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On the nature of Ellerman bombs and microflares as observed with the 1.5m GREGOR telescope

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and the GFPI[1] & GREGOR[1,2,3,4,5,6,7] teams

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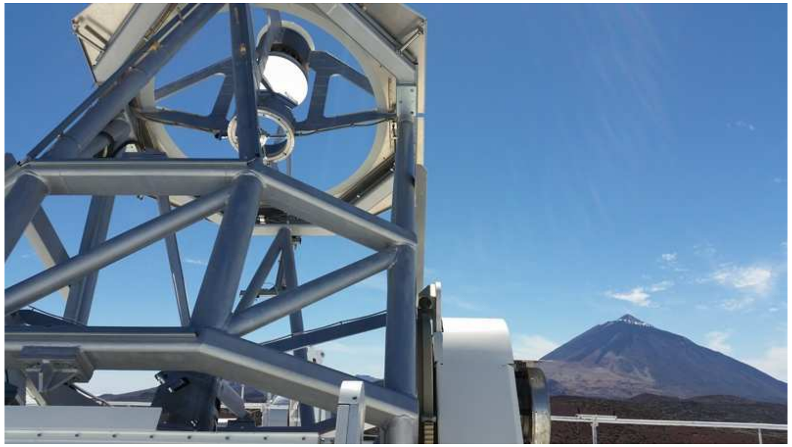
#thinkshop12

Outline

- The 1.5m GREGOR Telescope
- The GFPI@GREGOR Instrument
- Activity in NOAA 12139 as seen from space and ground (high-res)
- Ellerman bombs and microflares observed with GREGOR: observational characteristics
- Conclusions

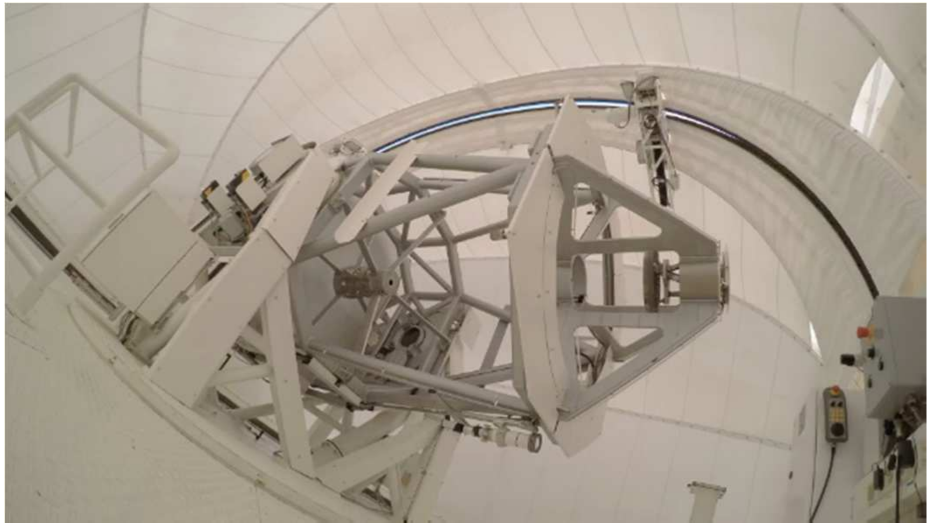
The GREGOR Telescope

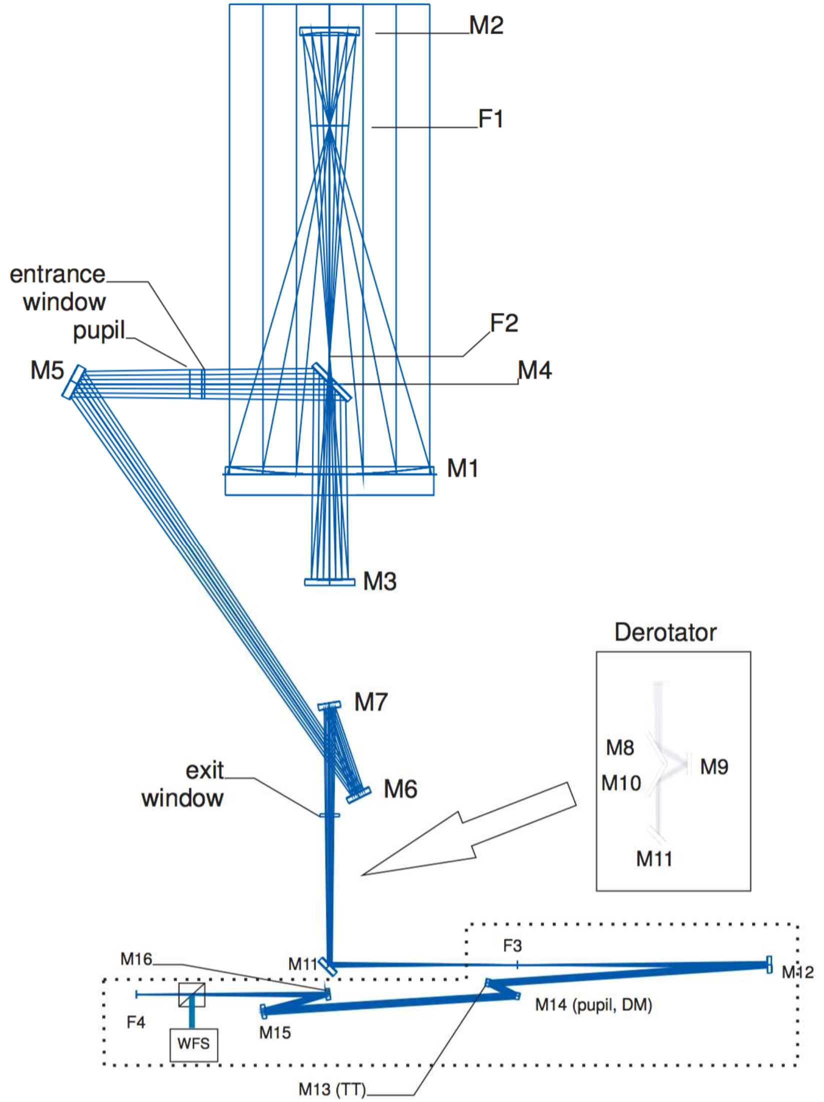
- Alt-azimuthal mount
- 1.5-meter free aperture
  - Primary mirror M1
  - Light-weighted Zerodur
- Double Gregory configuration
  - M2: D = 43 cm, F / 1.29
  - M3: D = 36 cm, F / 3.97
- Effective focal length: 55.6 m (F / 38)
- Nominal field-of-view: 150″ × 150″ (max. 300″ × 300″)
- Wavelength coverage: 350 nm – NIR
- Integrated (multi-conjugate) adaptive optics



The GREGOR Telescope

- ❑ Diffraction-limited resolution
  $\alpha = \lambda / D = 600 \text{ nm} / 1.5 \text{ m} = 0.082''$
  $\rightarrow$ 60 km on the solar surface





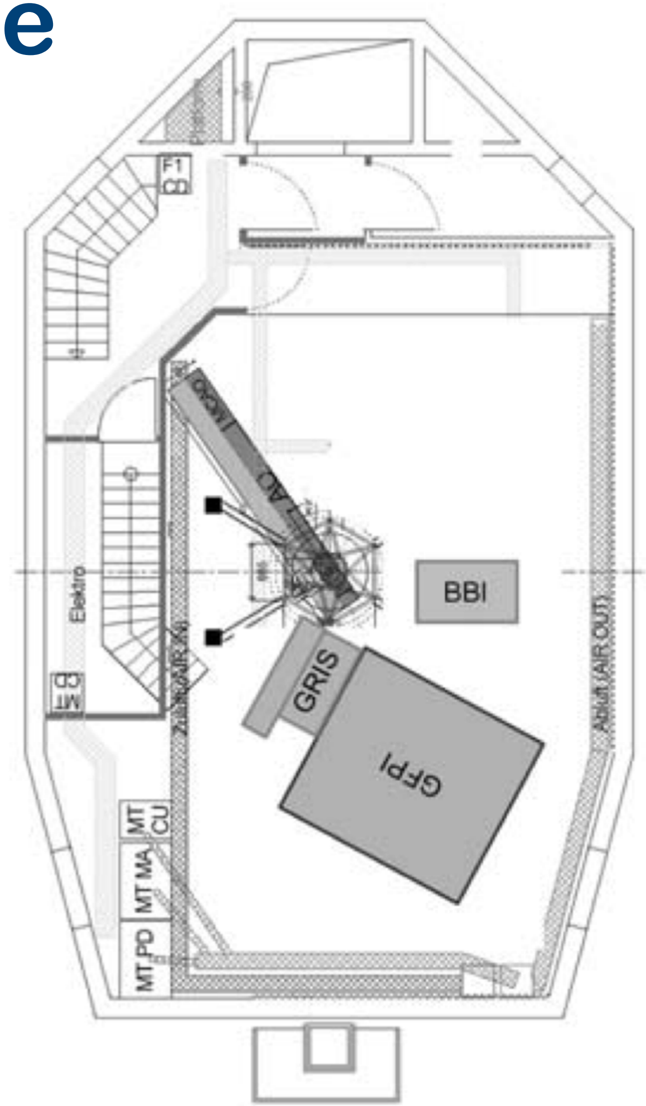
The GREGOR Telescope

Instruments

- Instrumental Calibration Unit (ICU), in F2
- GREGOR Adaptive Optics System (GAOS)
- Broad-Band Imager (BBI)
- GREGOR Infrared Spectrograph (GRIS)
- GREGOR Fabry-Pérot Interferometer (GFPI)/ Blue Imaging Channel (BIC)
- Zurich IMaging POLarimeter (ZIMPOL)

