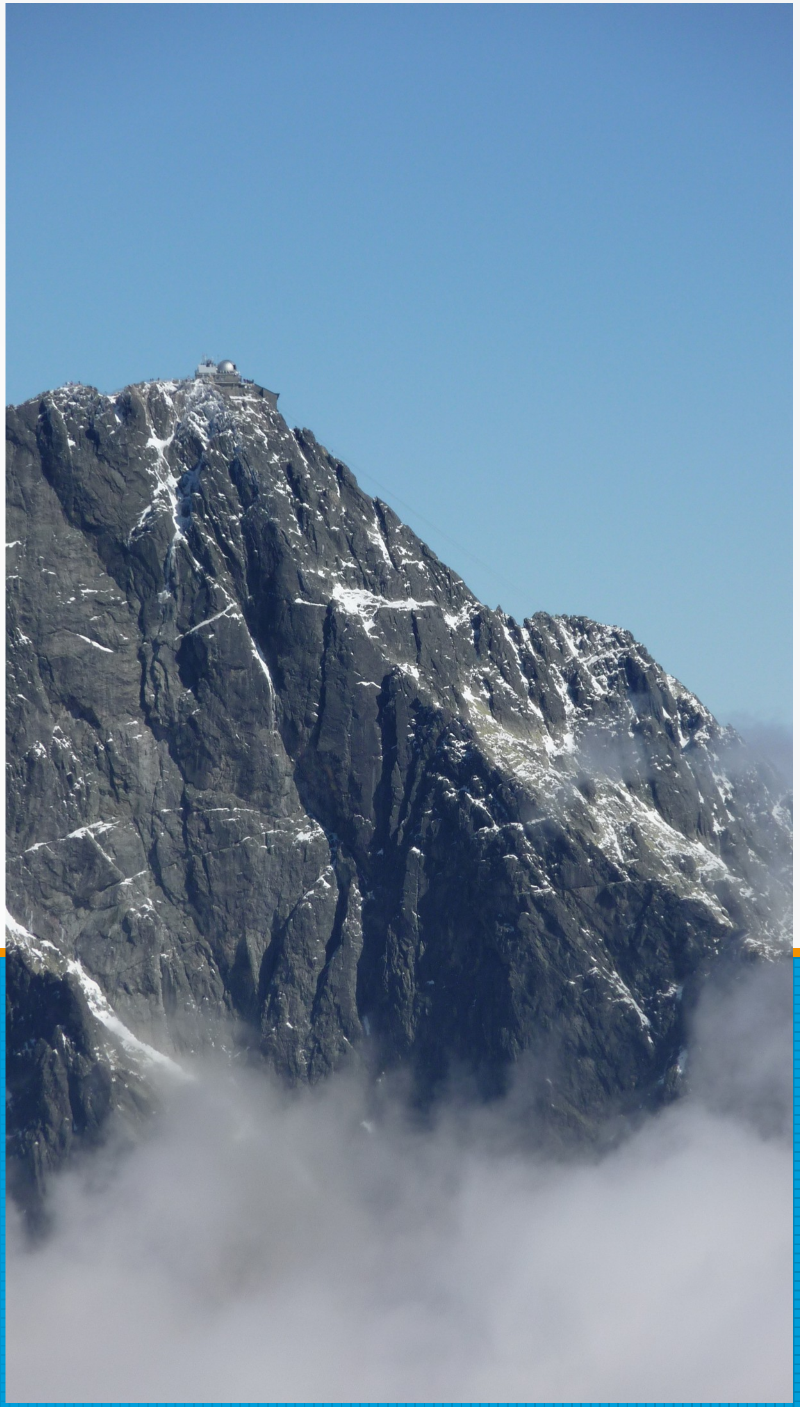
LSO summer internship program: science

Ján Rybák
Lomnický Štít Observatory (LSO)
AI SAS, Tatranská Lomnica, Slovakia

2024



Content:

- Main topics:
  - Tornado for (in)stability of prominences
  - Total mass of prominences
  - coronal rain
  - coronal waves

Tornados in prominences?

- Cold plasma rotation in the tornado-like prominence of July 13, 2014: a real motion or an illusive effect?

  Rybak et al.

Cold plasma rotation in the tornado-like prominence of July 13, 2014: a real motion or an illusive effect?

J. Rybák[1], J. Ambróz[1], P. Gömöry[1], J. Kavka[1], J. Koza[1], M. Kozák[1], A. Kučera[1], P. Schwartz[1], S. Tomczyk[2], S. Sewell[2], G. Capobianco[3], S. Fineschi[3], M. Temmer[4], V. Posch[4]

1 – Astronomical Institute, SAS, Tatranská Lomnica (Slovakia)
2– High Altitude Observatory, NCAR, Boulder (USA)
3 – INAF - Astrophysical Observatory of Torino, Pino Torinese (Italy)
4 – Institute of Physics, University of Graz, Graz (Austria)

24. celoštátny slnečný seminár, Kežmarok, 2018/05/22-25

Tornadoes in the terrestial atmosphere

credit: www.pitara.com

Wikipedia: “A tornado is a violently rotating column of air that is in contact with both the earth and a cloud” (traveling and changing its shape...)

Tornadoes in the solar atmosphere?

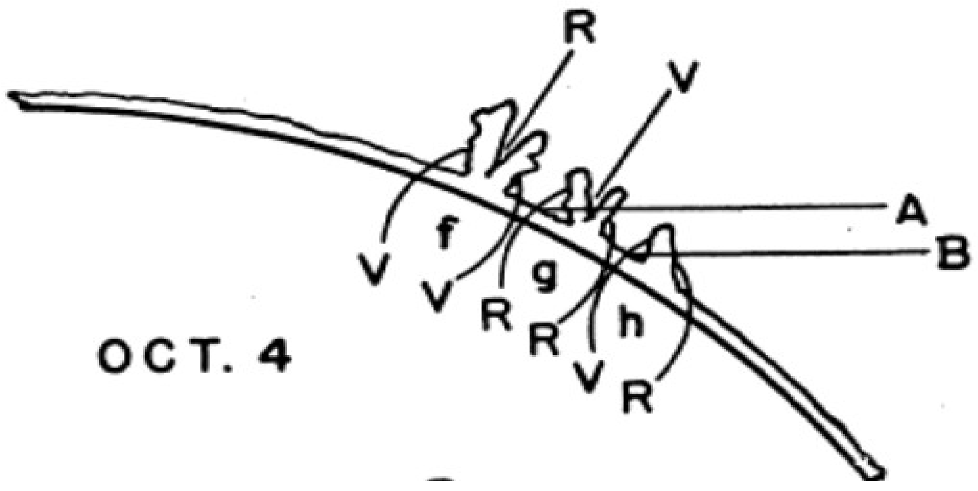
Prominences closely resembling terrestrial tornadoes in form, when projected on the solar limb

Historical records:

- observed spectroscopically since 1868 (Secchi, 1877)
- shapes, sizes, plane-of-sky motions, types (Pettit, 1925, 1932, 1941,…, also Rušin and Scheirich, 1984)
- also line-of-sight motions from the Doppler shifts (e.g. Petit, 1946)

Nowdays:

- TRACE, Hinode, and SDO/AIA satellite capabilities...
- helical structures with "apparent" rotational motions: (TRACE: …, SDO/AIA: Li et al. 2012, Su et al., 2012; Panesar et al., 2013, Mghebrishvili et al., 2015,...)
- structures with directly measured Doppler motions:
  - rotation - VTT/OdT: Orozco Suárez et al., 2012; EIS/Hinode: Su et al. 2014, Levens et al. 2015;; IRIS: Yang et al., 2018
  - no rotation - MSDP/Meudon: Schmieder et al., 2017; THEMIS+IRIS: Levens el al., 2016, 2017
- Panasenco et al. (2014): apparent rotational motion is only observed in 2D projection at the limb in the plane of the sky



Pettit, 1946, PASP 58, 146

Tornadoes in the solar atmosphere?

Prominences closely resembling terrestrial tornadoes in form, when projected on the solar limb

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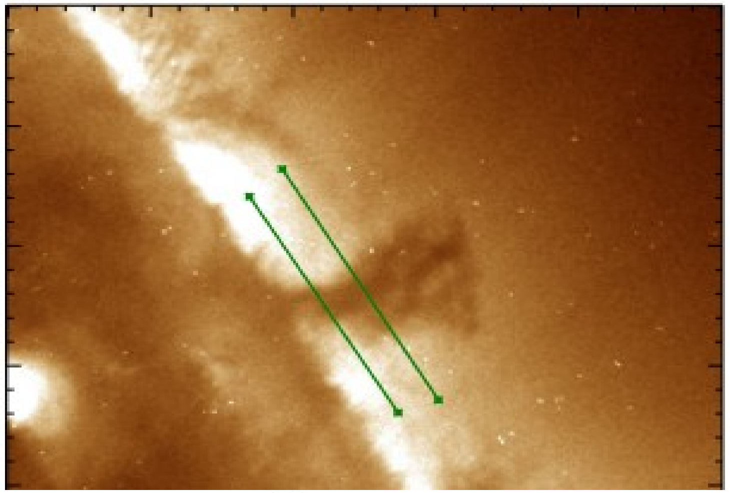
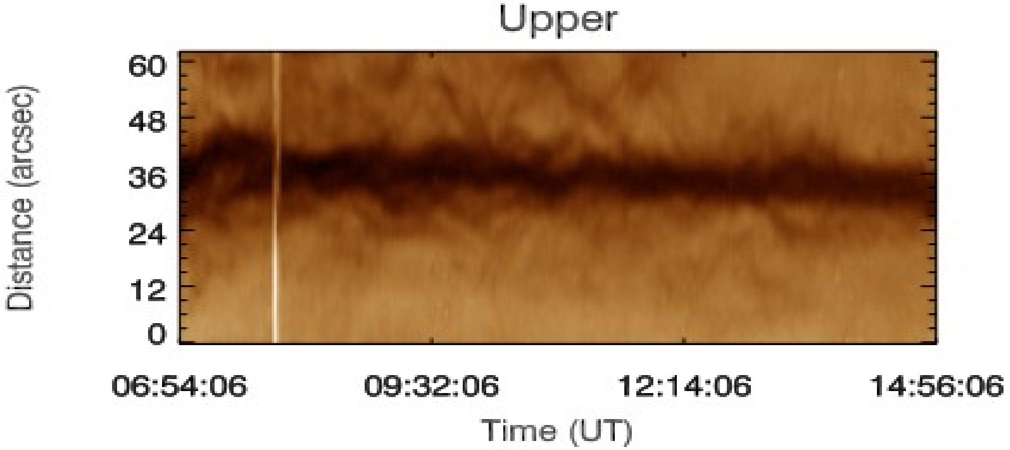




SDO/AIA 193 Å
Schmieder et al., 2017

CoMP-S/LSO

Instruments:

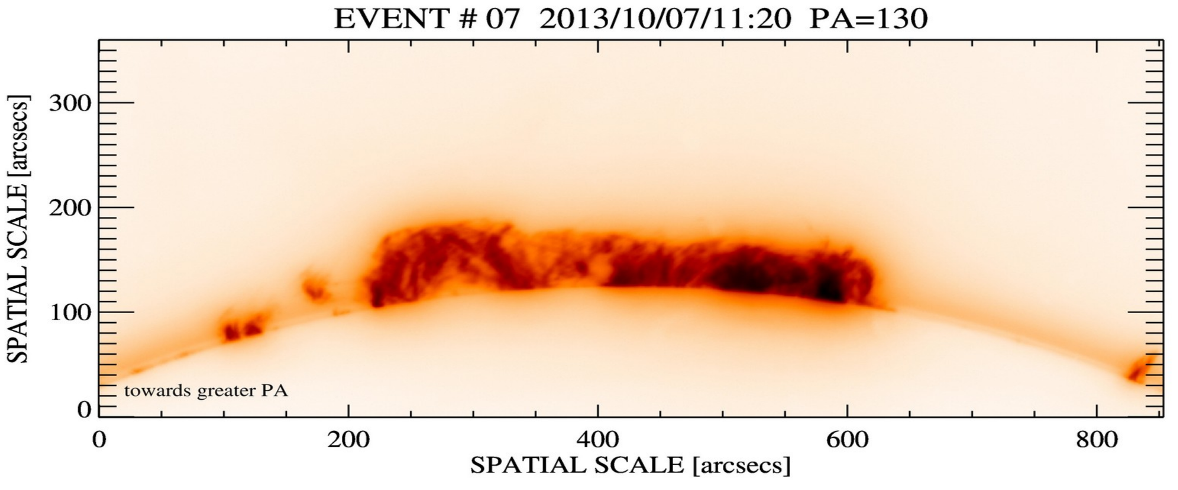
- ZEISS 200/3000/4000 Lyot coronagraph (Lexa, 1963) + photoelectric pointing system
- CoMP-S instrument:
  - tunable Lyot filter + Stokes polarimeter (Tomczyk et al., 2008, Kučera et al., 2011)
  - VIS and near IR ranges from 500 to 1100 nm – list of the selected emission lines:
    - corona: Fe XIV 530.3, Ca XV 569.5, Fe X 637.5, Fe XI 789.2, Fe XIII 1074.7, 1079.8 nm
    - prominences: He I 587.6, H I 656.3, Ca II 854.2, He I 1083.0 nm
  - bandpass FWHM: 0.028 - 0.13 nm (530 – 1083 nm)
  - PCO sCMOS detectors: 2560*2160 pixels, 0.33 "/pixel @ 656.3nm, FoV 860"*680"

