Interactions between emerging and pre-existing magnetic fields observed with IRIS

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Contributed Talk

3. Magnetic coupling and mass flux through the atmosphere

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We report multi-wavelength ultraviolet observations taken with the IRIS satellite, concerning the emergence phase in the upper chromosphere and transition region of an emerging flux region (EFR) embedded in the unipolar plage of active region NOAA 12529. These data are complemented by full-disk, simultaneous observations of the SDO satellite, relevant to the photosphere and the corona, and Hinode spectropolarimetric measurements.

Recurrent intense brightenings that resemble UV bursts, with counterparts in all coronal passbands, are identified at the edges of the EFR and in the region of the arch filament system (AFS) cospatial to the EFR. Jet activity is found at chromospheric and coronal levels as well. The analysis of the IRIS line profiles reveals the heating of dense plasma in the low solar atmosphere and the driving of bi-directional high-velocity flows with speeds up to $\pm 100\,\mathrm{km\,s^{-1}}$ at the same locations. We also find a correlation between line centroid and skewness in the UV bursts, with blue-shifted lines having a redward asymmetry and red-shifted lines having a blueward asymmetry.

Comparing these signatures with previous observations and numerical models, we suggest evidence of several long-lasting, small-scale magnetic reconnection episodes between the emerging bipole and the ambient field.

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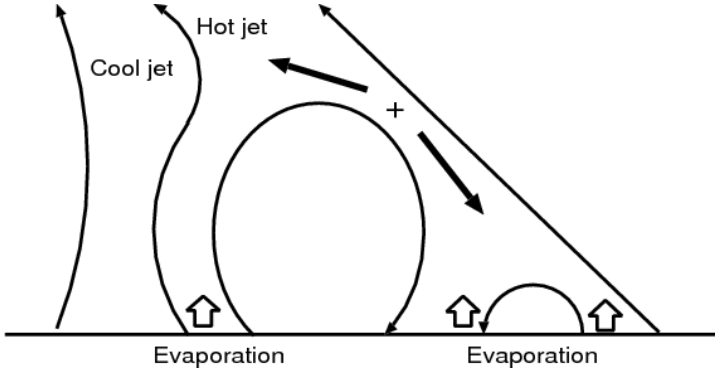
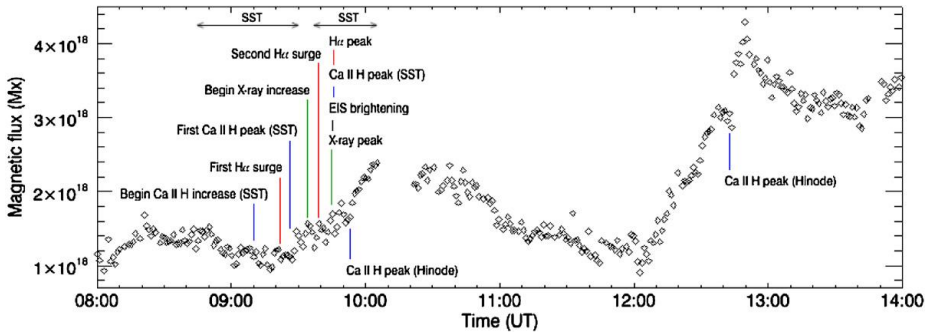
Interactions between new and pre-existing flux

- A number of magnetic flux emergence studies analyse the phenomena occurring as a result of changes induced by emerging flux regions (EFRs) to the pre-existing fields.
  - **flux cancellation, brightenings, ejections, … even flaring!**
- The main responsible for these effects is thought to be **magnetic reconnection**.
  - "the cutting of stressed magnetic field lines, which is associated with a **violent release of energy**"
  - X-ray jets and Hα surges can be ejected simultaneously
  - heating -> brightenings