- Multi-instrument observations:
- GRIS-GFPI-BIC

- GREGOR@Night



Schmidt et al. (2012)

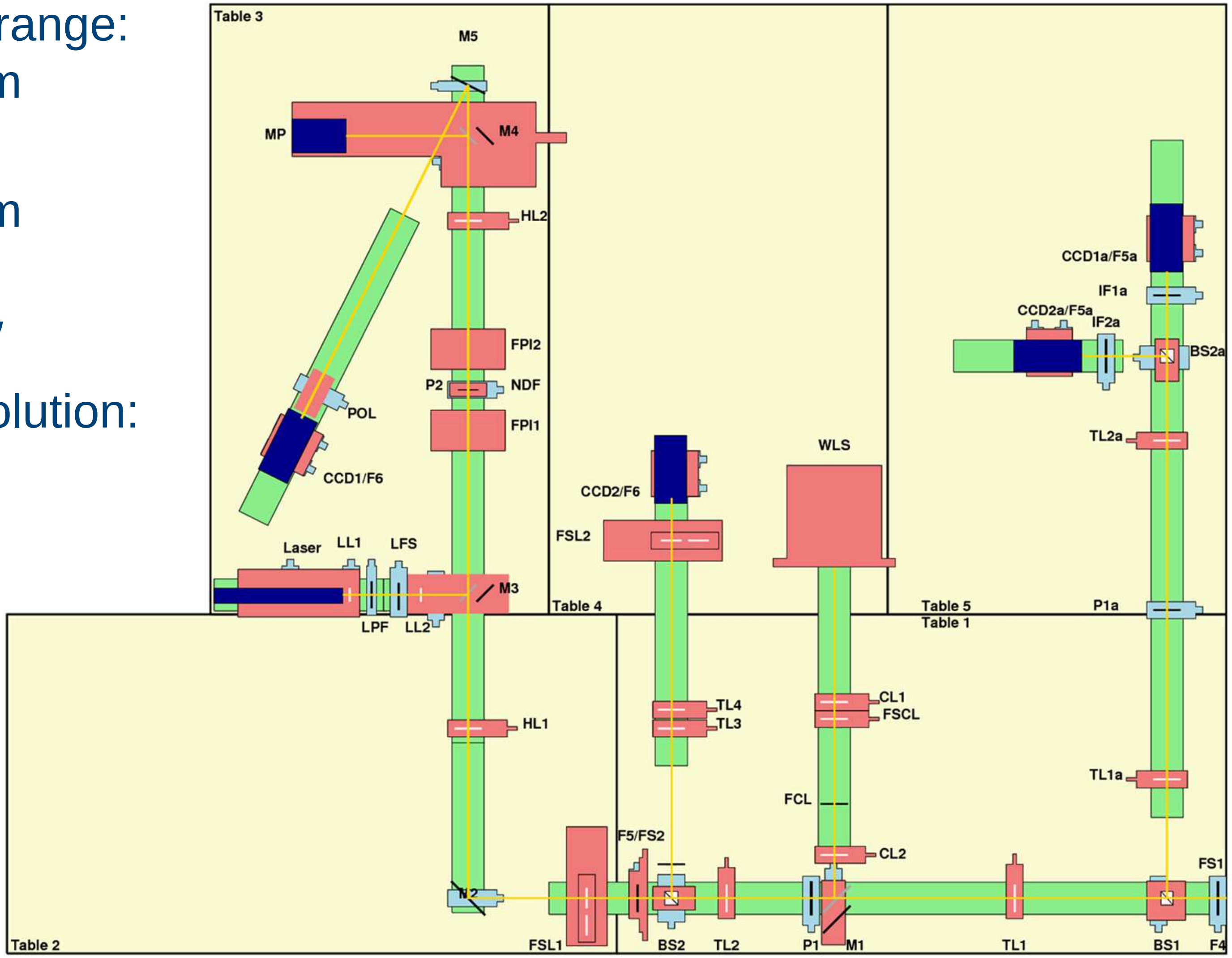
GREGOR Fabry-Perot Interferometer (GFPI)

Wavelength range:
530 – 870 nm

Polarimetry:
580 – 660 nm

FOV GFPI:
52.2″ × 39.5″

Spectral resolution:
~250,000



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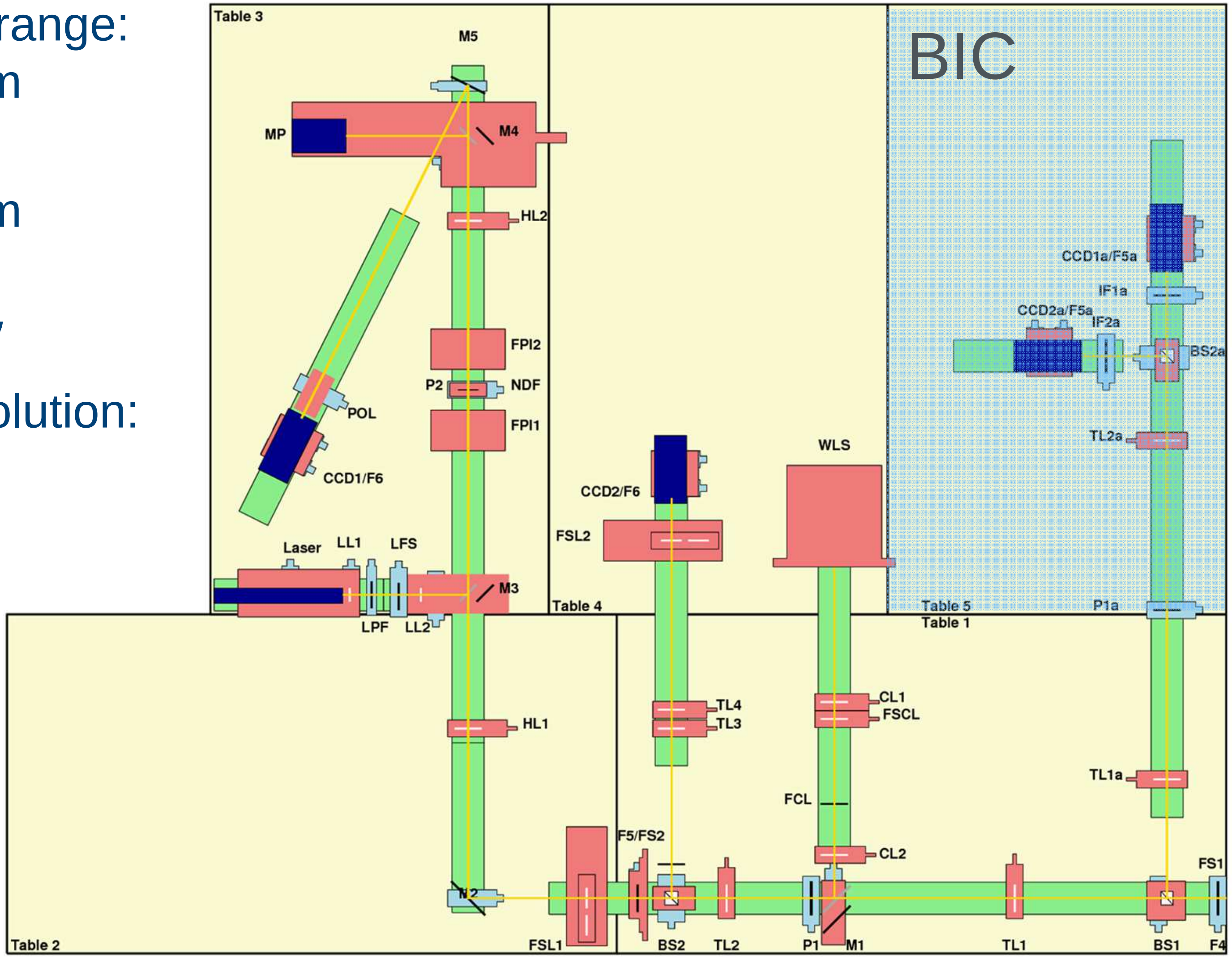


