Coronal Spectroscopy of active regions and preflare.

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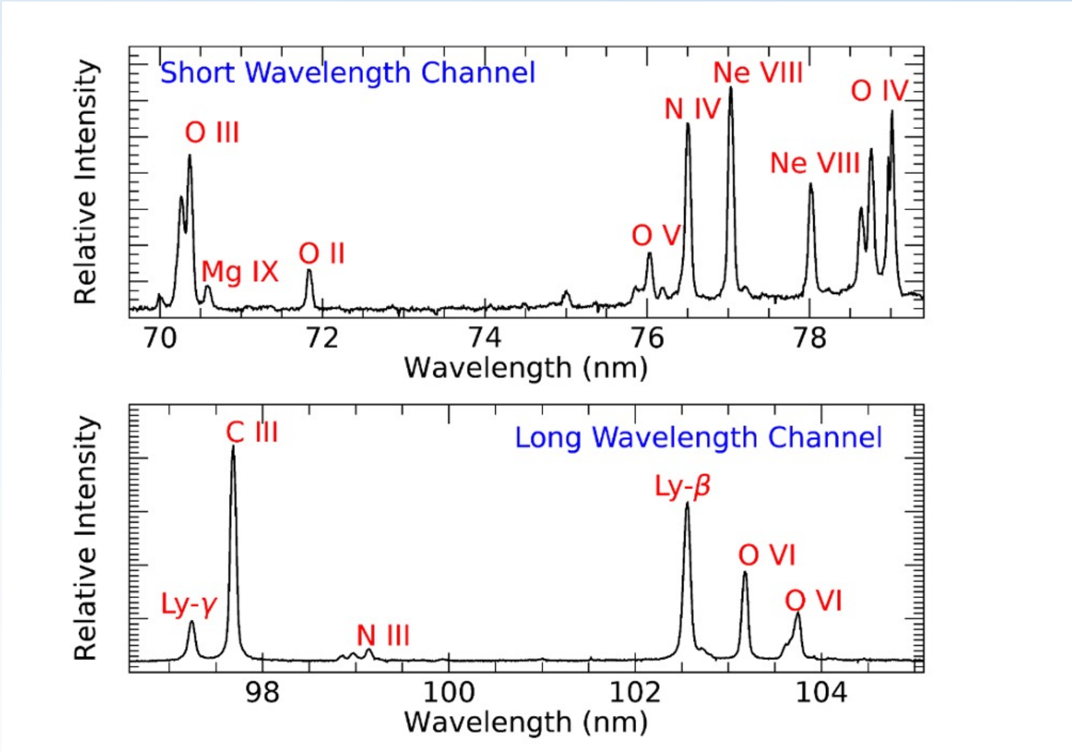
PMOD/WRC and ETH-Zürich



Fludra et al., 2021

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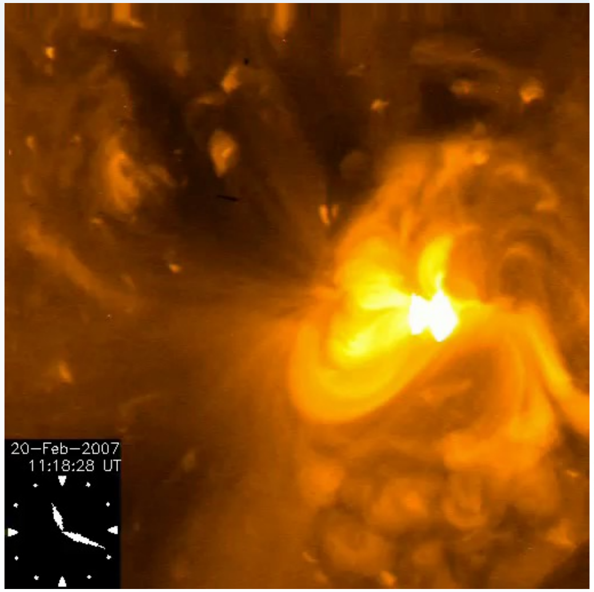
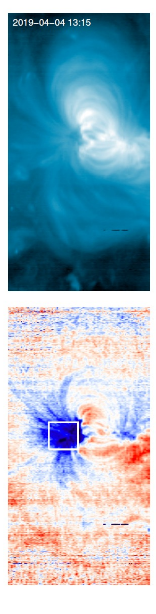
Active regions: upflows at the edges

