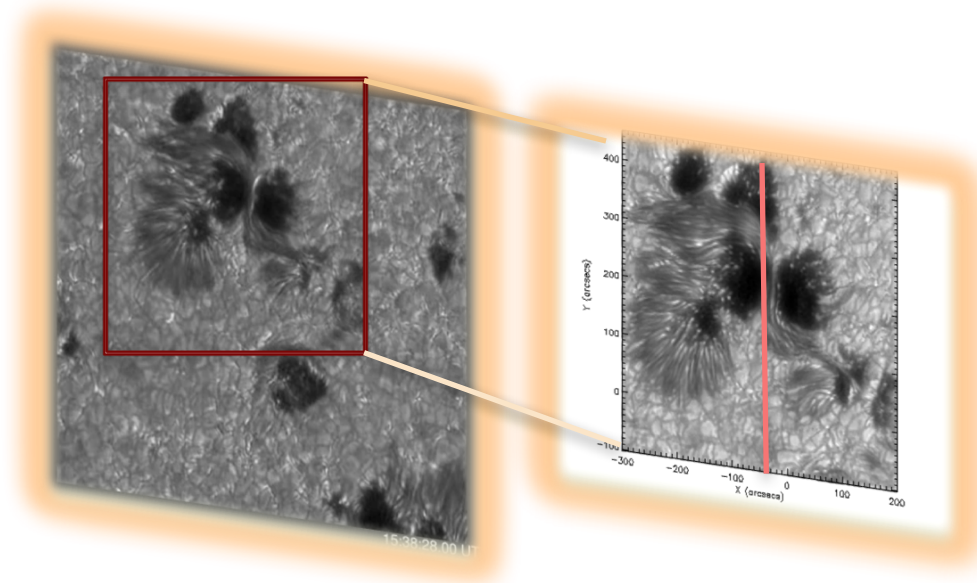


Continuum emission enhancements in flares observed by IRIS and ROSA



F. Zuccarello, V. Capparelli, M. Mathioudakis, P. Keys, L. Fletcher, S. Criscuoli, M. Falco, S.L. Guglielmino, M. Murabito



IRIS 9
June 25-29, 2018
Gottingen, Germany

Poster

4. Eruptions in the solar atmosphere

Continuum emission enhancements in flares observed by IRIS and ROSA

F. Zuccarello¹, V. Capparelli¹,

M. Mathioudakis², P. Keys², L. Fletcher³, S. Criscuoli⁴, M. Falco⁵, S.L. Guglielmino¹, M. Murabito^{1,6}

¹*Università degli Studi di Catania, Catania, I-95123, Italy*

²*Astrophysics Research Centre, School of Mathematics & Physics, Queen's University Belfast, Belfast, BT7 1NN, UK*

³*SUPA, School of Physics & Astronomy, University of Glasgow, G12 8QQ, Scotland, UK*

⁴*NSO - National Solar Observatory, Sacramento Peak - Box 62, Sunspot NM 88349, USA*

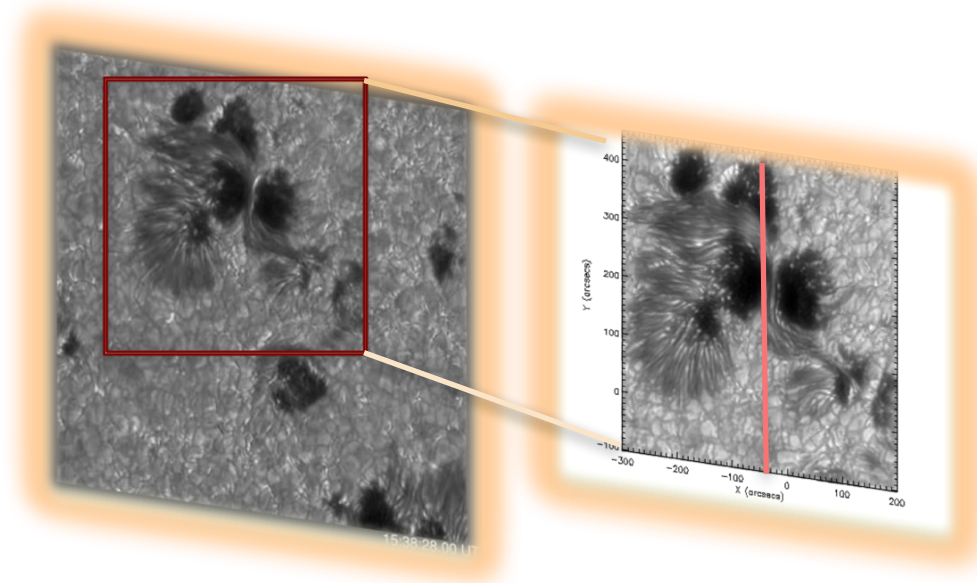
⁵*INAF - Osservatorio Astrofisico di Catania, Catania, I-95123, Italy*

⁶*INAF - Osservatorio Astronomico di Roma, Monte Porzio Catone, I-00078, Italy*

During solar flares, magnetic energy can be converted into electromagnetic radiation from radio waves to γ rays. In the most energetic events, enhancements in the continuum at visible wavelengths may be present (white-light [WL] flares). Recently, the WL emission has also been correlated with enhancements in the FUV and NUV passbands. In this context, we describe observations acquired by ground-based (ROSA@DST) and satellite (IRIS) instruments during two consecutive C7.0 and X1.6 flares occurred in active region NOAA 12205 on 2014 November 7.

The results of the analysis of these data show the presence of continuum enhancements during the evolution of the events, observed both in ROSA images and in IRIS spectra. Moreover, we analyze the role played by the evolution of the δ sunspots of the active region in the flare triggering, discussing the disappearance of a large portion of penumbra around these sunspots as a further consequence of these energetic flares.

