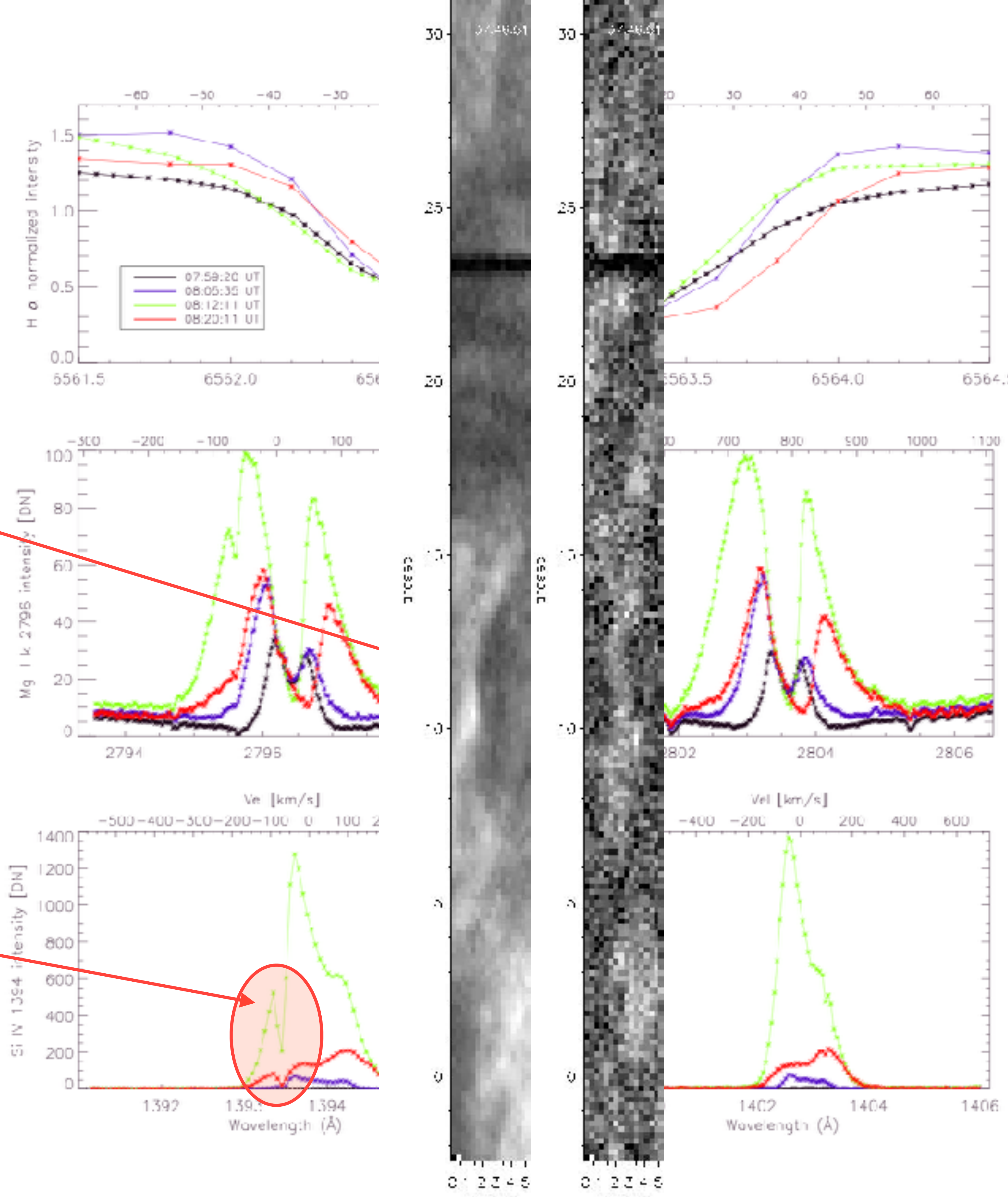
- UV burst lags 6-7 min after the EB appearance