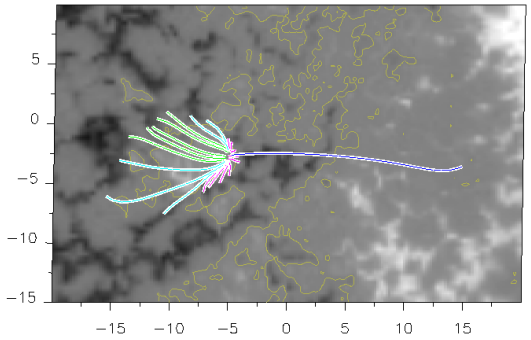


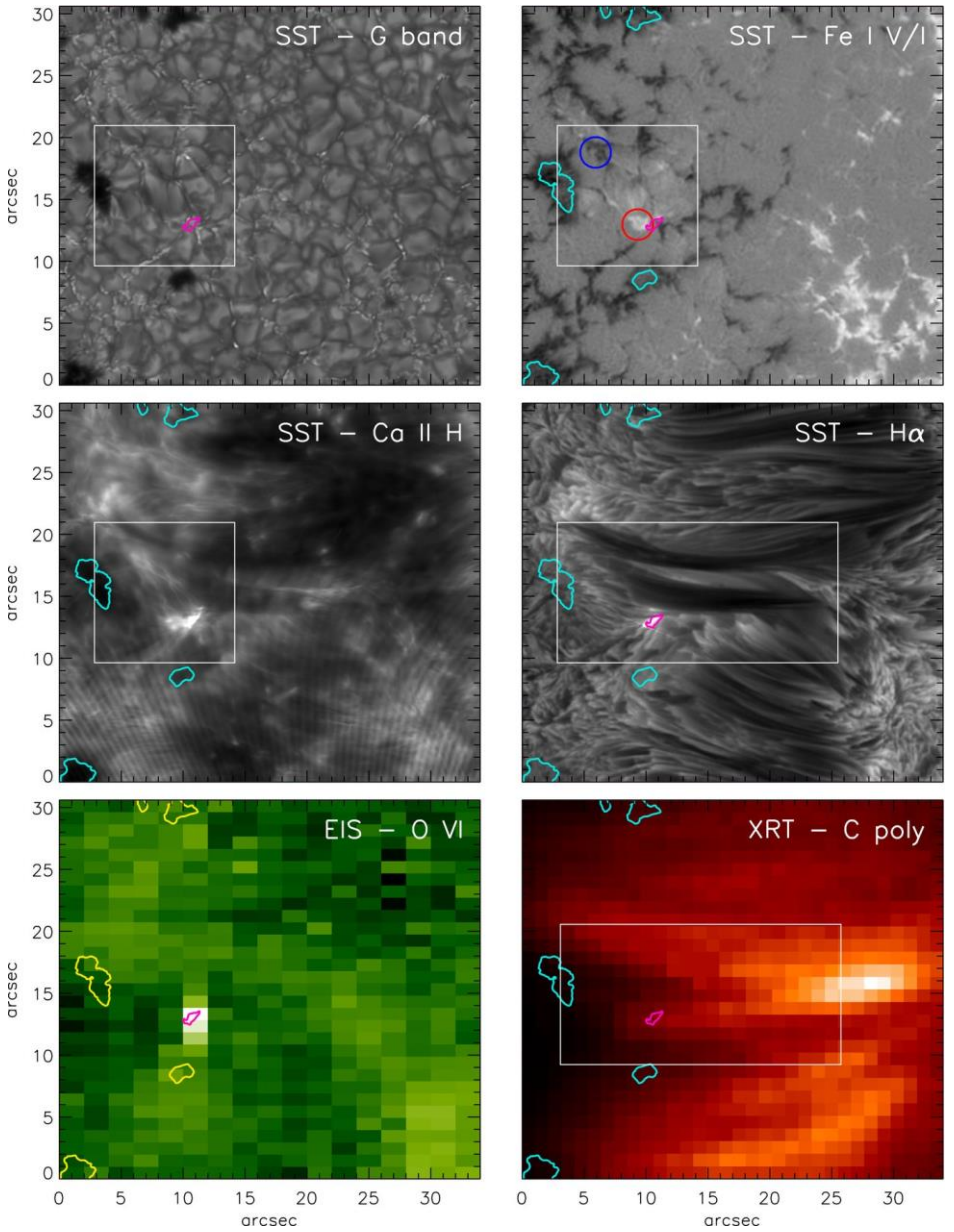
Shibata et al. (1992), **Yokoyama & Shibata** (1995)

- **HOW**: EFR evolution from the photosphere to the corona.



- EFR observed by SST and *Hinode* (**SOT-EIS-XRT**), with signatures in **all the layers** of the solar atmosphere.
- **Brightenings** in Ca II H and Hα lines, first in the low atmosphere, and a surge.
- **Reconnection** suggested by extrapolations.



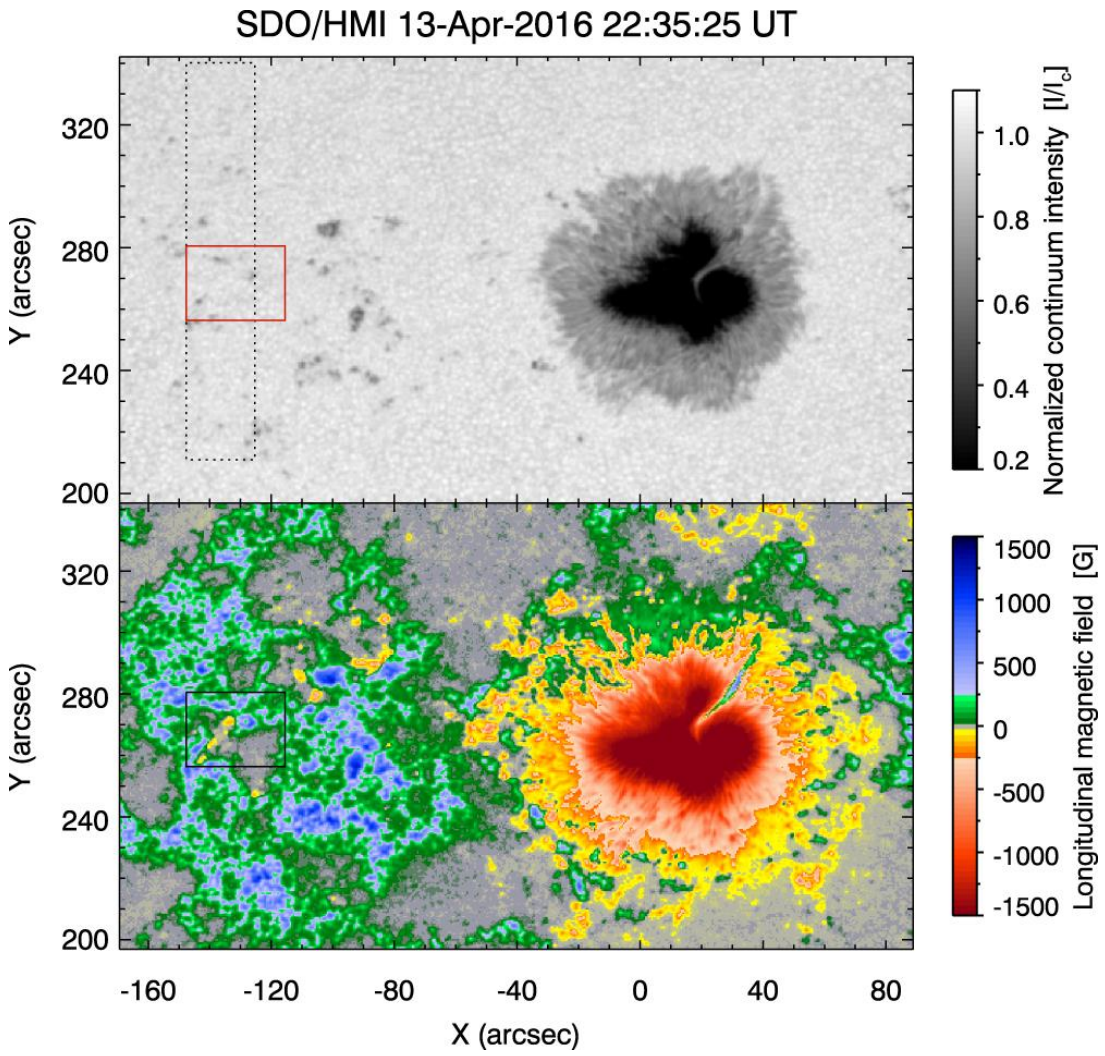


Guglielmino et al. (2008, 2010)