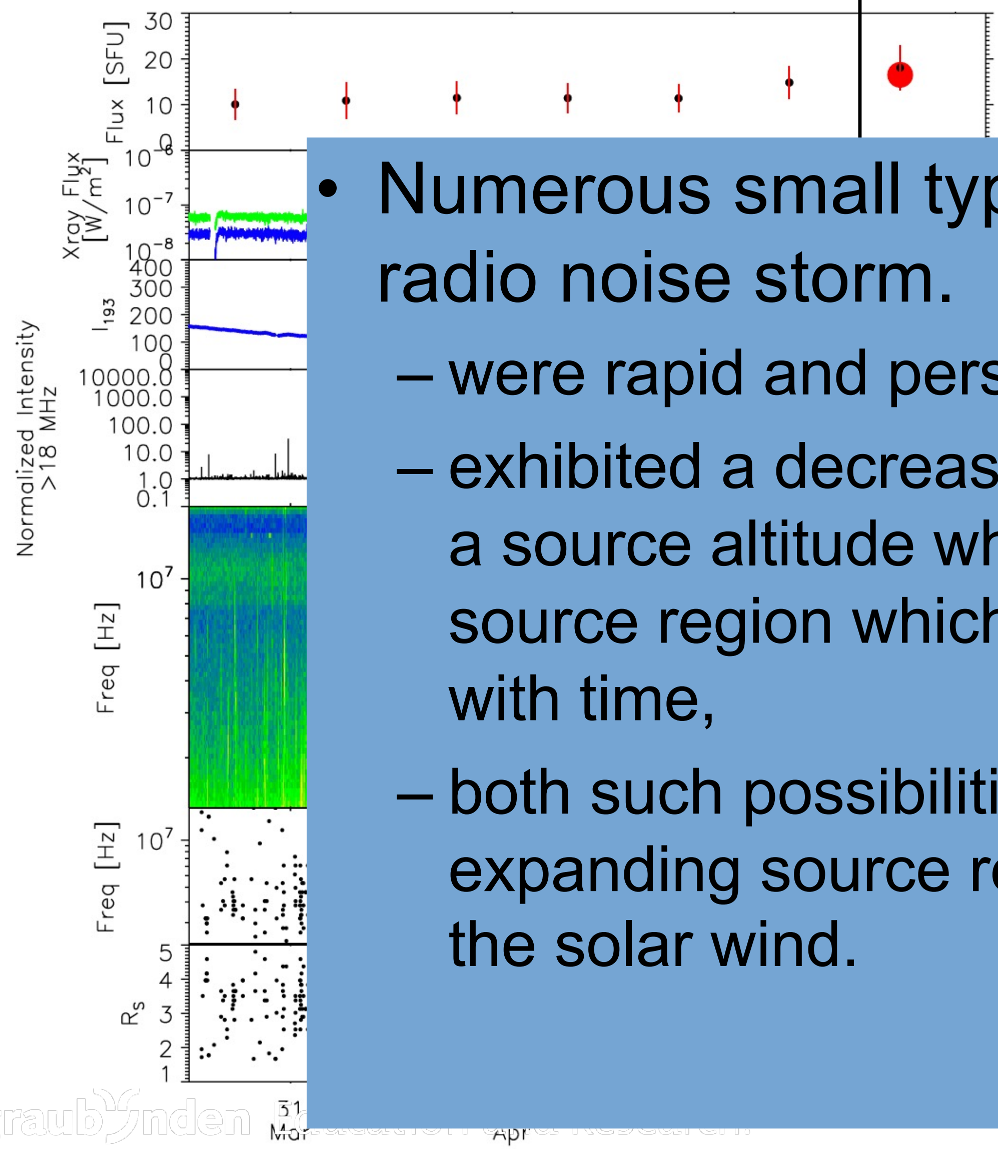
Harra et al., 2008, Sakao et al., 2008



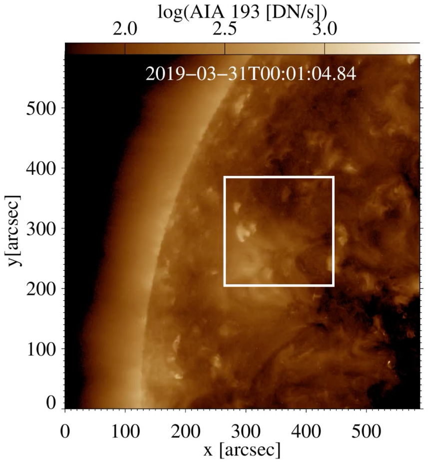


The slow solar wind has multiple sources,.
One potential source is upflows in active regions.
See review by Tian et al., 2021

Second encounter of Parker Solar Probe
~ 35.7 solar radii



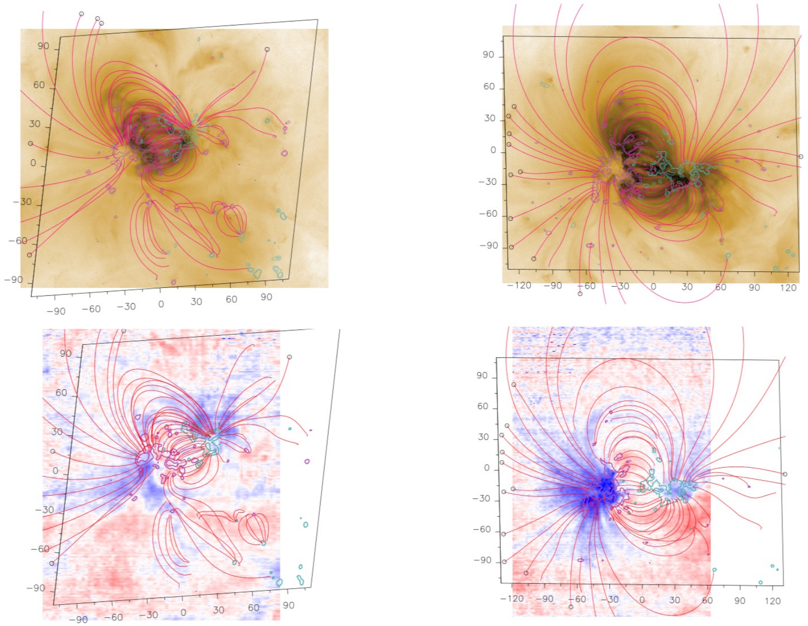
- Numerous small type III bursts constitute a radio noise storm.
  - were rapid and persistent during the time interval,
  - exhibited a decreasing peak frequency indicating a source altitude which is climbing in time, or a source region which is becoming more rarified with time,
  - both such possibilities are consistent with an expanding source region becoming more open to the solar wind.



