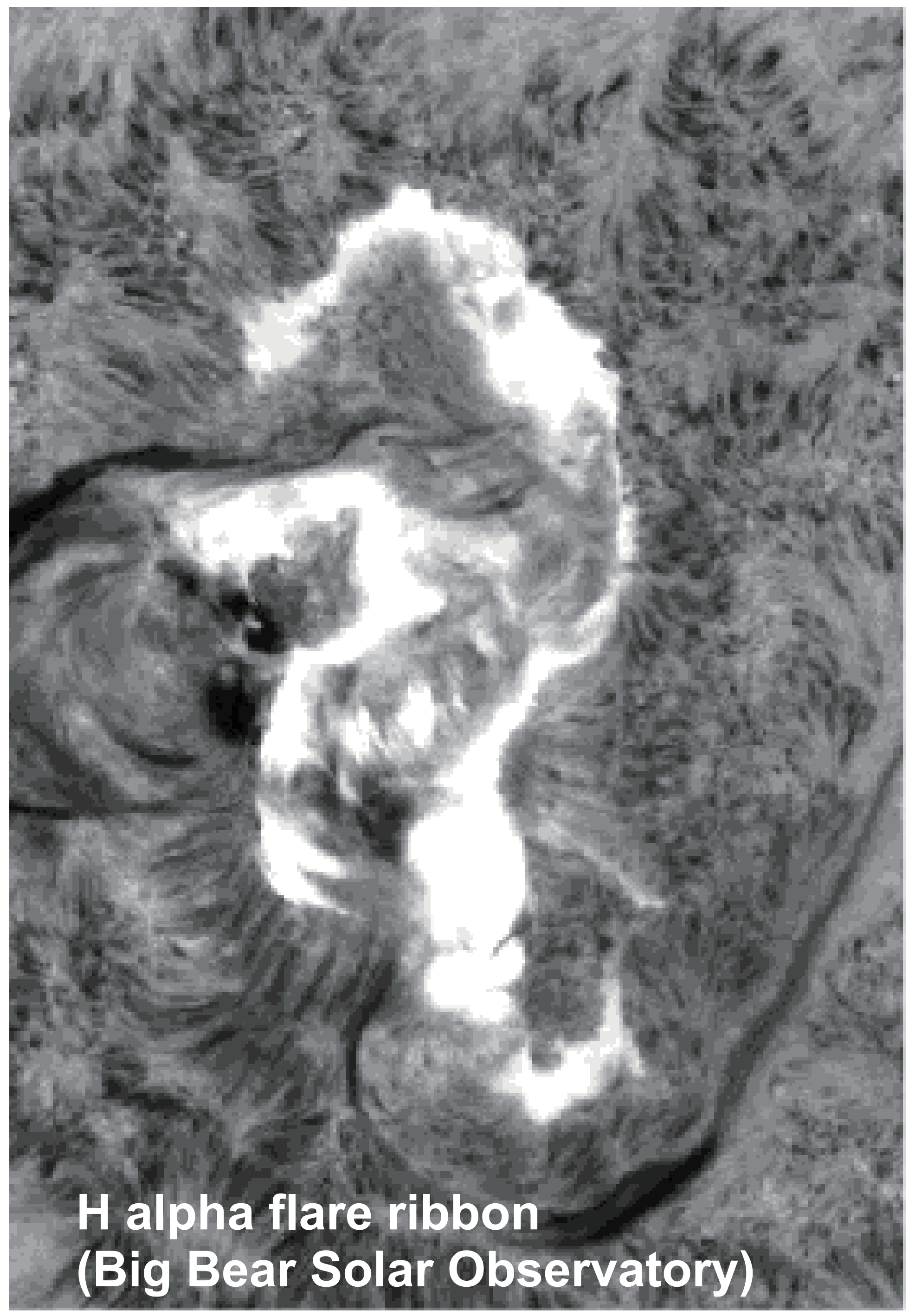
STRUCTURE AND DYNAMICS OF THE HOT FLARING LOOP-TOP SOURCE OBSERVED BY HINODE, SDO, RHESSI, AND STEREO

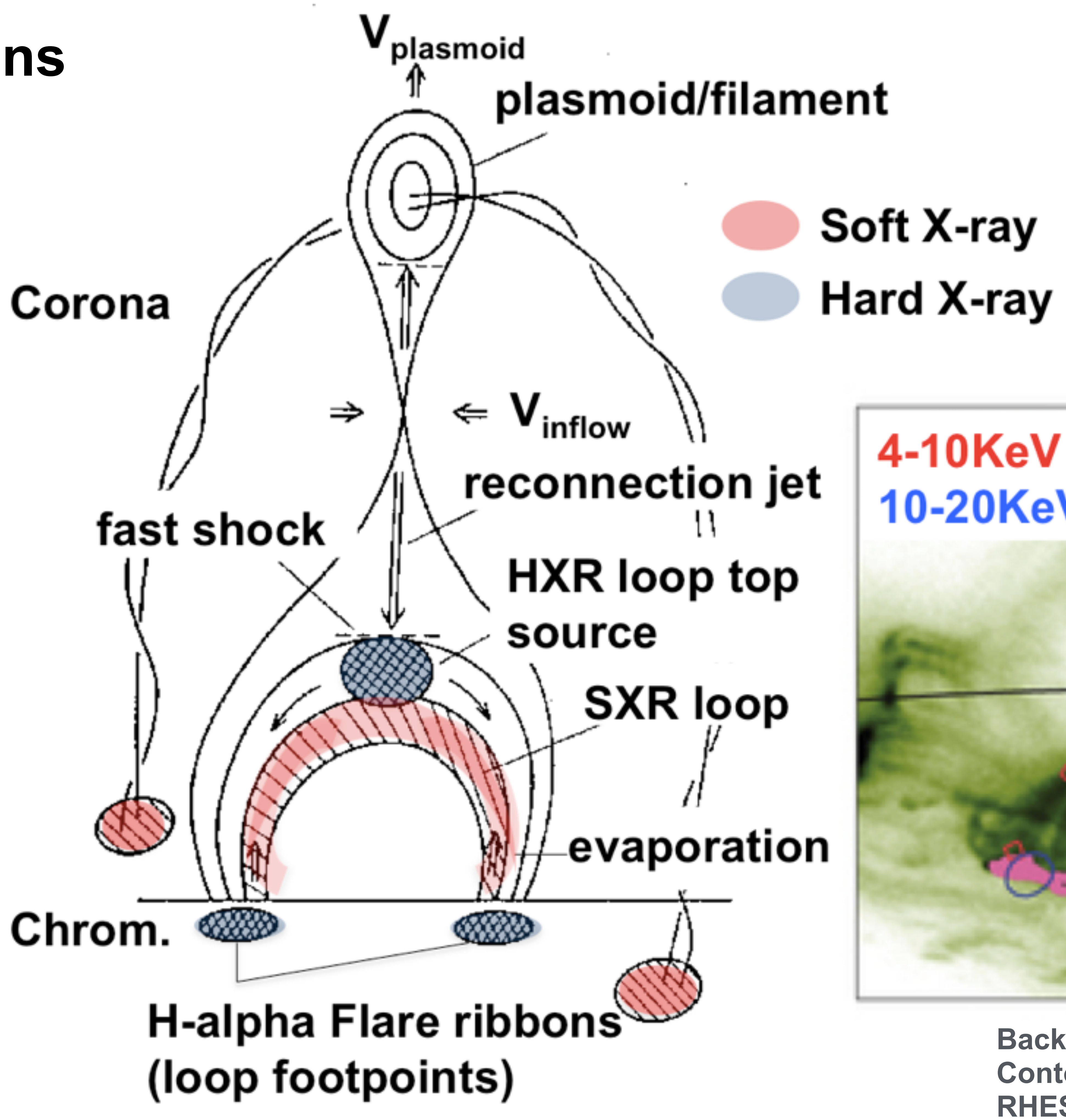
Kyoung-Sun Lee[1], Hirohisa Hara[2], Kyoko Watanabe[3], Anand D. Joshi[2], Shinsuke Imada[4], David H. Brooks[5], Phillip, Dang[6], Toshifumi Shimizu[7], and Sabrina L. Savage[8]

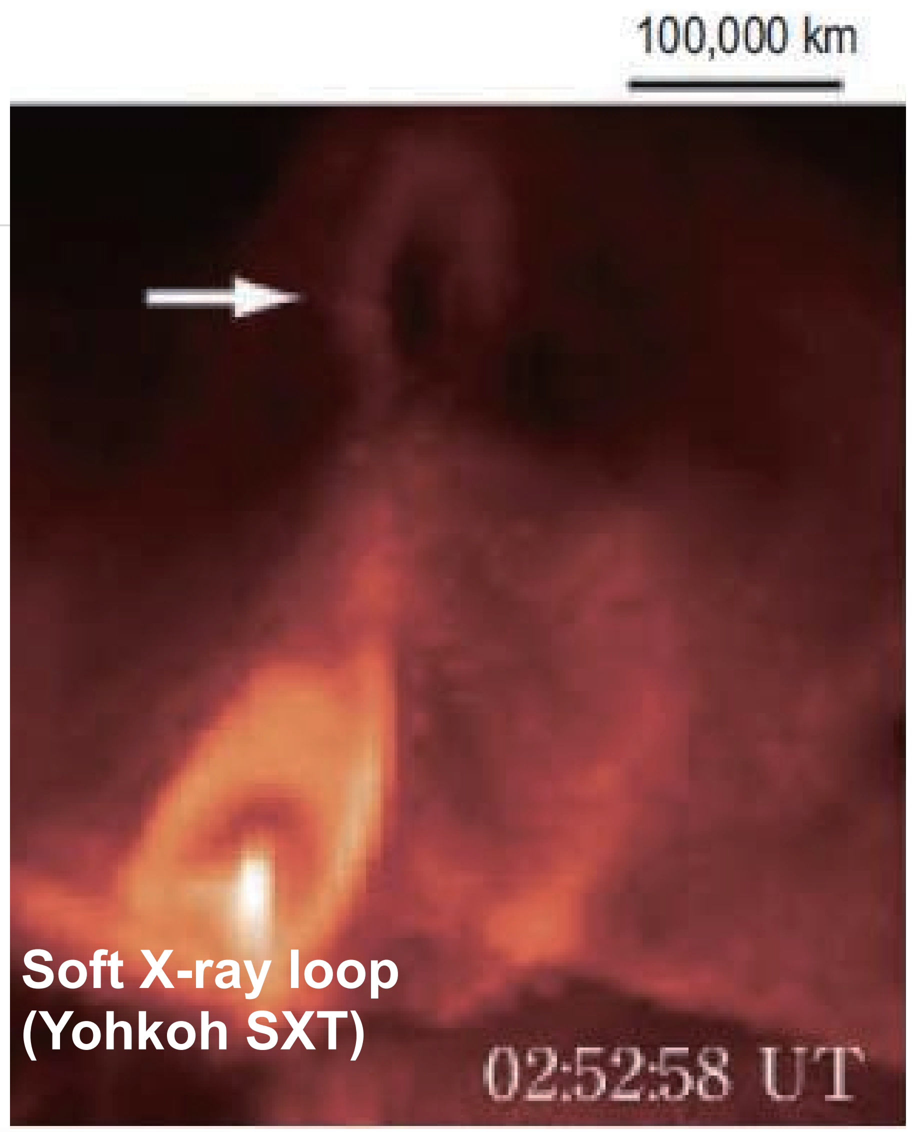
AFFILIATION: [1]CSPAR, UAH, [2]NAOJ, [3]NAGOYA UNIVERSITY, [4]GEORGE MASON UNIVERSITY, [5]SOFTWARE DEVELOPER AT CALL BOX, [6]ISAS/JAXA, [7]MSFC