IRIS observations of an EFR embedded in a plage

Active Region NOAA 12529 – April 2016

Guglielmino et al. (2018), ApJ, 856, 127
Guglielmino et al. in preparation



NOAA 12529

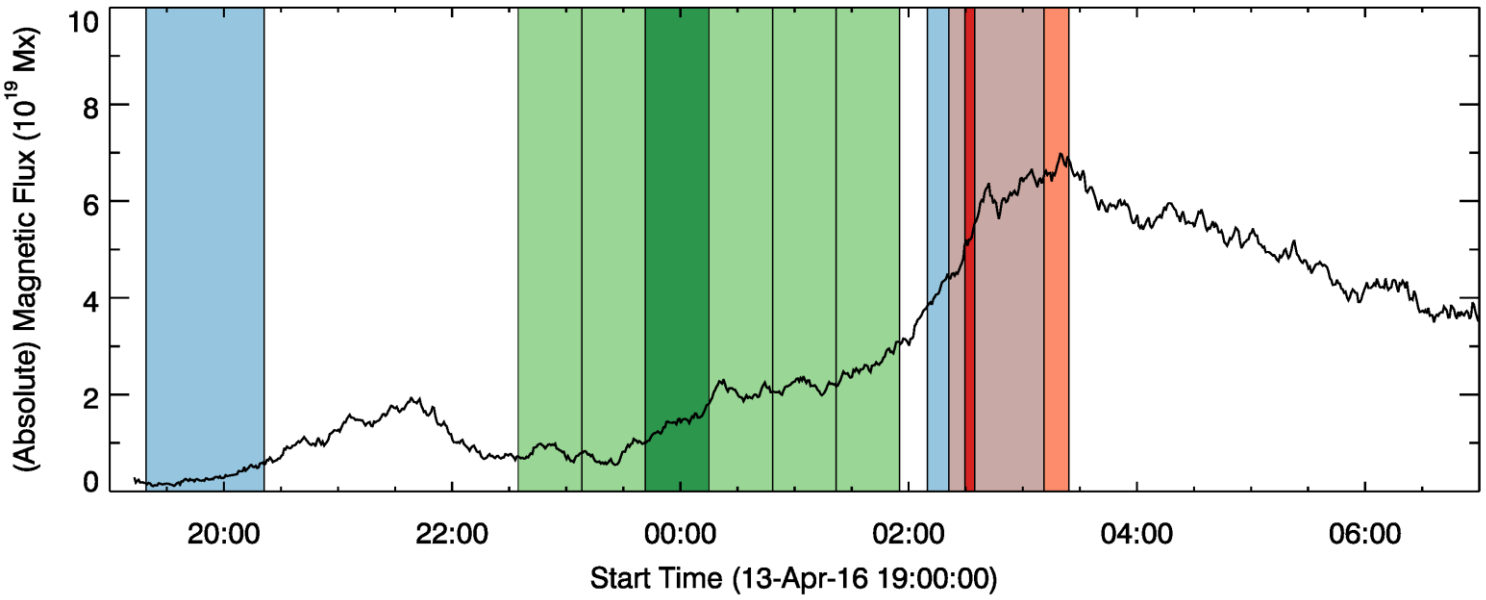
A large bipolar AR:

- giant preceding sunspot
- diffuse following polarity

An EFR was seen emerging embedded in the plage of the following polarity (**red box**).

The area was also scanned by *IRIS* during a six raster scans sequence (**dotted line**).

IRIS observations



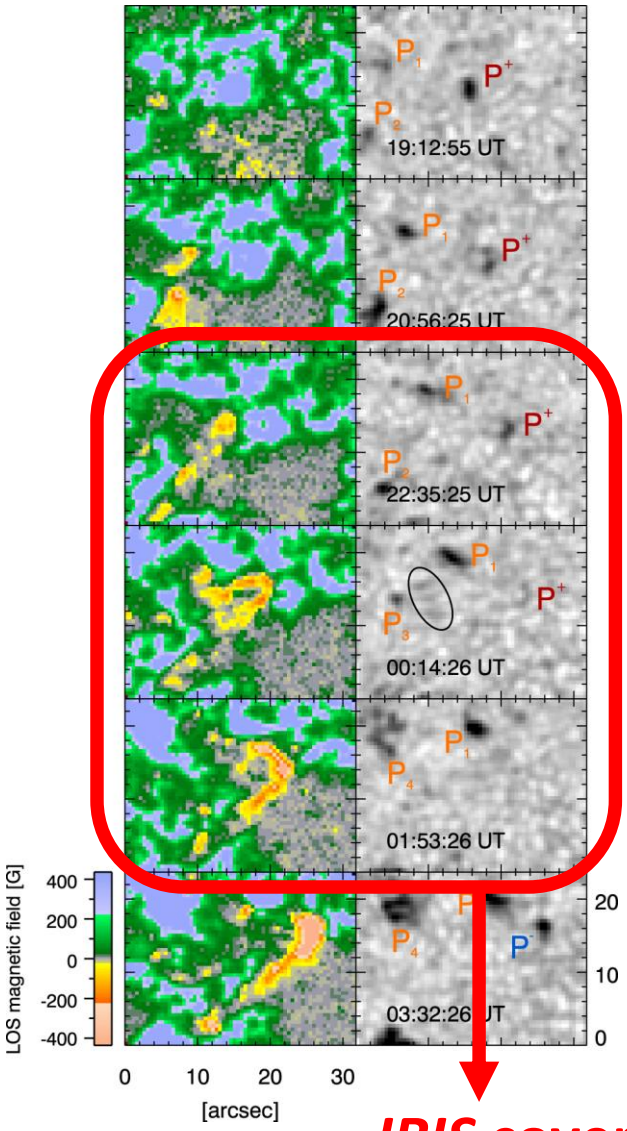
IRIS single 400-step rasters (**blue strips**)

IRIS sequence of six 64-step rasters (**green strips**; profiles from the dark one are analyzed here)

SOT/SP raster scan (**red strip**; the darker band is relevant to the EFR observations)