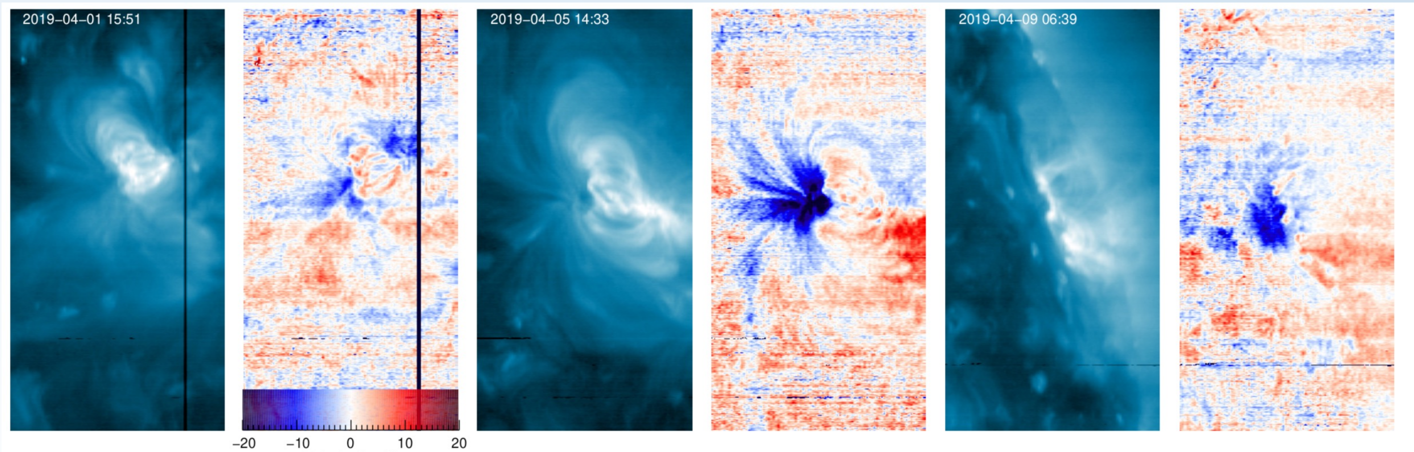
Active region expands

- Between 1 and 4 April, as the noise storm evolved, the active region also showed significant changes:
  - the area of the blue-shifted outflow region increased by an order of magnitude,
  - the FIP bias increased in the blue-shifted region by a significant amount (consistent with an increase in SEPs; Reames 2018),
  - the whole active region expanded and more magnetic field lines became 'open' (including in the outflow).