MULTI WAVELENGTH IMAGING OBSERVATION

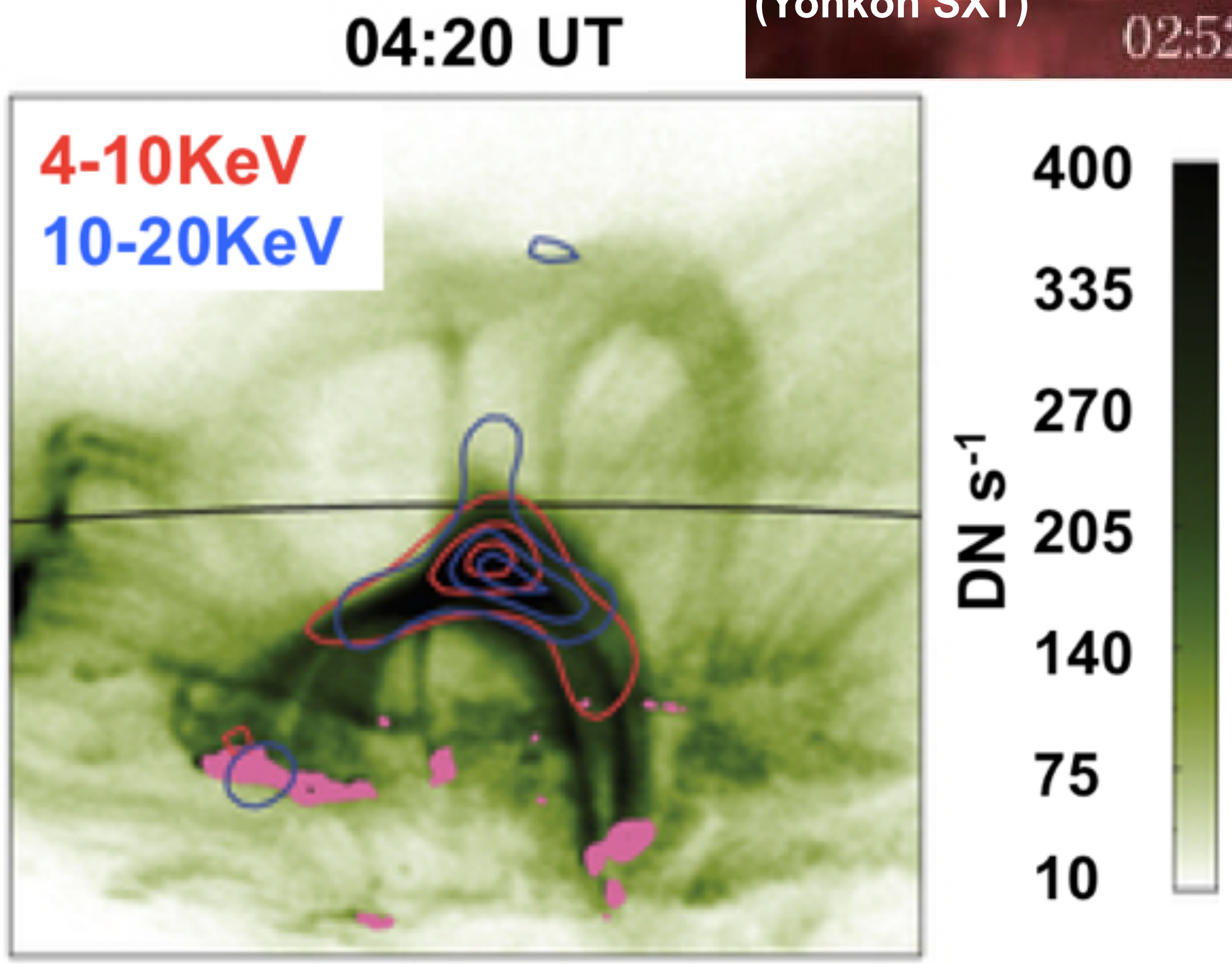
- Standard flare model (CSHKP)
  - **Imaging observations**
  - **Spectroscopy**


H alpha flare ribbon
(Big Bear Solar Observatory)





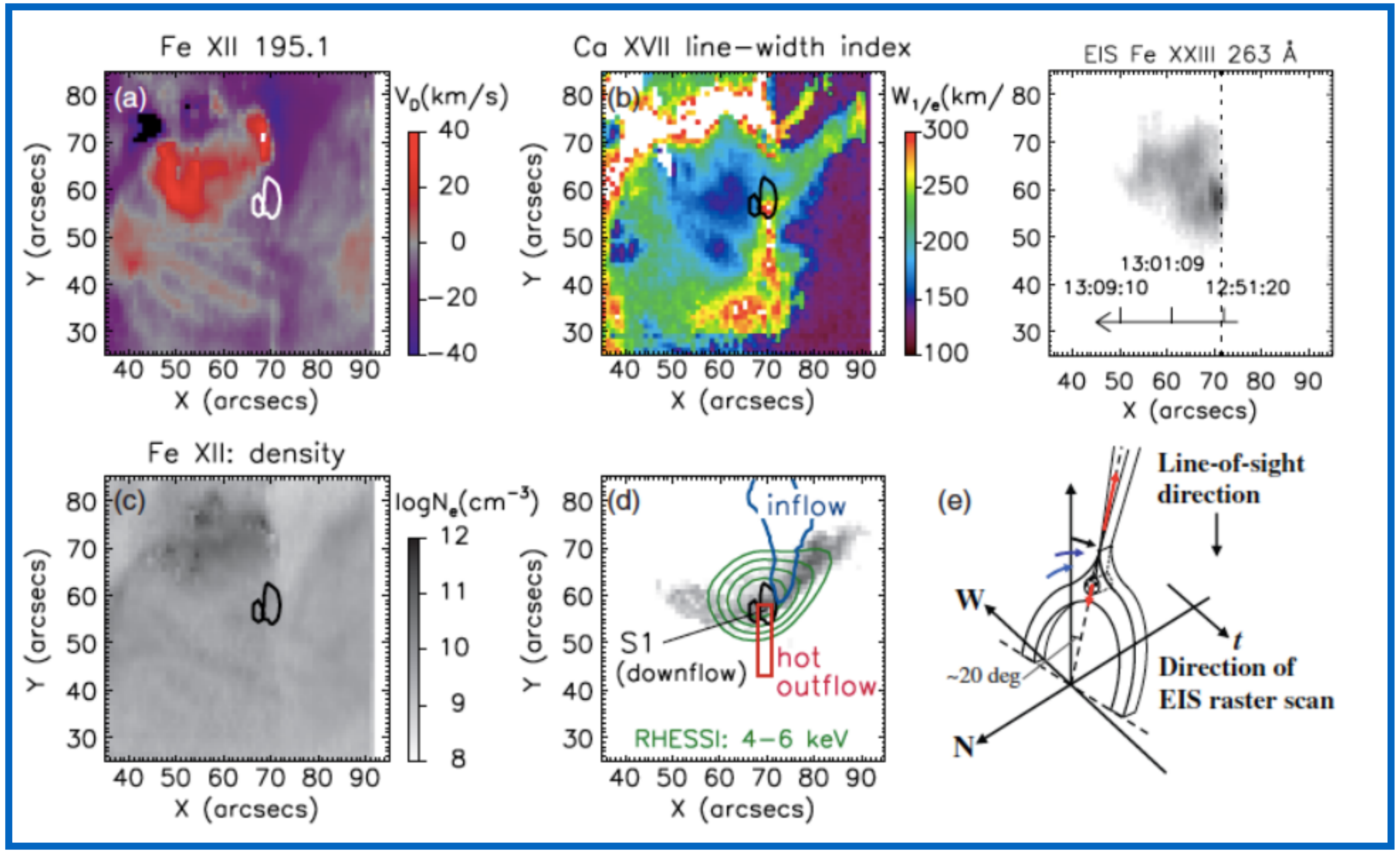
Soft X-ray loop
(Yohkoh SXT)



Background: EUV loop from SDO/AIA
Contour: HXR (blue) and SXR (red) from
RHESSI obs.

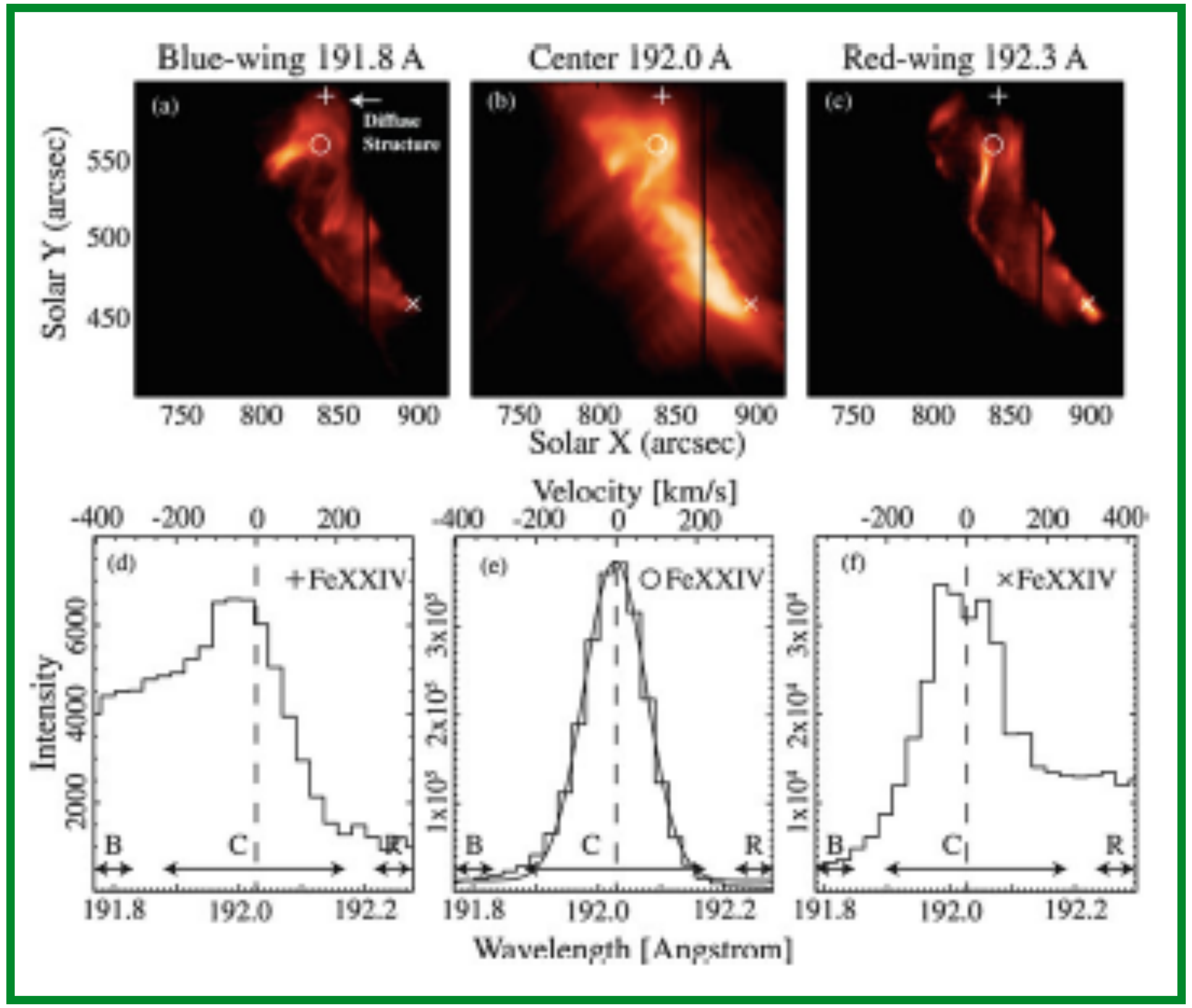
HINODE/EIS (EUV IMAGING SPECTROMETER)

- EIS Flare studies *(higher spatial (~2”) imaging and spectral resolution)*
  - **Reconnection outflows, inflows, line broadening** (, temperature, density - Iron lines)



B9.5 flare (disk) on 2007 May 19 (Hara et al. 2011)

- **hot reconnection outflow (Fe XXIIII/XXIII), cooler ion inflow (Fe XII), Density (Fe XII)**



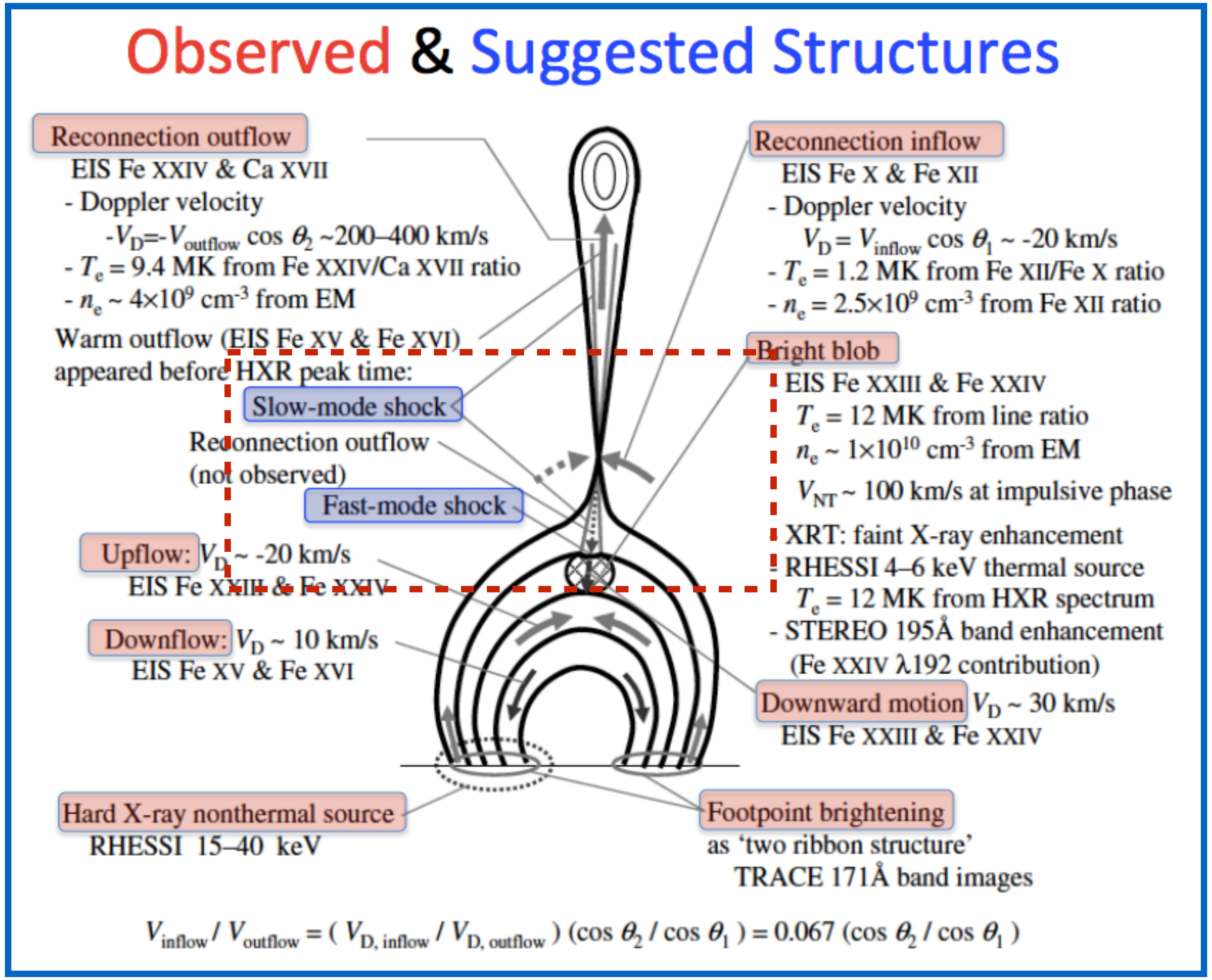
X1.7 flare (limb) on 2012 January 27 (Imada et al. 2013)