Continuum emission enhancements in flares observed by IRIS and ROSA



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IRIS 9
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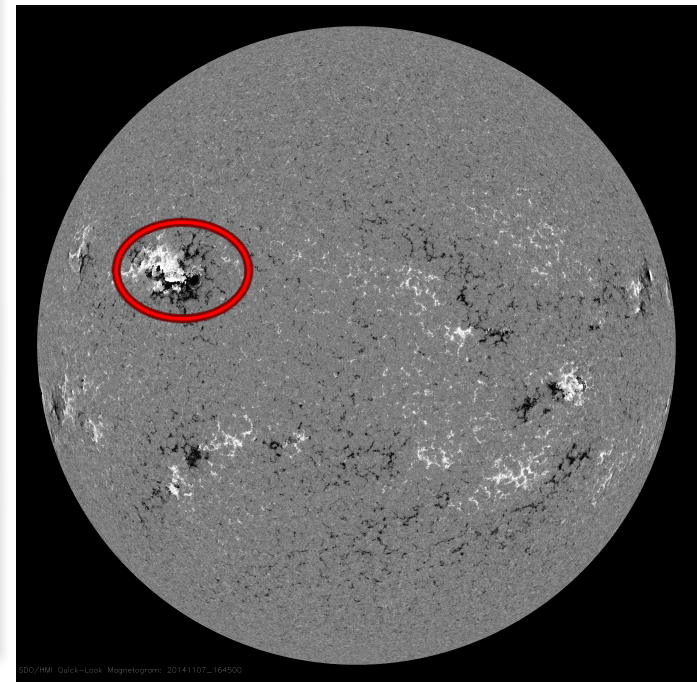
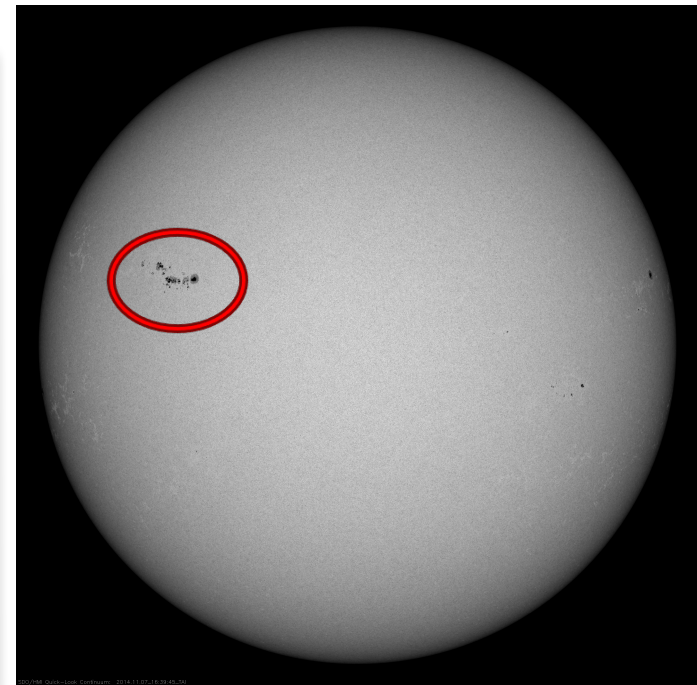
SOL20141107

- Coordinated Observing Campaign
“Searching for signatures
of WL flares”
IRIS & ROSA
(+) SDO & HINODE

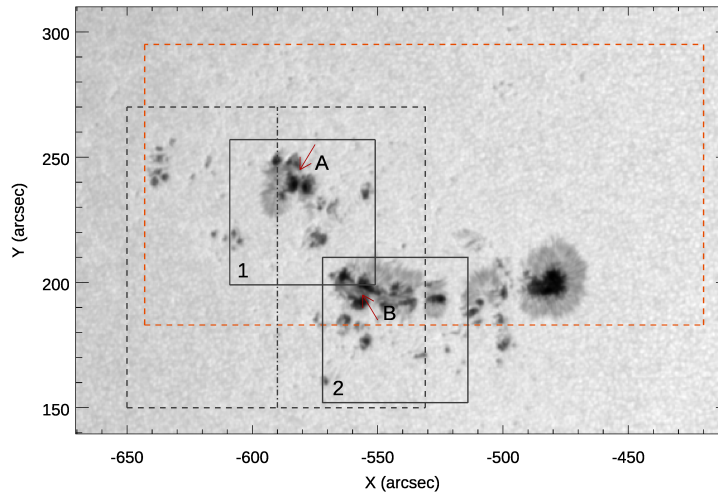
Location: N13E35 (AR 12205)

**A C7.0 flare started at 16:10 UT,
with peak at 16:39 UT**

**An X1.6 flare started at 16:53 UT,
with peak at 17:26 UT**



SDO/HMI Continuum 7-Nov-2014 16:58:12.9 UT

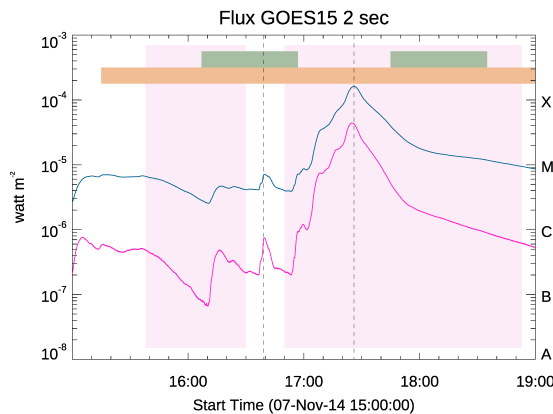
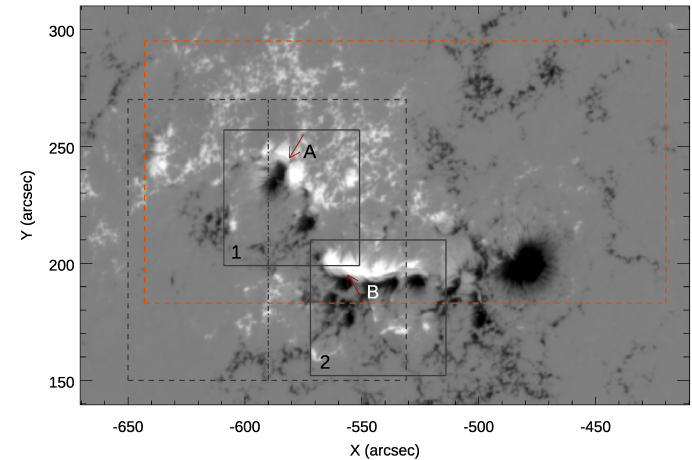


Field of view of the different instruments:

- Dashed box: IRIS SJI FOV
- Dotted-dashed vertical line: IRIS slit
- Solid box: ROSA FOVs (1 & 2)
- Red dashed box: Hinode/SOT FOV.