6th September 2016

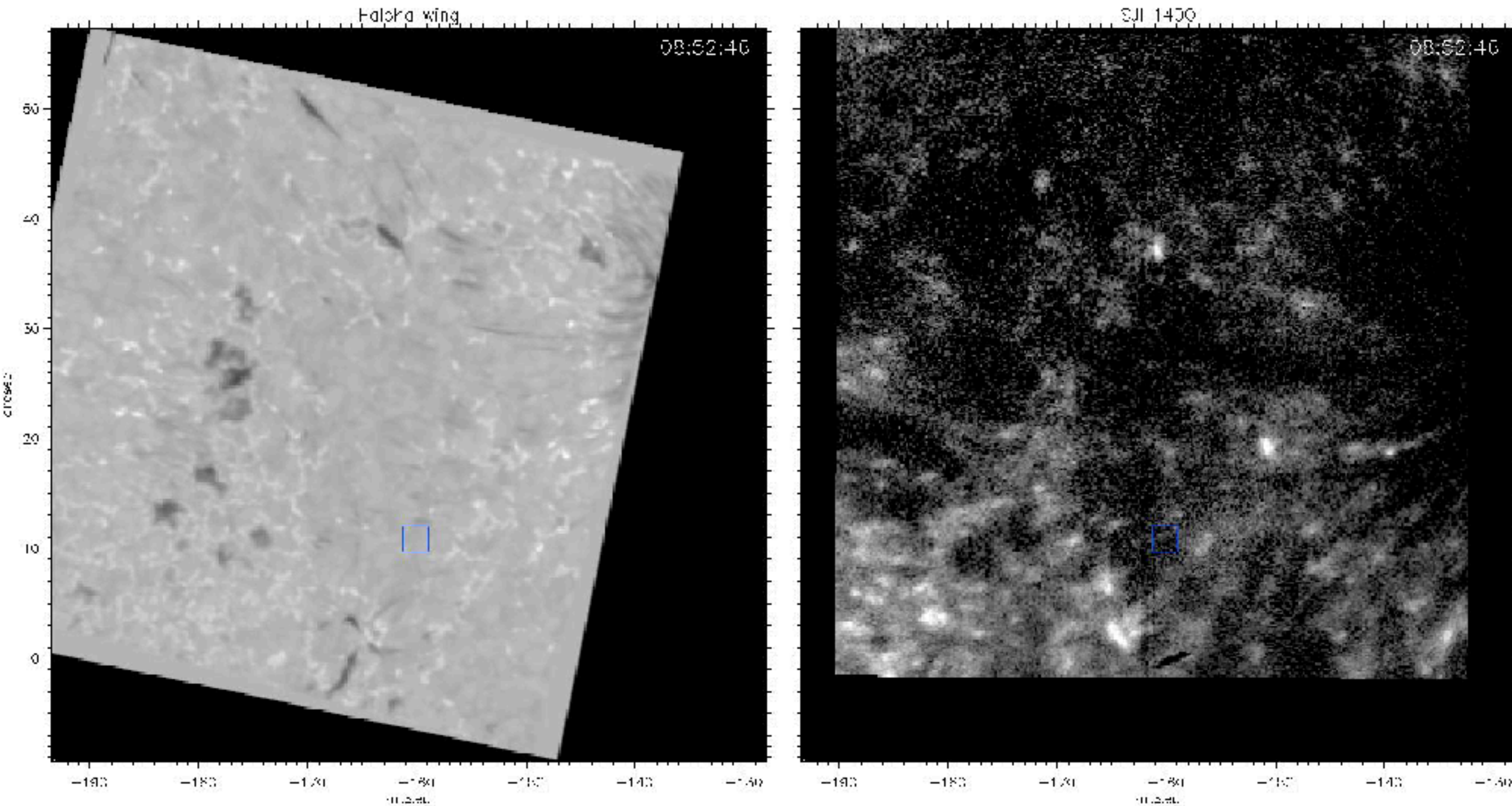
- **Mg triplet** appears when the lower chromosphere gets heated: coincides with **peak brightness** of UV burst

- **Absorption** in blue wing of Si IV 1394 Å shows the presence of **cold material** along the LOS of the UV burst