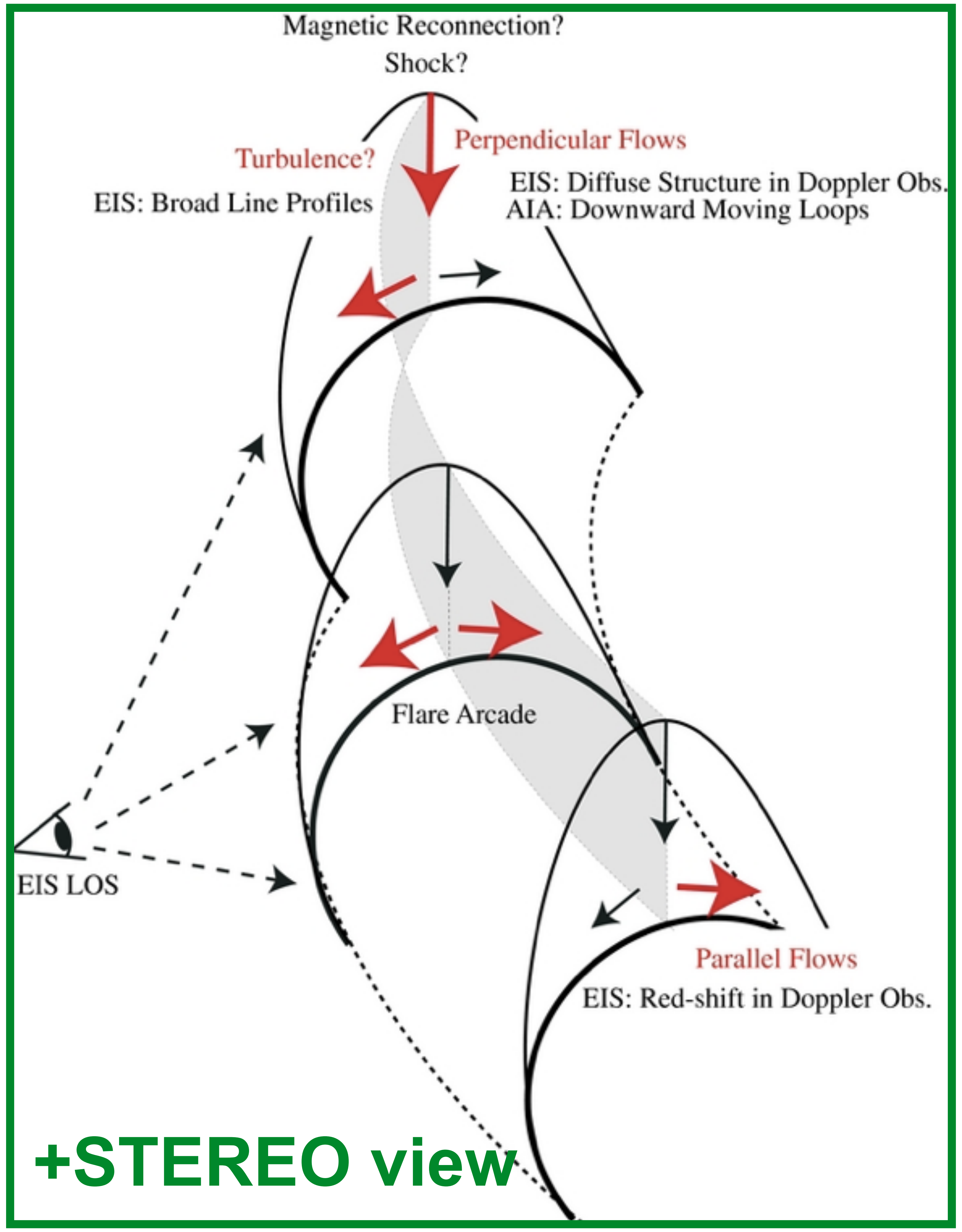
- **hot plasma flow over the loop arcade**

INTRODUCTION: SUGGESTED FLARE STRUCTURE MODEL

HINODE/EIS (EUV IMAGING SPECTROMETER)

- EIS Flare studies *(higher spatial (~2”) imaging and spectral resolution)*





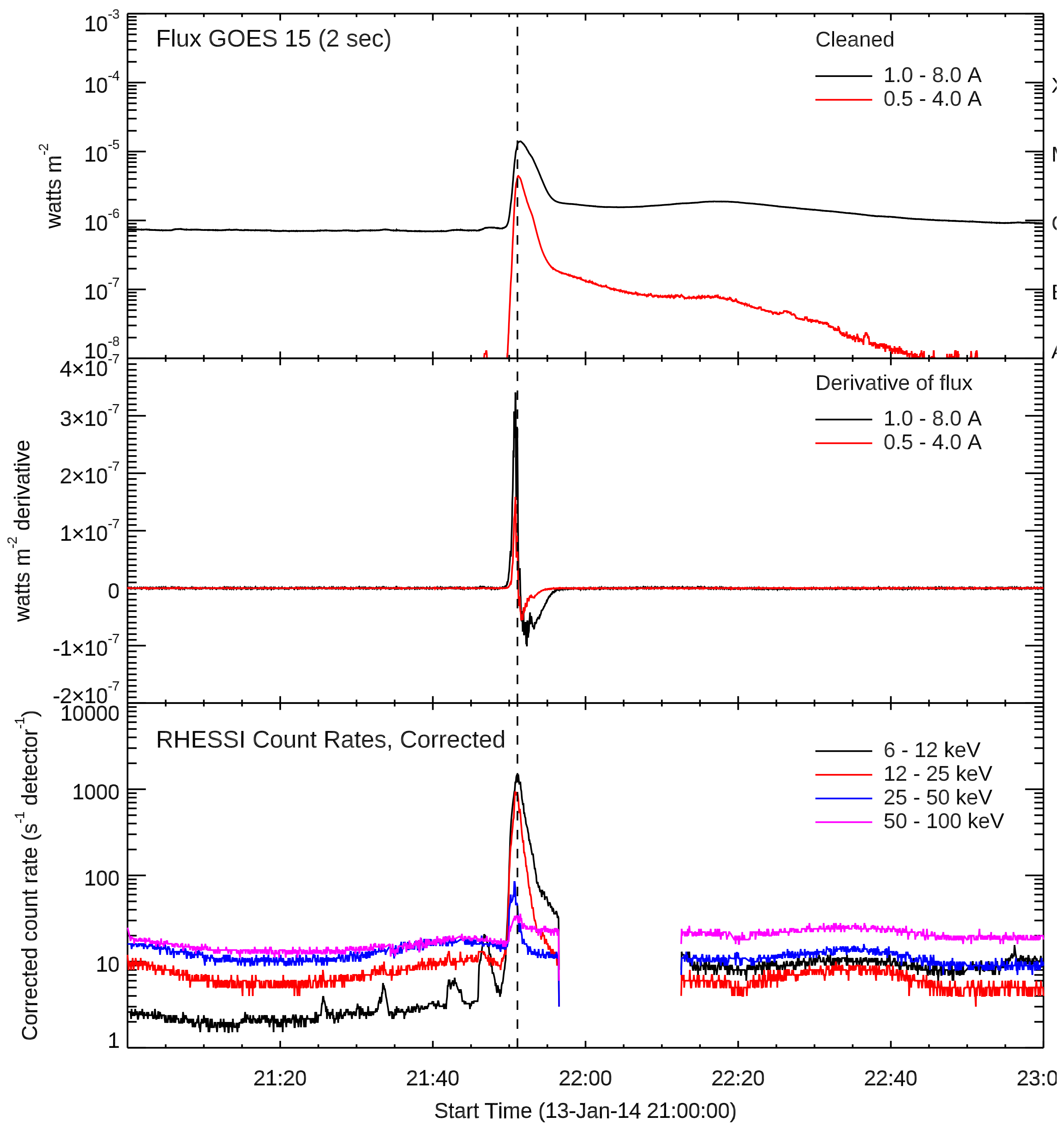
Hara et al. (2011)

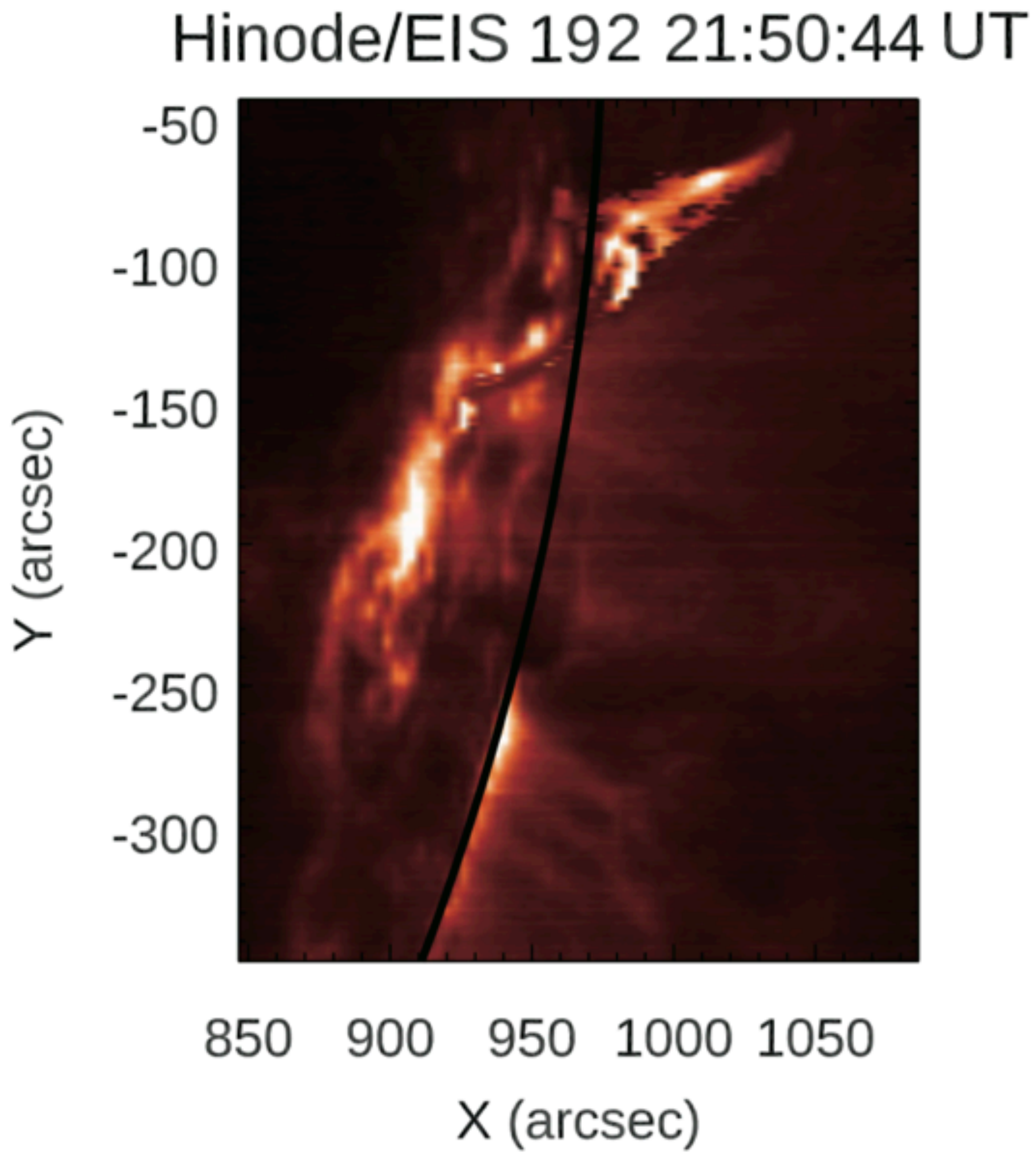
Imada et al. (2013)