4 April



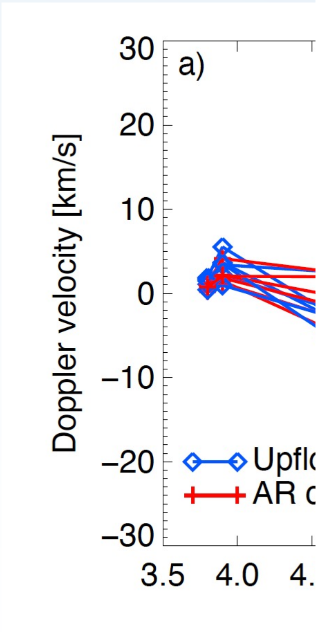
Upflows formed early on in lifetime

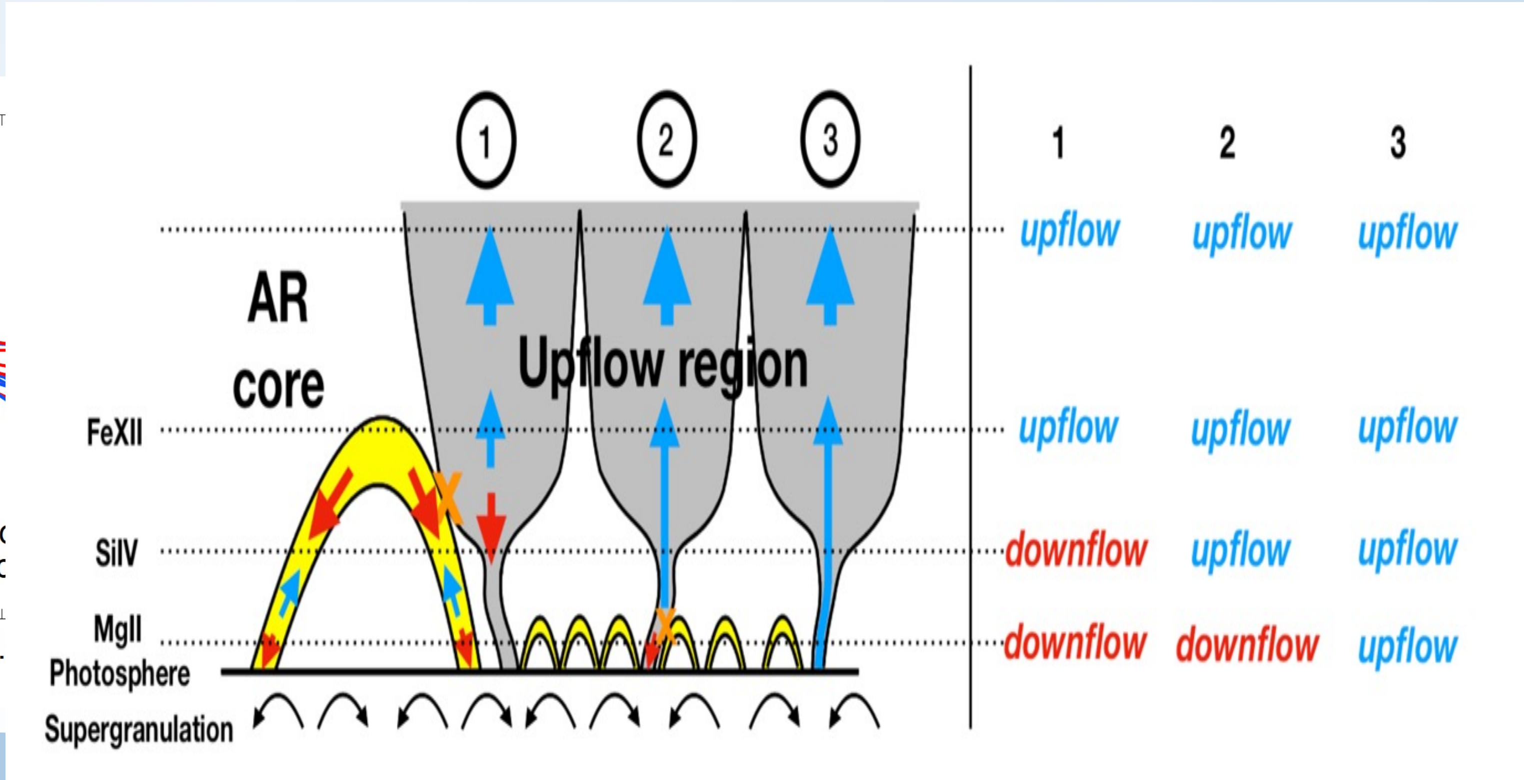


- Upflow forms quickly, low down in the atmosphere, and that its initiation appears associated with a small field-opening eruption and the onset of a radio noise storm detected by PSP.
- Upflows existed for the vast majority of the time the active region was observed.

Brooks et al., 2021

What happens between the layers in the upflow regions?





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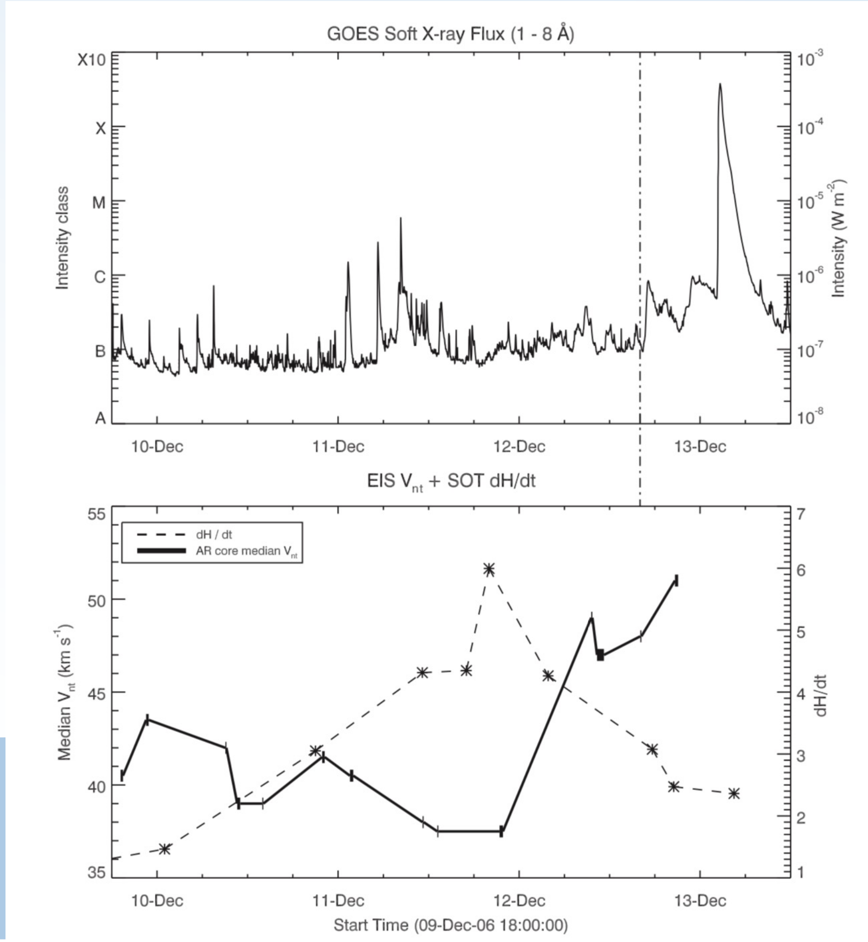
Enhancements in coronal lines widths seen before the flare



We found an increase in the coronal spectral line widths, beginning after the time of saturation of the injected helicity as measured by Magara & Tsuneta.

In addition, this increase in line widths (indicating nonthermal motions) starts before any eruptive activity occurs.