The arrows indicate the presence of two δ spots (A and B) in both the continuum image (photosphere) and in the magnetogram

SDO/HMI Magnetogram 7-Nov-2014 16:58:12.9 UT

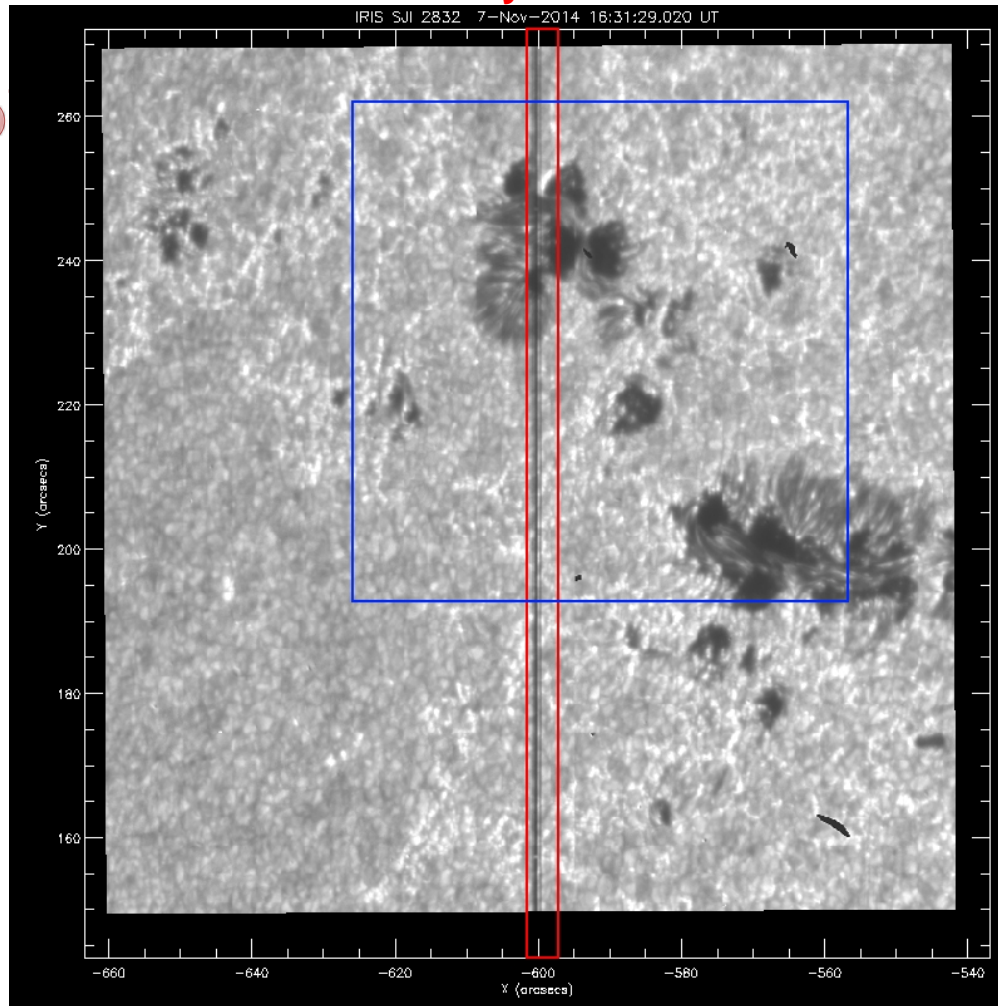


GOES soft X-ray flux at 0.5 – 4 Å (purple line) and 1.0 – 8.0 Å (blue line).

- ❖ Vertical dashed lines : peak time of the C7.0 (16:39 UT) and X1.6 (17:26 UT) flares
- ❖ Pink rectangles: ROSA acquisition time intervals for FOV1 (left) and FOV2 (right)
- ❖ Green rectangles: IRIS acquisition time intervals
- ❖ Orange rectangle: Hinode/SOT acquisition time interval.

ROSA & IRIS DATASETS

IRIS SJI 2832 Å



➤ ROSA

- **Ca II K core (3933 Å)**
512x512 0.138 arcsecs/pixel
FOV=70"X70", cadence 2.45 s
- **G band (4305 Å) and blue continuum (4170 Å)**
1004x1002 0.069 arcsec/pixel
FOV=70"X70", cadence 2.112 s .

➤ IRIS

- **SJI images**
(**C II 1330 Å, Mg II k 2796 Å , Mg II wing 2830 Å**)
760x774 pixels
0.16 arcsec/pixel
FOV=126".43 x128".76
from 16:07 to 16:57 UT
80 images with $\Delta t=37.57$ s
- **Raster (large 4-step coarse)**
(**C II 1336, 1343, Fe XII 1349, O I 1356, Si IV 1403, 2832, 2826, Mg II k 2796**)
FOV=6"x128".76
from 16:07 to 16:57 UT
80 rasters with $\Delta t=37.57$ s
raster step 9.7 s