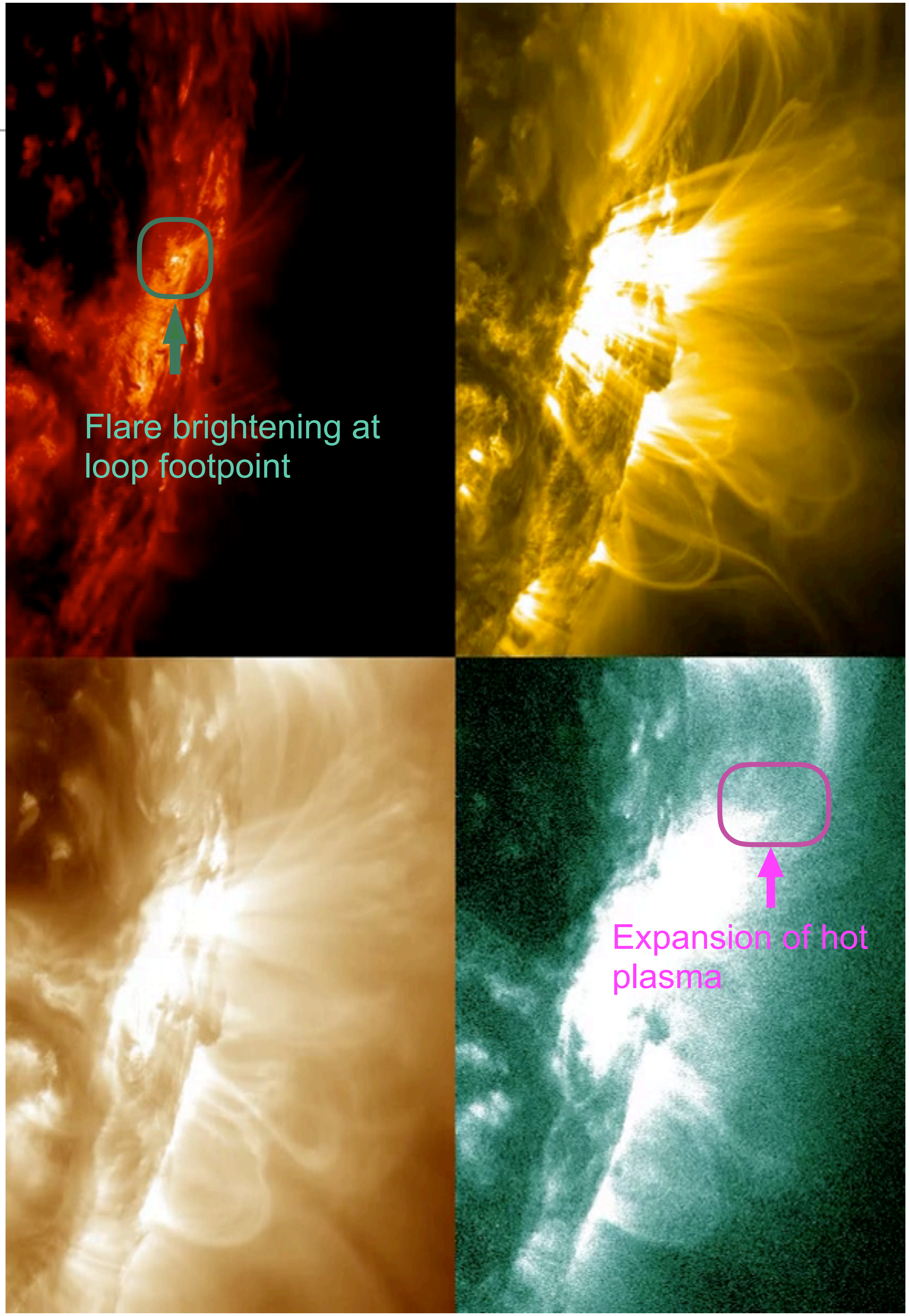
OBSERVATIONS

M 1.3 FLARE ON 2014 JAN 13

- Impulsive flare at the west limb
- Hinode/EIS scan observation with flare trigger
  - Sparse raster obs (3” jump)
  - 5 sec exposure / 6 raster scan with 9 min cadence



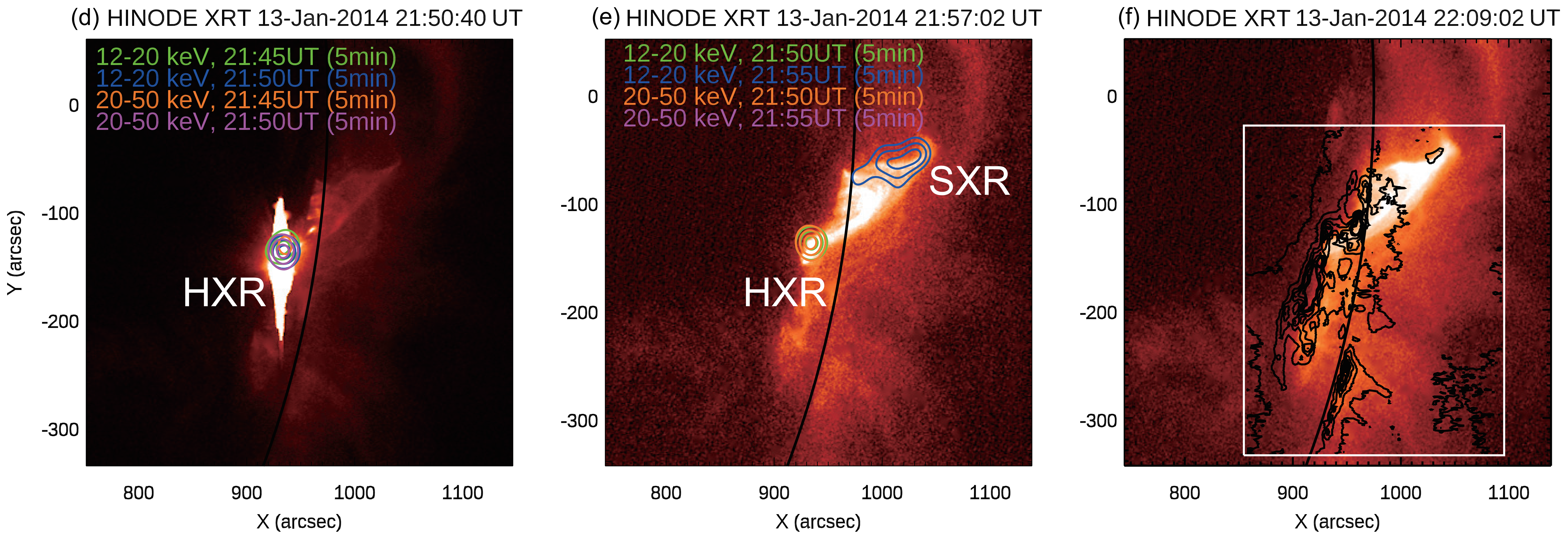




OBSERVATIONS

HINODE/XRT & REHSSI OBS. - HOT FLARING LOOP-TOP SOURCE

- **Hot flaring loop exist before the M flare**
- **RHESSI obs. with blue (SXR) and red (HXR) contours**
- **Black contours: EIS 192Å window intensity**

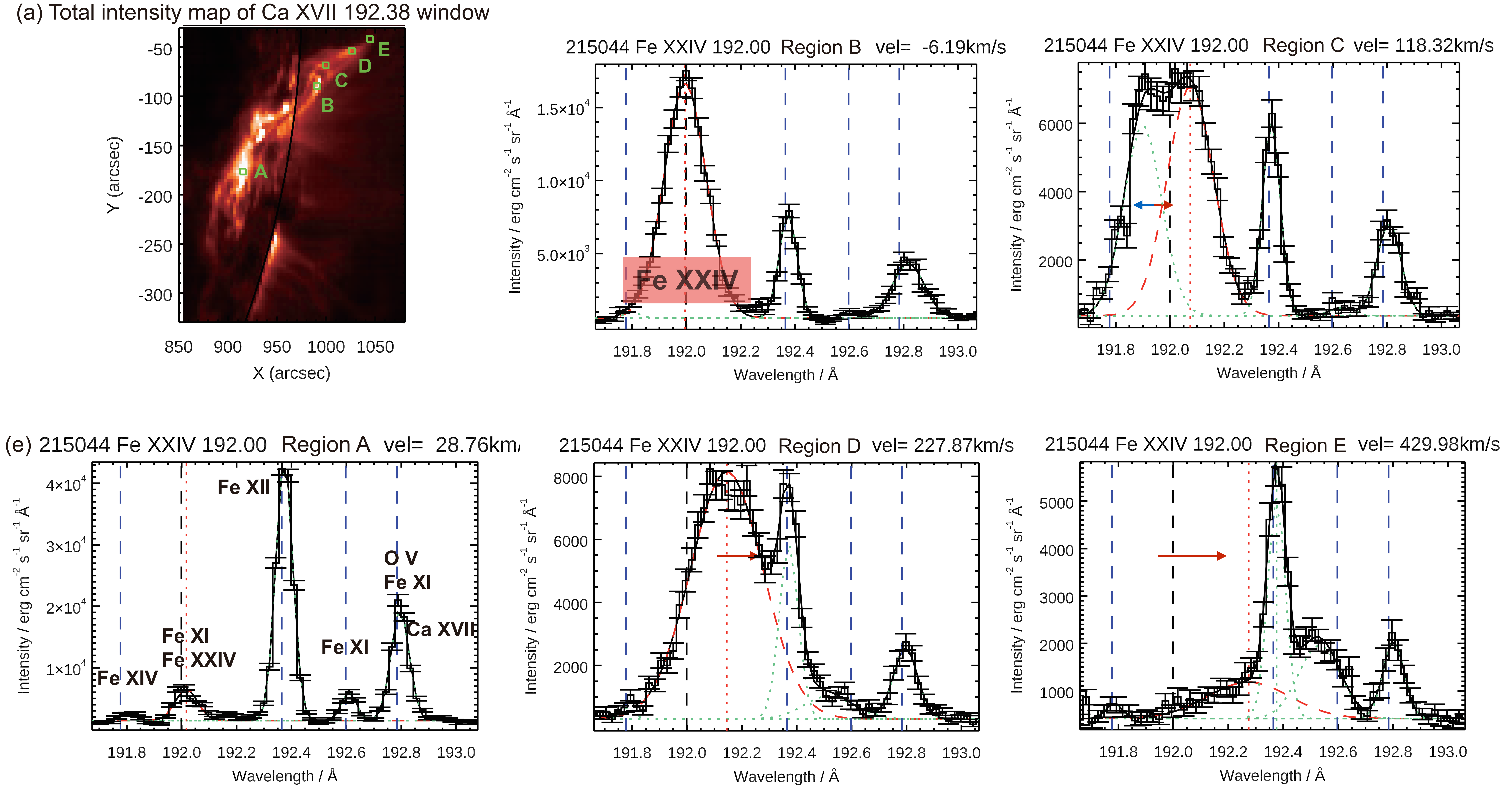


ANALYSIS - SPECTROSCOPY

HINODE/EIS - DOPPLER VELOCITY OF FE XXIV

- 1st raster (at 21:50:44 UT): Flare start timing

- Weak red & blue shift at the loop-top (region C)
- Strong red shift above the loop-top (region D& E)