Not always EB+UV Burst
5th September 2016: 20 minutes from 8:52 UT

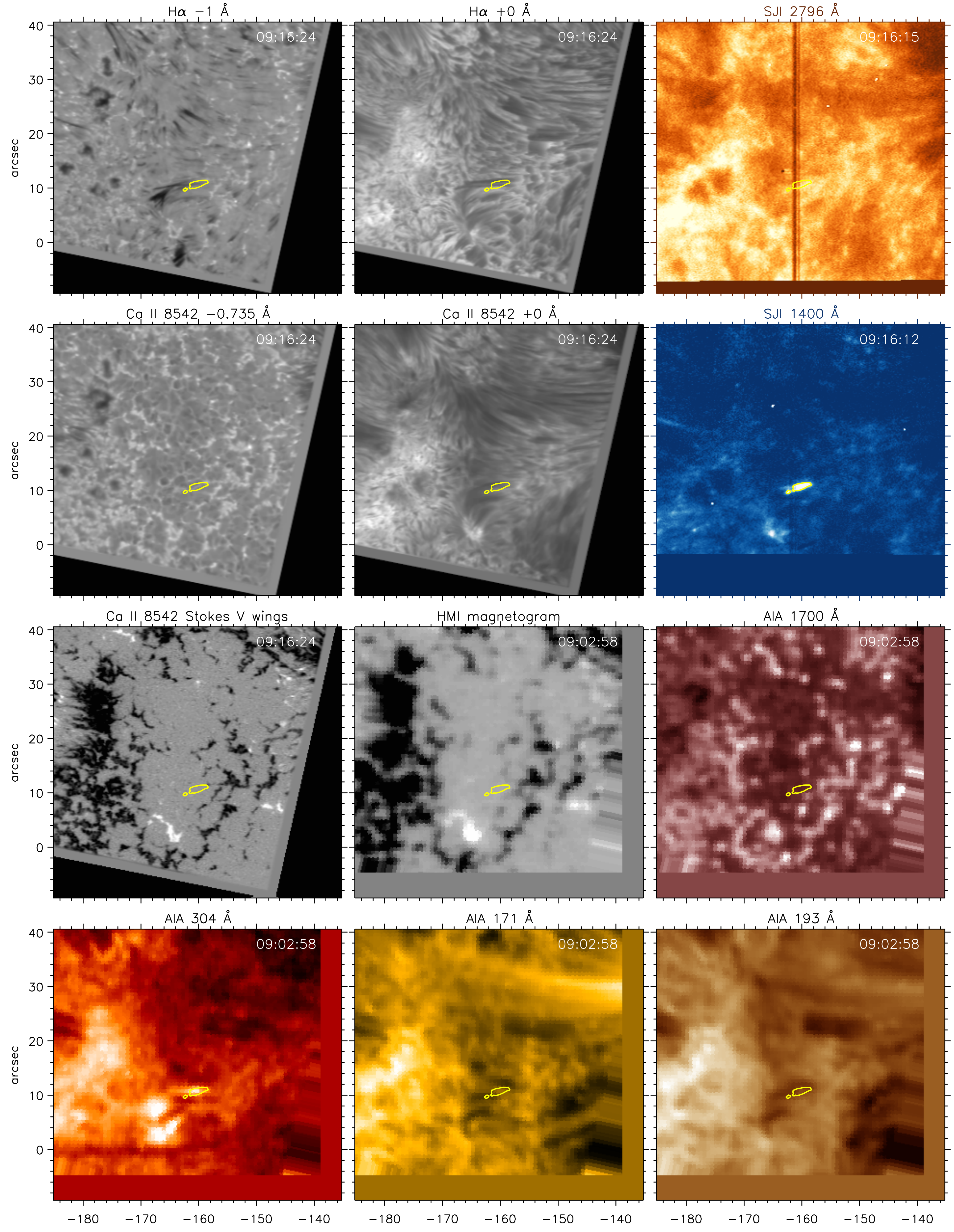
UV burst only (special case: FAF)