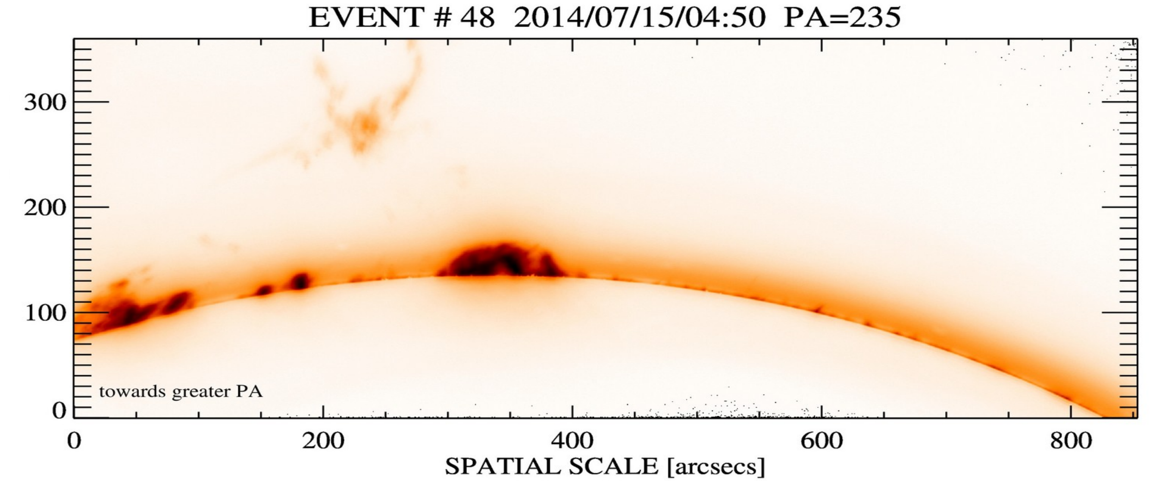
CoMP-S/LSO: observing program

Observing program:

- CoMP-S/LSO obs_prog_002
- Hα spectral line: 656.28 nm - 9 points, 0.025 nm step, exposure time: 50 ms, scan time: 22 s
- FoV: 2560*2160 pixels, 0.33 “/px @ 656.3 nm, FoV 860”*680”
- time series: typically a sequence of ~1/2 hour runs interrupted by calibration measurements
- time period: 2013/08/02-2014/08/19: in total 52 promising targets of different type/quality observed
- CoMP-S/LSO obs_prog_002 summary page :

EVENT #	DATE YYYY/MM/DD	POSITION [degrees]	TIME [UT]	SPANS [minutes]	DATA ACQUSITION [type]	CoMP-S/LSO notes	CoMP/MLSO before/after
52	2014/08/19	90	05:29-06:55	86	DARK,FLAT,OBSE		
51	2014/08/03	120	05:18-05:34	16	THRO,	some cirruses	
50	2014/07/20	290	06:47-06:15	28	DARK,FLAT,OBSE,THRO,OREX		
49	2014/07/19	270	05:32-06:18	46	DARK,FLAT,OBSE,THRO	cirruses at the end of the OBSE sequence	
48	2014/07/15	235	04:50-05:38 05:40-06:32	48 52	DARK,FLAT,THRO,OBSE,TARG,OREX	some cirruses	
47	2014/07/13	230	04:46-05:34	48	DARK,FLAT,THRO,OBSE,TARG,OREX		





CoMP-S/LSO Hα spectral line: 656.28 nm - raw data

CoMP-S/LSO and HOP237

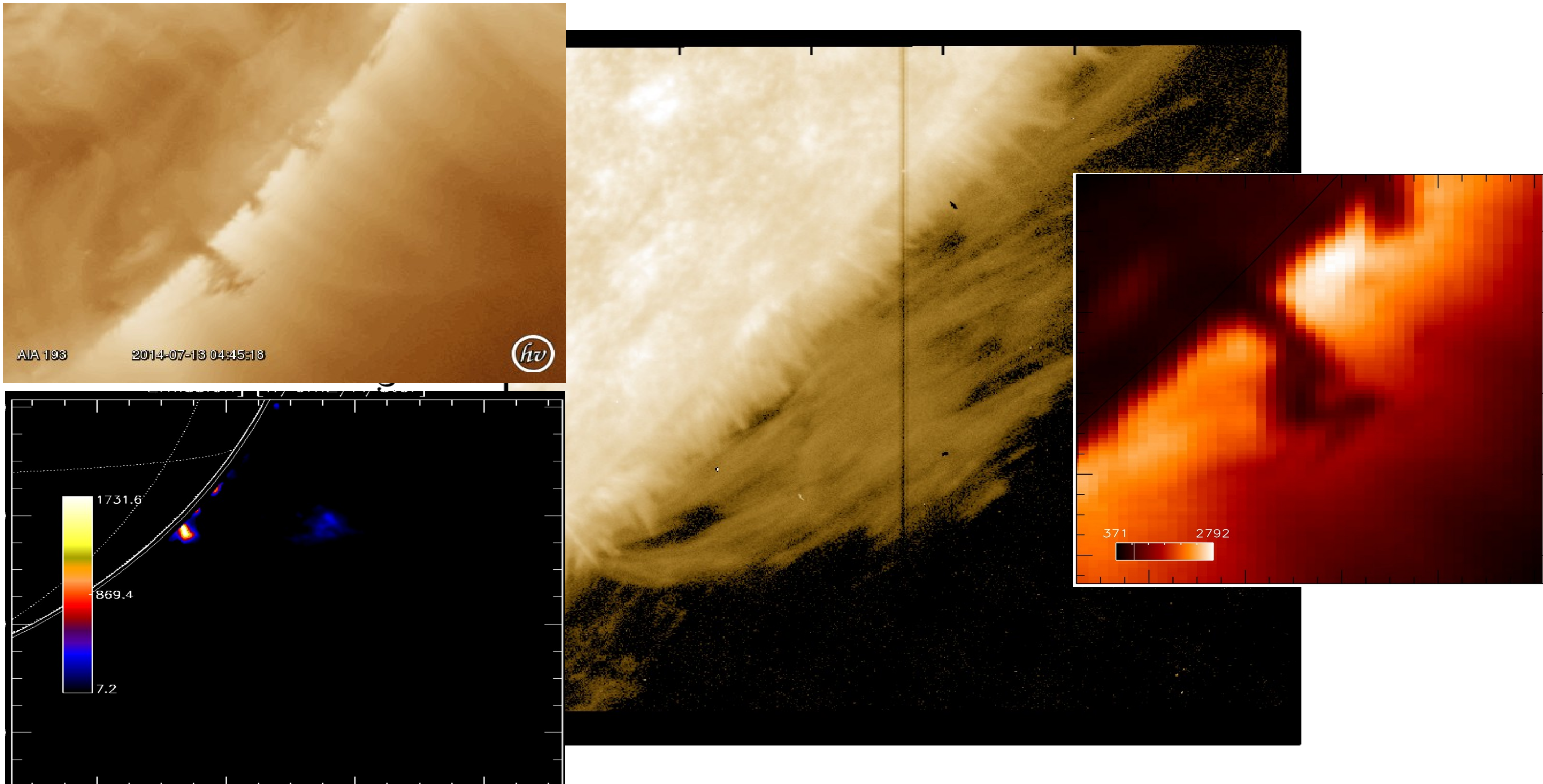
HOP 237: Hinode/EIS (SDO/AIA + IRIS)

- Hinode observing program: Spectroscopic study of “magnetic tornadoes" - proposers: Su, Veronig, Temmer, Gömöry, Rybák → contact persons: Gömöry + Culhane
- EIS: Fe X 184.54, Fe VIII 185.21, Fe XII 186.88, Ca XVII 192.82, Fe XII 195.12, Fe XIII 202.04, Fe XIII 203.82, He II 256.32, Si VII, 275.35 Å
- Strategy: 2D raster, 1D sit-and-stare, 2D raster
- Targets: well-defined prominences (with significant “shadows” in several SDO/AIA channels)
- Campaigns: 2013/09/09 - 09/29, 2014/07/12 – 07/19, 2015/11/01-2015/11/30
- Real observations: 2013/09/09,11,12,16,18; 2014/07/13,14,15,16,19

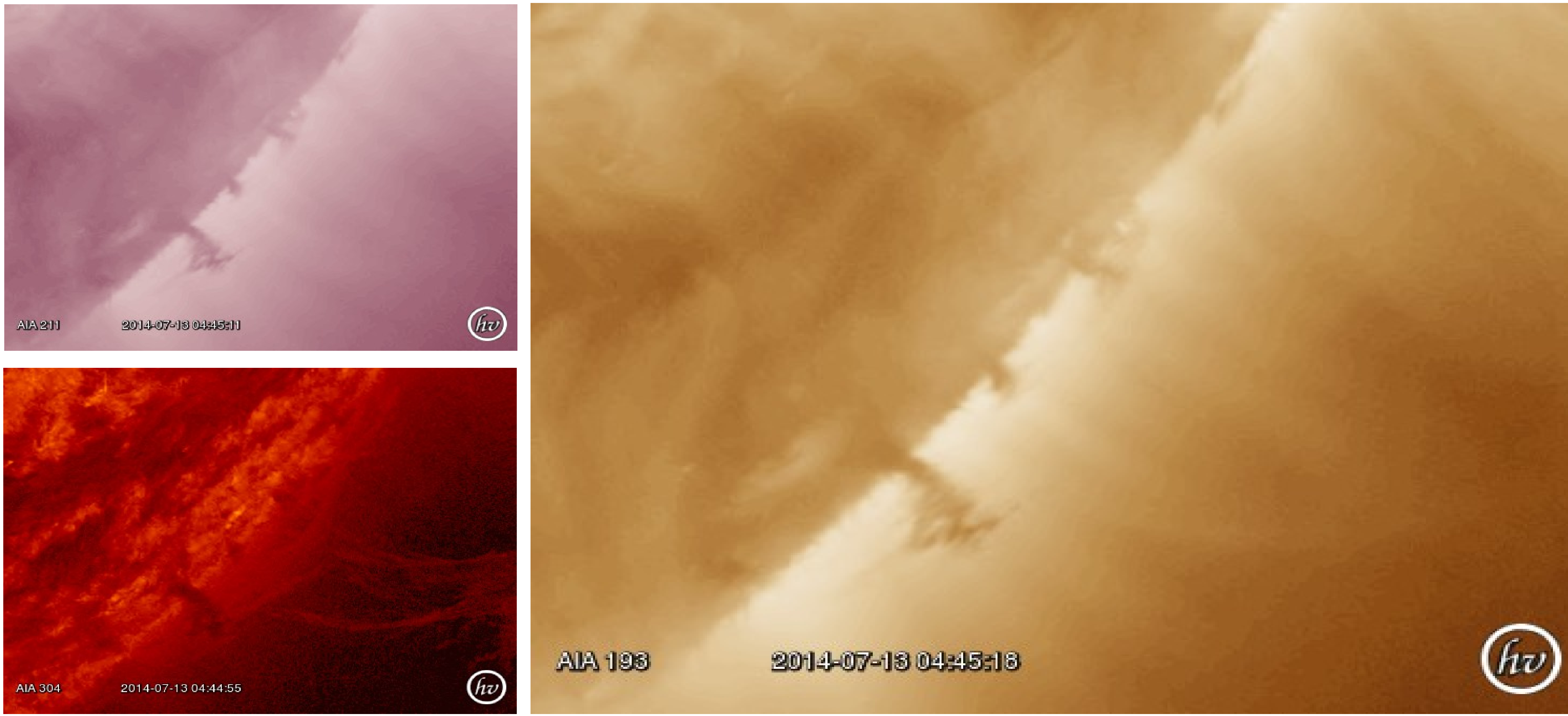
Hinode HOP237 + CoMP/LSO obs_prog_002 (+ IRIS) together:

- 13/07/2014: a nice target - a tornado-like prominence (centre: X,Y = [+730”,-635"]), good CoMP-S data, EIS raster data only, IRIS SJI+SP
- Timing: CoMP-S : 04:46-05:34 → 48min
  EIS : 05:27-06:10 raster → 43 min
  IRIS : 05:00-05:09 SP SaS → 9min, 05:00-05:23 SJI → 23 min
  SDO/AIA : “business as usual...”
- CoMP-S/LSO ~ EIS/Hinode:
  - simultaneously: no simultaneous EIS spectra with the CoMP-S 2D spectral scans
  - the closest moments: **a raster scanning the prominence ~20 min after the CoMP-S 2D spectra**
- CoMP-S/LSO ~ IRIS:
  - simultaneously: IRIS **sit-and-stare SJI+SP (X=734") with the CoMP-S 2D spectral scans for 23 min**