Blue box: ROSA FOV I

Red box: region scanned by the IRIS slit



Queen's University
Belfast

University
of Glasgow

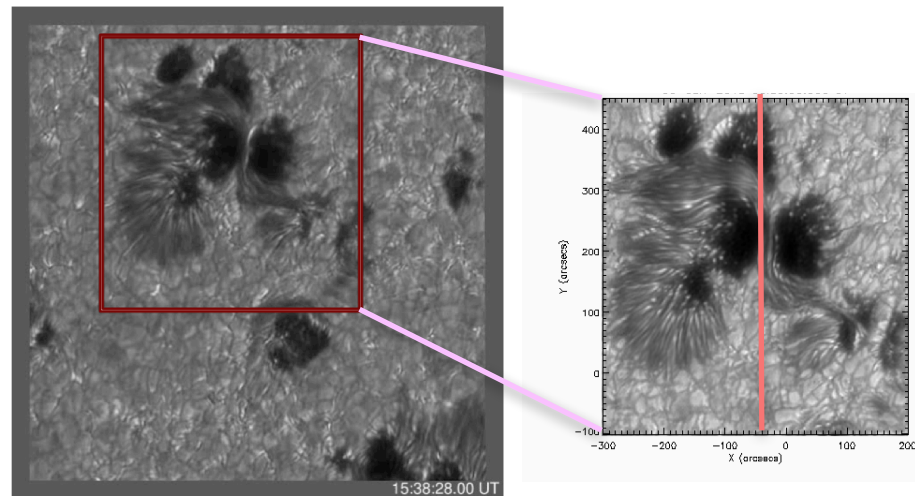
NSO
National Solar Observatory



ROSA observations

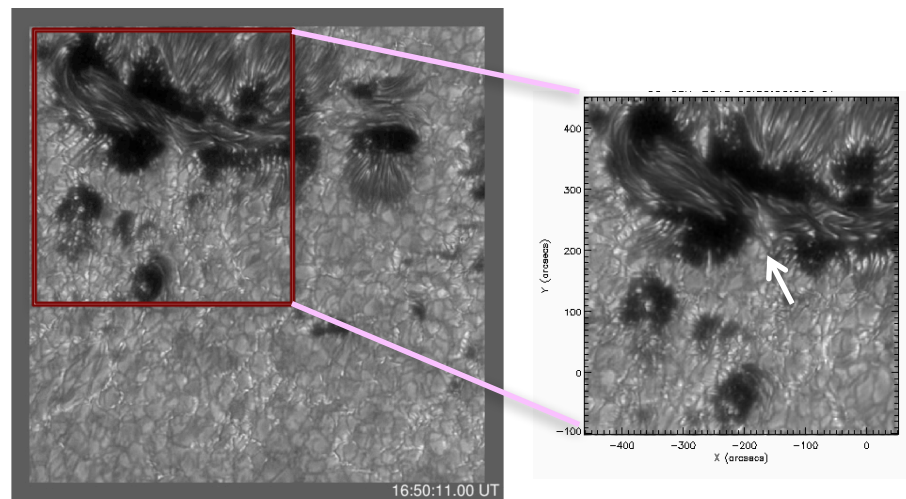
Left: ROSA G band image showing FOVI, before the occurrence of the C7.0 flare.

Right: zoomed image showing **δ -spot A**, characterized by the presence of sheared penumbral filaments within the two umbrae of opposite magnetic polarities. The pink vertical line shows the IRIS slit approximate position.



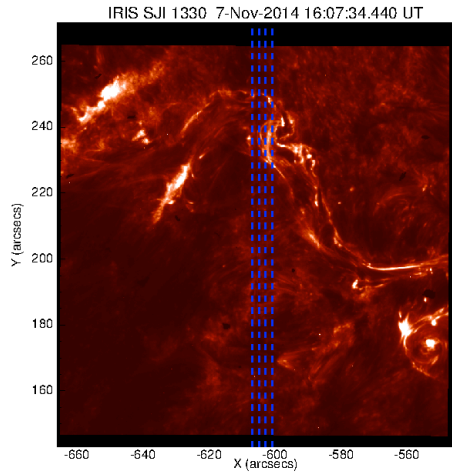
Left: ROSA G band image showing FOV2, during the occurrence of the X1.6 flare.

Right: zoomed image showing the location of a **ribbon observed in the continuum** (white arrow) at about 17:22 UT (i.e., few minutes before the flare peak). The ribbons, separating at an average velocity of 10 km s^{-1} , were observed also in the 4170 \AA continuum.