Observations

Date: 2014 August 13

Observations with GFPI: Time-series of filtergrams (~ 38 min) scanning along the Hα line provided two-dimensional spectroscopic information of <u>two</u> solar phenomena taking place simultaneously within the observed FOV:

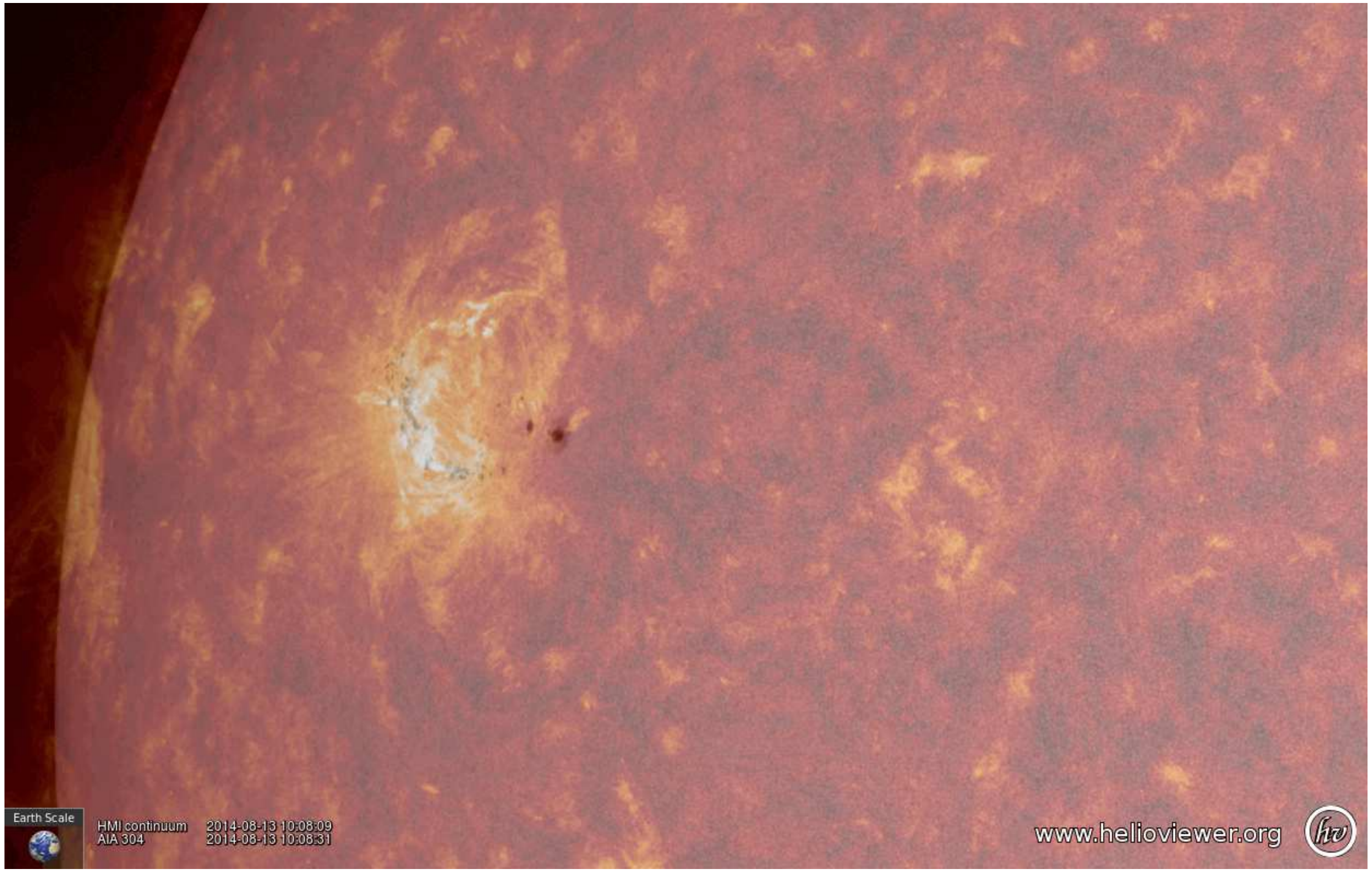
(1) Ellerman bombs clearly visible in the wings of the Hα line, and

(2) a microflare only visible in the higher chromospheric layers where the Hα inner-core forms

NOAA 12139

HMI continuum + AIA 304 Å composite (2014 August 13, 10:08UT):

flare activity mainly in the developing following polarity area



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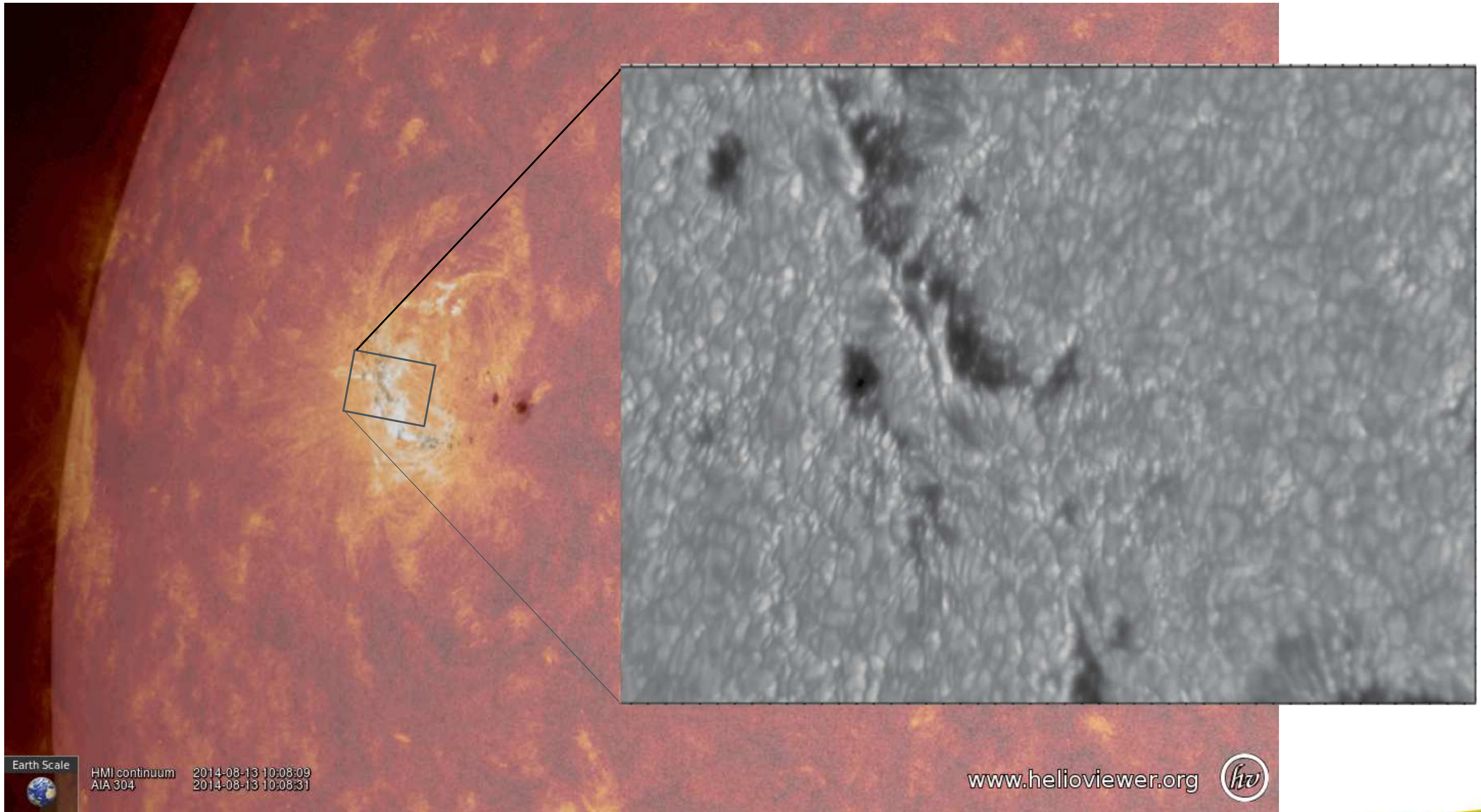
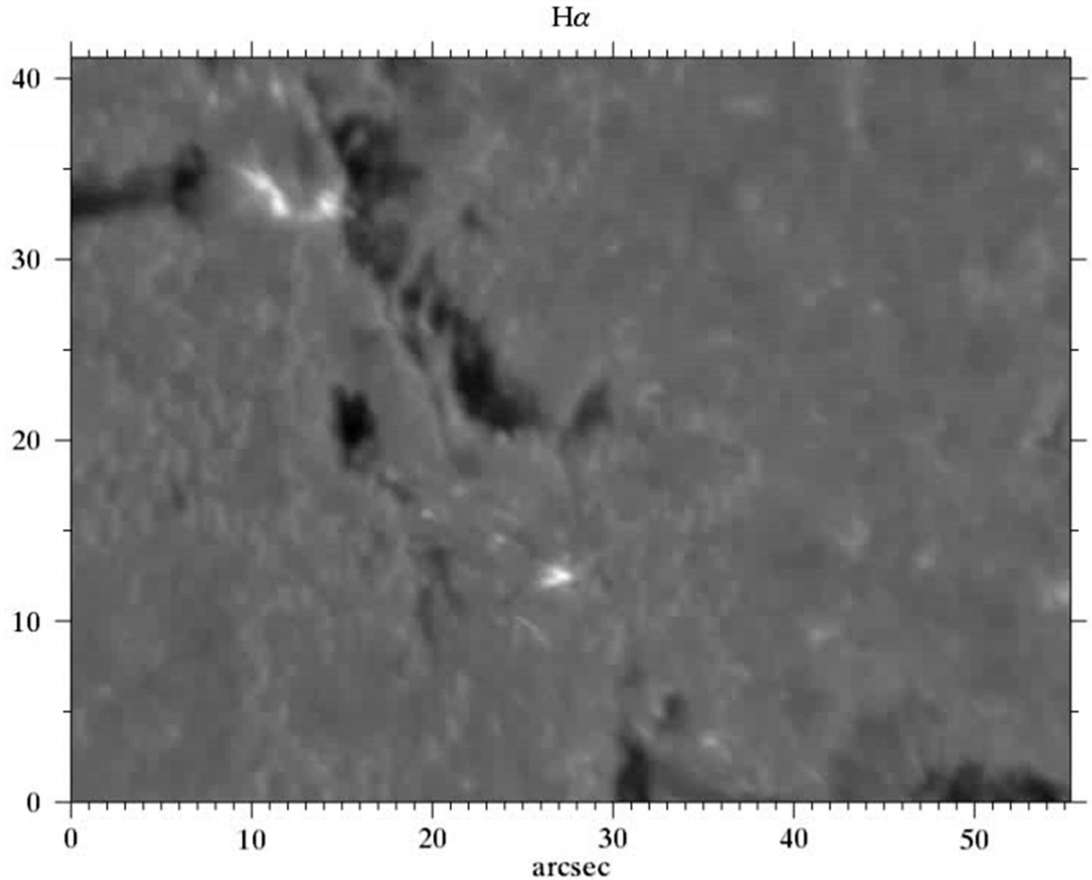