CoMP-S/LSO and HOP237: 2014/07/13 target

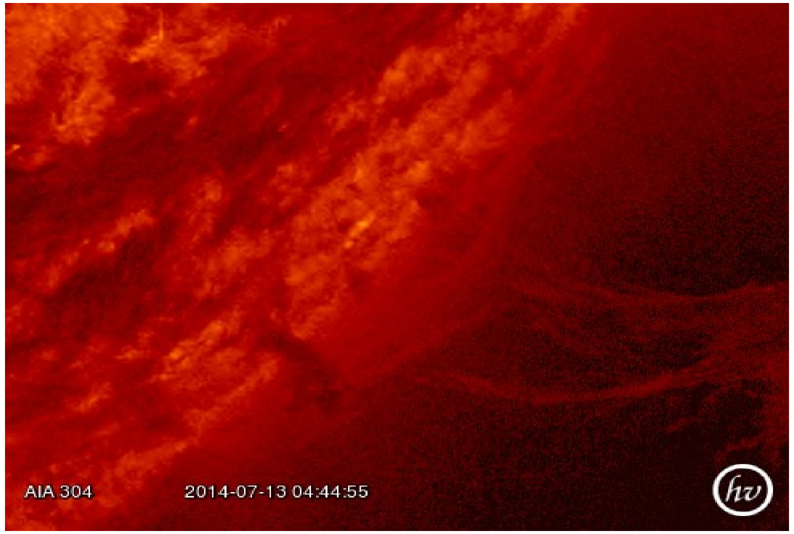


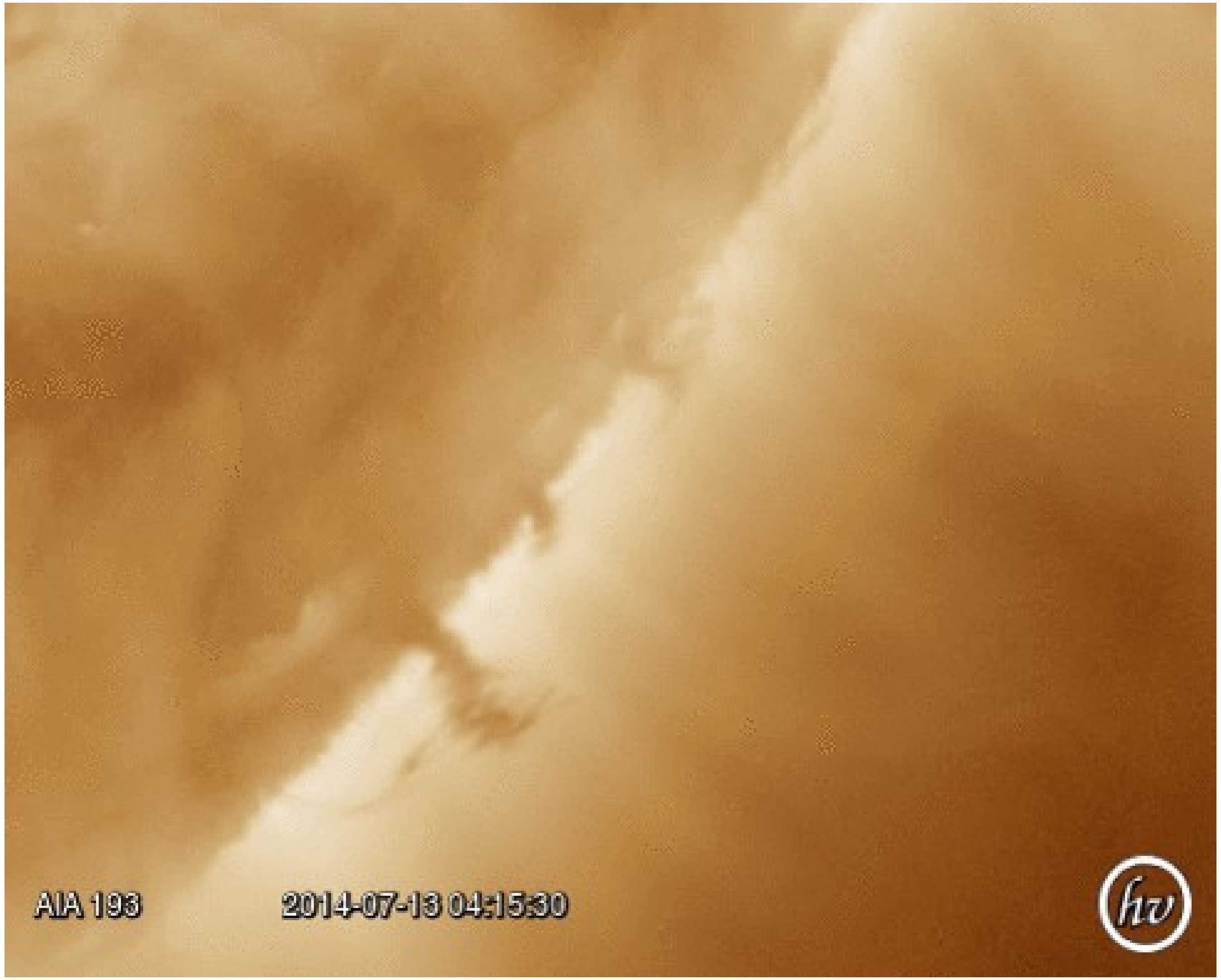
SDO/AIA: 2014/07/13 observations



SDO/AIA 211, 304 image + 193 image (starting snapshot for movie at the next slide)

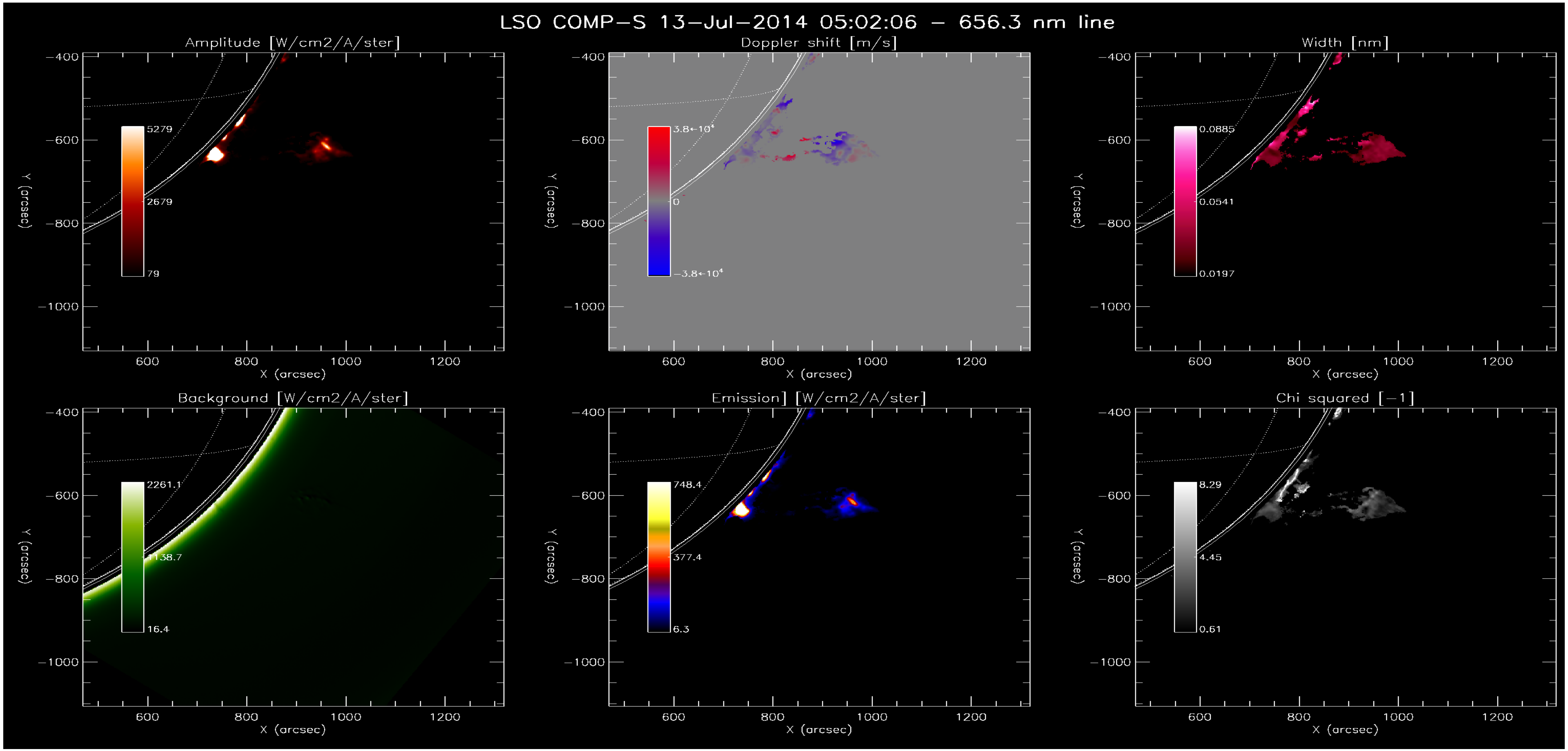
SDO/AIA: 2014/07/13 observations





SDO/AIA 211, 304 image + 193 movie

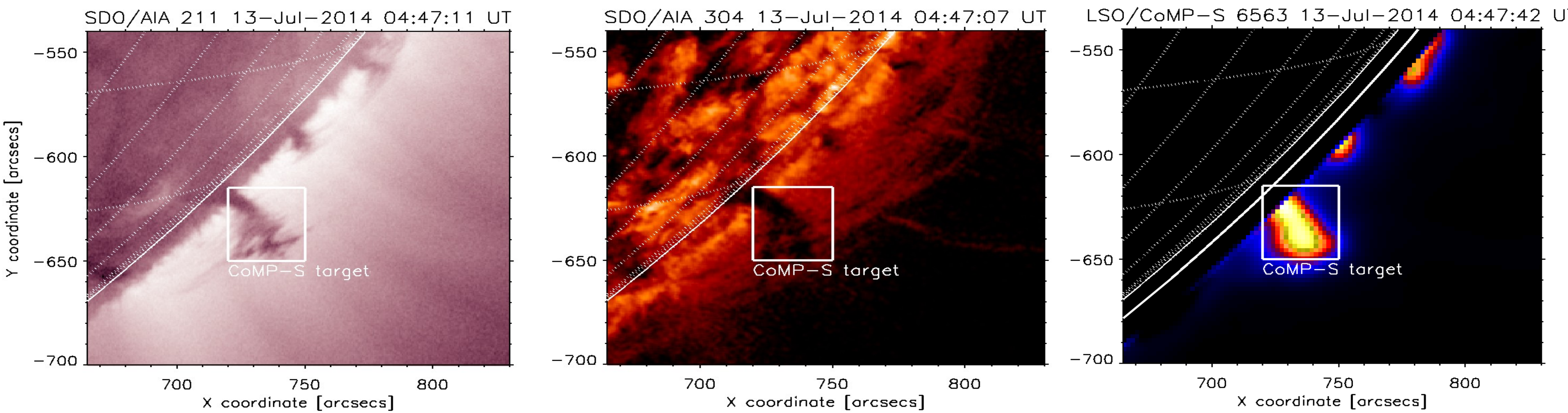
CoMP-S/LSO: 2014/07/13 observations



CoMP-S/LSO Hα 656.28 nm - 2014/07/13 05:02:26, PA=235: the Gaussian line parameters and κ^2 maps