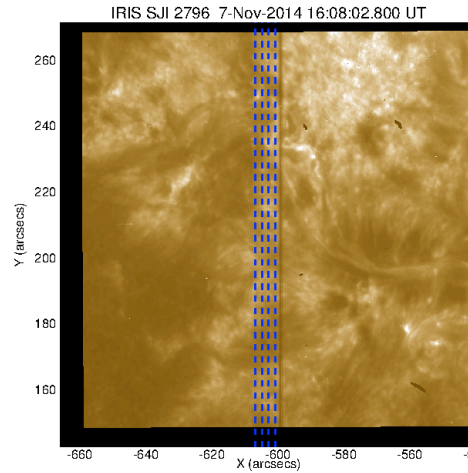


IRIS DATA

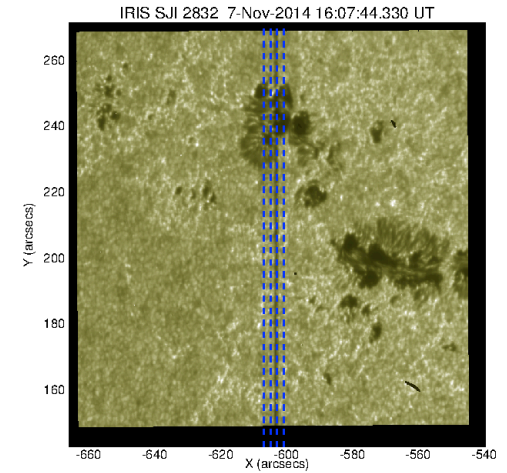
C II 1330 Å 30000 K



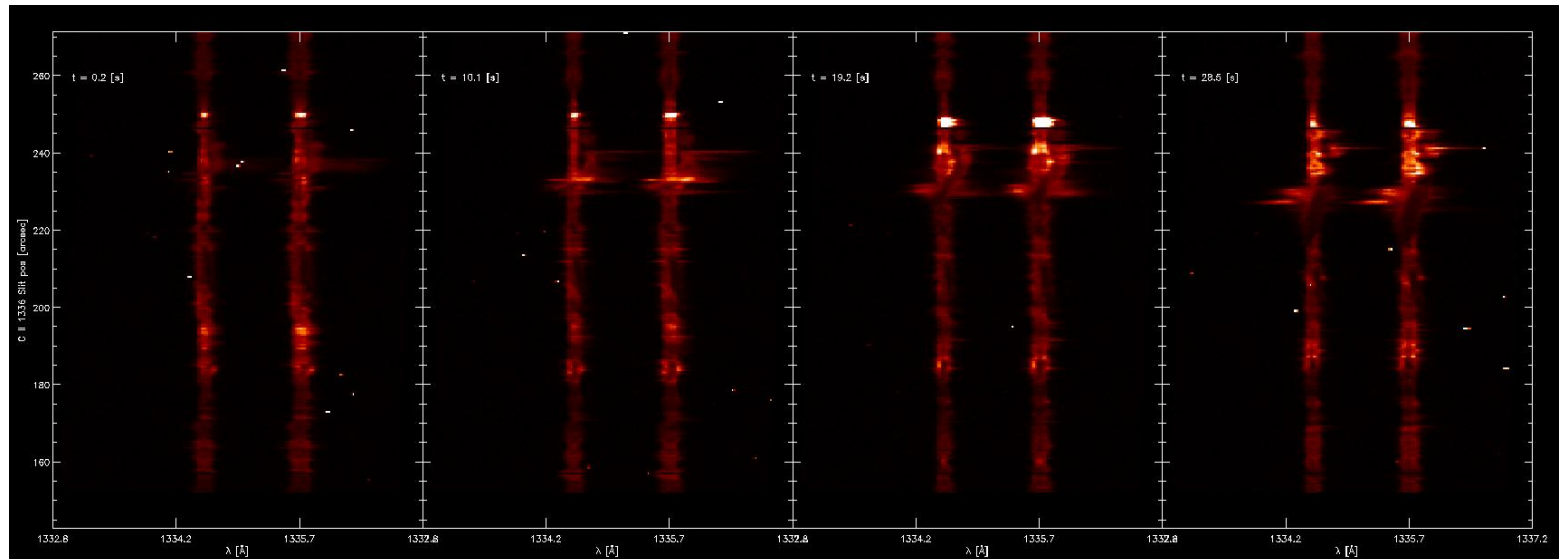
Mg II k 2796 Å 10000 K



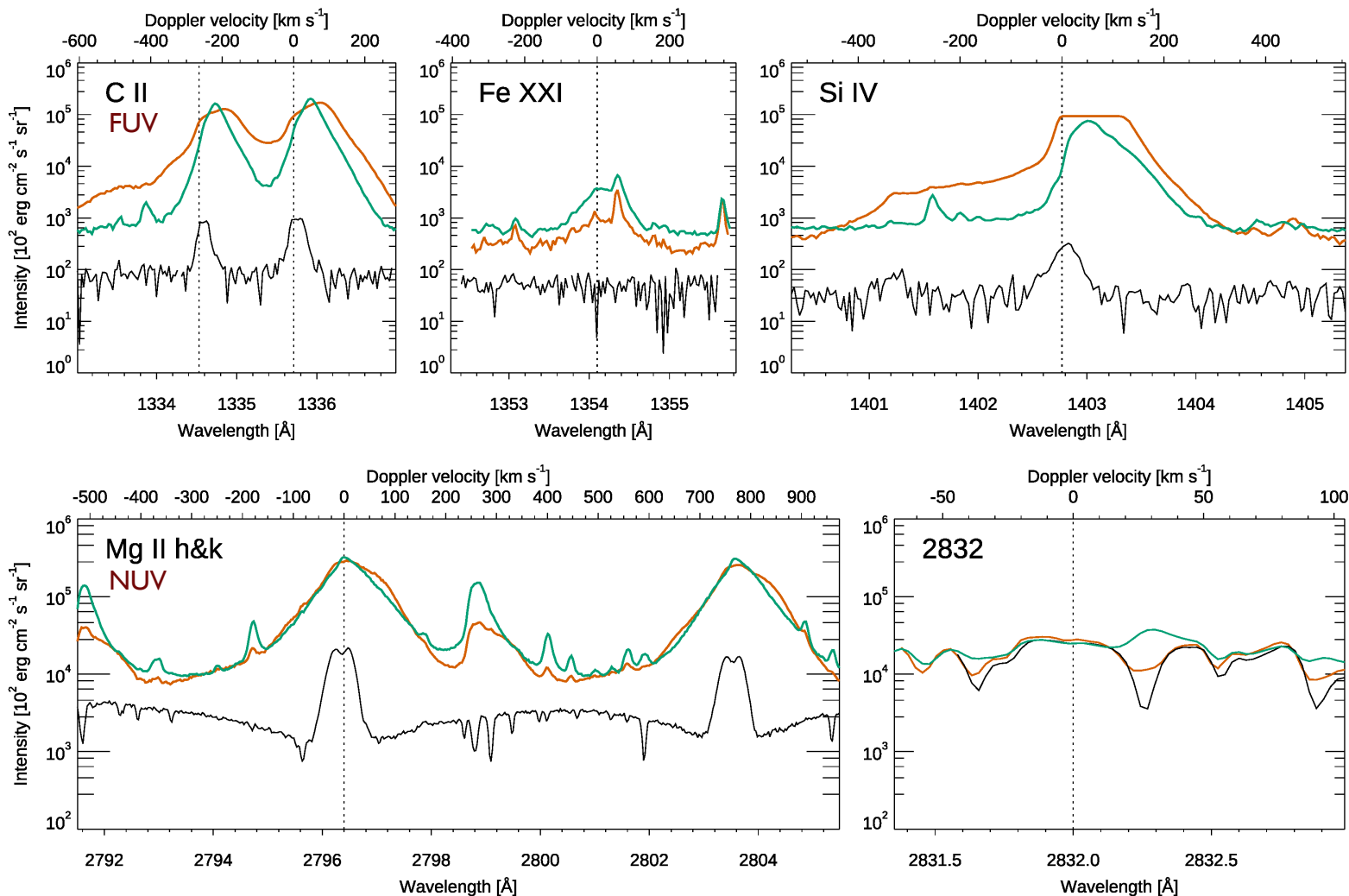
Mg II k wing 2832 Å 6000 K



Raster (1-4) @ C II 1334 and 1335 lines, start time 16:07:34 UT, Δt between two acquisitions 9.7 s



Continuum enhancement in FUV and NUV @ the rise phase of the XI.6 flare



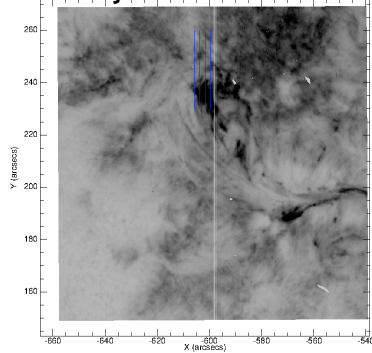
- **Orange line:** average intensity in five of the IRIS spectral windows in the pixels at raster position (3,[543:545]) at 16:55:32 UT
- **Green line:** same as orange line, for raster position (3,[558:560])
- **Black line:** average intensity calculated at the same time along 20 consecutive slit positions (from I60 to I79), corresponding to a **quiet-Sun region**.