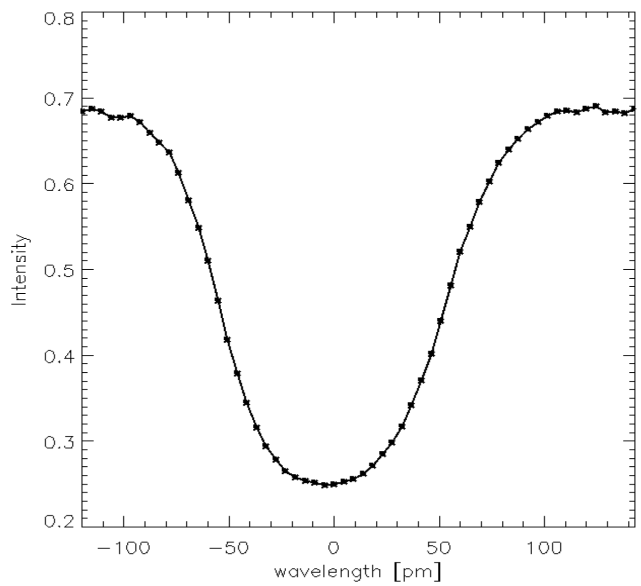
Ellerman bombs (EBs)

- EBs are conspicuous small-scale (~1") brightenings visible in the hydrogen Balmer lines and observed in complex and developing active regions
- EBs are especially well seen in both wings of the Hα line from approximately 0.5 Å on outwards of the line center, while the inner Hα core is not affected
- The scenario of magnetic field <u>reconnection</u> taking place in the <u>lower layers</u> of the solar atmosphere is widely accepted as the triggering mechanism of EBs

GFPI @ GREGOR

- Date: 13 August 2014
- Time: 9:46 – 10:24 UT
- Scanning time: ~ 50 s





- GFPI Hα scan: 58 steps

GFPI @ GREGOR

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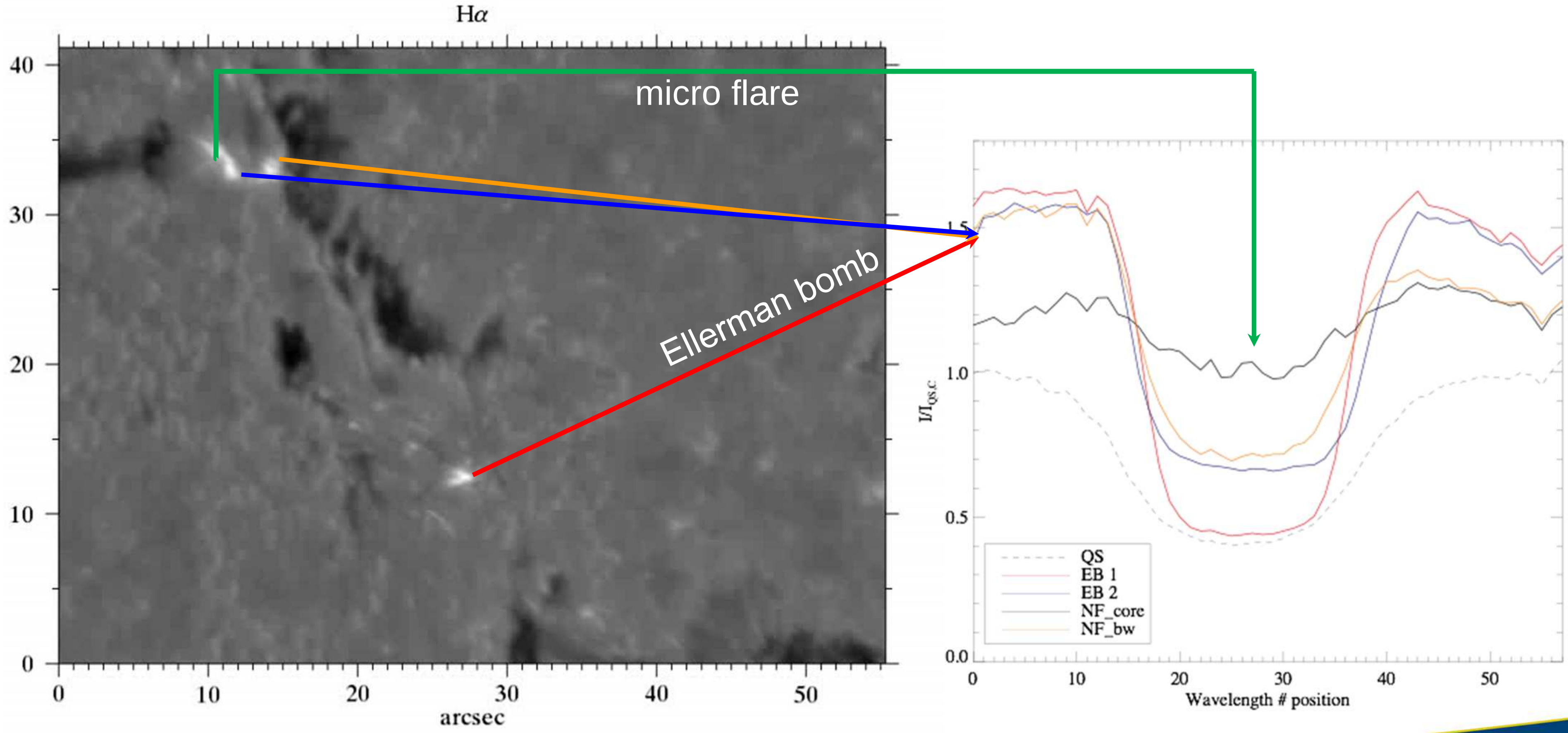
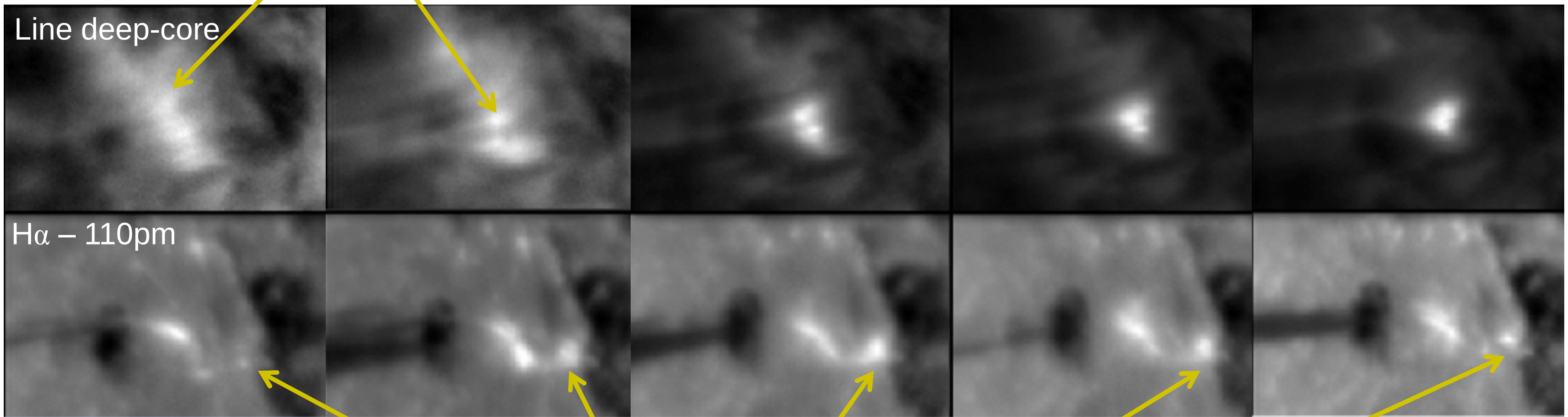