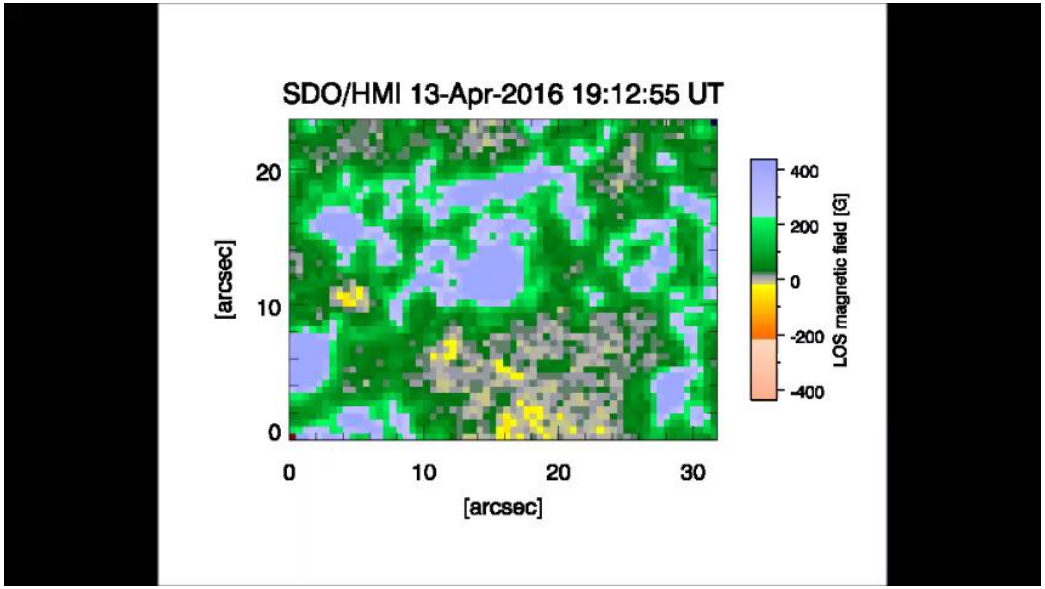
SDO/HMI and SDO/AIA provided a simultaneous, continuous coverage of the event

- The *IRIS* scan sequence caught the **emerging phase** of the EFR, which carried a flux content of an ephemeral region (≈10^{20} Mx).
- SOT/SP observations were obtained close to the flux peak.



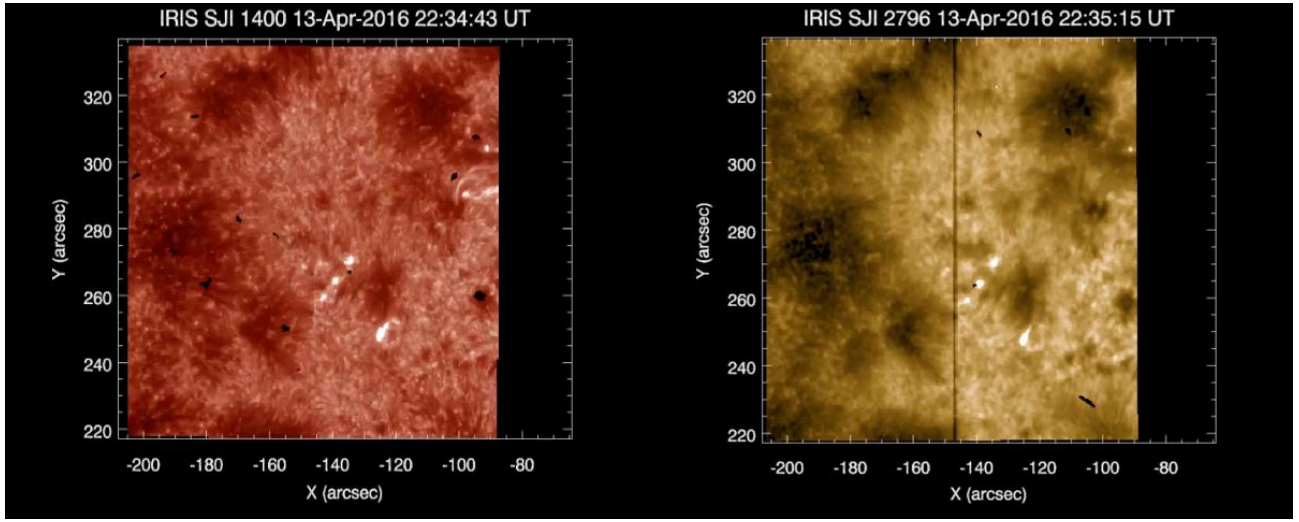
IRIS coverage

SDO/HMI sequence

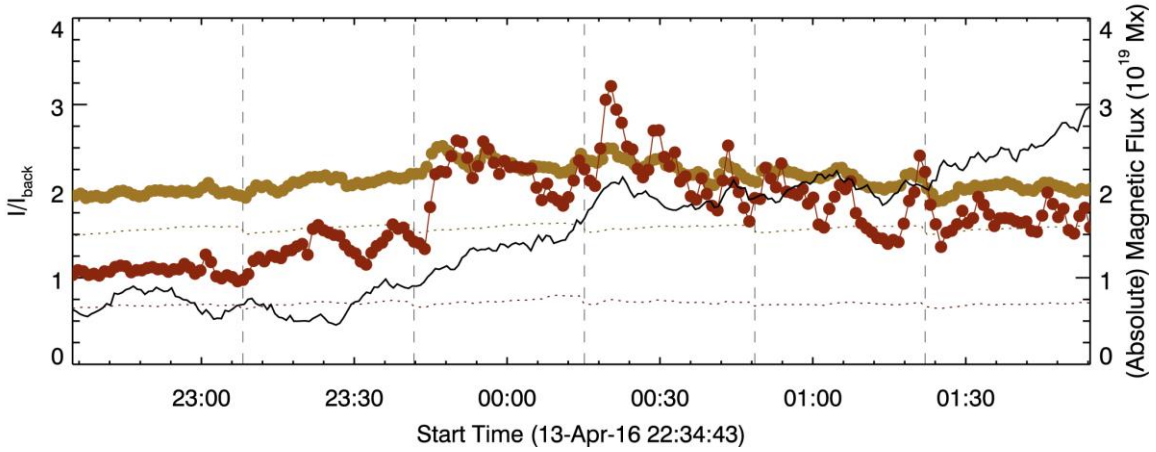


- An EFR emerged in a unipolar plage
- **P+** became smaller and disappeared
- New flux formed **P-**