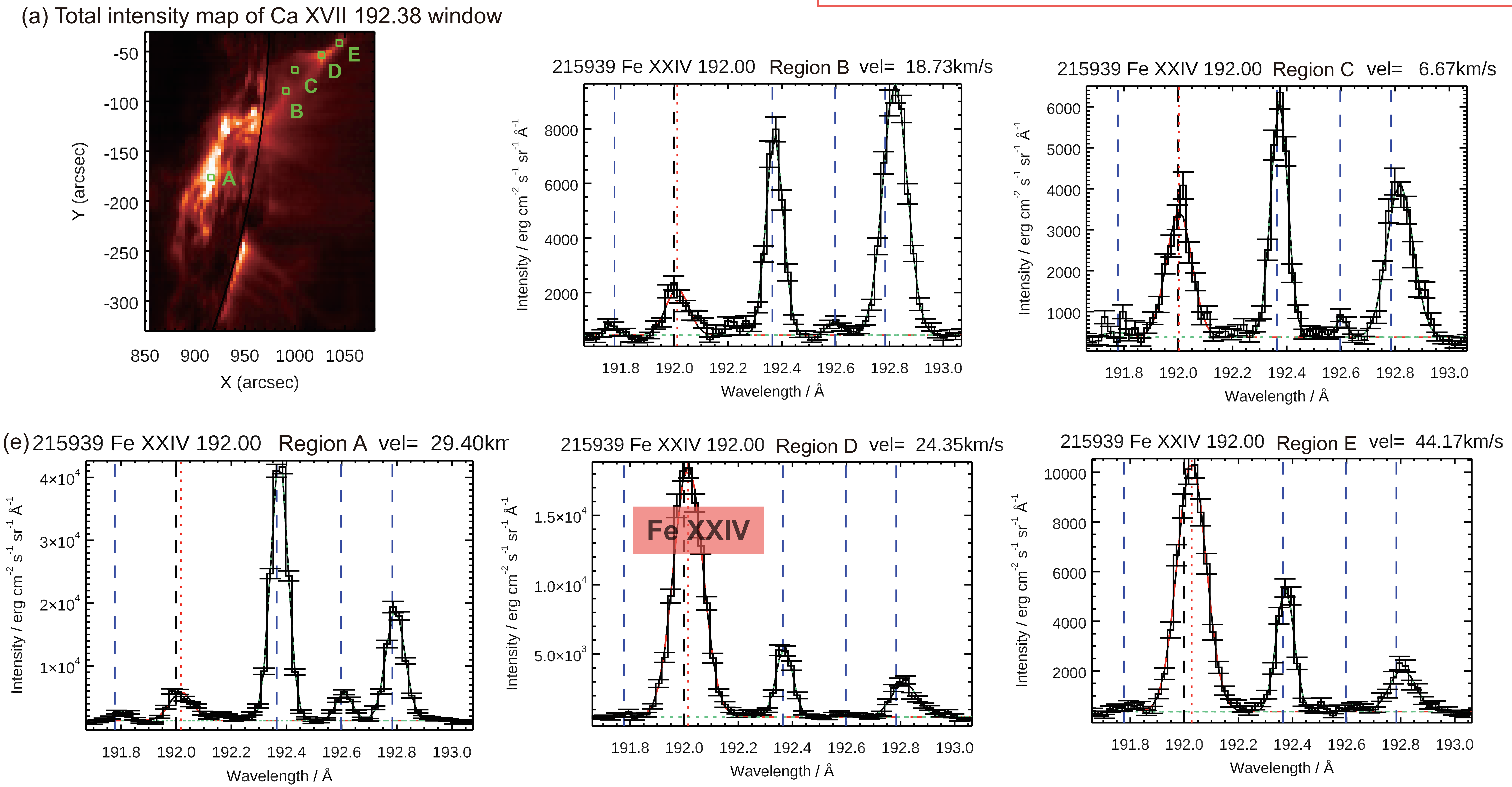


ANALYSIS - SPECTROSCOPY

HINODE/EIS - DOPPLER VELOCITY VELOCITY OF FE XXIV

- 2nd raster (at 21:59:39 UT): SXR flare peak time

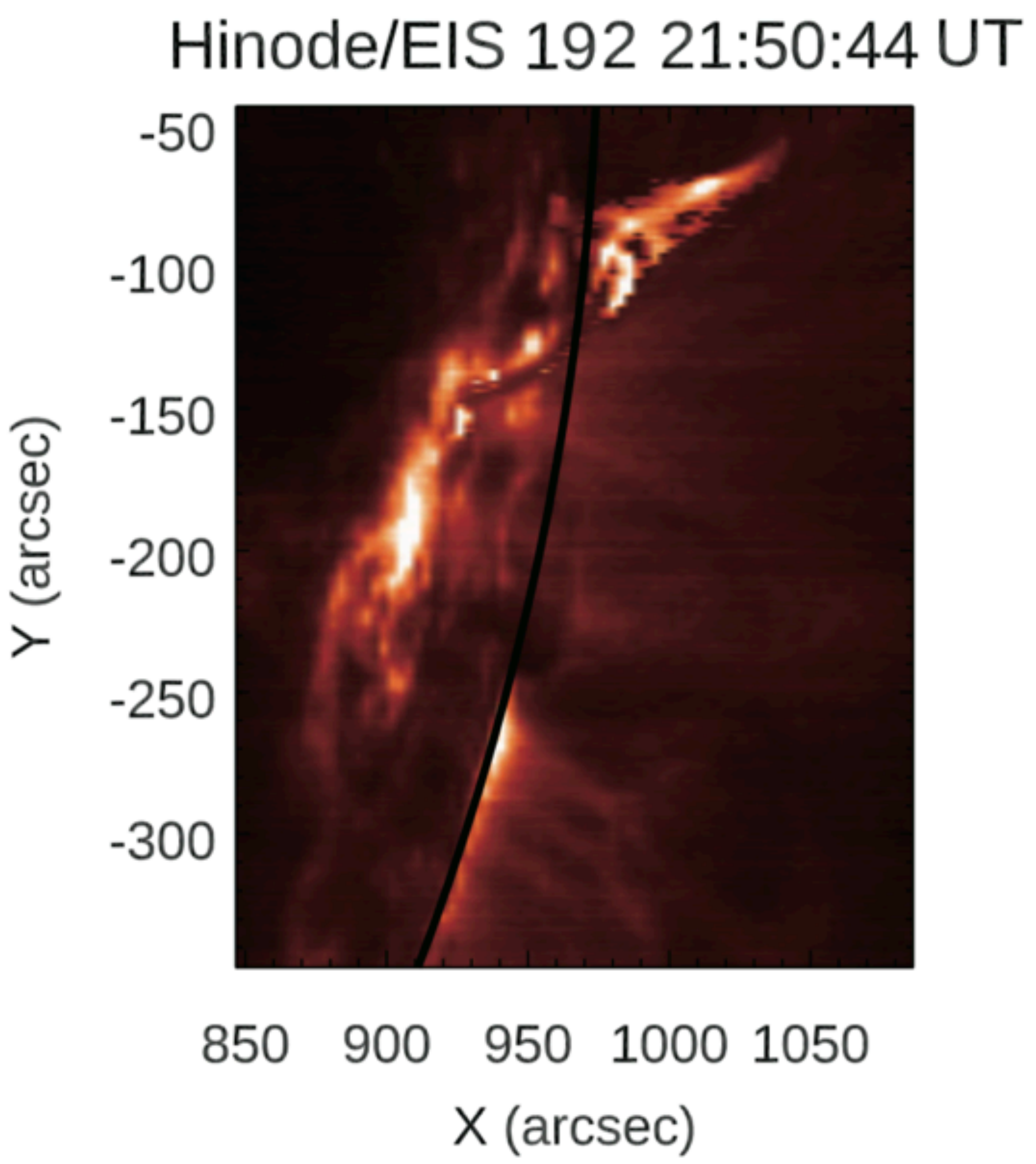
- Weak Doppler velocity
- Intensity enhancement at the loop-top

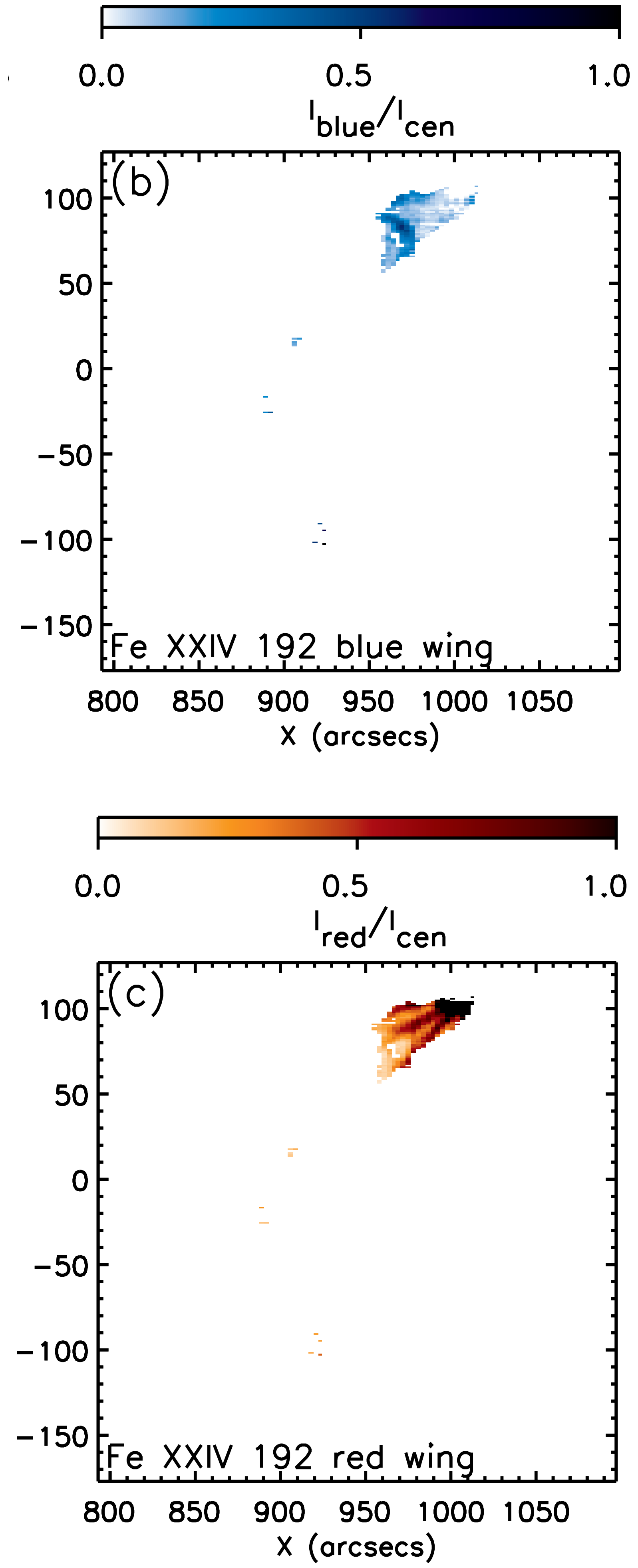


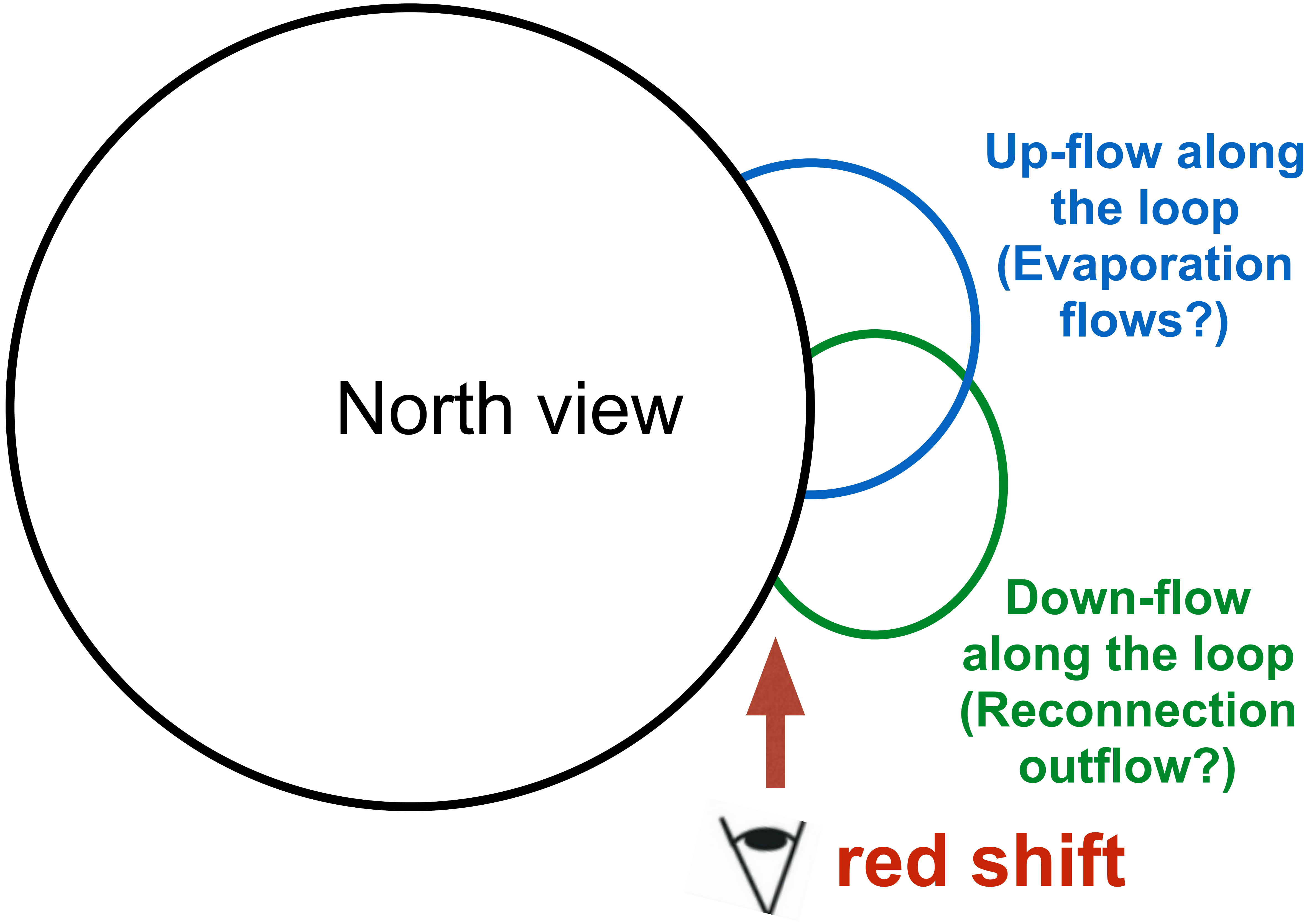
RESULTS - SPECTROSCOPY

THE STRUCTURE AND PLASMA DYNAMICS OF THE M 1.3 FLARE

- Doppler velocity - strong red shift along the loop (loop-top)