Harra et al., 2009

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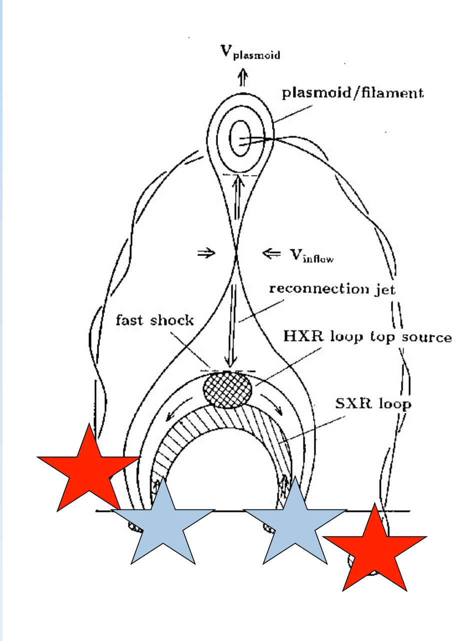
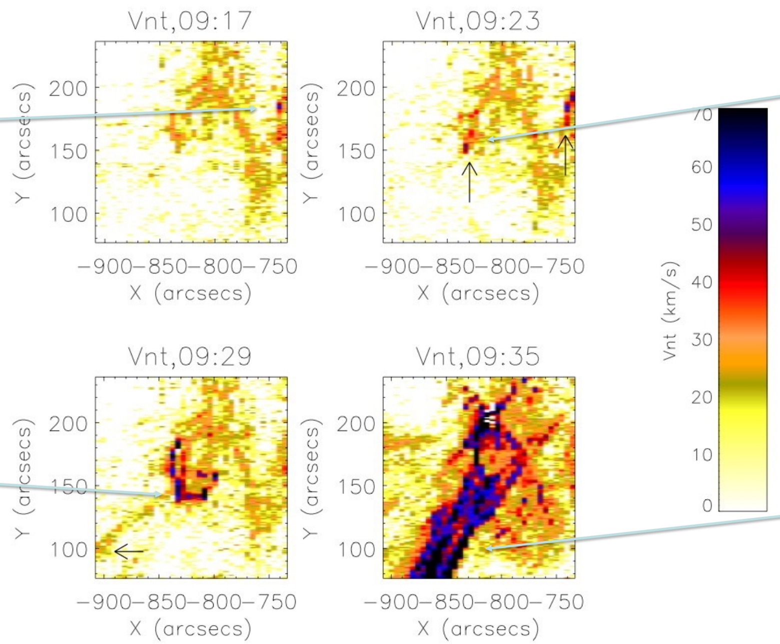
Early Vnt enhancements are NOT always in the core flaring region in eruptive flares.



Preflare

Early phase



Flare peak

Eruption

Harra et al., 2013

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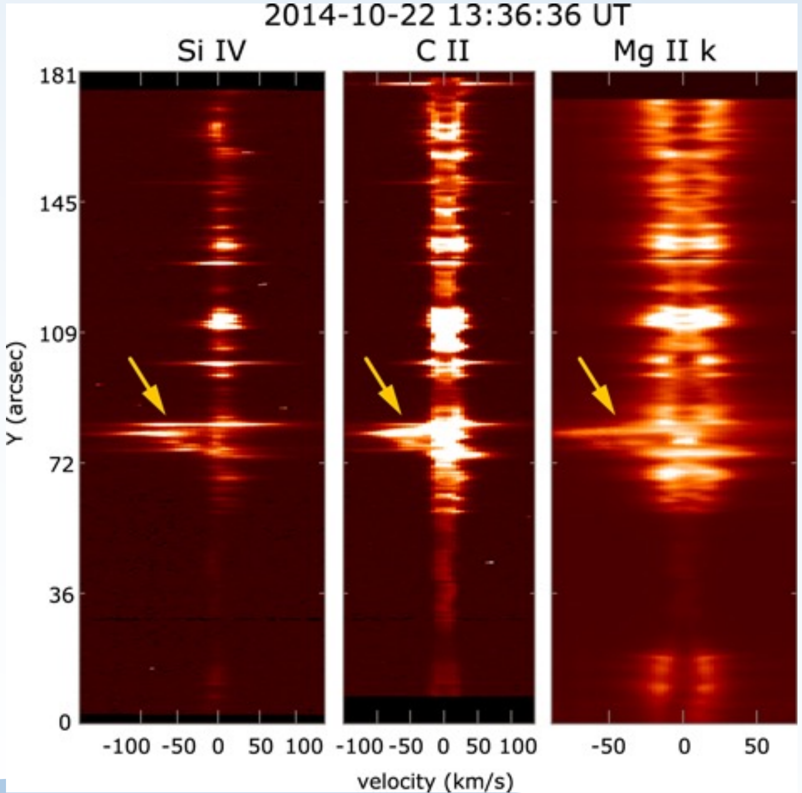
Flows seen on small-scales before flares