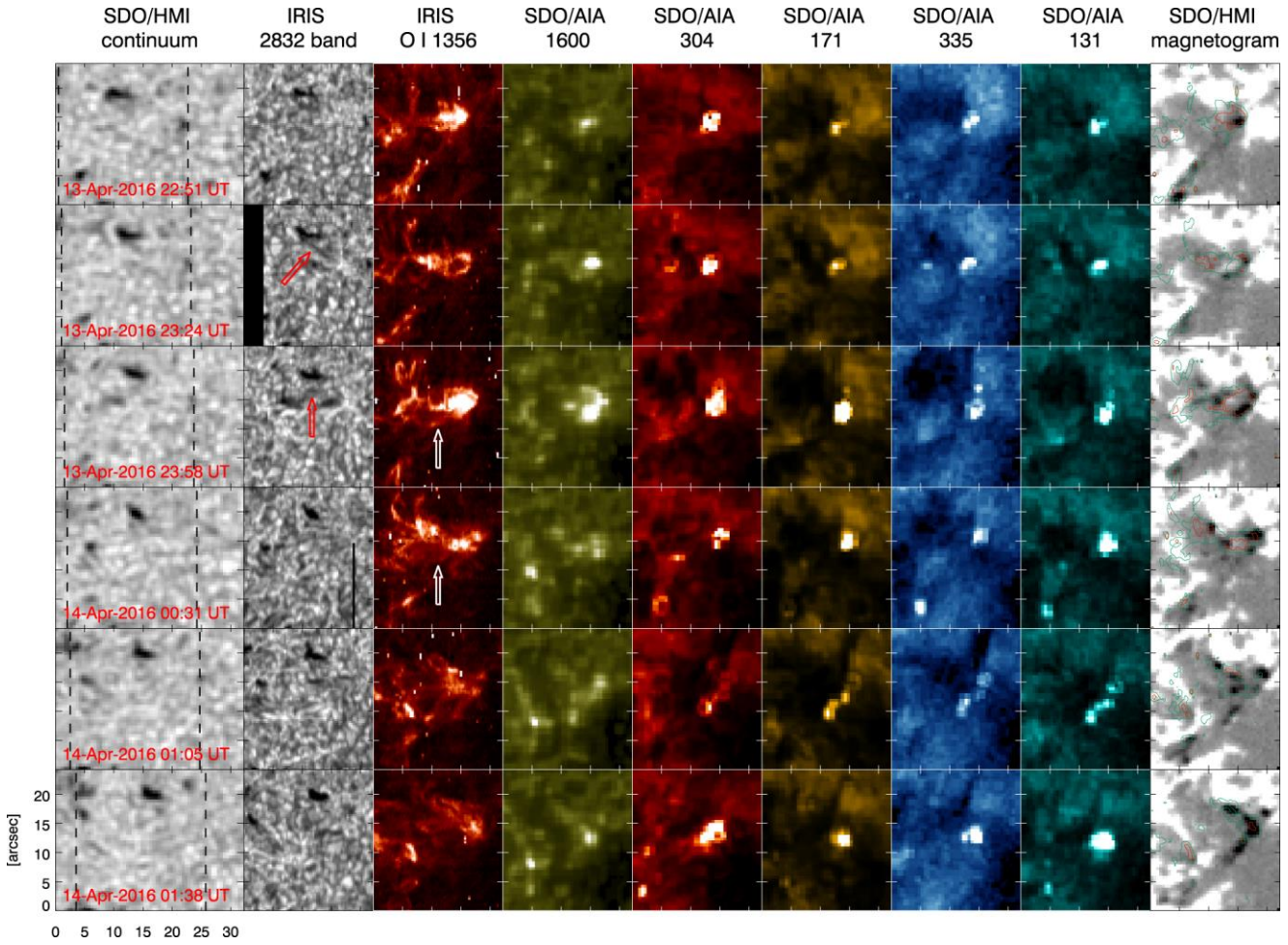
Response to flux emergence of the upper atmospheric layers



Recurrent UV **brigthenings** in the EFR site.