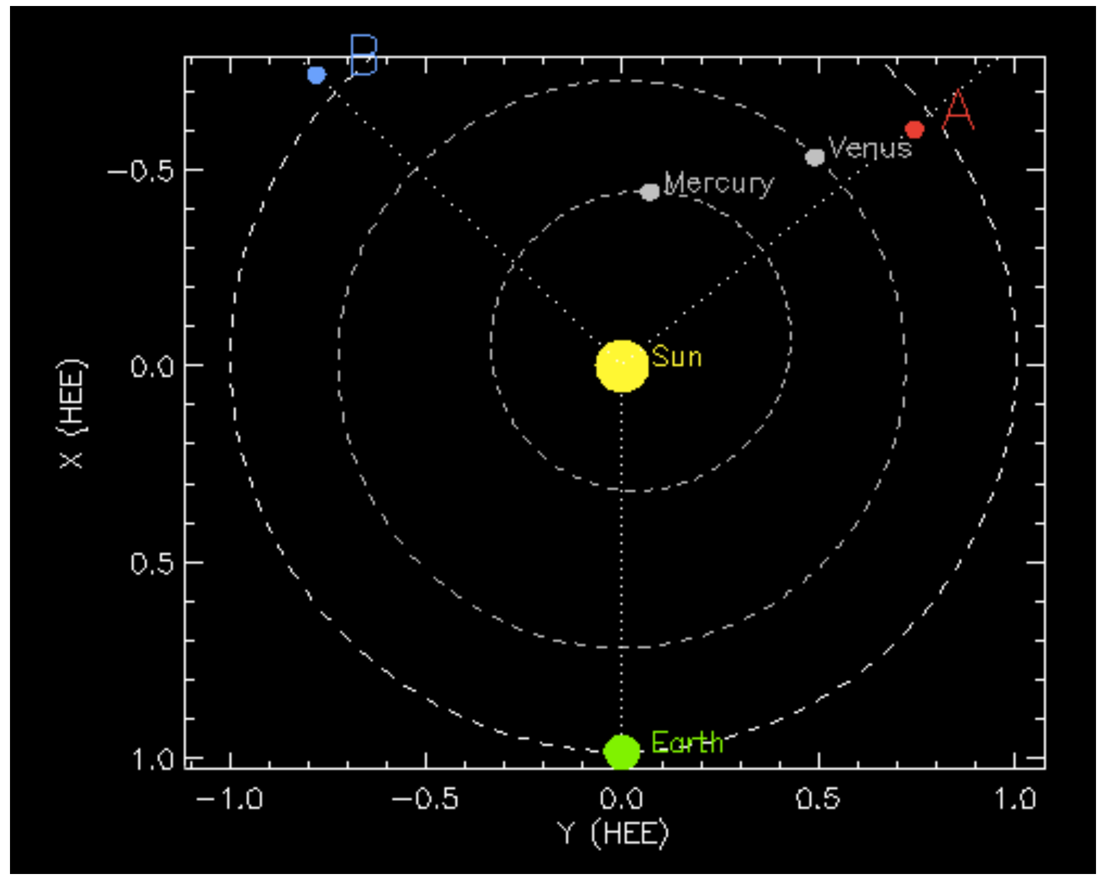




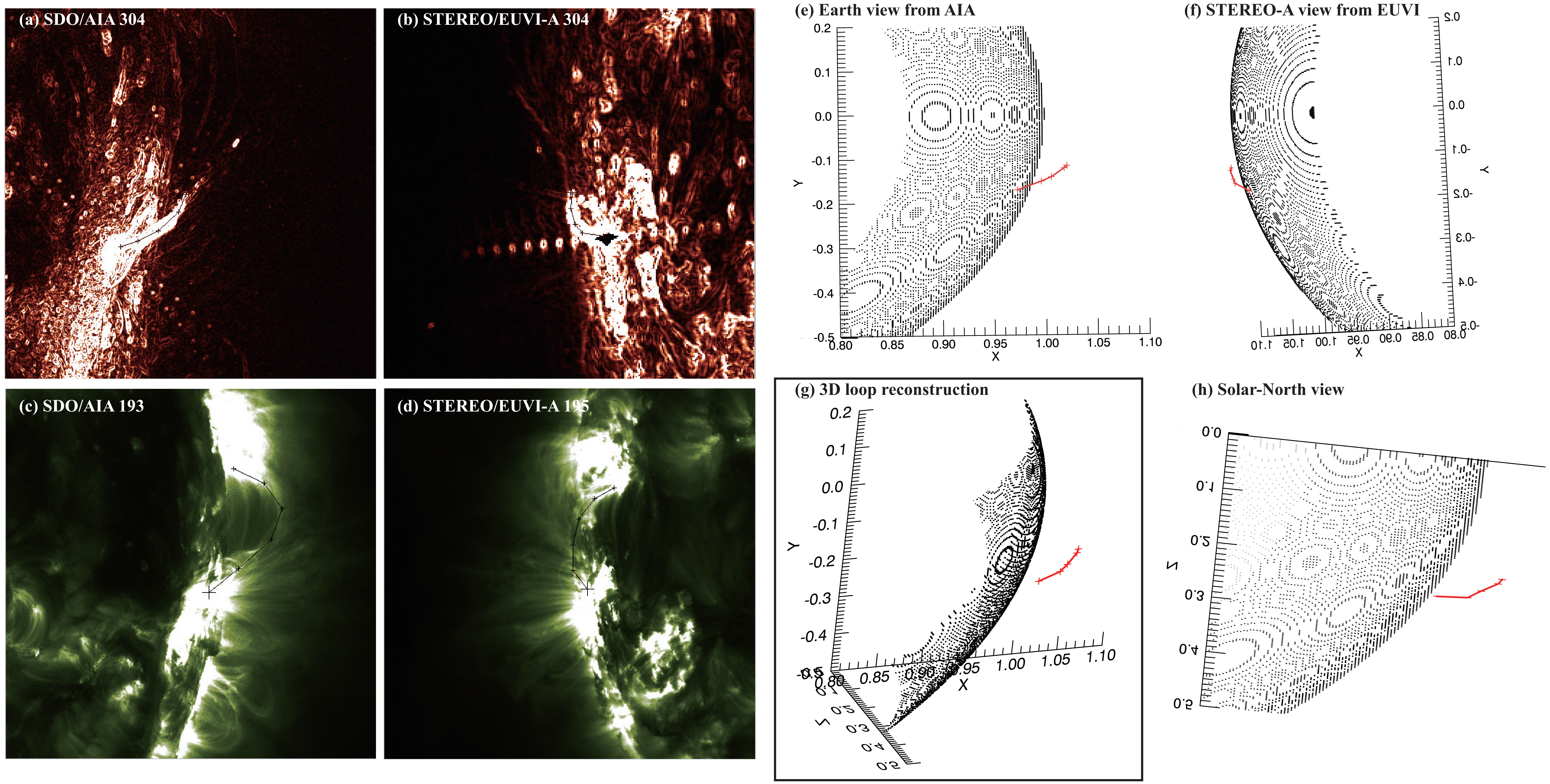
ANALYSIS - STEREOSCOPY

THE LOOP TILT ANGLE MEASURED FROM THE STEREOSCOPY USING THE STEREO/EUVI-A AND SDO/AIA

- SDO-STEREO orbit



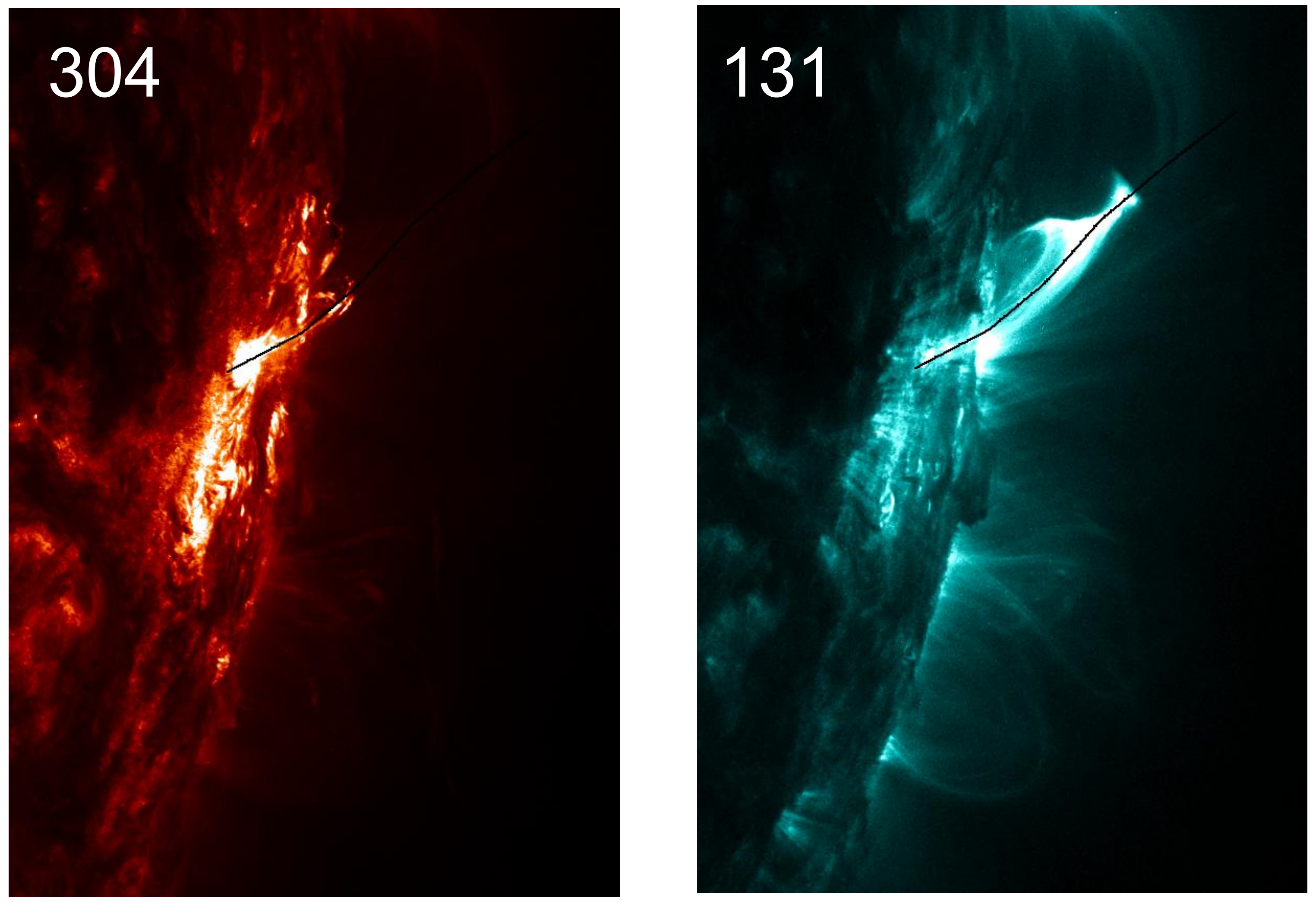
"ssc_measure.pro"