CoMP-S/LSO: 2014/07/13 observations

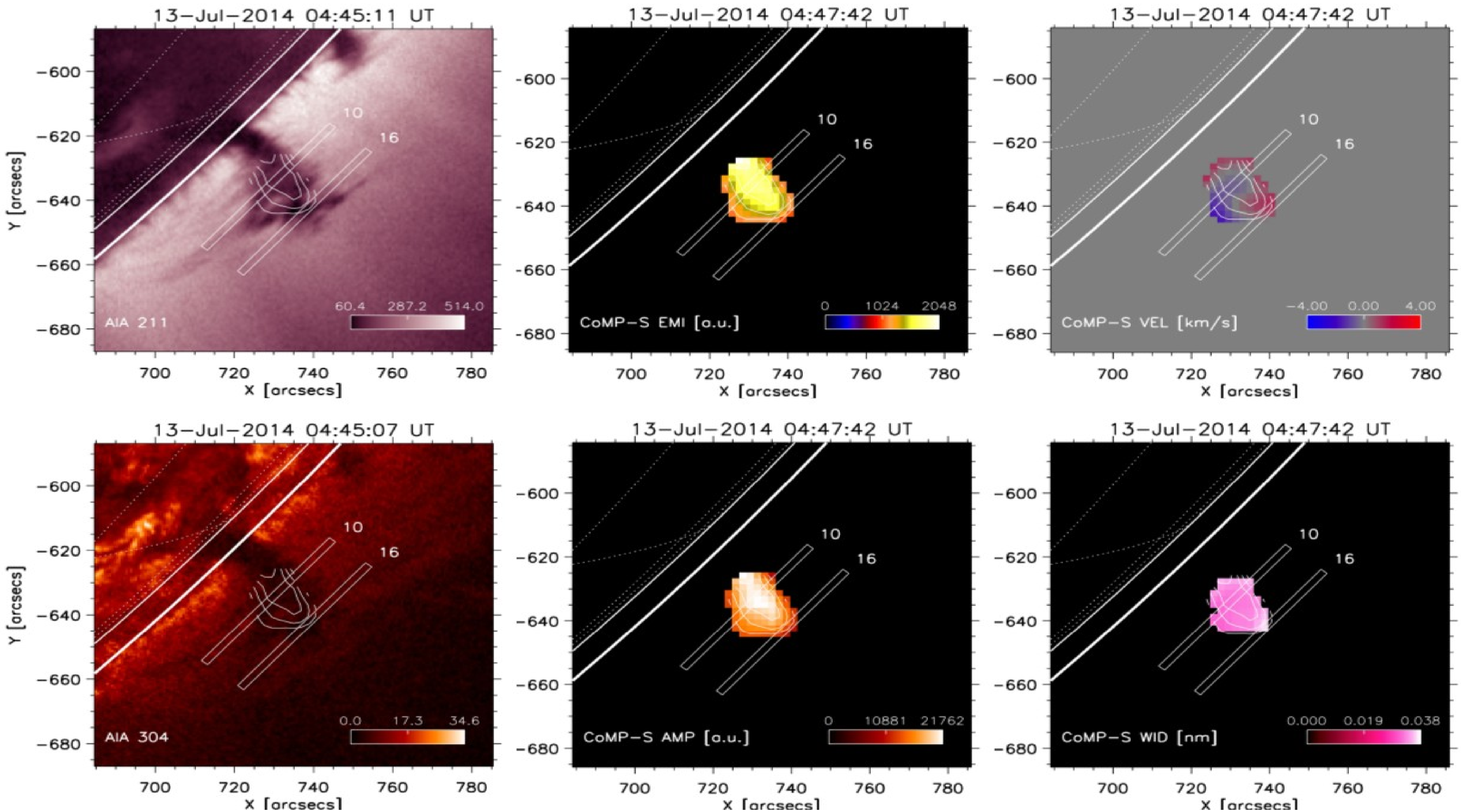
- date/time/observer: 2014/07/13: 04:47–05:32 UT, J. Kavka (and work of the LSO staff made before)
- photometric data reduction
- Stokes I parameter data only, 4x4 pixel binning for the resulting 1.33”/px spatial sampling
- sky background and the instrumental scattered light removed
- post-facto image jitter correction
- rest line wavelength correction
- Gaussian profile fitting to the individual Hα spectral line profiles
- temporal (3-scan) smoothing of the Gaussian fit parameters
- sub-arcsecond co-alignment to the SDO/AIA coordinates
- a tornado-like prominence: centre [X,Y] = ~ [+730”, - 635”]



SDO/AIA 211 and 304 Å + CoMP-S/LSO Hα time averaged integral emission

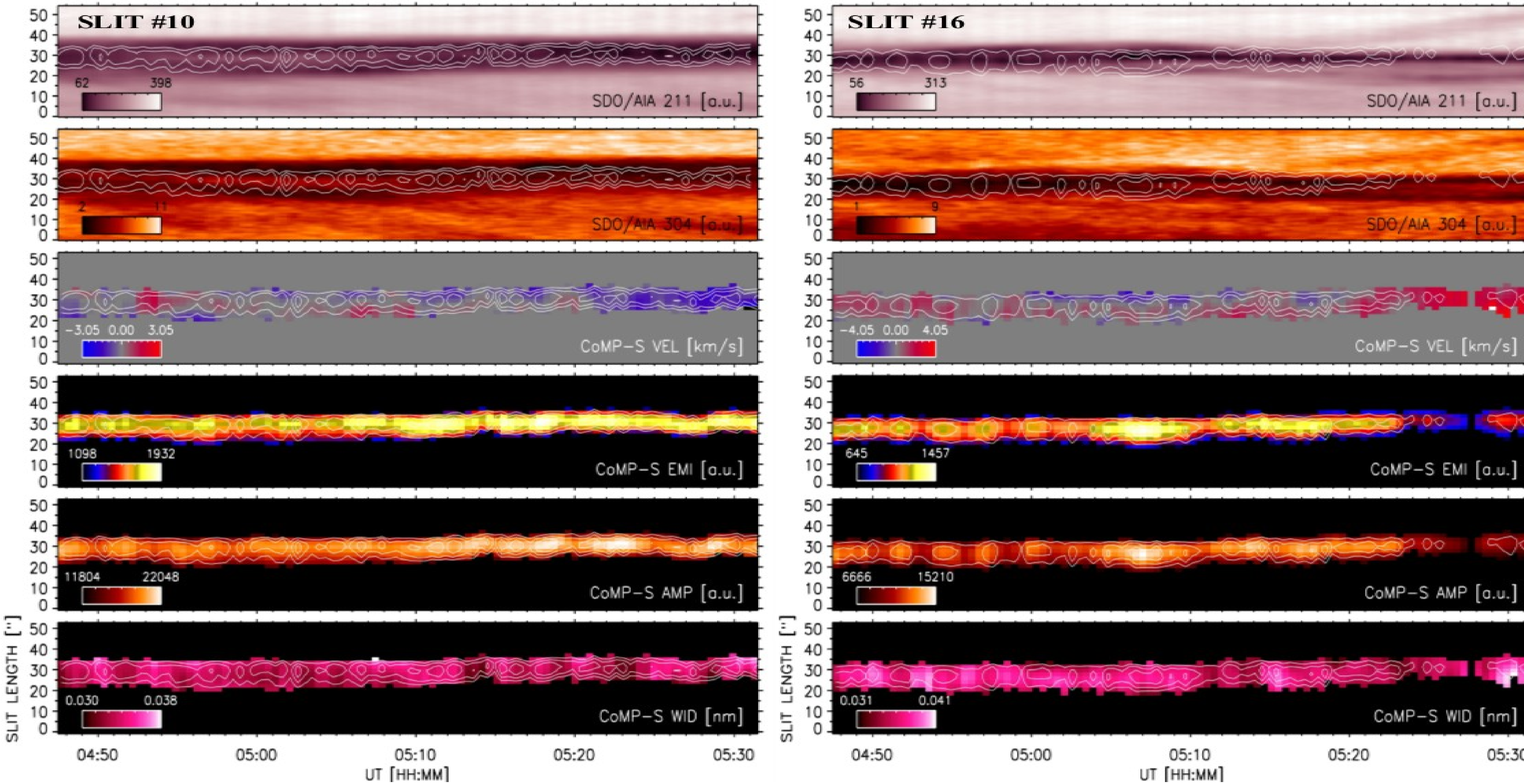
CoMP-S/LSO: 2014/07/13 observations

- A tornado-like prominence: centre [X,Y] = ~ [+730", - 635"] → spatial pseudo-slits



SDO/AIA 211 and 304 Å & CoMP-S/LSO Hα integral emission, Doppler shifts, the Gaussian amplitude and line width

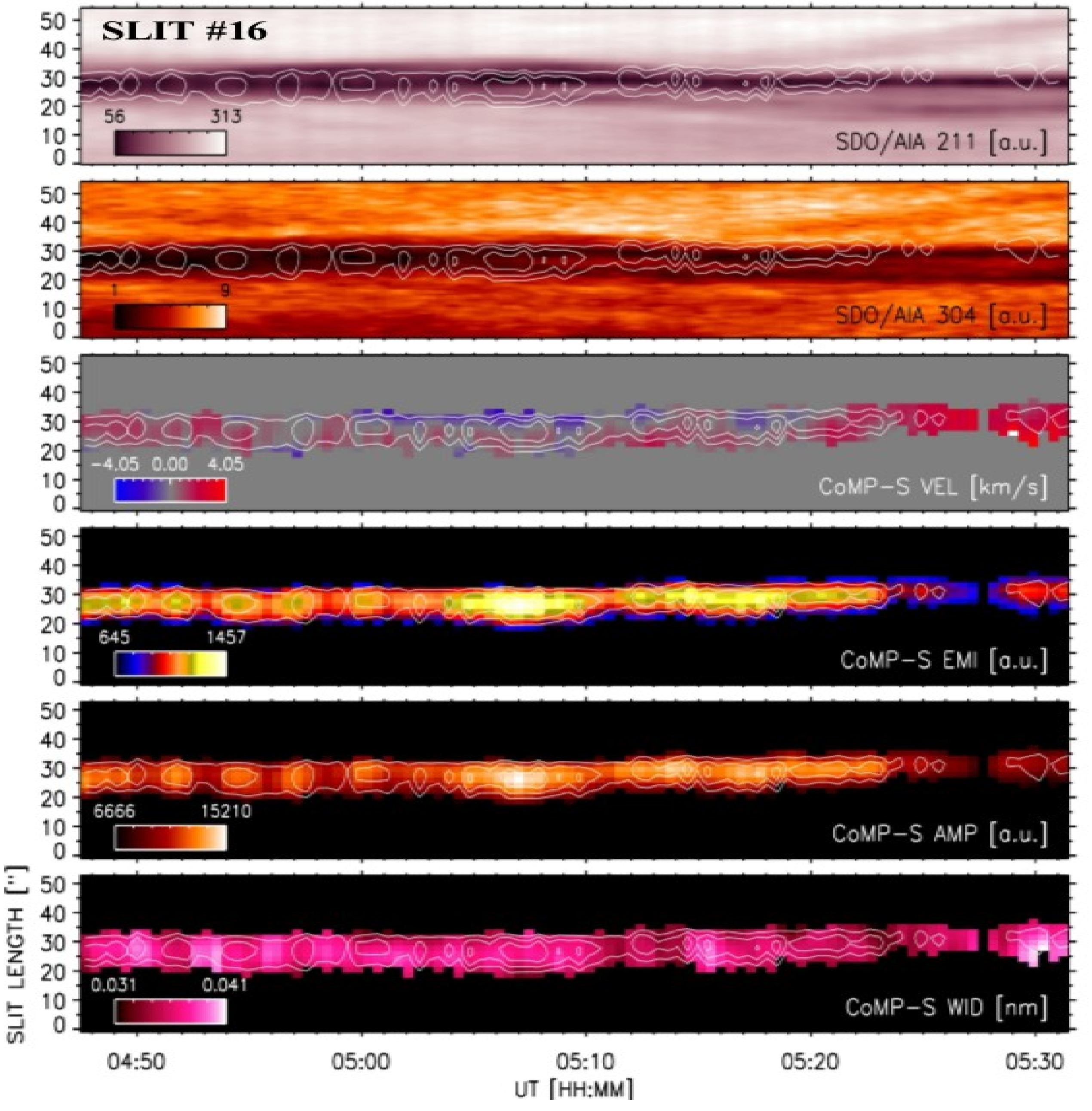
CoMP-S/LSO: 2014/07/13 results



SDO/AIA 211 and 304 Å & CoMP-S/LSO Hα Doppler shifts, integral emission, the Gaussian amplitude and line width

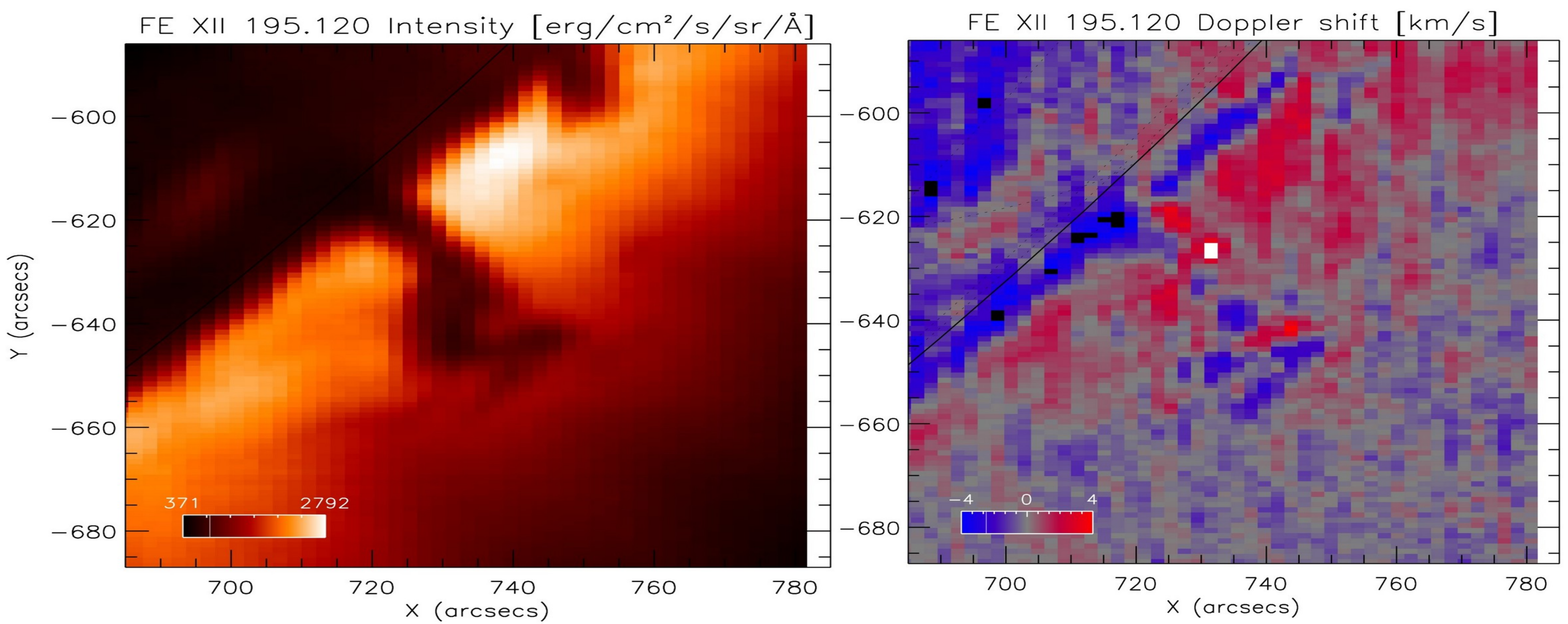
CoMP-S/LSO: 2014/07/13 results

- clear apparent vortical motions in the SDO/AIA intensity movies lead to a typical time-space behaviour of this tornado-like structure
- the Doppler shifts do not show a permanent blue/red-shift pattern along the vertical axis of the structure during the observing time
- interval although there are short time intervals (~10 minutes) of the opposite Doppler shifts across the structure
- in general, the Doppler shifts variations are not clearly matching the Hα integral line emission or the EUV AIA intensity behaviour
- the Doppler shift variations do not show any regular oscillatory behavior in time