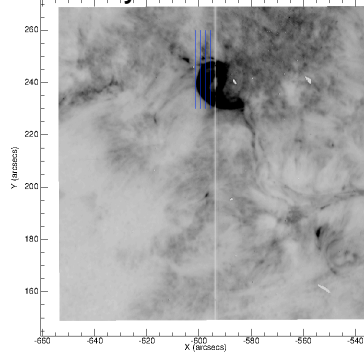
Queen's University Belfast



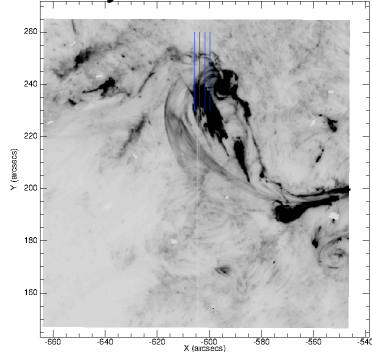
IRIS SJI 2796 16:18:02 UT



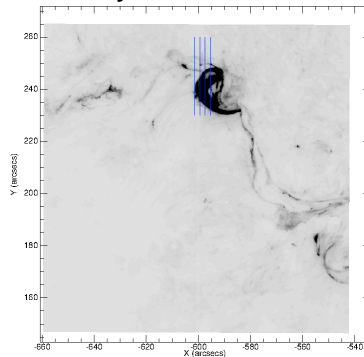
IRIS SJI 2796 16:55:32 UT



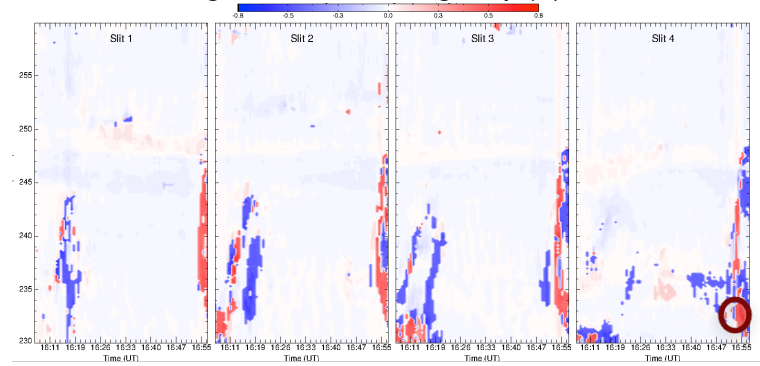
IRIS SJI 1330 16:17:34 UT



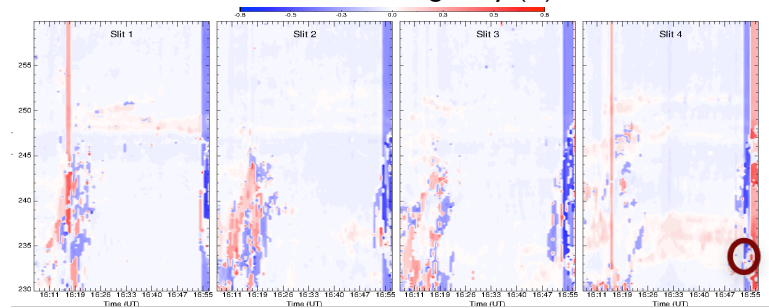
IRIS SJI 1330 16:55:00 UT



Mg II k line center of gravity (\AA)



C II line center of gravity (\AA)



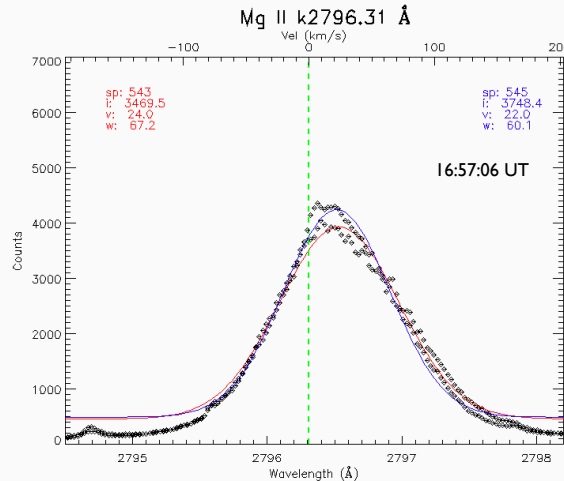
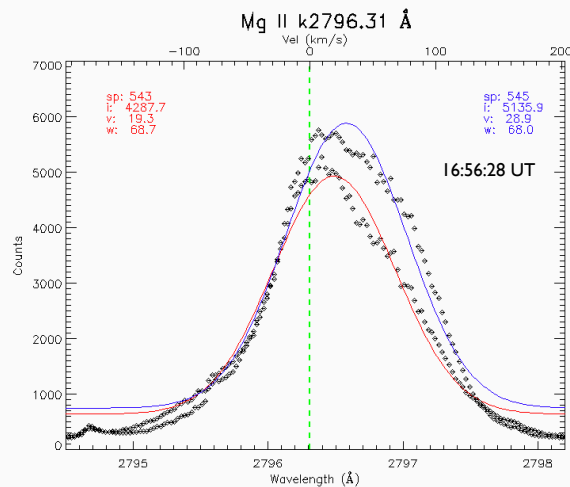
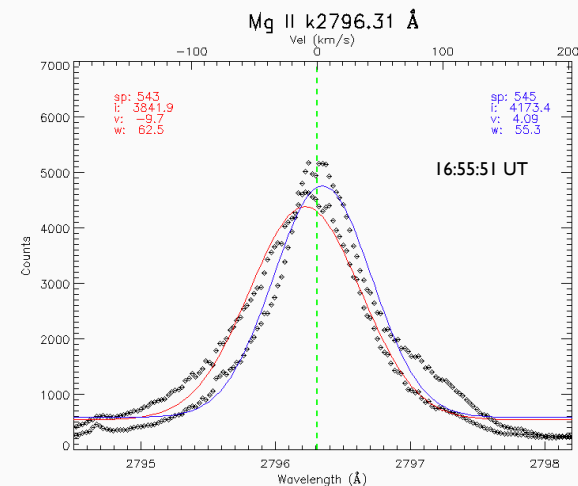
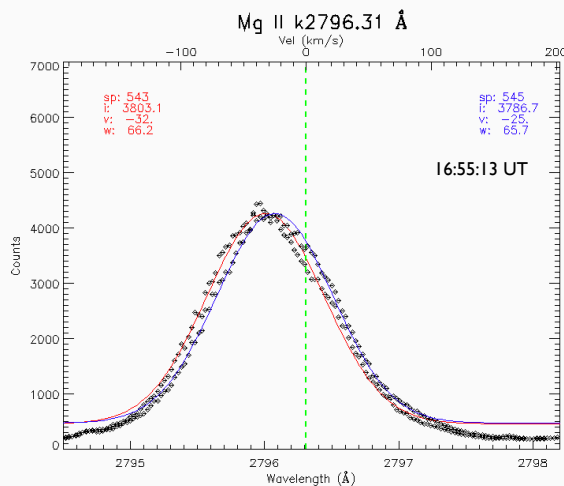
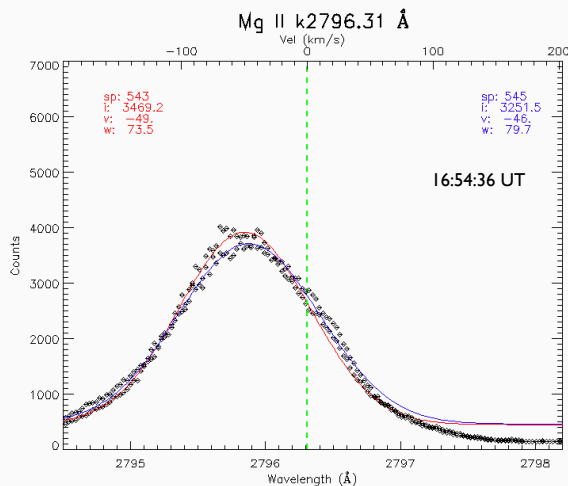
IRIS SJI images at 2796 \AA Mg II k (*top*) and at 1330 \AA C II (*bottom*) before the peak of the C7.0 flare (*left*) and during the rise phase of the X1.6 flare (*right*).