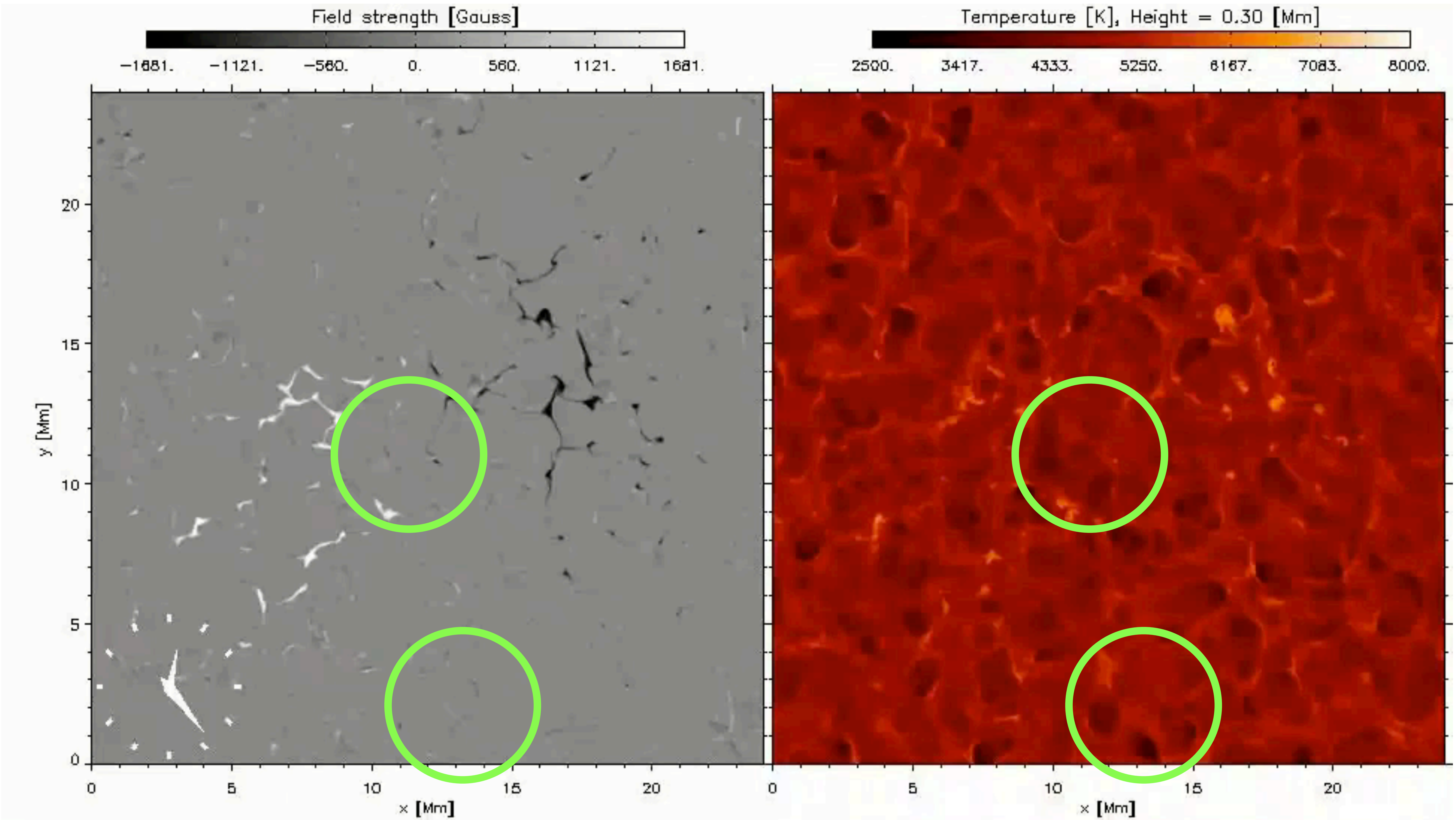
EB box tracking

UV burst box tracking

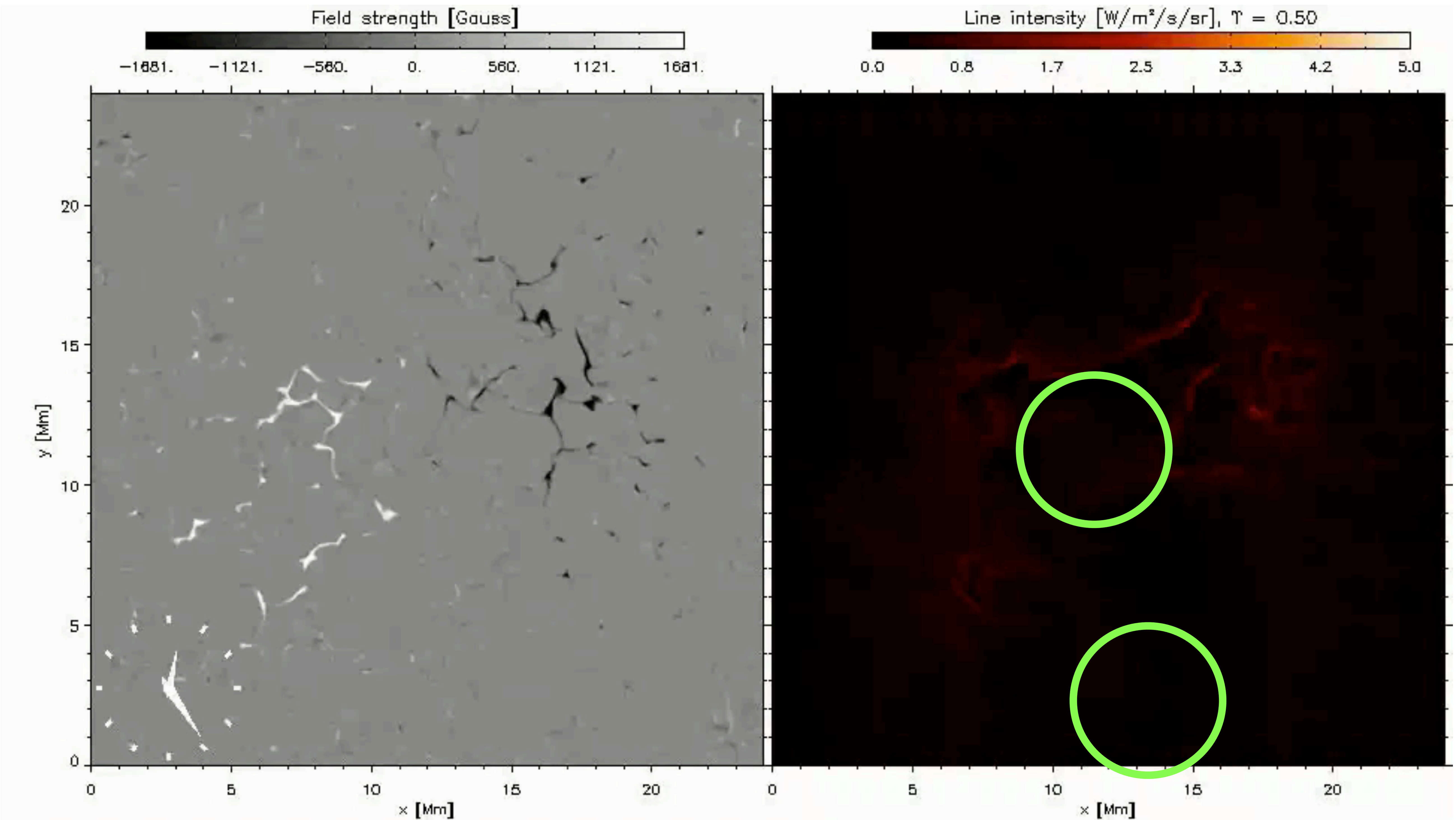
- (old) dark loops seen in Hα core
- He II 304 bright
- no signal in AIA 1700
- mainly dark in Fe IX 171 and Fe XII 193, but both light up at certain times