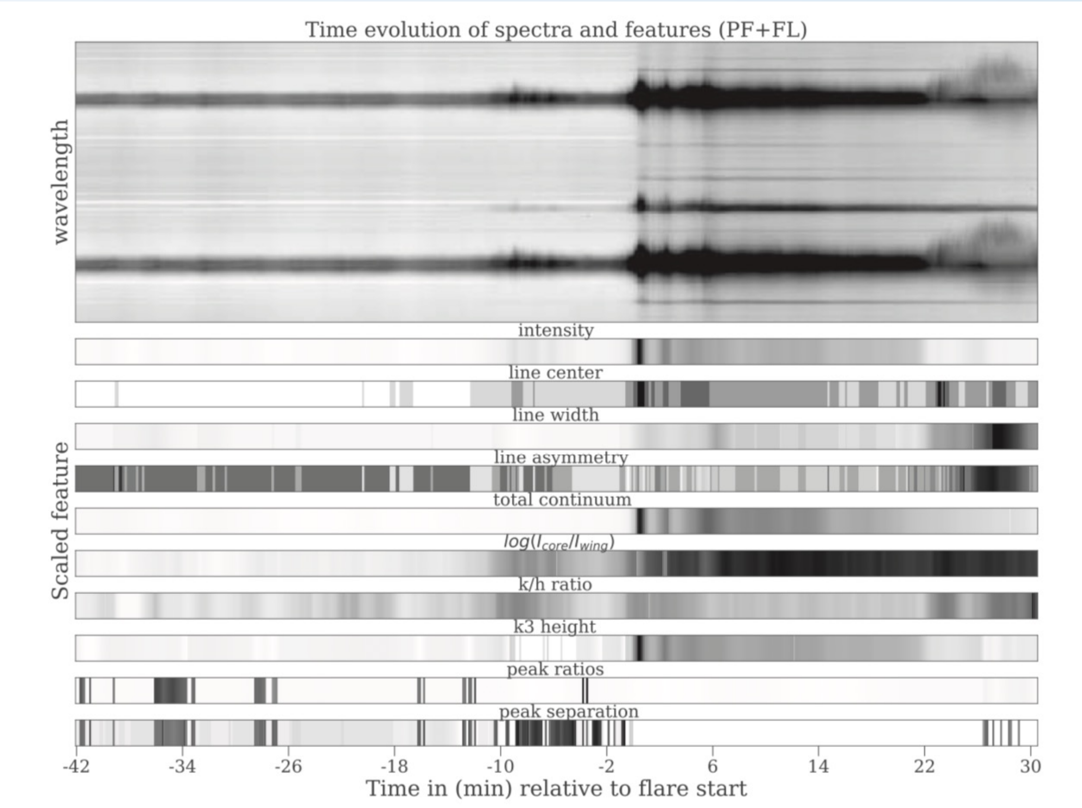


Flare was ~20 minutes after these strong flows were seen. Suggestive of magnetic reconnection occurring in lower chromosphere, and destablised the large-scale coronal loops that forms part of the flaring loops.

Bamba et al., 2017

Similar small scale flows also observed by Woods et al, 2017.

Flare prediction based on changes in spectra



Regions that are about to flare generate spectra that are distinguishable from non-flaring active region spectra. Their algorithm correctly identify pre-flare spectra approximately 35 minutes before the start of the flare (Panos & Kleint, 2020)

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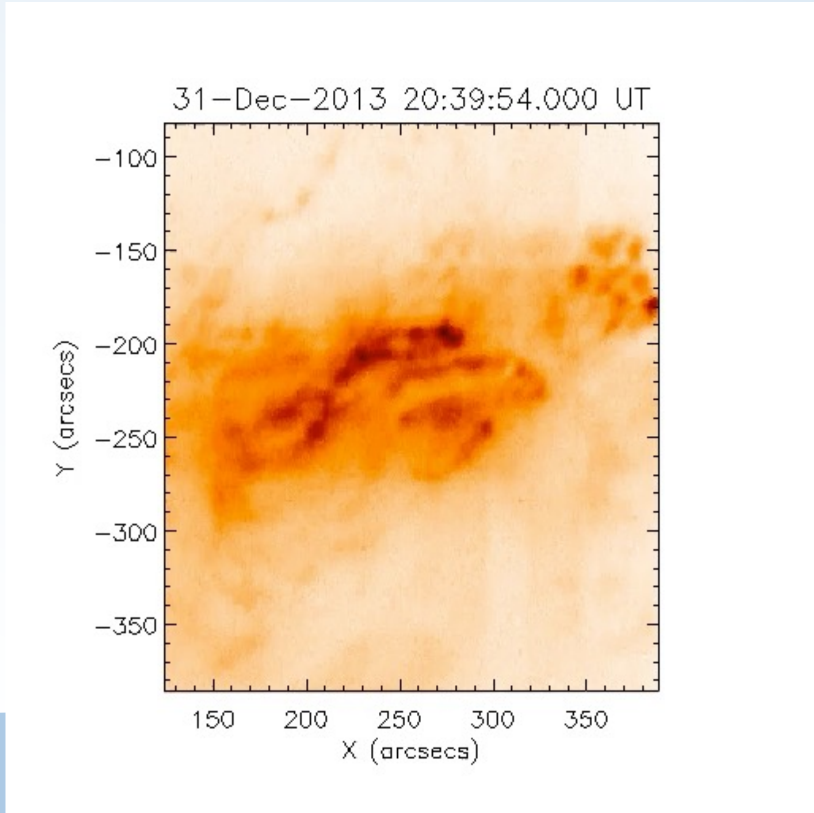
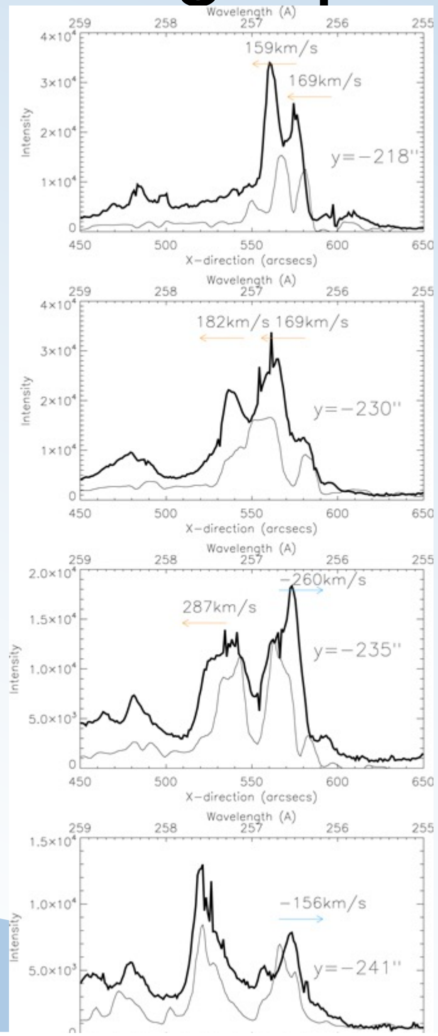
Exploring early phases using ‘spectroheliograms’