LOS velocity along the 4 slit positions as a function of time in correspondence of the blue vertical lines drawn on the images on the left.

Between 16:54 and 16:57 UT, at the end of the IRIS acquisition time, in some slit positions, there are indications of a **sudden change from upflows to downflows** (i.e. the dark red circles)



Mg II k line profiles from 16:54:36 to 16:57:06 UT



Line profiles for different pixel positions (233.7 and 234.0 arcsec) of the IRIS slit for Mg II k 2796,31 Å between 16:54:36 and 16:57:06 UT.

The green vertical lines indicate the position of the line center.

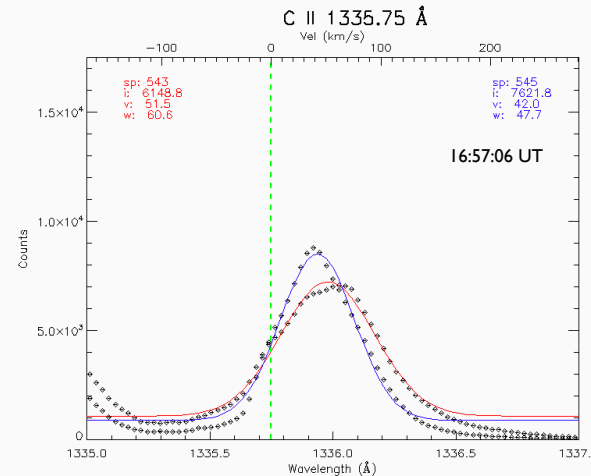
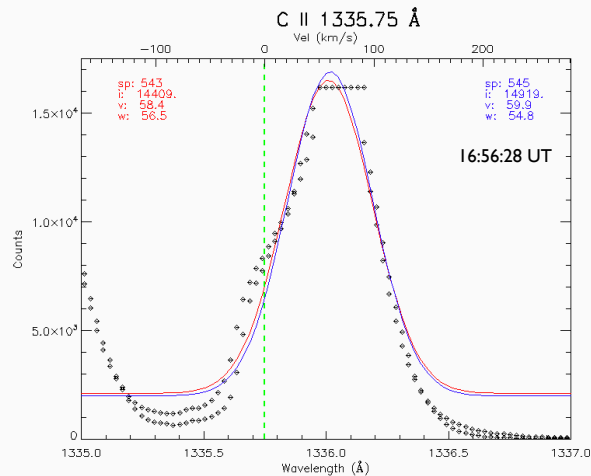
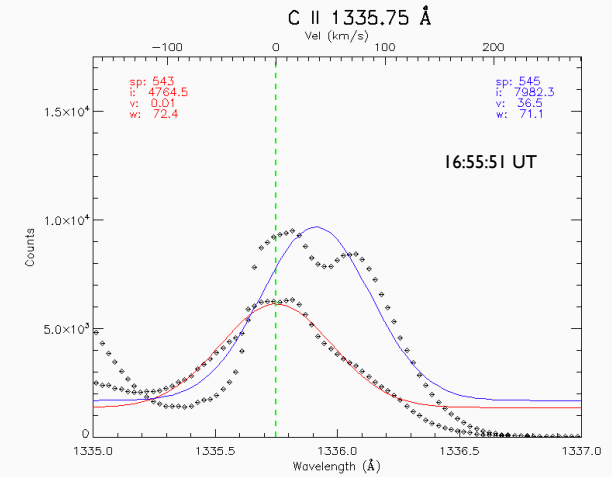
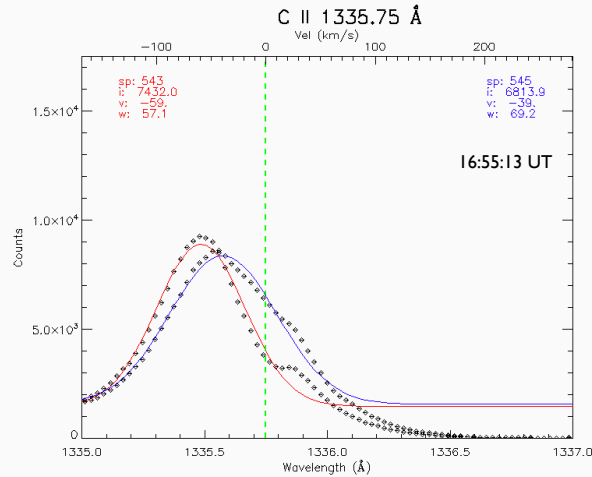
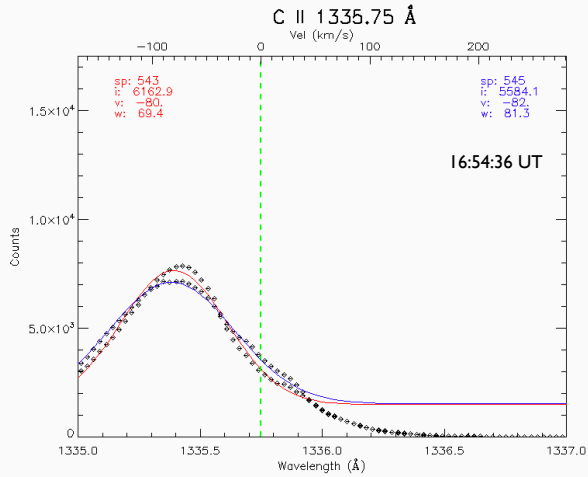
Continuous lines indicate the single Gaussian fit (to give an estimate of the centroid) and different colors refer to different slit position.