Morphology

Not visible in AIA high-layer bands

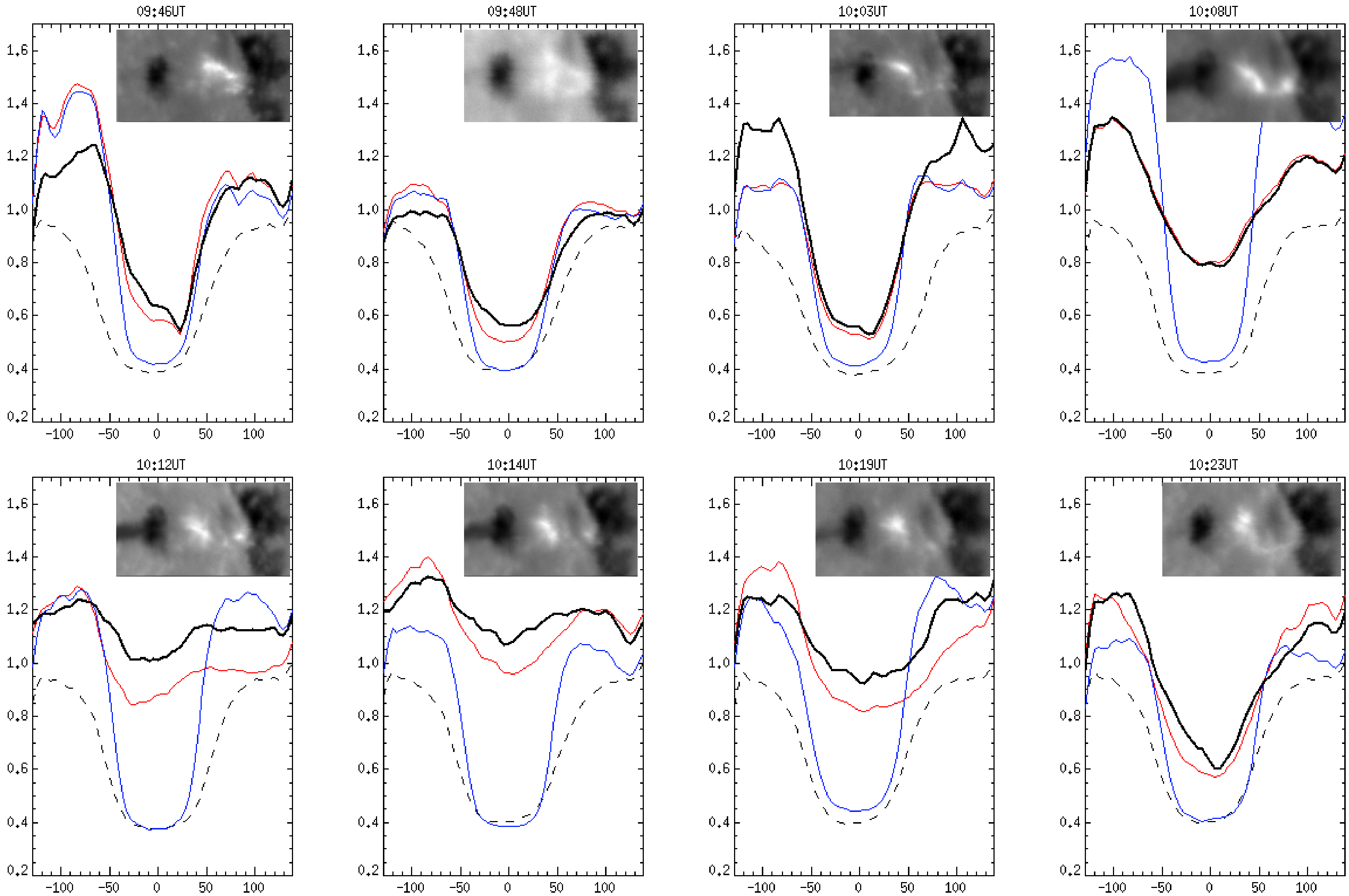
Two flaring merging cores
No flary filamentary structure → no FAF



Ellerman bomb

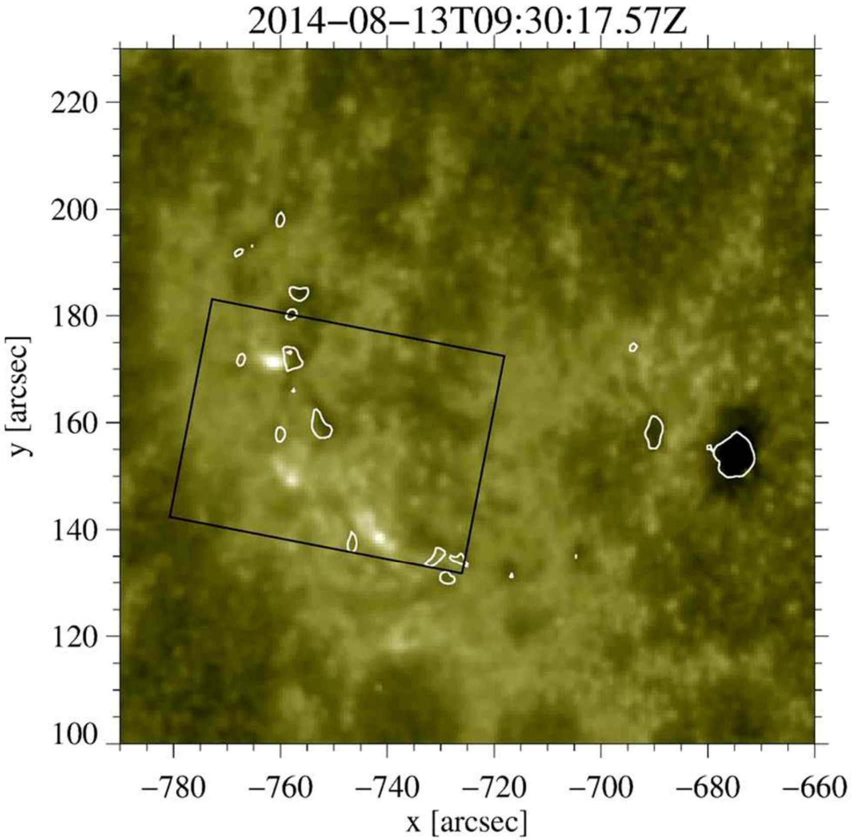
Evolution

Time series: 38 min (09:46 – 10:24UT)