We found the blueshift velocity during the very early part of the filament eruption to be between 156 and 260 km s^{-1}

We also found downflows to occur in the locations where the subsequent raster data showed strong chromospheric evaporation.

Harra et al., 2017

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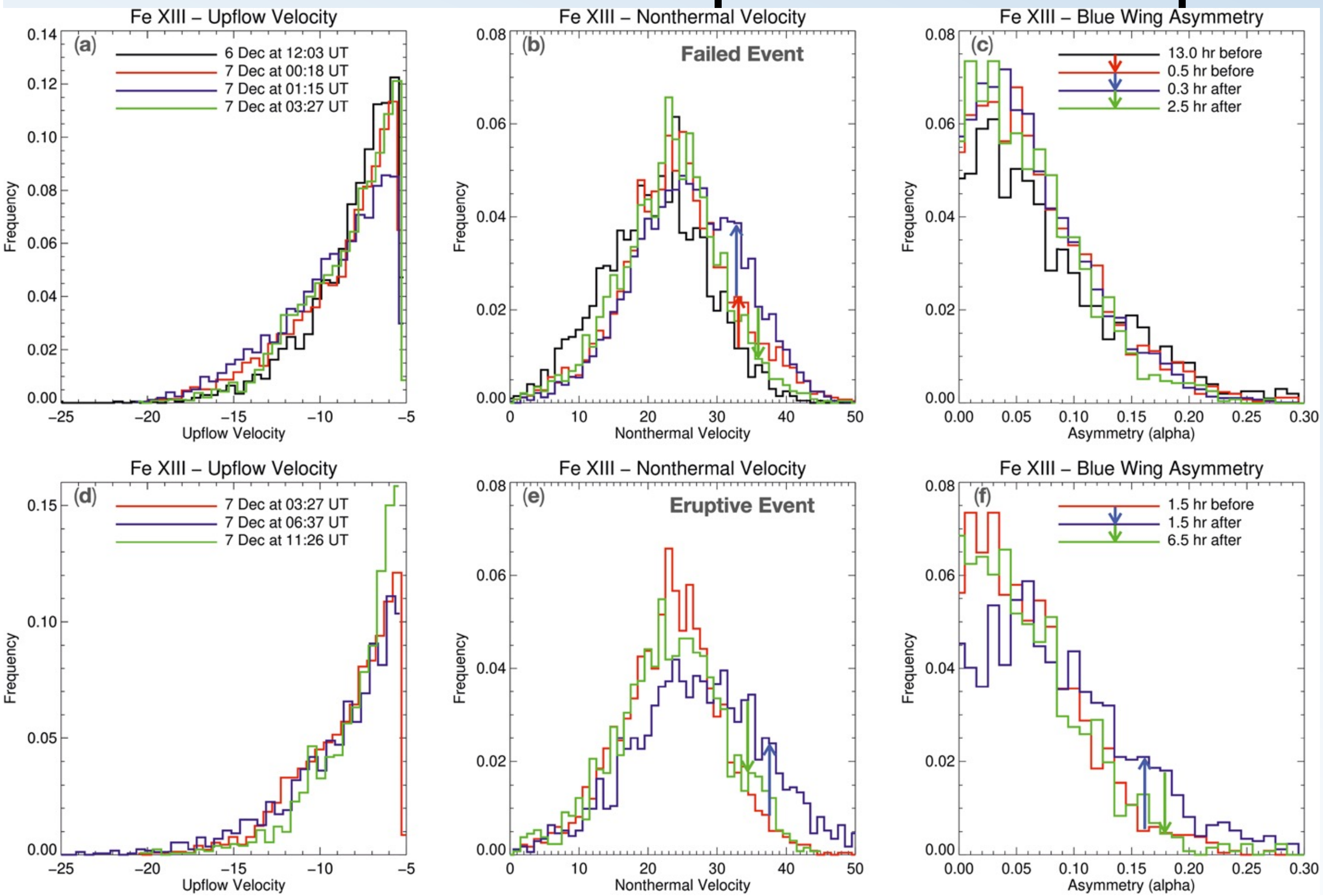
Behaviour of flows before and after failed eruption and eruption



All ARs have blue-shifts at the edges. In this example, strong blue-wing asymmetries are seen during eruption of a flux rope.

Flows are driven by pressure gradient when dense, hot loops reconnect with extended arcades above.

The mechanism is similar to that of the persistent upflows.

Baker et al., 2021.