Hinode/EIS: 2014/07/13 observations

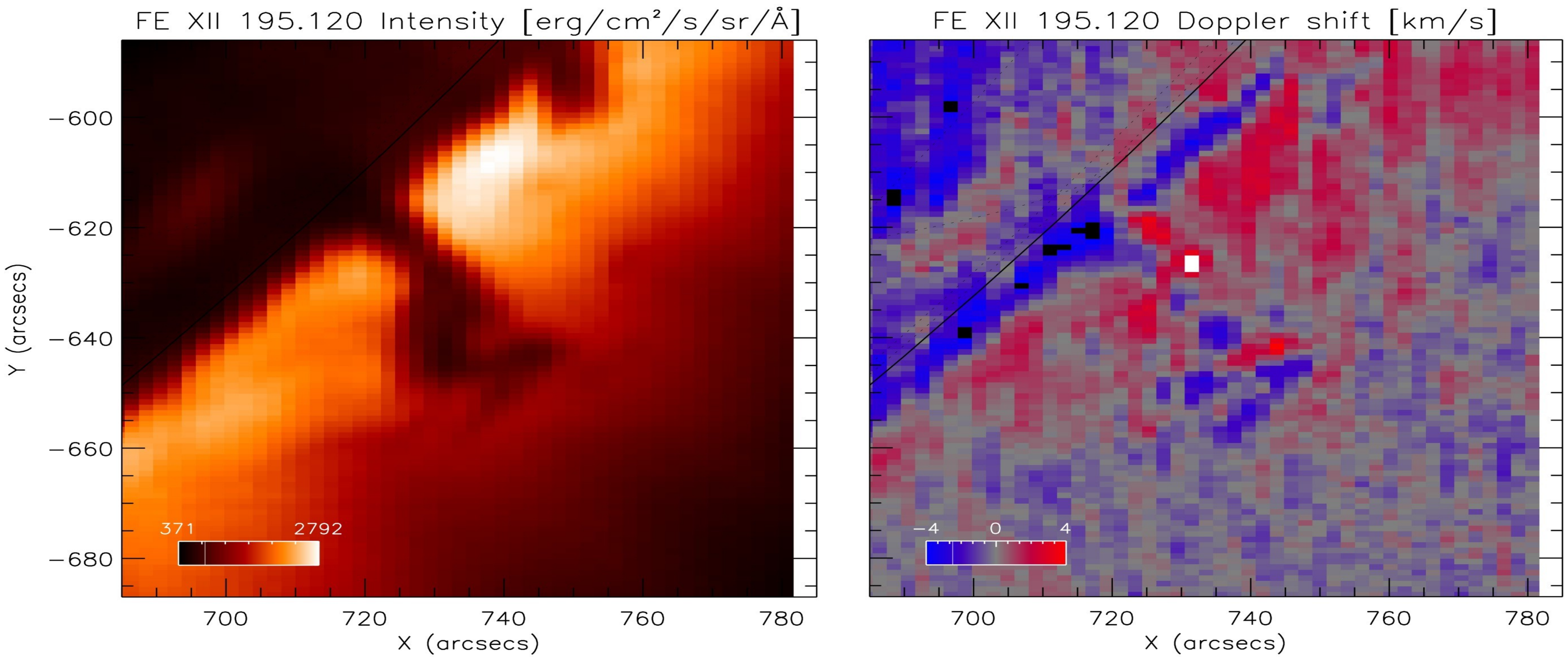
- Data summary:
  start raster + 3 s-a-s runs + end raster
  05:27-06:10 06:10-06:35 + 07:00-08:10 + 08:40-09:10 09:10-09:53 UT
- spectral lines: Fe X 184.54, Fe VIII 185.21, Fe XII 186.88, Ca XVII 192.82, Fe XII 195.12 (logT=6.1), Fe XIII 202.04, Fe XIII 203.82, He II 256.32, Si VII, 275.35 Å
- basic reduction + Gaussian fitting of 5 lines + zero point Doppler shift correction + EIS~AIA coalignment



EIS/Hinode Fe XII 195.12 Å raster: the Gaussian line amplitude + the Doppler shifts

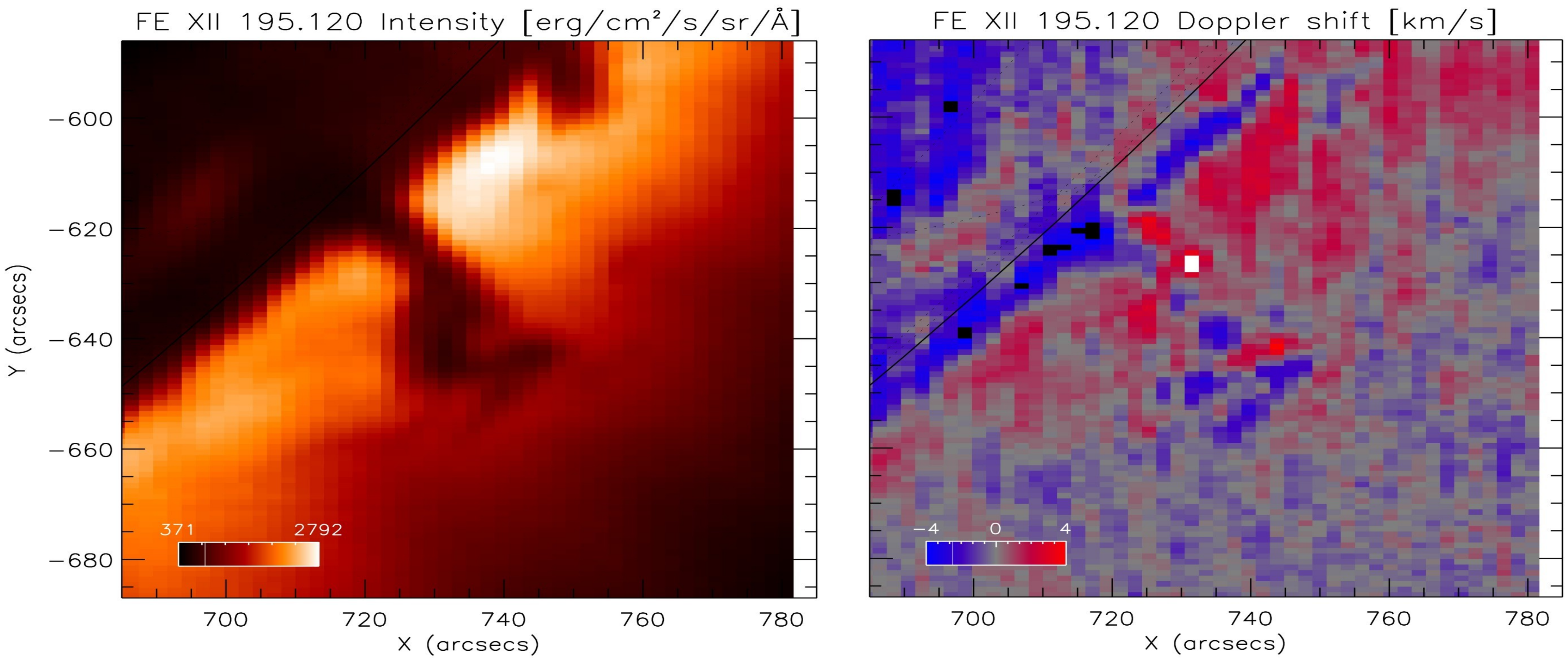
Hinode/EIS strange things

- **A hot plasma flow above the white-light limb?** And for all investigated 5 spectral lines?



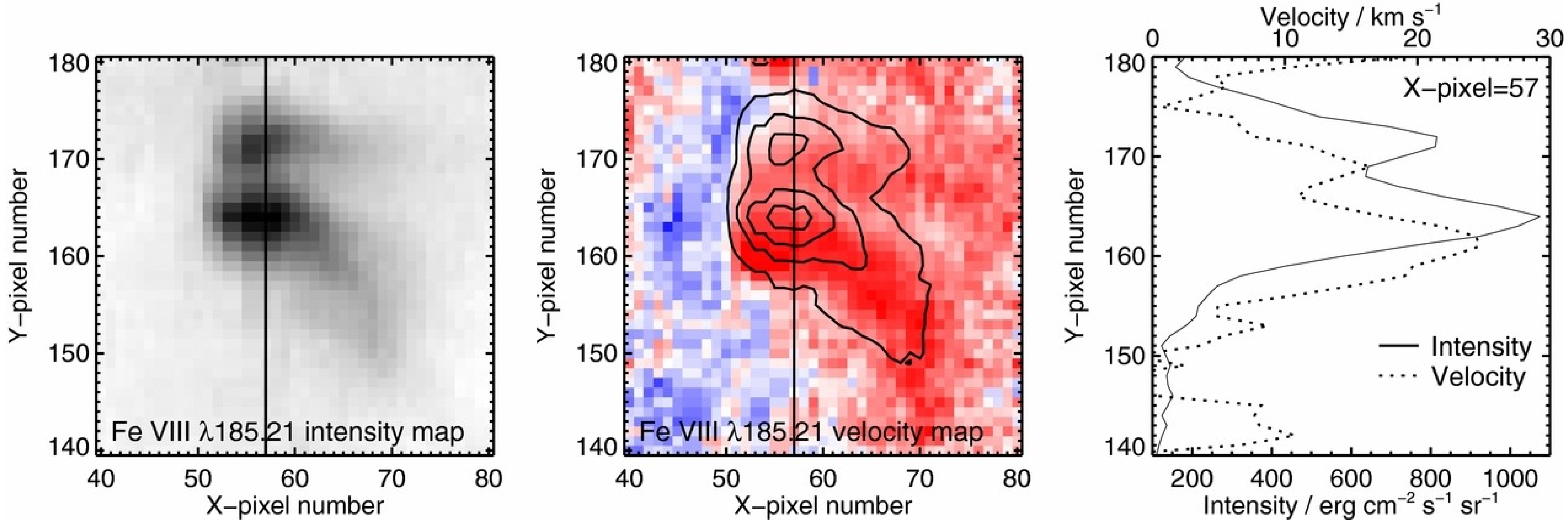
Hinode/EIS strange things

- **A hot plasma flow above the white-light limb?** And for all investigated 5 spectral lines?
- Let's search the ADS reply for "EIS" and "velocity" OR "Doppler shift" keywords: moving backwards checking the paper titles and searching for the "reference" authors (and/or EIS WIKI reading of as many as possible subpages...)