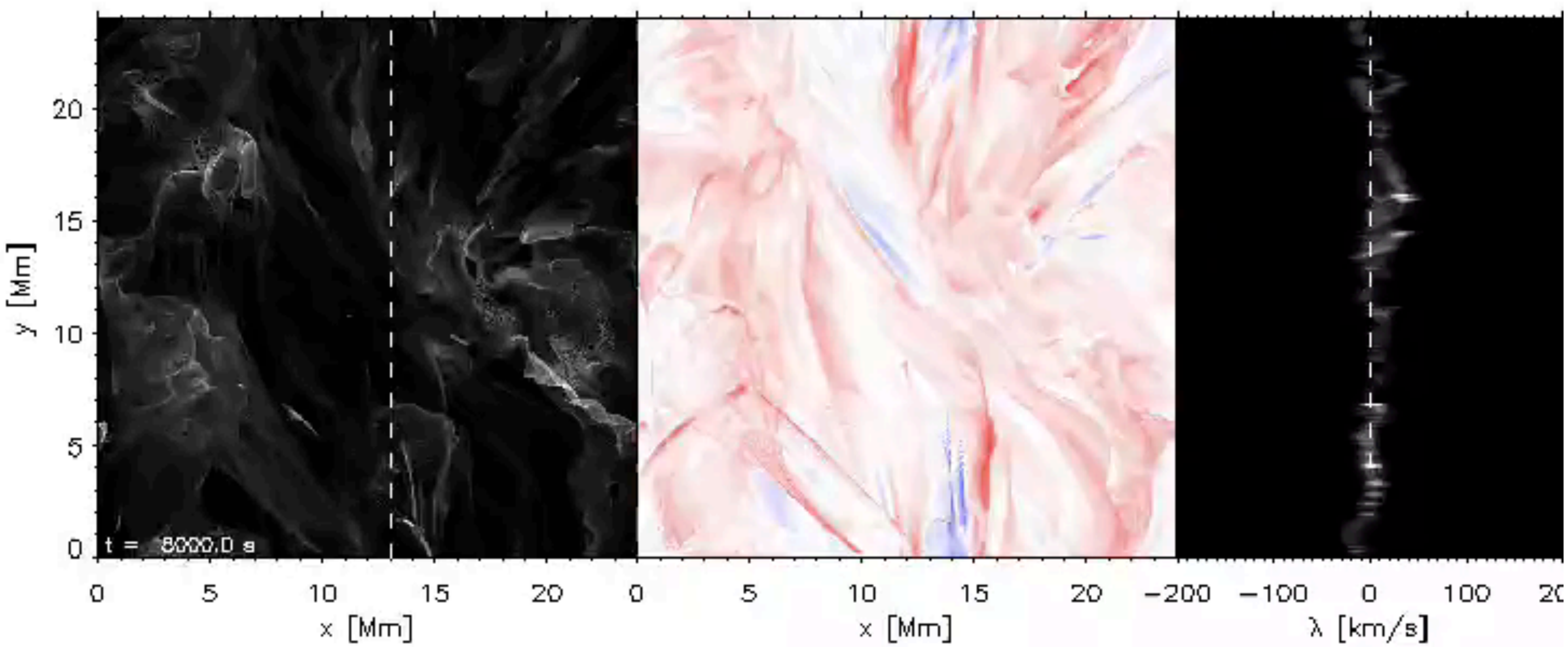
Flux emergence simulation produces EBs (?)