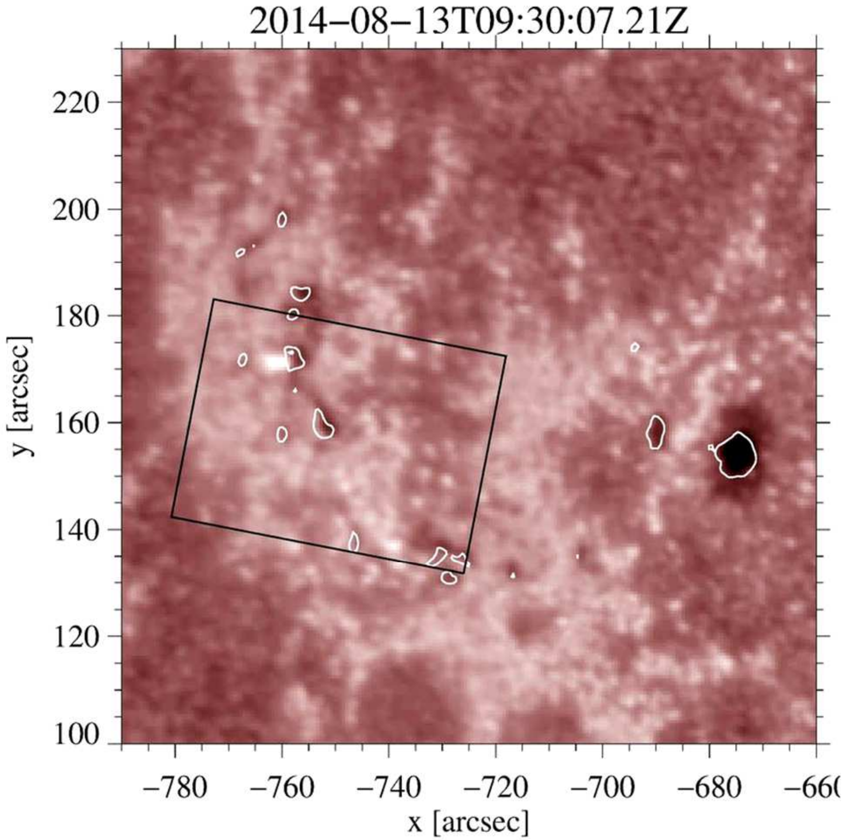


EBs observed with AIA

1600 Å



1700 Å



Ellerman bombs (EBs)

- Correlated with some brightening in photospheric layers (HMI)
- Nothing conclusive in HMI magnetograms by eye inspection
- EB show flary appearance only in AIA1600 & 1700, no filamentary structure but rather circular
- The isolated EB is very long lasting

Solar flares

- Solar flares are believed to have their origin in magnetic reconnection processes in the corona, depositing part of their released energy in the transition region and chromosphere where the plasma is heated to temperatures above 10^7 K

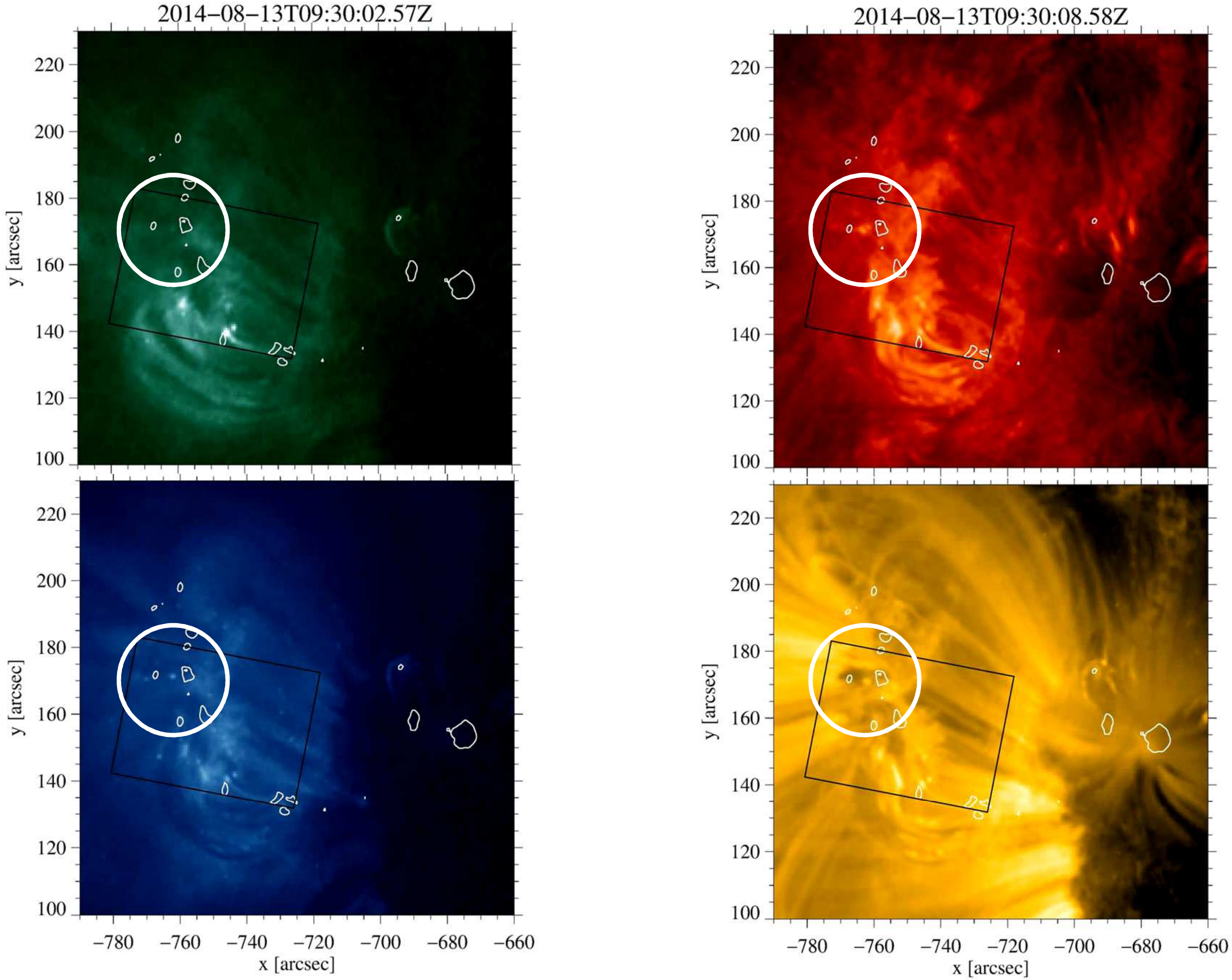
- Microflares (and nanoflares) are defined after the fraction of thermal plasma energy they contain compared with the largest observed flare events

- Observations show that microflares have a similar nature as large flares in terms of their spectral and X-ray properties