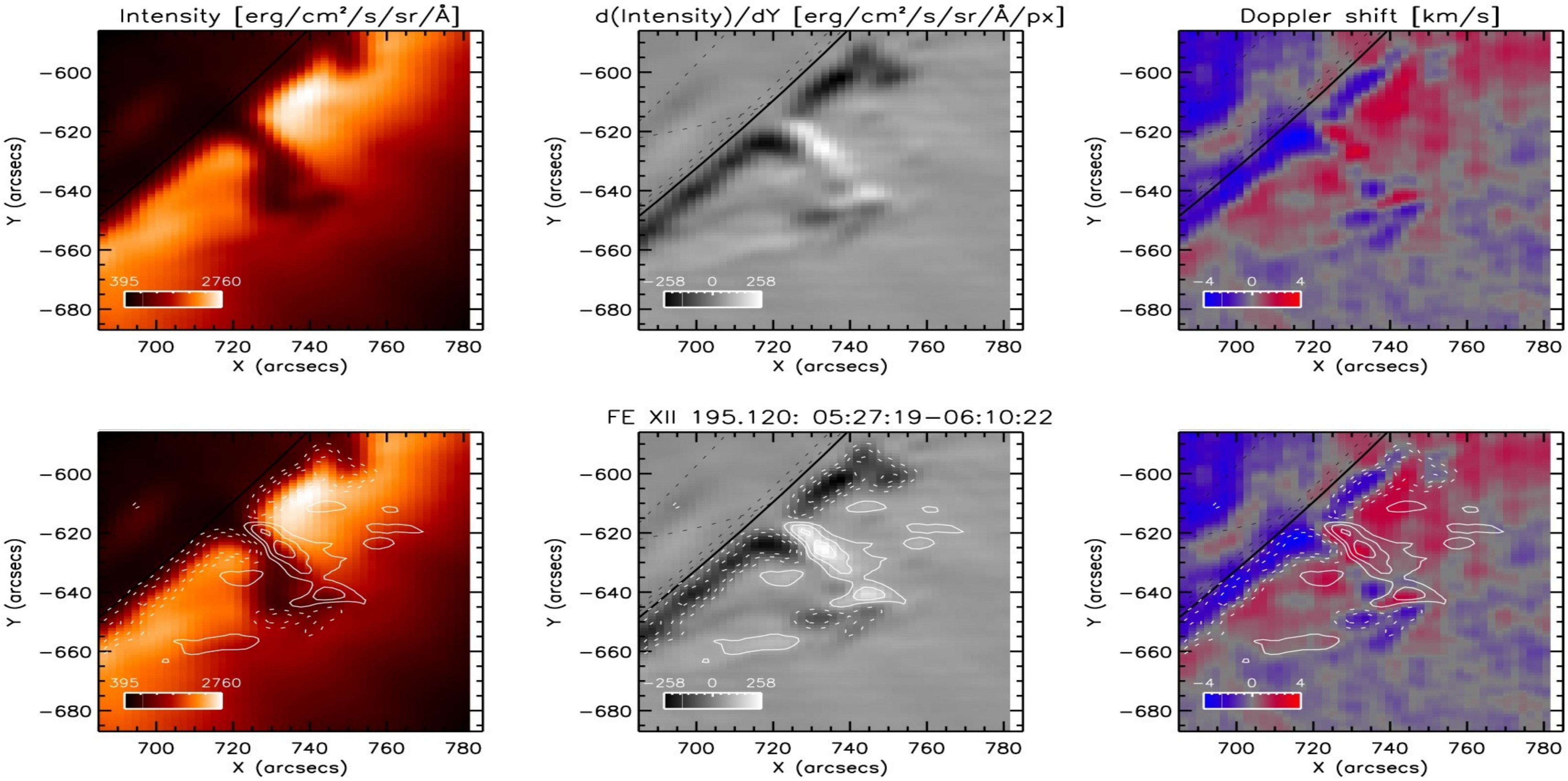
Hinode/EIS strange things

- "A striking feature of velocity maps obtained from EIS is that regions of strongest redshift or blueshift are often spatially offset from regions with the highest intensity" - reference: Young, O'Dwyer, Mason, 2012, ApJ 744, 14, Appendix B
- EISWIKI: solarb.mssl.ucl.ac.uk:/eiswiki/ "Spatial offset of velocity features relative to intensity features"
- Reason: an asymmetric PSF of the EIS spectrometer with an "ellipse major axis" tilted relatively to dispersion/slit → V+5 or V-5 km/s over 3-4 pixels



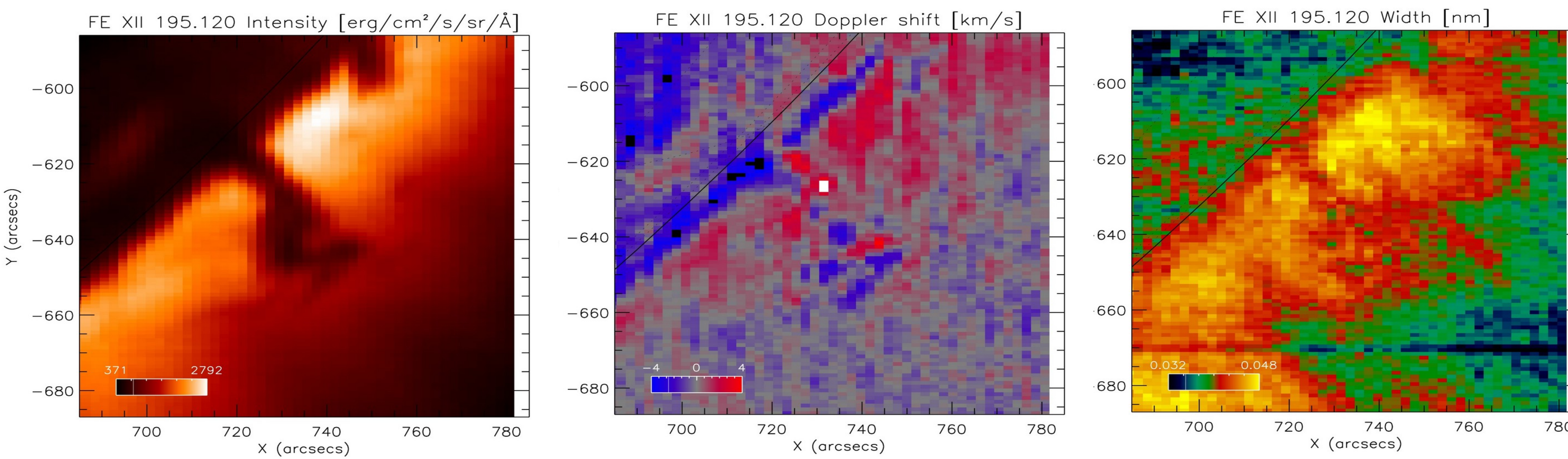
Hinode/EIS strange things

- A selected measure of the effect: an intensity gradient along the slit - dI/dY [erg/cm^2/s/sr/Å/pixel]



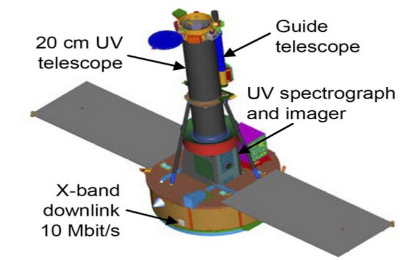
ESI/Hinode: 2014/07/13 results

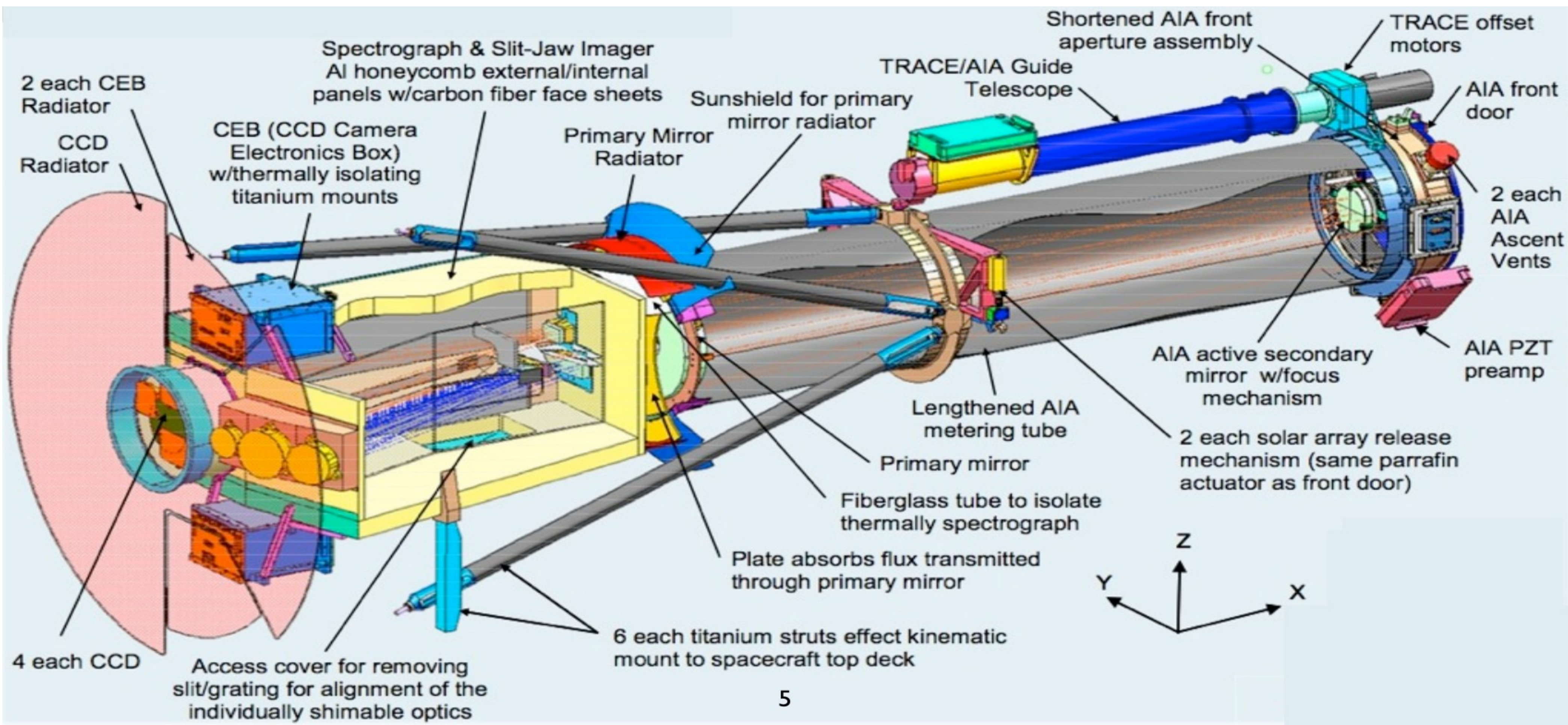
- the EIS instrumental artifact for most of the target area in all 5 spectral lines
- maybe there are possibilities: high dI/dY mask over the the EIS raster SPCHs
- previous results on tornado plasma rotation from the EIS Doppler shift (e.g. Su et al. 2014, Levens et al. 2015 – artifacts (maybe polar plumes are not affected and can be used for such analysis)



IRIS satellite

- a 20-cm aperture classical Cassegrain telescope: 0.167”/px image, 170*170” FOV
- is a Czerny-Turner spectrograph with a predisperser: 2775-2825 + 1332-1406 Å
- a slit-jaw imager: C II 1330, Si IV 1400 (80 kK), Mg II h/K 2796 (~10 kK), …
- exposure time: 1-10 s
- spectral sampling: 12.5/25.0 mÅ/px
- since June 2013: in few seconds exposure → sub-arcsec & ~1 km/s resolution





IRIS 2014/07/13 observations

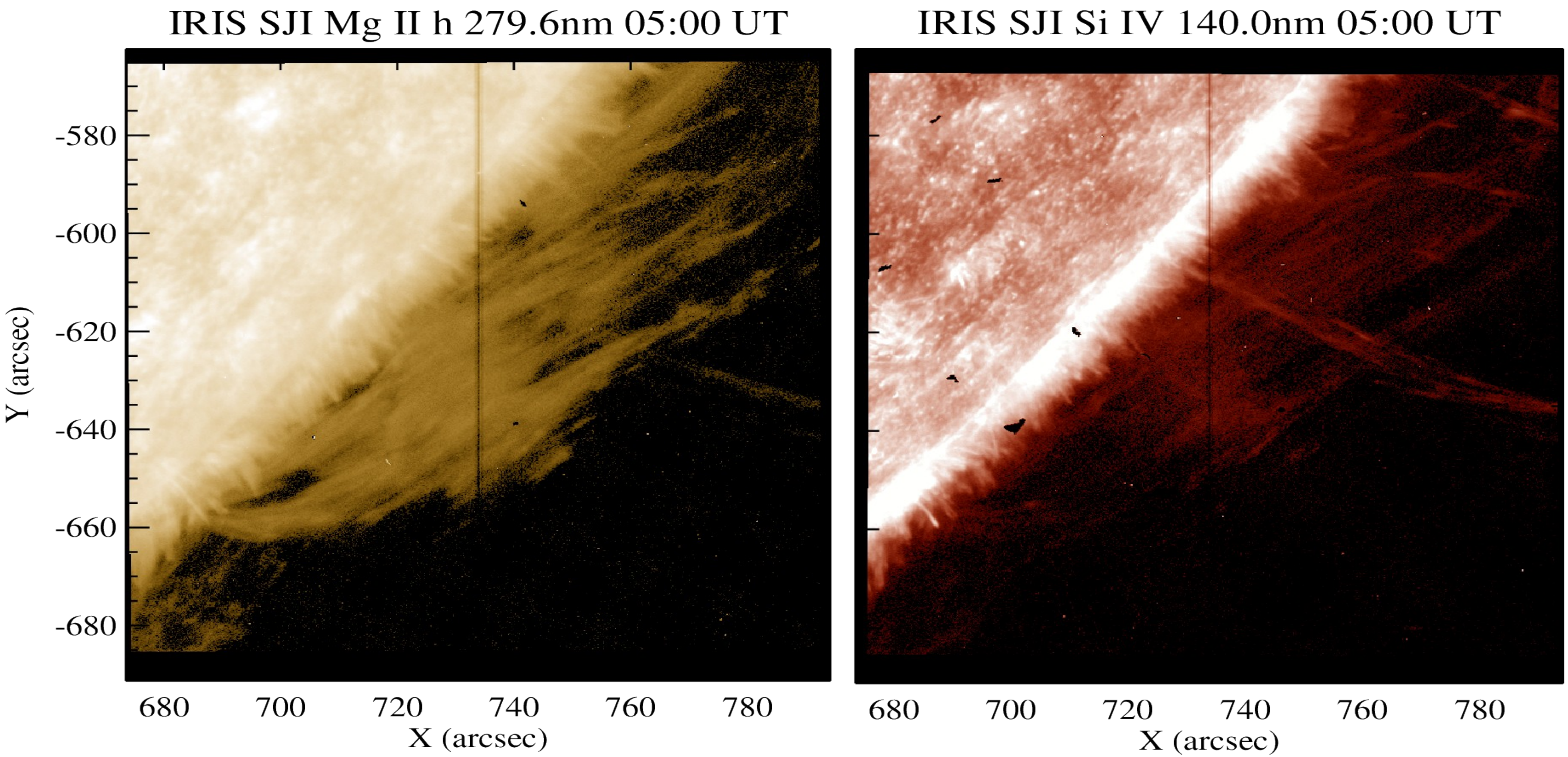
- Data summary:
  sit-and-stare run + the dense rasters
  05:00-05:23 06:30:31-07:03