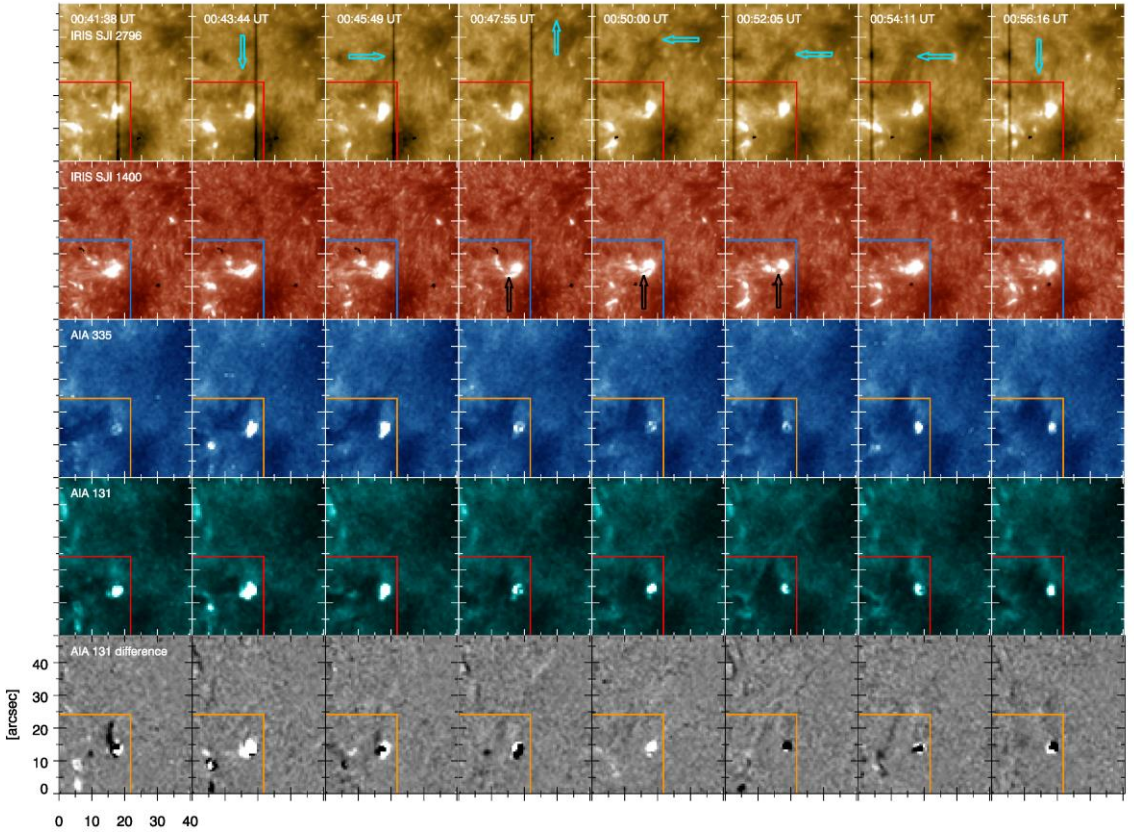
Response to flux emergence



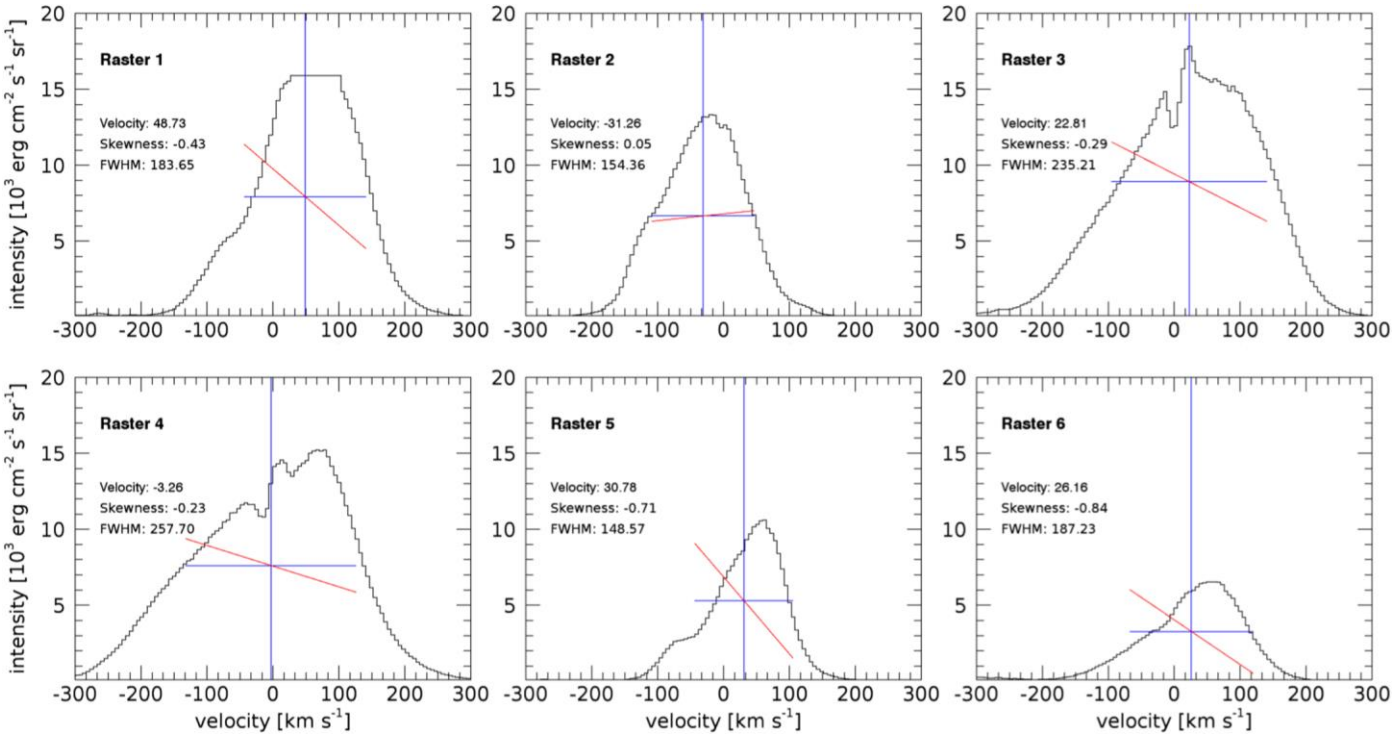
- ***IRIS*** sequence shows **brightenings** near the "contact" region.
- **ALL** SDO/AIA channels exhibit a counterpart of the event.

Surge and jet activity

- **Plasma ejections**, with a length of about 10", are observed in regions close to the UV brightenings.
- Surge/jet-like ejecta appear in UV/EUV images as long **thread-like structures**.
- They occur repeatedly in the same locations.
- The projected speed of the ejecta in the horizontal direction is about **40 km s^{-1}**.
- **Enhanced emission** is found at the base of jet locations.