Microflares observed with AIA

94 Å

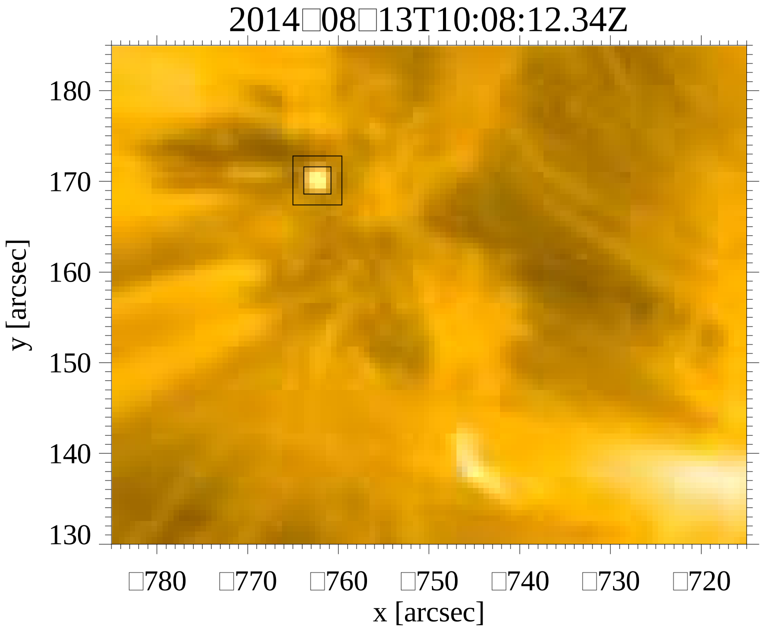
304 Å

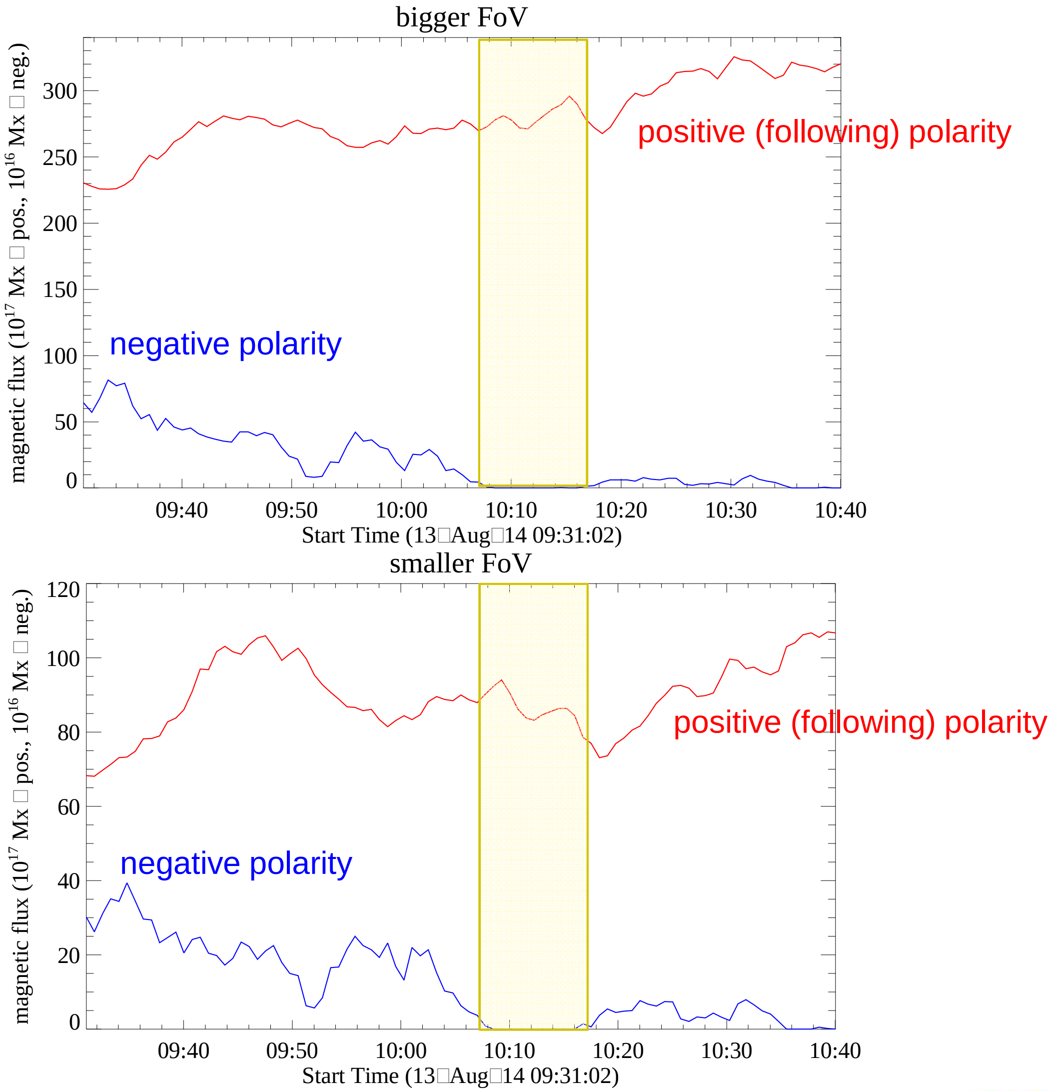


335 Å

171 Å

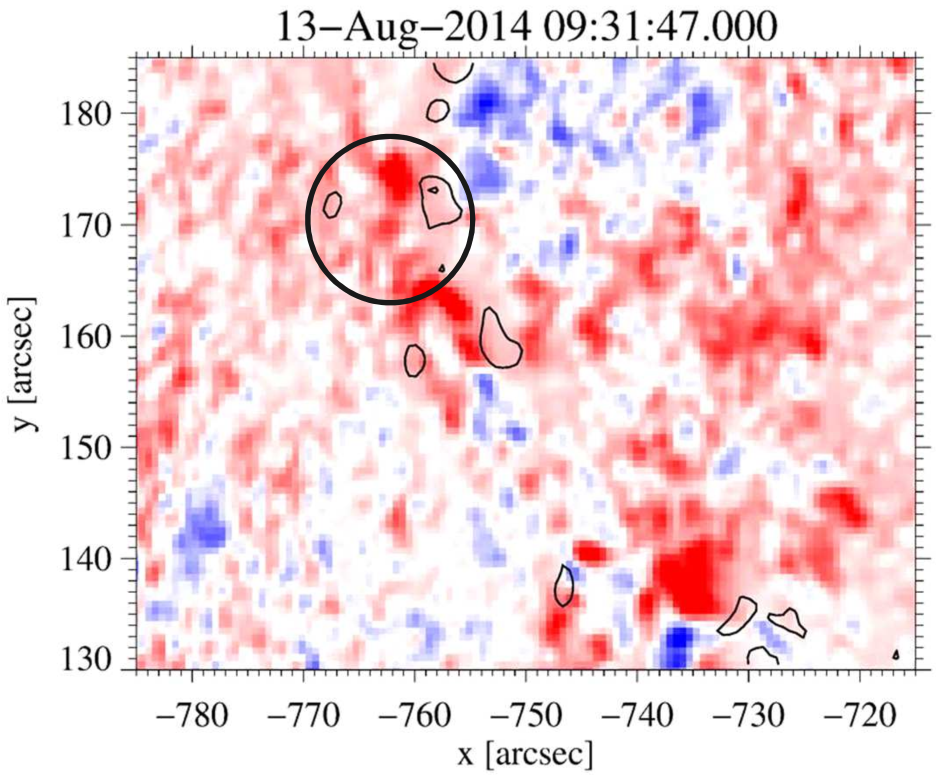
Microflare: observed properties

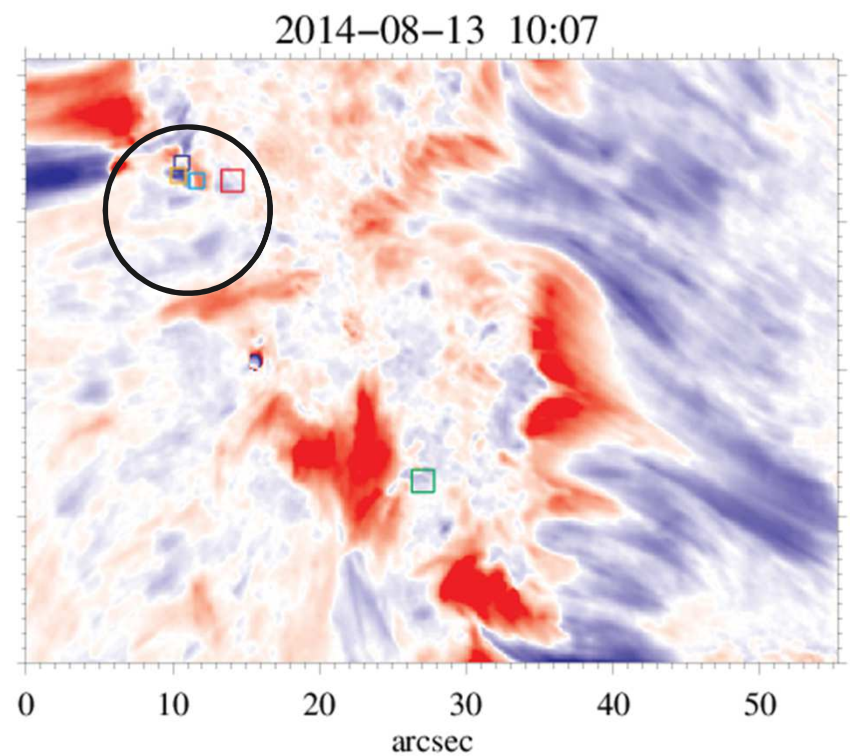




Cancellation of flux of magnetic polarity during the event (window) as seen by HMI magnetograms