The line profiles and the velocity values indicate a **sudden change from upflows to downflows.**

A process of chromospheric evaporation is followed by a condensation.



C II line profiles from 16:54:36 to 16:57:06 UT



Line profiles for two different pixel positions (corresponding to $[-596.4, 233.7]$ and $[-596.4, 234.0]$) of the IRIS slit for C II 1336 Å between 16:54:36 and 16:57:06 UT.

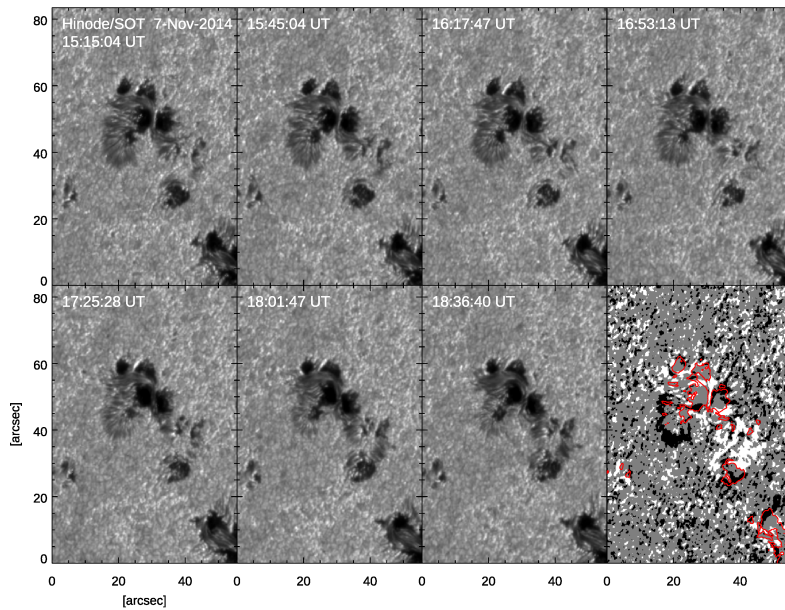
Green vertical line: position of the line center.

Continuous lines: single Gaussian fit; different colors refer to different slit position.

Also in this line there are indications of a sudden change from upflows to downflows.

A process of chromospheric evaporation is followed by a condensation.



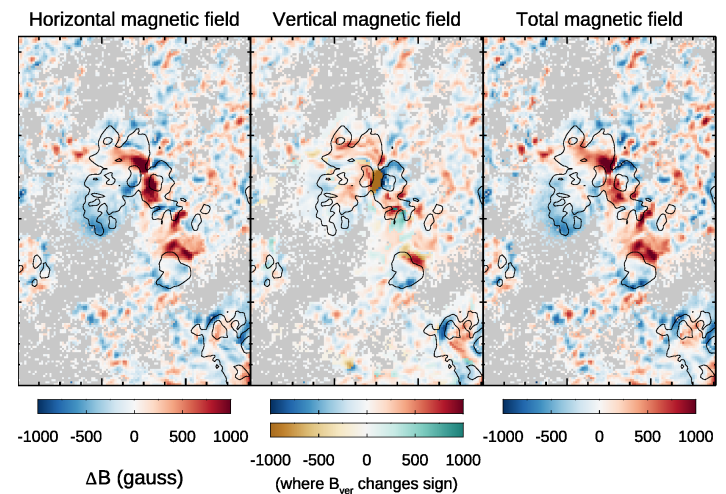


Panels 1–7: Photospheric evolution of the δ complex A during the C7.0 and X1.6 flares, (Hinode/SOT in the G band).

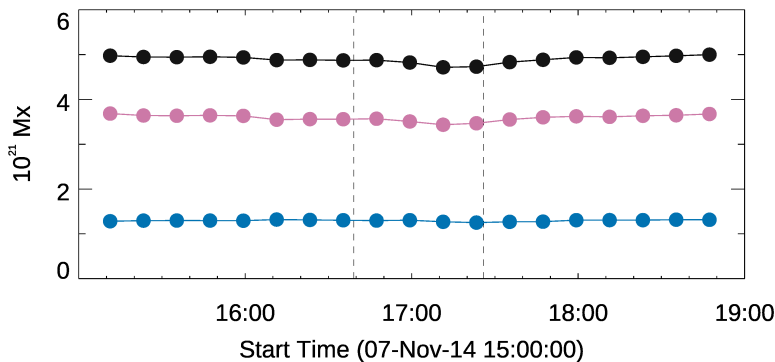
Bottom-right panel: **Difference image between the first and last G-band filtergrams. White (black) areas indicate region with penumbral enhancement (decay).** Red contours indicate the umbral boundary at the beginning of the sequence.

Difference images between the final and initial maps of:

- ❖ **horizontal field** component
- ❖ **vertical field** component
- ❖ **total magnetic field** strength.



Magnetic flux



Total unsigned magnetic flux (black), positive flux (magenta), and negative flux (blue, in absolute value), relevant to the subFOV shown in the previous Figure.

Vertical dashed lines: peak time of the C7.0 (16:39 UT) and X1.6 (17:26 UT) flares.

Conclusions

- ❑ During the first flare an enhancement of continuum emission in FUV and NUV, as well as **signatures of emission in the wing of the Mg II k line** were detected, while during the second flare, ribbons (**separating at an average velocity of 10 km s^{-1}**) were observed in the **G band** and in the **4170 Å continuum**.
- ❑ For selected time intervals and slit positions the line profiles of C II 1335,75 Å and Mg II k 2936,31 Å (IRIS dataset) indicate a process of **chromospheric evaporation followed by a condensation**.
- ❑ Both flares **involved δ sunspots** in the northern and southern parts of the AR. **Changes in the penumbrae** of these sunspots are related to **magnetic fields becoming more vertical or more horizontal**.