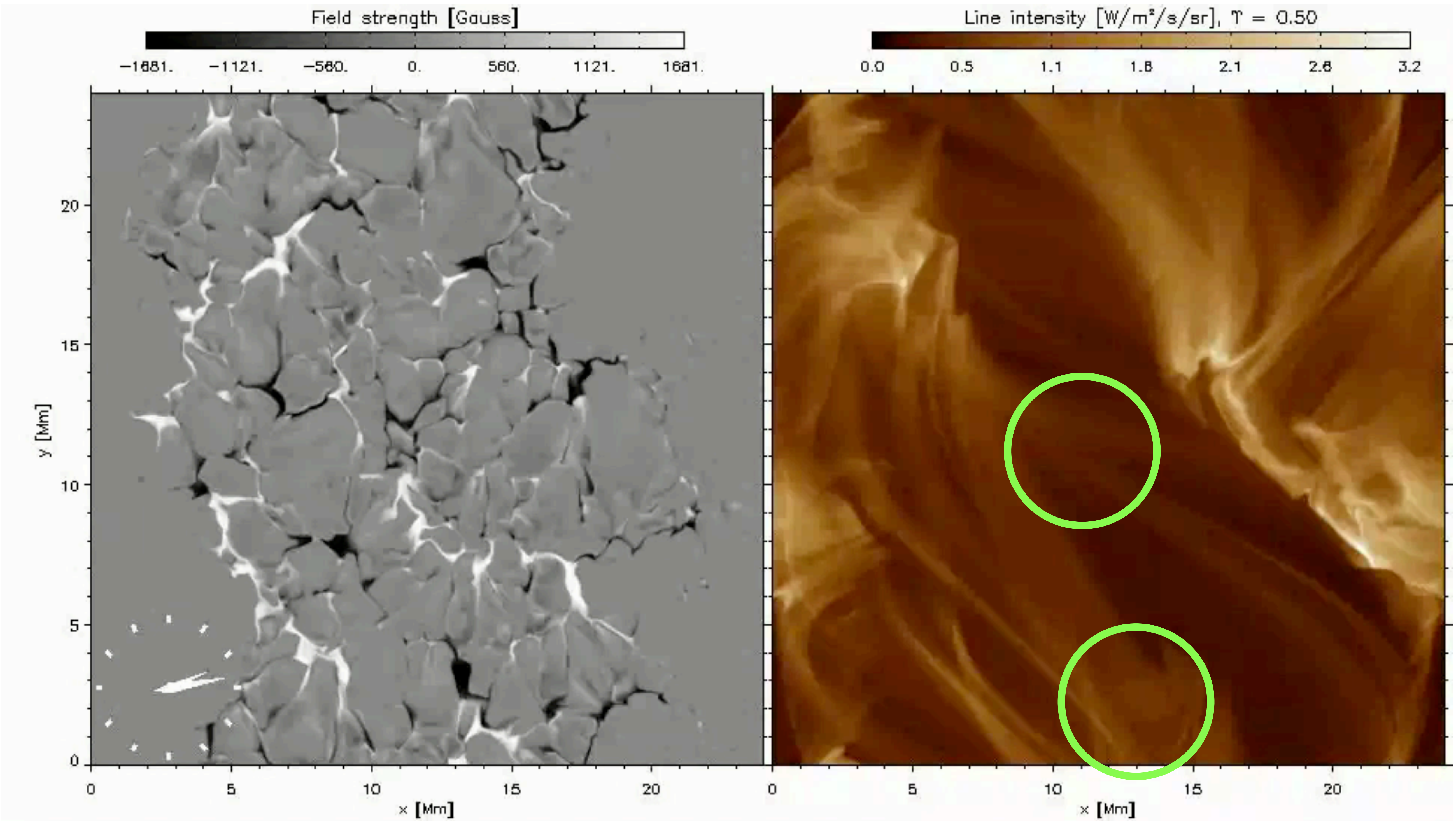
Si IV 1393 response to flux emergence (Chianti)