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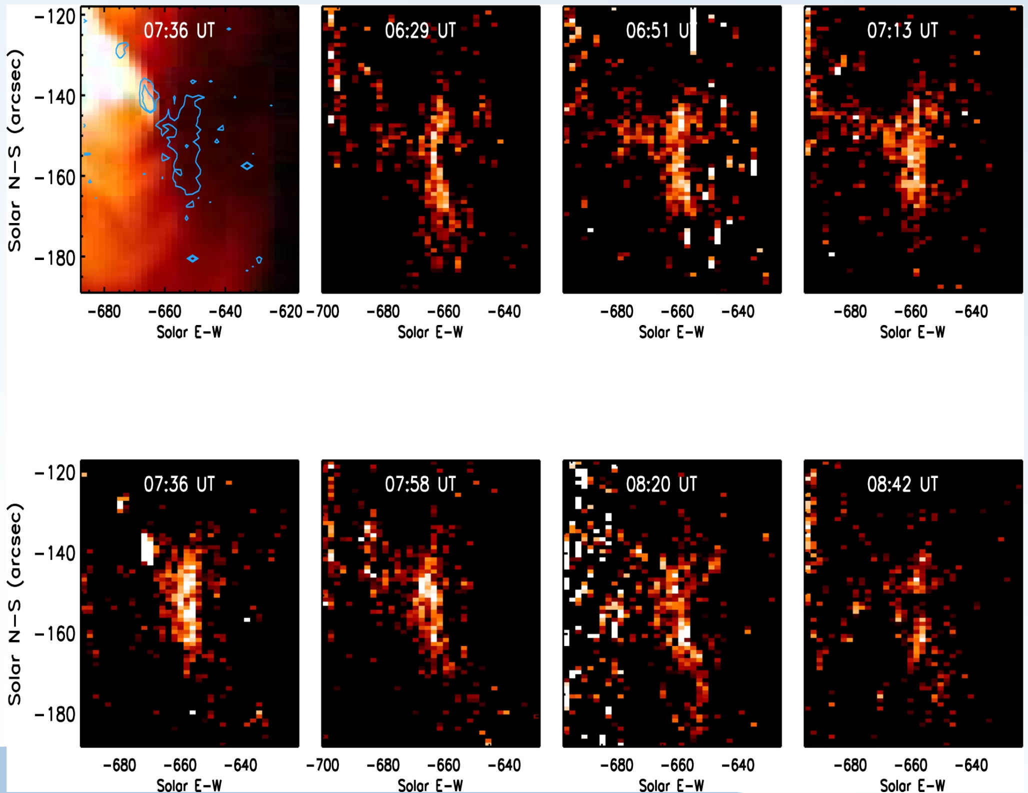
Coronal magnetic field measurements



Landi et al., 2021 have demonstrated a new method of using a magnetic field induced transition (MIT) that can be observed in the FeX lines in EIS to measure the field at the onset of a C2 flare.

The C2 flare started at 07:49 during the 4th raster shown.

A large magnetic field enhancement is seen in the early phase (350-500G).

Magnetic energy associated with this is equivalent to the radiative losses of the flare.

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Conclusions

- Spectroscopy is powerful! The spatially resolved spectroscopy is now able to explore the potential sources of solar wind, preflare disturbances.
- The new methods (machine learning) combined with new views of the Sun, will provide new results in the coming years.
- AND there is a new array of spectrometers coming along!

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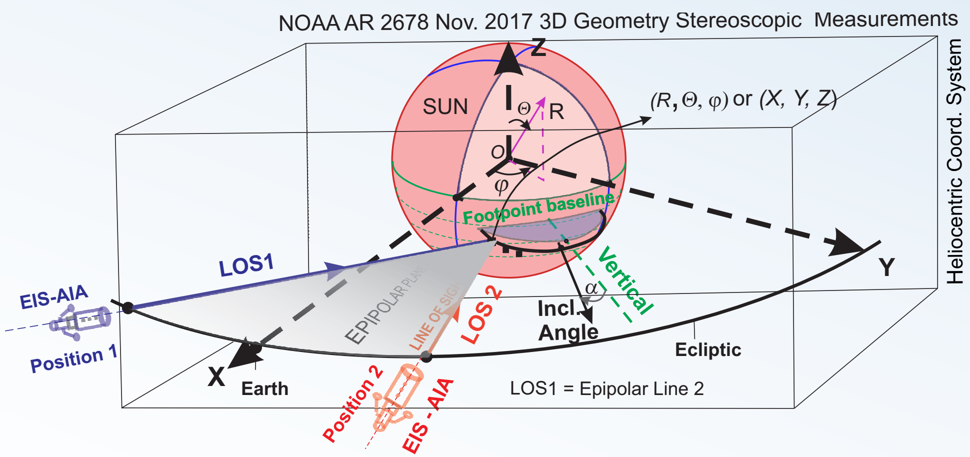
Future of coronal spectroscopy



Podladchikova et al., 2021

- IRIS and EIS continue to operate well.
- Solar Orbiter SPICE- science phase starts at the end of this year.
- Magixs – soft X-ray spectra – spatially resolved (go to AGU!!).
- Aditya includes X-ray spectrometer (launch next year).
- Solar-C EUVST, and SoSpIM – launch ~ 2026
- Multi-slit solar explorer (phase A) – 37 slit UV (EUV) spectrograph (e.g. De Pontieu et al., 2021).

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