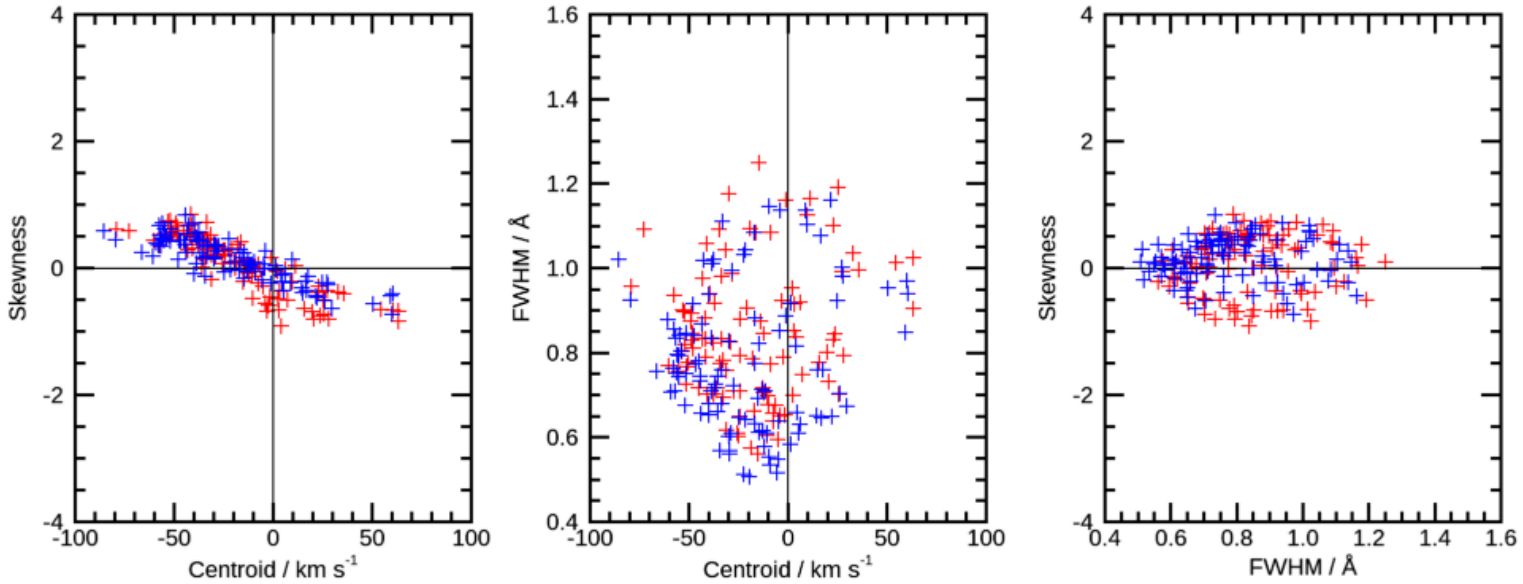
IRIS profiles



- Spectral profile of the Si IV 1402 Å line in the brightest spatial pixel of each *IRIS* raster scan (no evolution).
- Peak: 3rd-4th scan (exposure time changes: 30s 1st scan, 18s others).
  - **FWHM: 250 km s^{-1}**
  - **multi-component**