Si IV 1393 UV Burst line profiles



Fe XII 195 response to flux emergence (Chianti)

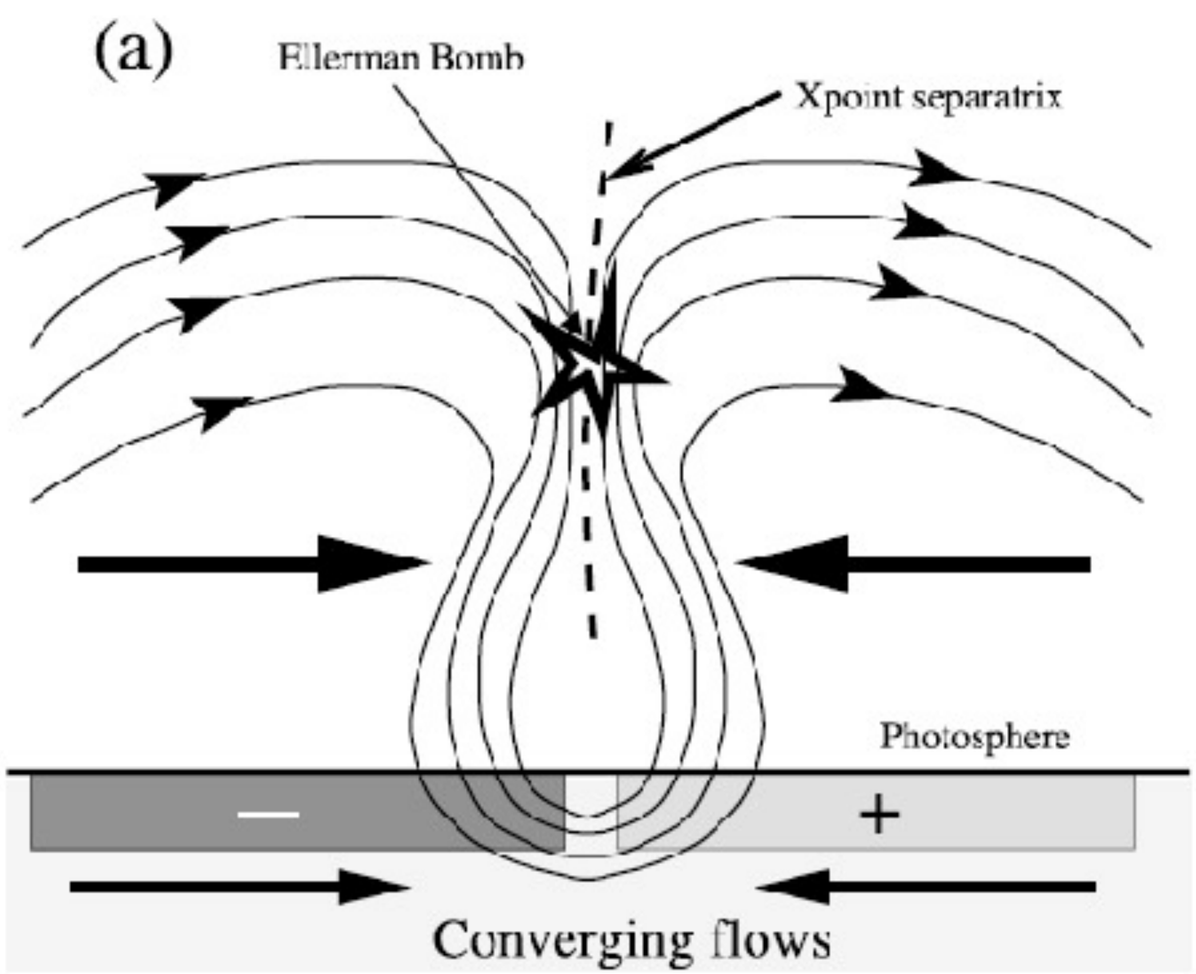


Discussion

- 3/9/16: 48% EB-only, 43% UV-burst only, 9% EB+UV
- 6/9/16: 48% EB-only, 36% UV-burst only, 16% EB+UV
- Possible to produce Hα wing EB emission if photosphere or TMR > 20,000-80,000 K?
- Almost all EBs have accompanying cold surges
- Velocities in Si IV (line width) is very high ~200 km/s
- Temperature in UV bursts *could* be much higher than 80000 K.