- Sit-and-stare run: **REAL** SJ+SP DATA: 05:00:17-05:23:17, center = x,y: 734",-627",
  SJ : FOV 119"x119", cadence: 33s, 1400 Å: 44 images, 2796: 43 images
  SP: FOV: 1D 119" Cadence: 16.4s, lines: **Mg II k&h 2796 Å**, (C II 1336, O I 1356, Si IV 1394+1403, Fe XII 1349 Å – no prominent signal, binning needed)

- Dense synoptic rasters: 06:30:31-07:03:29, center = x,y: 734",-626"
  SP : FOV: 33"x174" Steps: 96x0.35" Step/raster cadence 16.5s/991s, 2 rasters
  the same lines – CII lines with a weak signal
  SJ : FOV: 167"x174", SJ 1400: 33s, 60 imgs, 2796: 33s, 60 imgs

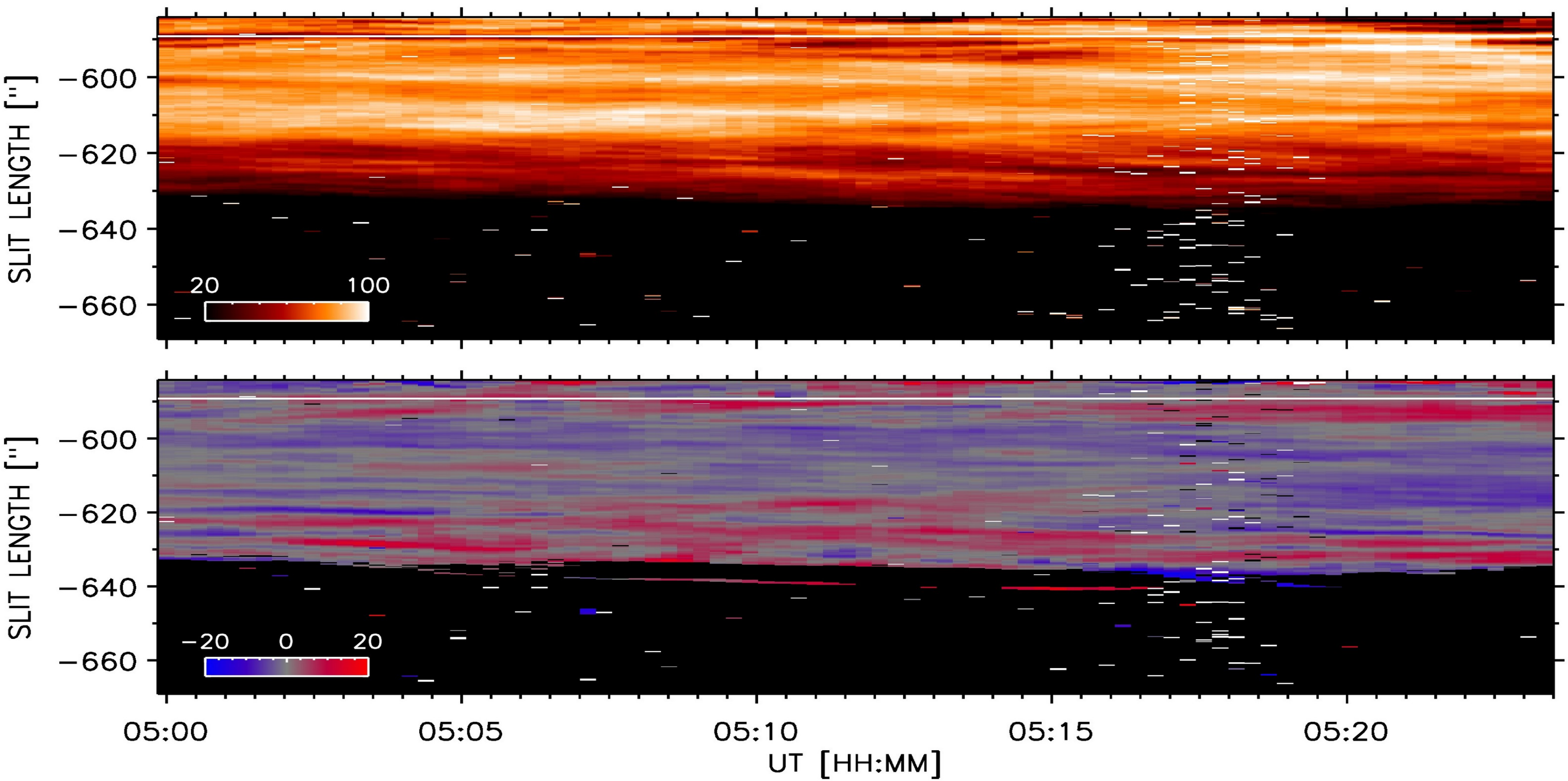
- Basic data reduction
- Mg II h 2796 Å line Doppler shifts: 2 level Gaussian fitting (1/ full line profile with no initial guess → 2/ the line far wings only and the initial guess from fit 1/)

IRIS 2014/07/13 observations: sit-and-stare run



IRIS sit-and-stare run: SJ Mg II h 2796 Å + Si IV 1400 Å

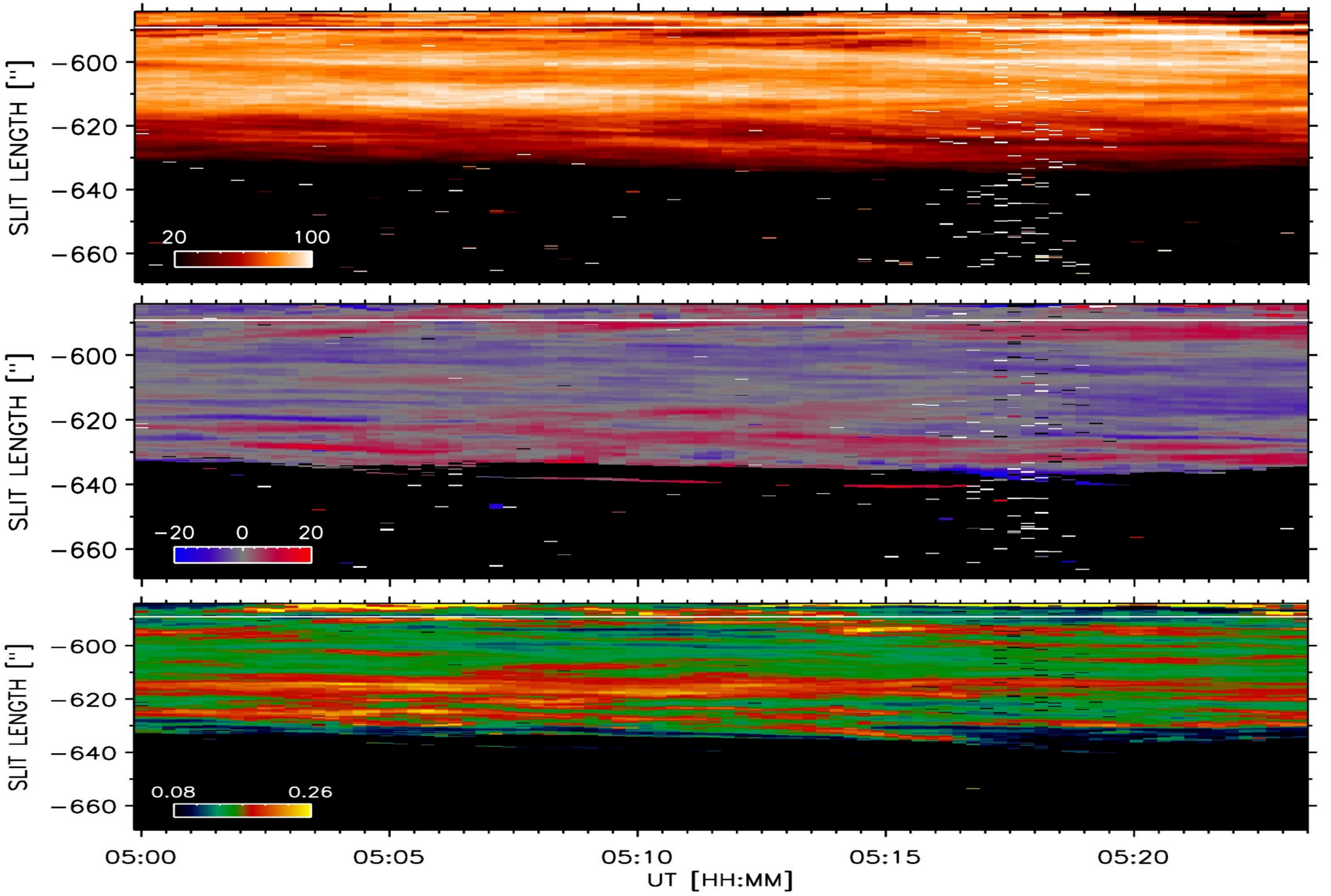
IRIS 2014/07/13 observations: intensity & Doppler shifts



IRIS Mg II h line sit-and-stare run: intensity (a.u) & Doppler shifts (km/s)

IRIS 2014/07/13 observations: intensity & Doppler shifts

- clear apparent vortical motions in the IRIS intensity movies lead to a typical time-space behaviour of this tornado-like structure
- the Doppler shifts do not show a permanent blue/red-shift pattern along the vertical axis of the structure during the observing time
- highly structured non-uniform beha-viour of the Doppler shifts (±20 km/s) in general confirming no rotation of the “tornado” body along its vertical axis
- the Doppler shift variations do not show any regular oscillatory behavior in time



IRIS Mg II h line sit-and-stare run: the Gaussian line amplitude (a.u), the Doppler shifts (km/s), the Gaussian line width (Å)

Summary

- target: particular tornado-like prominence 2014/07/13, ~05 UT, centre X,Y = [~ +730”,~ -635”]
- observations: the limited space-time coverage with only partial overlapping of different data

- the Hα line: the Doppler pattern cannot be interpreted as rotation of plasma in this “tornado” (±4 km/s)
- the UV high-temperature imaging: apparent rotational motion is observed (in 2D projection at the limb)
- the UV EIS/Hinode spectroscopy: the instrumental artifact (±5 km/s)!
- the UV Mg h line: the Doppler pattern shows highly structured non-uniform behaviour (±20 km/s) but in general confirms no rotation of the “tornado” body along its vertical axis

- results in line with previous results of: MSDP/Meudon: Schmieder et al., 2017; THEMIS+IRIS: Levens el al., 2016, 2017
- Panasenco et al. (2014): apparent rotational motion is only observed in 2D projection at the limb in the plane of the sky and no real physical rotation of the cold plasma is taking place

- One case study can not exclude generally possible tornadoes in the solar atmosphere (Wedemeyer et al., 2013, …)
- Nevertheless many of the apparently tornado-like structures considered to be physical whirpools just by analysis of the imaging data taken at the limb can be misleading interpretations (e.g. Li et al. 2012, Su et al., 2012; Panesar et al., 2013, Mghebrishvili et al., 2015)
- The CoMP-S/LSO observations can complement the high level satellite imaging observations providing an important information

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- Nevertheless many of the apparently tornado-like structures considered to be physical whirpools just by analysis of the imaging data taken at the limb can be misleading interpretations (e.g. Li et al. 2012, Su et al., 2012; Panesar et al., 2013, Mghebrishvili et al., 2015)
- The CoMP-S/LSO observations can complement the high level satellite imaging observations providing an important information

Summary

- target: particular tornado-like prominence 2014/07/13, ~05 UT, centre X,Y = [~ +730”,~ -635”]
- observations: the limited space-time coverage with only partial overlapping of different data