Microflare: observed properties

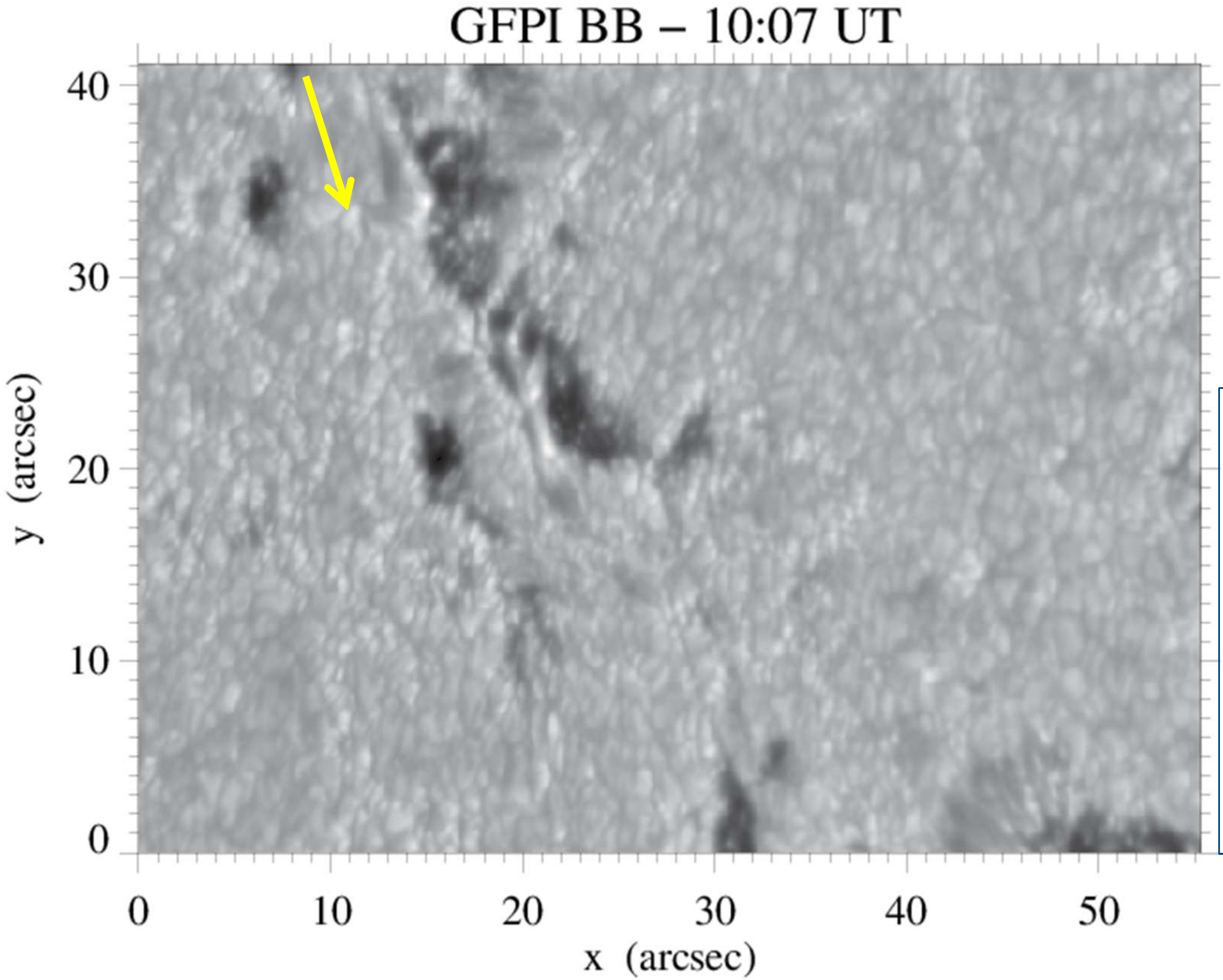




HMI (± 1.5 km/s)
Photosphere

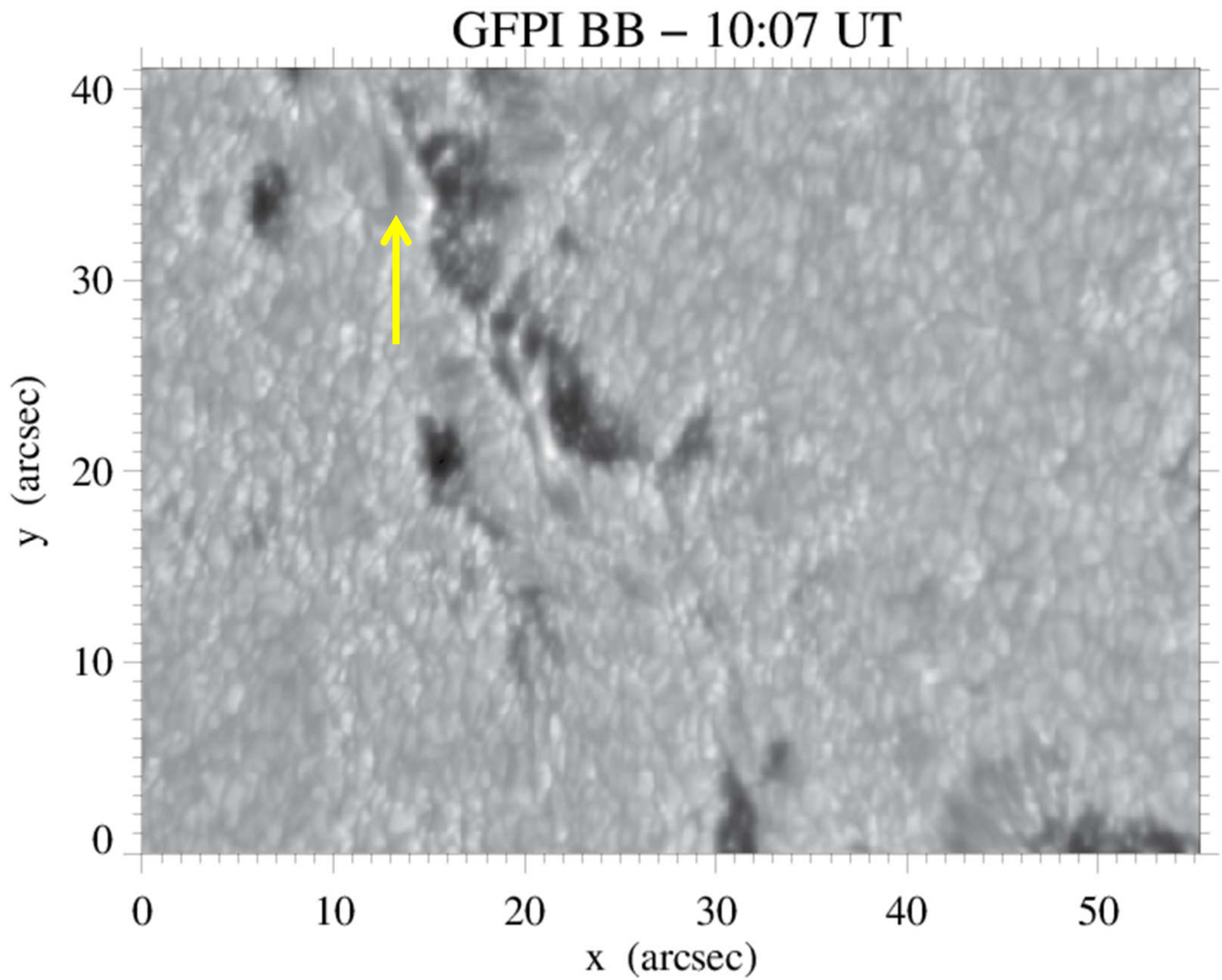
GFPI (± 12 km/s)
Chromosphere

Microflare: observed properties



The head of the microflare is well correlated with brightenings (granular hot walls) as seen in continuum – similarly to EBs

Microflare: observed properties



Formation of penumbra

Conclusions

- EBs and microflares share similar properties like morphology and lifetime and bright counterparts on the solar surface

- Yet, their spectral signatures as seen in Hα are most different: while EBs are visible exclusively in the line wings, the microflare is strongly visible in the deep line core

- Microflare characteristics:
  - Clear signatures in all AIA bands, i.e., in chromosphere, TR and corona
  - The roundish shape and no relation to a filament or arch does not match with the FAF morphological definition. Yet, the spectral properties are very similar
  - It is associated with blueshifts at photospheric and chromospheric levels

Conclusions

- The simultaneous and co-spatial appearance of EB + microflare is another indication of the entangled topology of the field in this area: reconnection happens at both photospheric – giving rise to EBs – as well as in the upper layers – originating the microflare
- The formation of penumbra in the nearby sunspot might be a consequence of the arrangement of the field lines during and after reconnection at various levels


Thank you