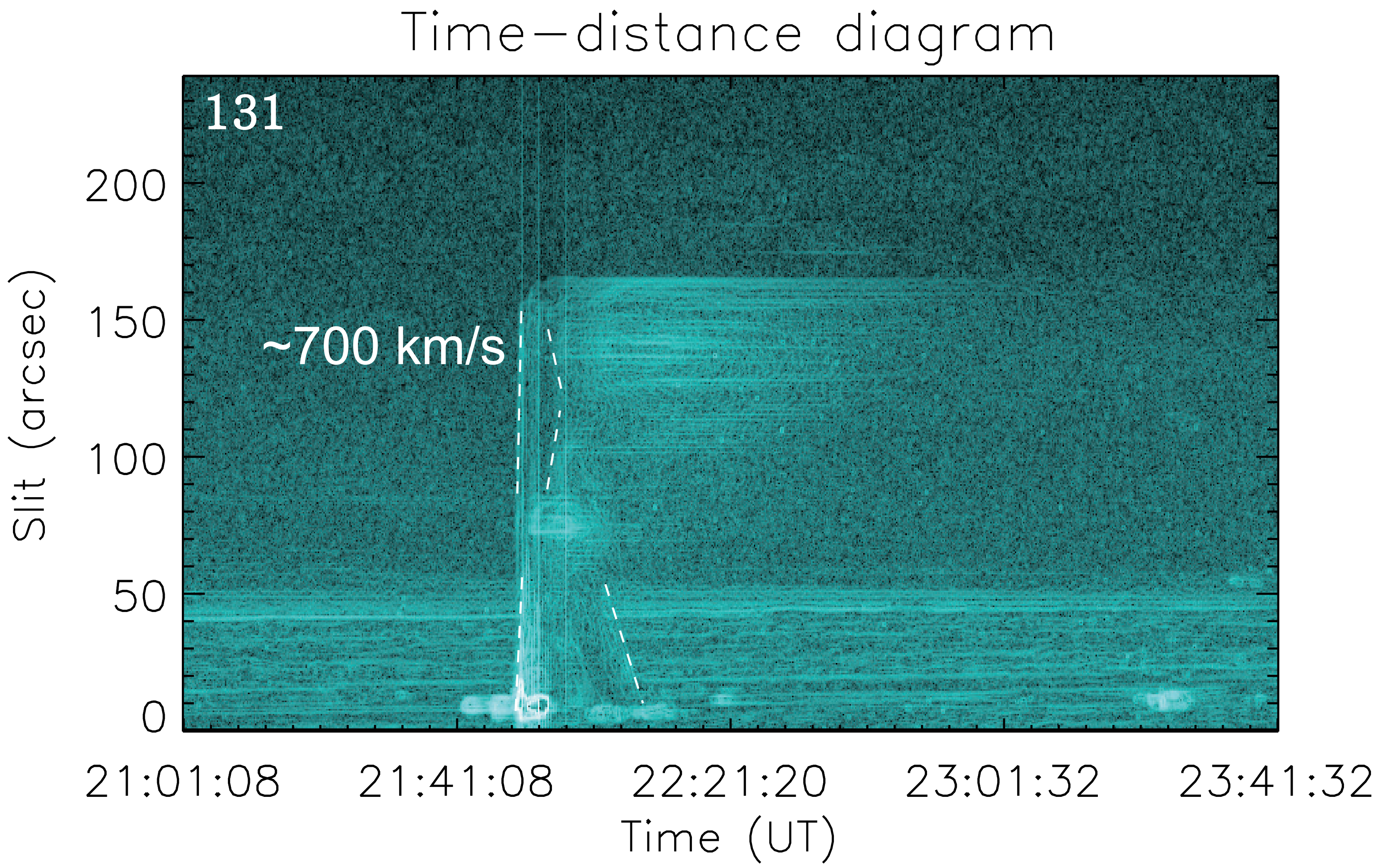


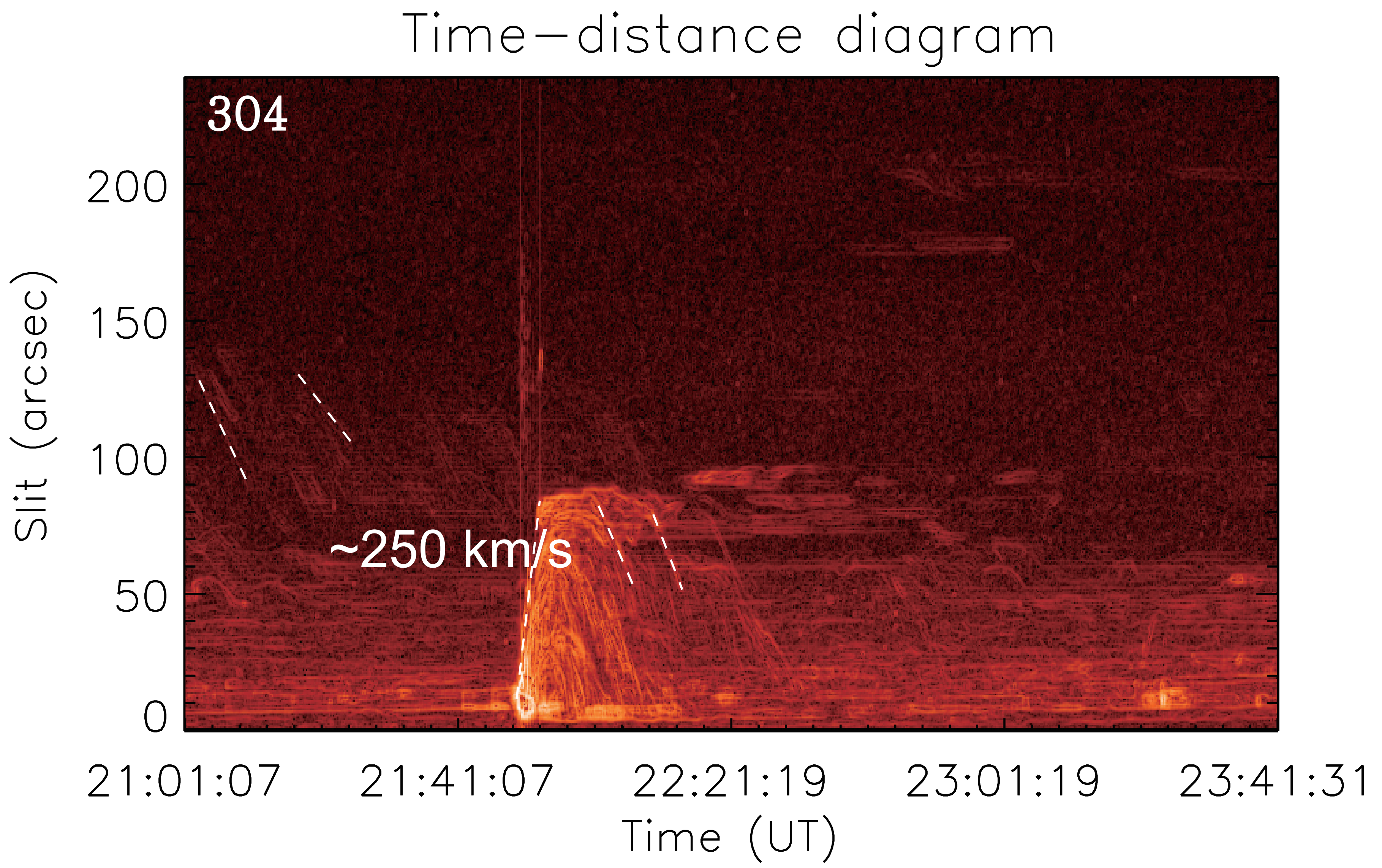
- The loop orientation is away from us - the **red shift flow** indicates **"upflow"**, 200~500 km/s

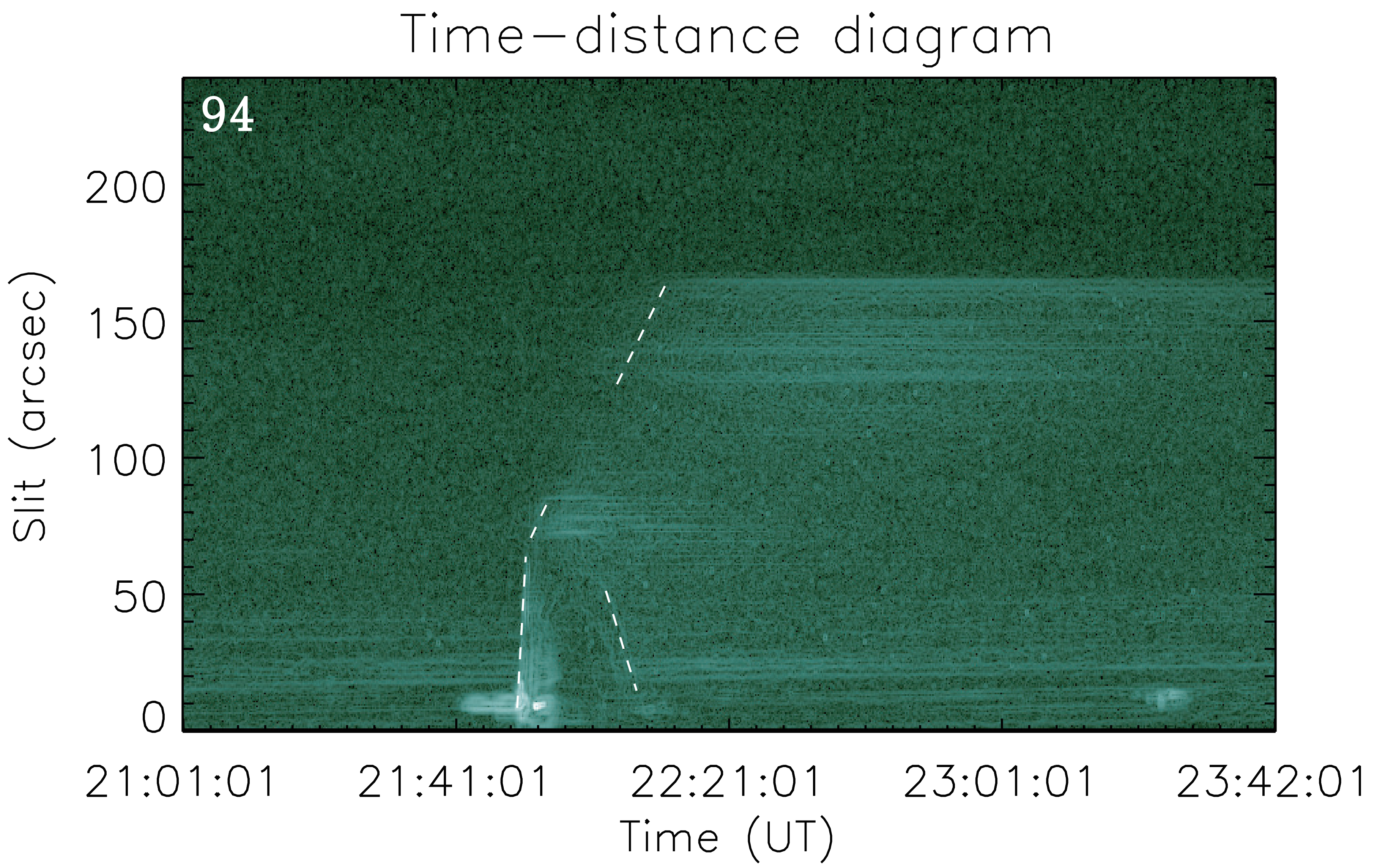
- Loop tilt angle from the cool jet and loop positions of two different spacecraft ~ 51 degree