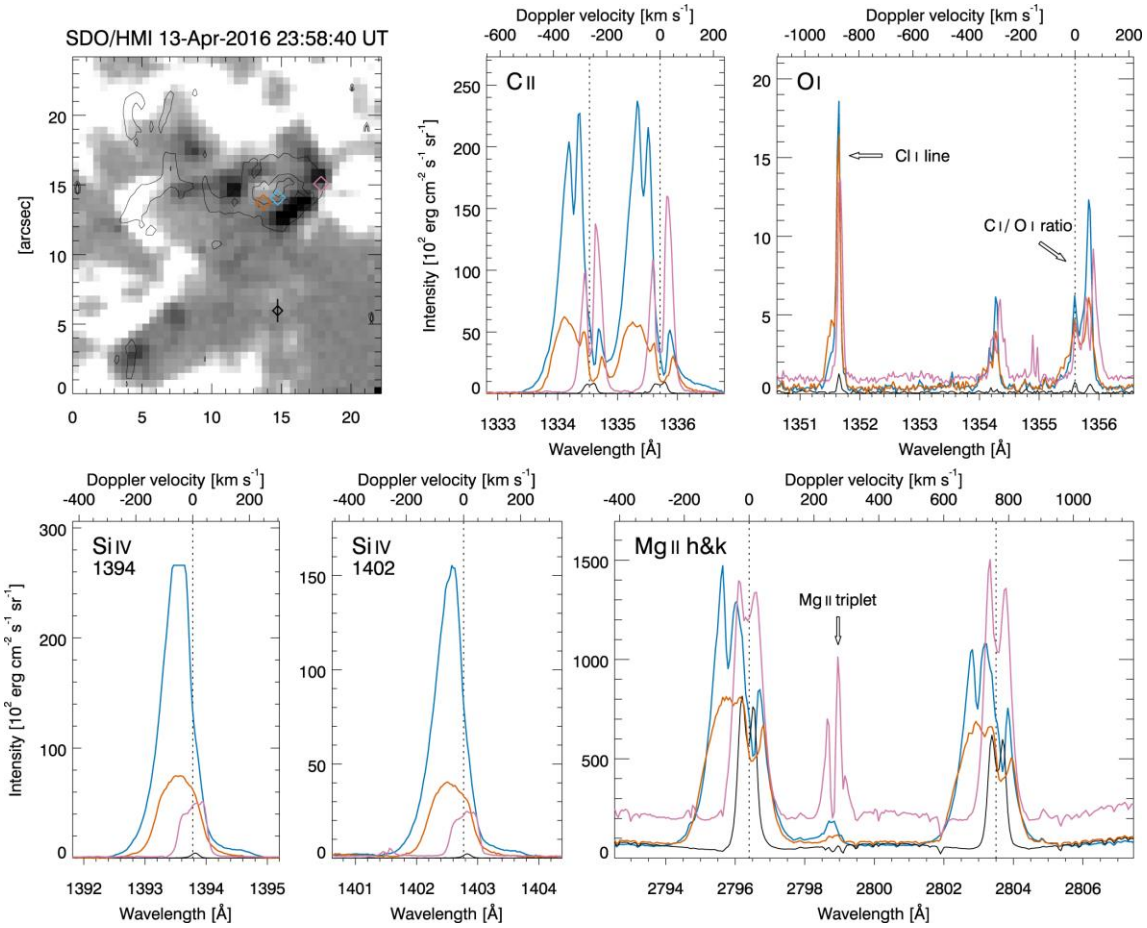
Asymmetry in profiles: statistics

Raster 3 red: 1402 blue: 1394



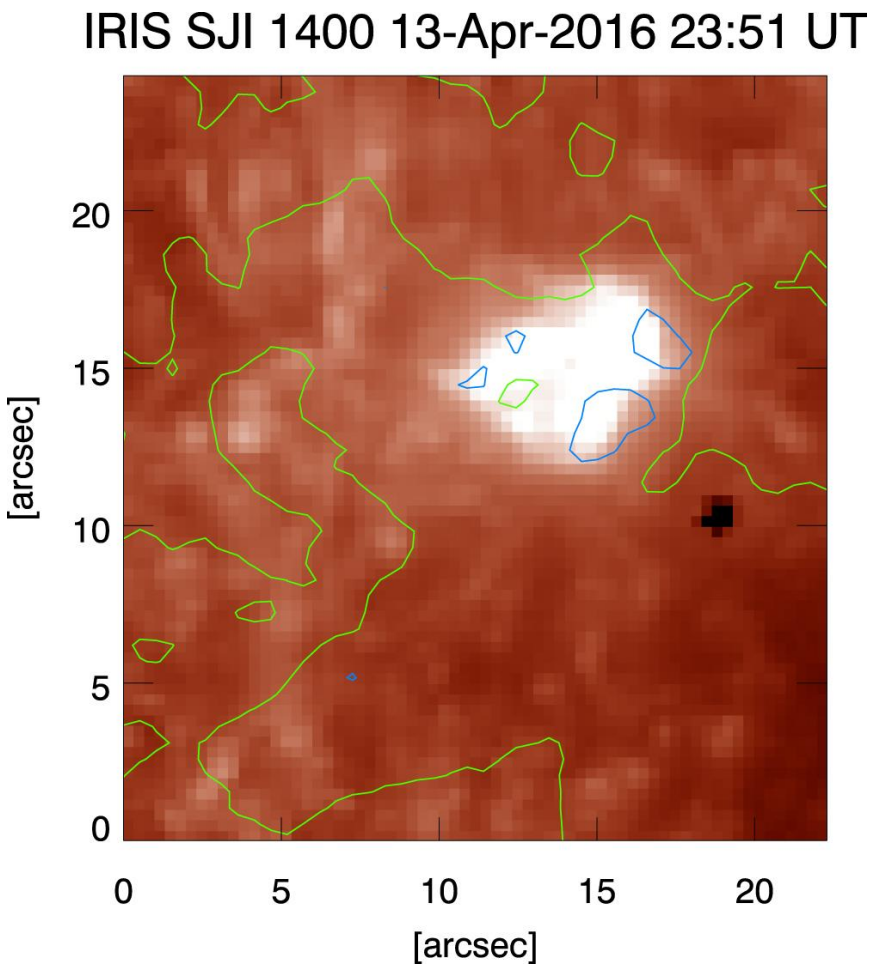
- We found a systematic trend of the skewness in the profiles relevant to the UV burst
  - the more (blue/red)-shifted the profile is, the larger skewness it has
  - the larger width the profile has, the larger the skewness is

Features of *IRIS* profiles



Orange, **blue**, **pink** profiles: random positions over the UV burst
Black profile: average over 6 quiet-Sun pixels

- **UV burst core**
  - blueshifts
  - components with different velocity
  - spectral features
    - "absence" of O IV line
    - Mg II triplet emission
    - inverted C I /O I ratio
    - detection of Fe XII line
- **Contact region**
  - plasma at rest
  - strong Mg II triplet emission



Position of the UV burst

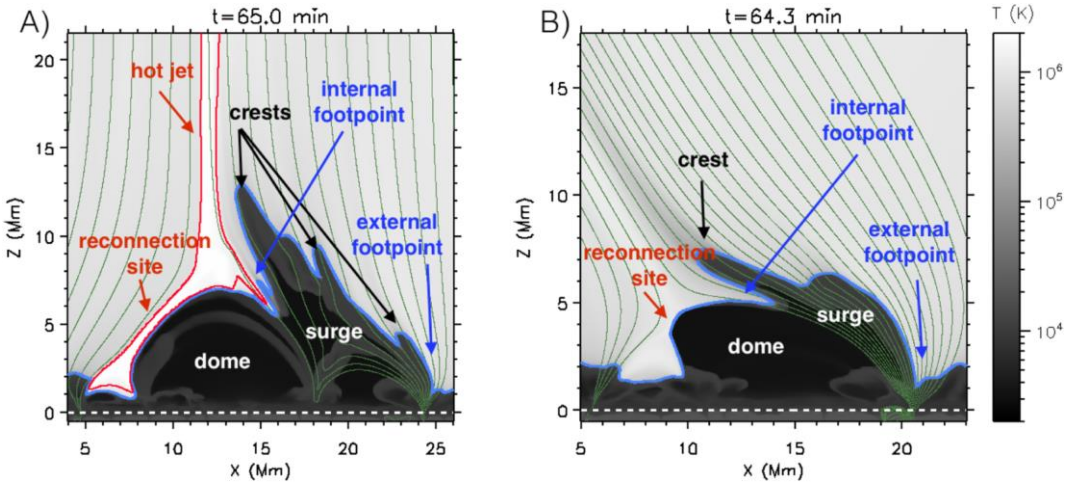
- The UV burst here studied is **not coincident** with the PIL between the **negative emerging** field and the **positive pre-existing** flux.
- It is further to the east, **toward the EFR center**.
- This occurs throughout the *IRIS* sequence.

Comparison with models

- The reconnection site lays higher in the dome.
- Thus, it is **displaced** with respect to the PIL at the photospheric levels.
- The **higher location** of the reconnection site may explain the observed UV spectral features in terms of **different densities**.
- Near the reconnection site a filamentary, Y-shaped jet occurs with **T~2-3 MK**.

Is the event is a result of **magnetic reconnection** between the emerging and the pre-existing field?

Agreement with radiative MHD numerical simulations, in particular **Nóbrega-Siverio et al. (2016, 2017)**, concerning surges and UV bursts observed in flux emergence experiments.



Conclusions

- **Cancellation** of pre-existing flux with an EFR: **P^+**.
- **Recurrent intense brightenings** that resemble UV bursts, with counterparts in all coronal passbands, are identified at the edges of the EFR, where cancellation occurs.
- **Jet/surge activity** is also observed at chromospheric and coronal levels, near the observed brightenings.

➢ **Heating** of dense plasma in the low solar atmosphere and the driving of **bi-directional high-velocity flows** with speed ≈100 km s^{-1} are observed at the same locations.

➢ **RECONNECTION** appears to occur at higher heights with respect to UV bursts, explaining the coronal counterpart.

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