Photosphere and/or higher chromosphere?

- **EBs** formed in (upper) photosphere
- **UV bursts** formed in same location? Or?

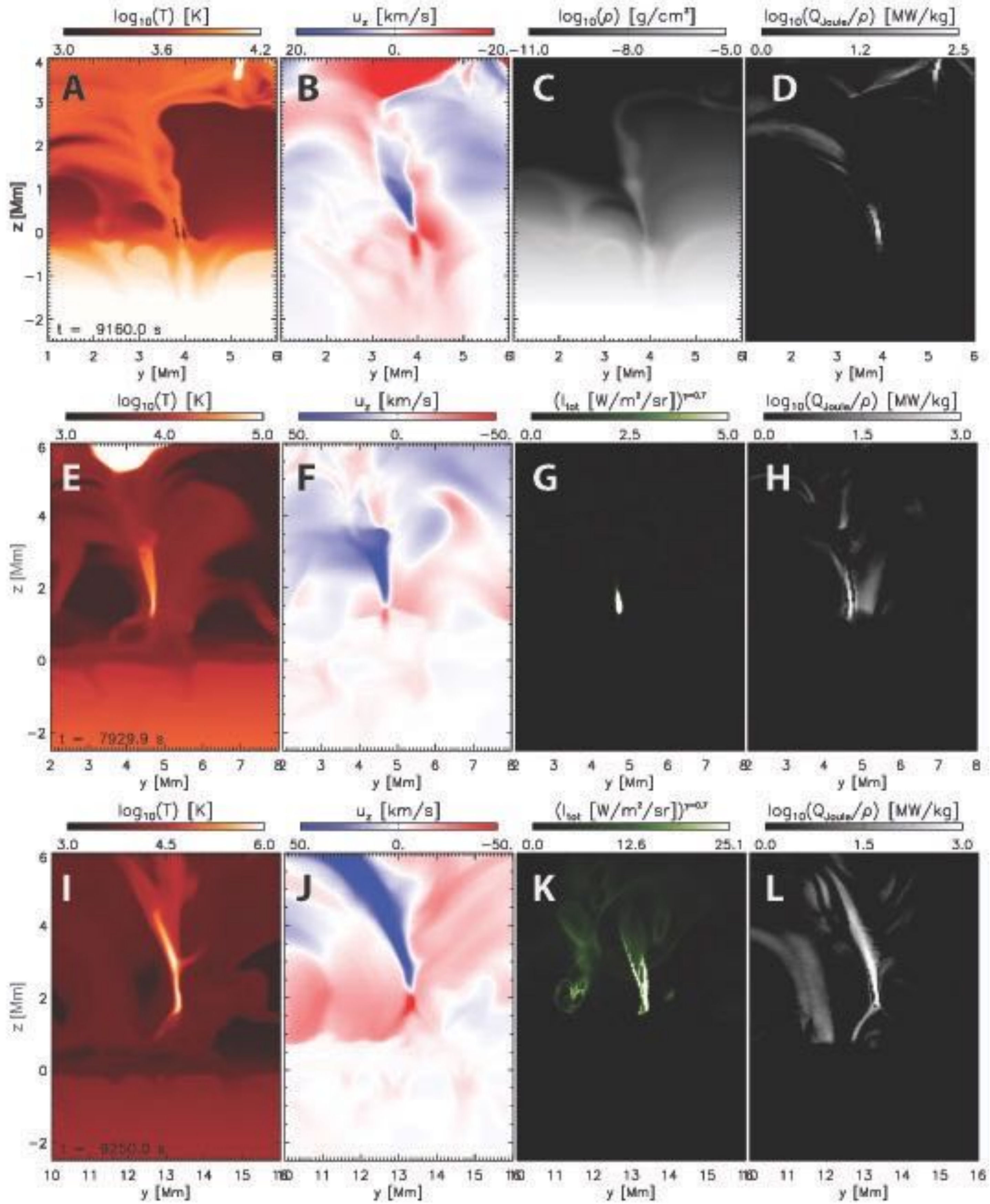


Georgoulis, M. K., Rust, D. M., Bernasconi, P. N., and Schmieder, B., "Statistics, morphology, and energetics of Ellerman bombs," ApJ 575, 506 (2002).

z = 0 Mm

z = 1.3 Mm

z = 1.8 Mm



Hansteen, Archontis, Pereira, Carlsson, Rouppe van der Voort, Leenaarts 2017, ApJ 839, 22

(strong) Flux emergence leads to reconnection…