SLIT-TIME DIAGRAM FROM SDO/AIA





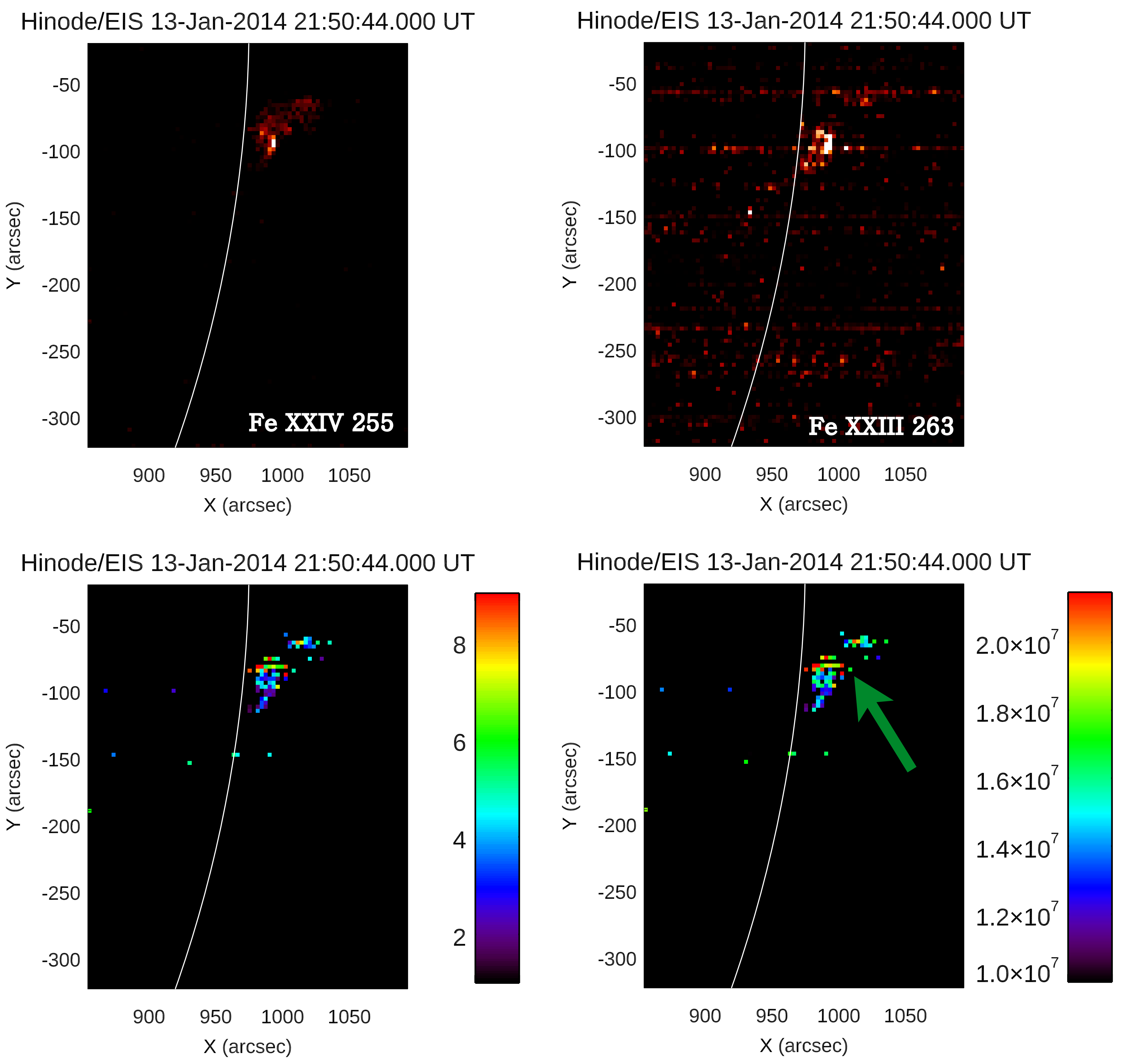


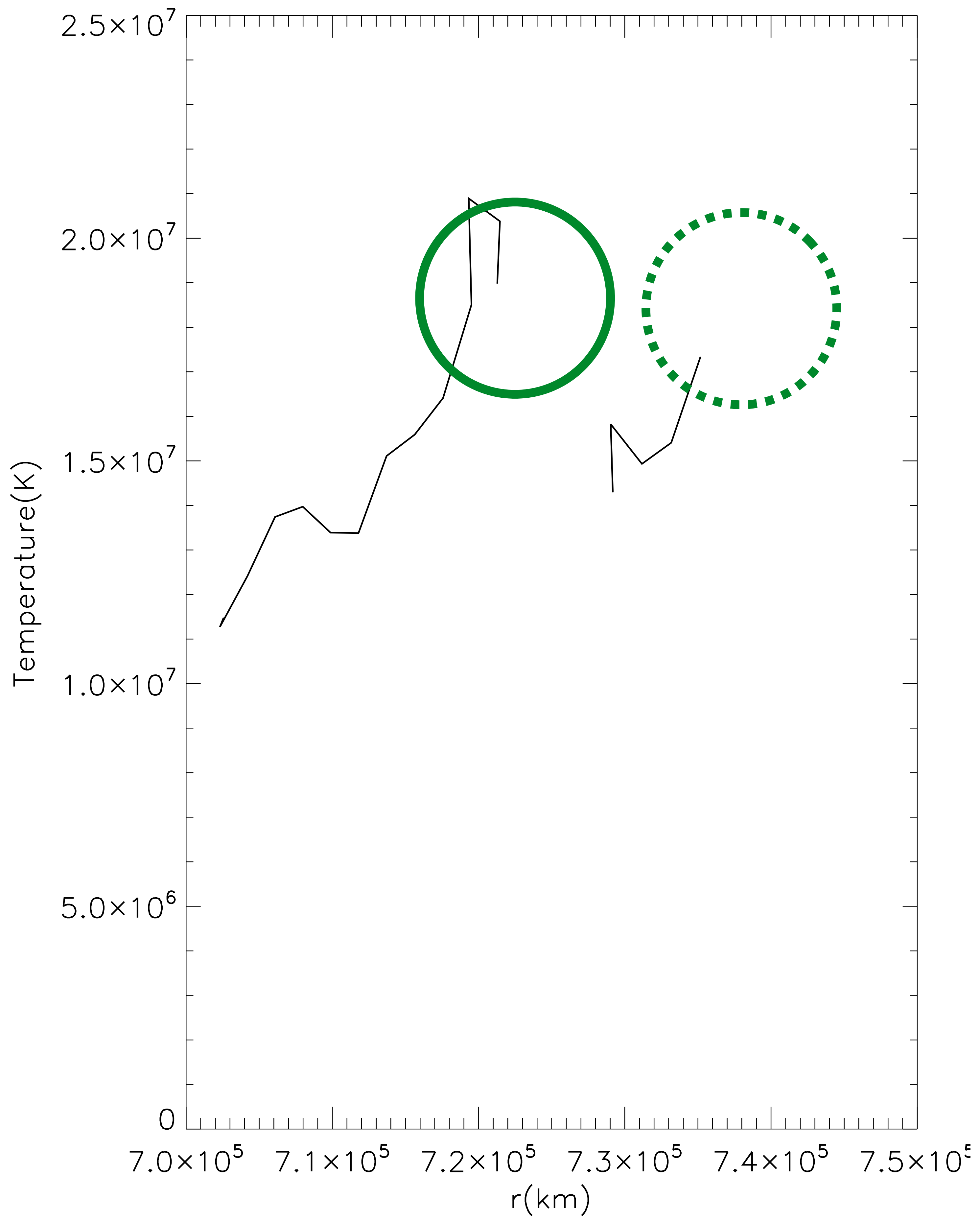


RESULT - TEMPERATURE DISTRIBUTION

HEIGHT VARIATION OF THE TEMPERATURE

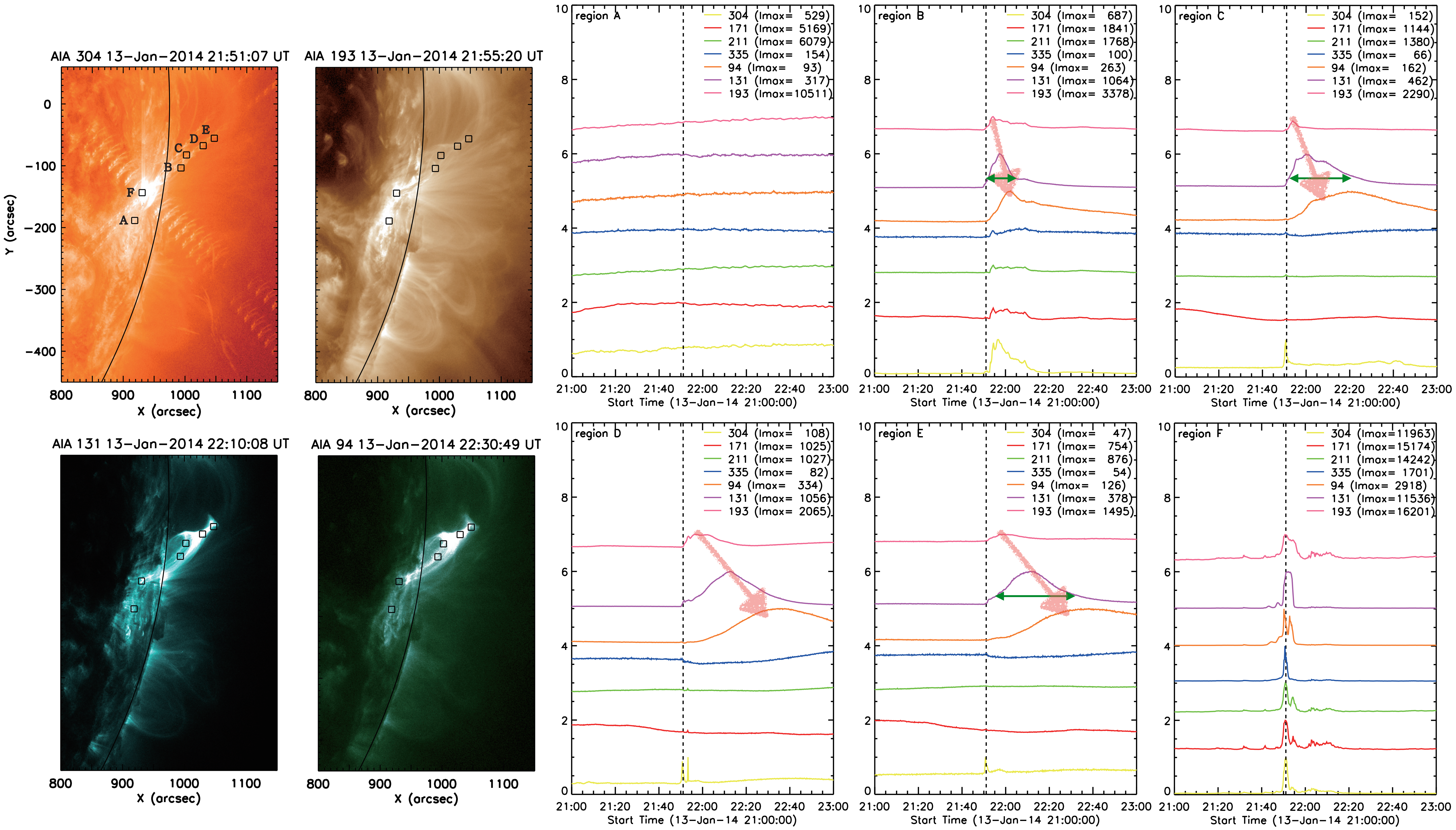
- **Temperature distribution from the ratio between EIS Fe XXIV 255 and FeXXIII 263**





RESULT - COOLING PROCESS

LIGHT CURVES IN MULTI WAVELENGTHS FROM SDO/AIA



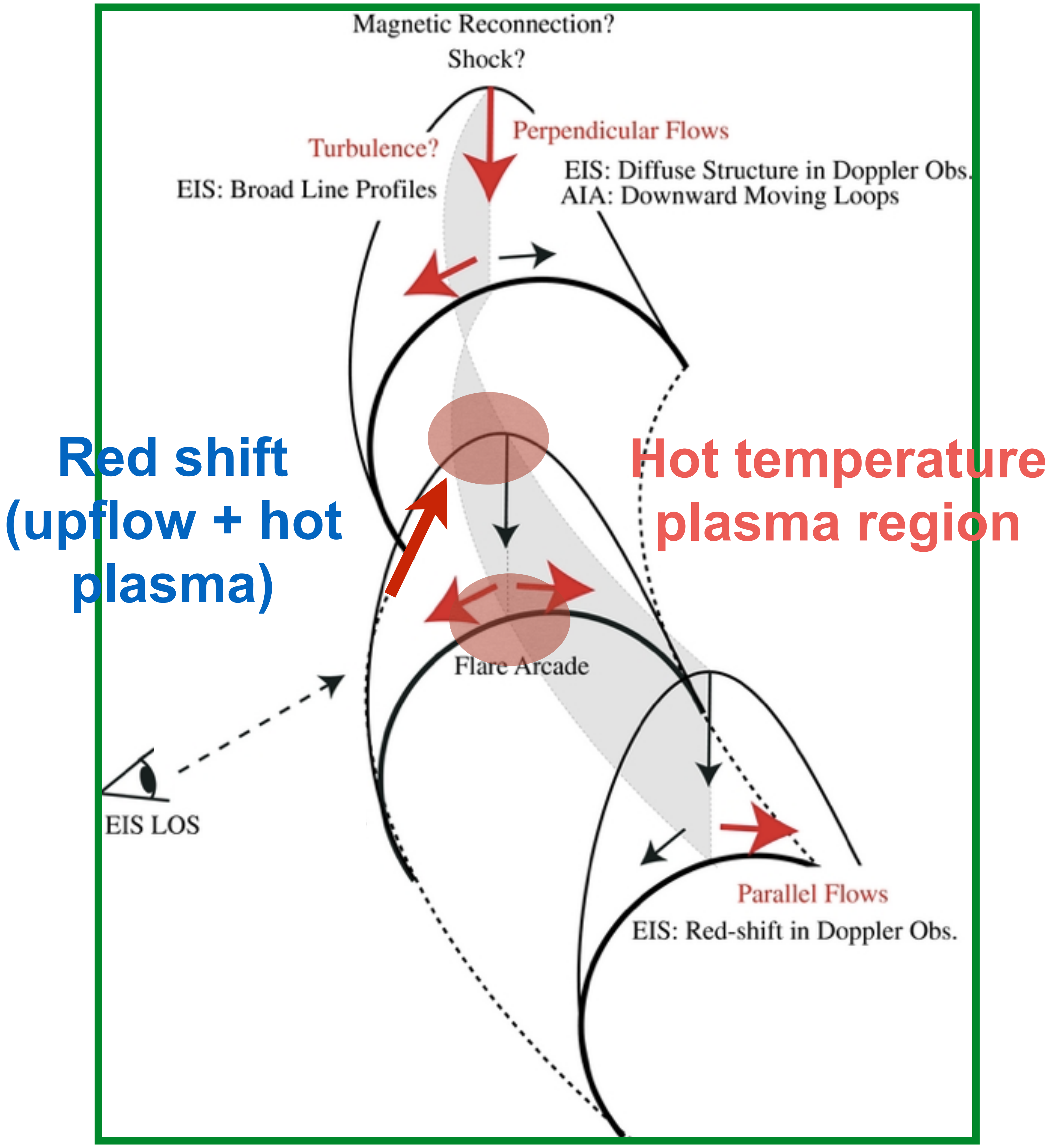
DISCUSSION & SUMMARY

MULTI-WAVELENGTH OBSERVATION OF LIMB FLARE

- We analyzed a limb flare (M1.3) using multi-wavelength observations
  - Hinode/EIS (Spectroscopic obs.)
  - STEREO/EUVI (Stereoscopic obs.)
  - SDO/AIA, Hinode/XRT, and RHESSI (imaging obs.)

- We investigated their plasma properties and flare loop configurations
  - We found hot red-shifted plasma (~500km/s) along the loop (especially loop-top) which imply an evaporation flows considering temperature and 3D loop configuration
  - HXR source only observed at the flare loop footpoint brightening
  - Non-thermal velocity of the loop-top region is larger than 100 km/s.
  - The temperature structure from EIS Fe XXIV/XXIII ratio shows there are two hot plasma regions, loop-top and above the loop-top.

- We couldn't observe (expected features…)
  - Donwflows as the reconnection outflows
  - HXR emission at the above the loop-top regions



FUTURE WORK

COOLING PROCESS AFTER THE EVAPORATION

- Light curves of the AIA multi wavelength intensity images show the cooling process with time
  - The cooling time is different from the loop height
  - The observed temperature parameters can be used for the calculation cooling time (conductive and radiative cooling time)

SOURCE OF THE HOT PLASMA

- The hot plasma filled in the loop-top region
- We plan to check the abundance and density of the plasma at the loop-top (and along the loop) with time
  - Photospheric or coronal abundances
  - Comparison the density of plasma (from lower chromosphere or higher coronal source)
  - Evaporated plasma or cooling down plasma