- the Hα line: the Doppler pattern cannot be interpreted as rotation of plasma in this “tornado” (±4 km/s)
- the UV high-temperature imaging: apparent rotational motion is observed (in 2D projection at the limb)
- the UV EIS/Hinode spectroscopy: the instrumental artifact (±5 km/s)!
- the UV Mg h line: the Doppler pattern shows highly structured non-uniform behaviour (±20 km/s) but in general confirms no rotation of the “tornado” body along its vertical axis

- results in line with previous results of: MSDP/Meudon: Schmieder et al., 2017; THEMIS+IRIS: Levens el al., 2016, 2017
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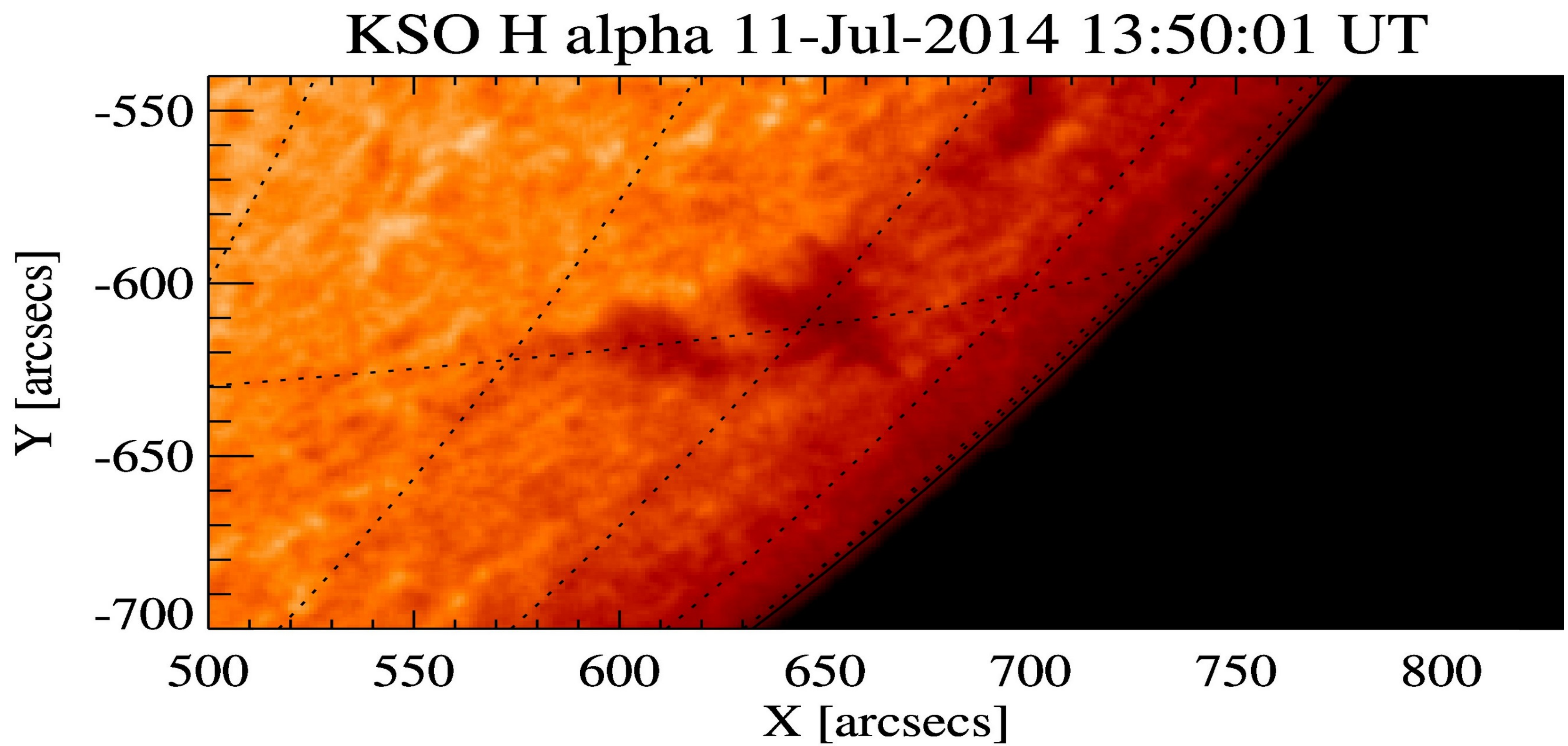
Target prominences few days before

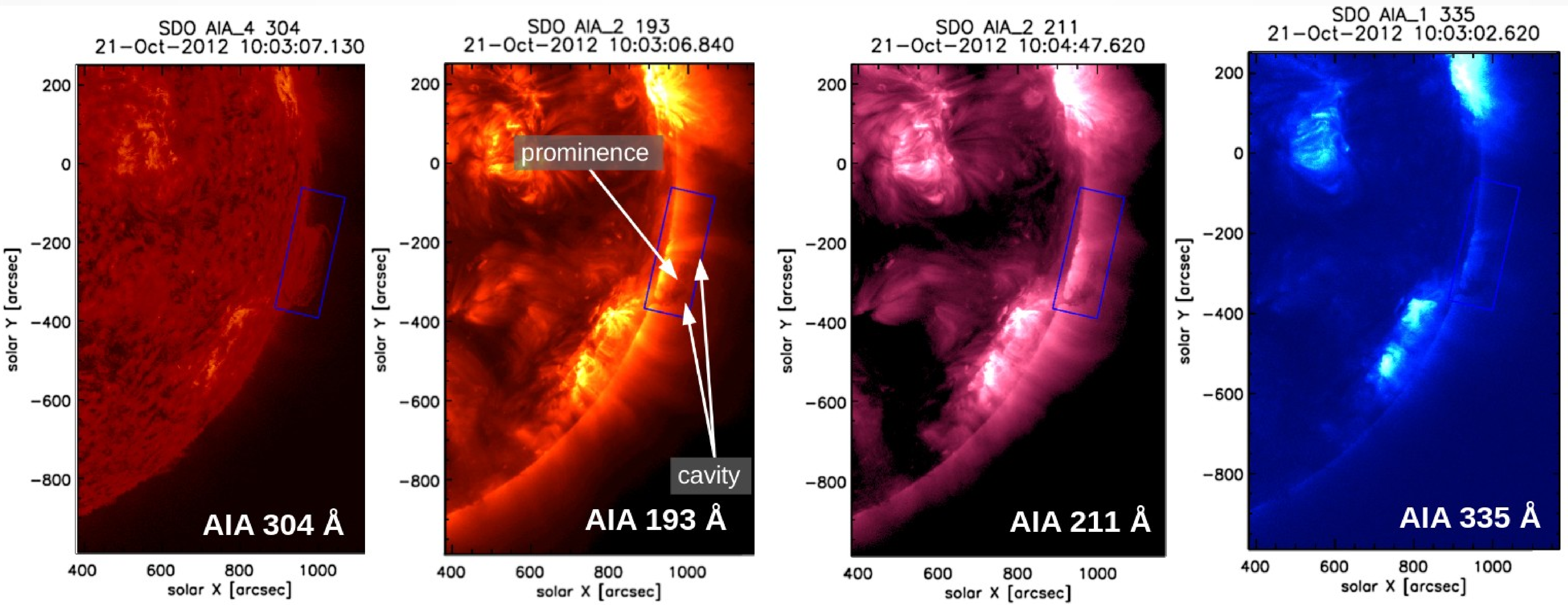


The CoMP-SCD target “tornado-like” prominence 37 hours ago

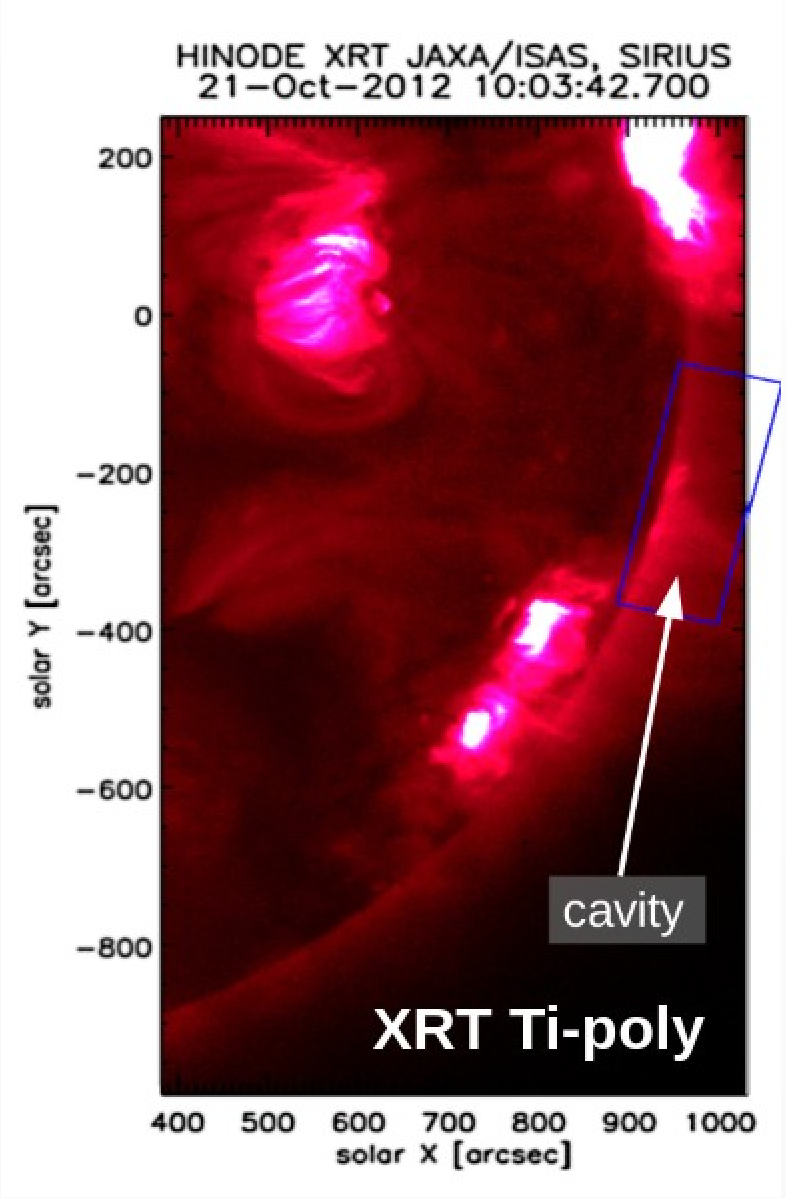
Total mass of prominences

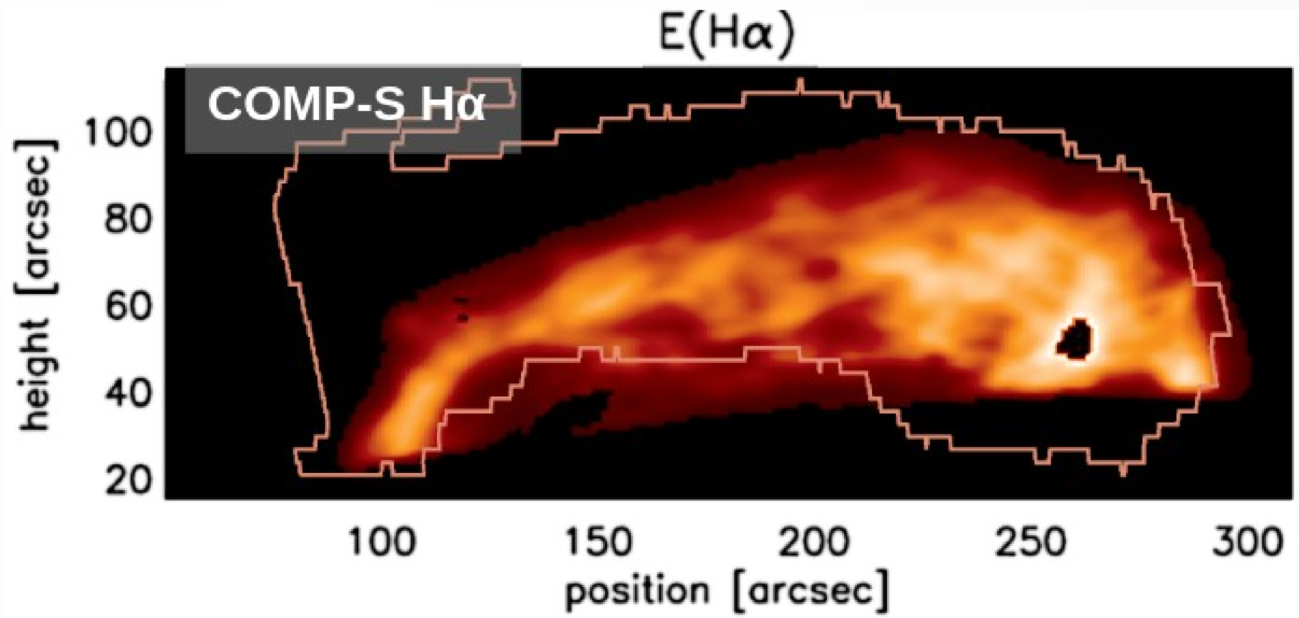
- Total mass of a prominence estimated from their observations in EUV, X-rays and the Hα and Ca II 8542 Å spectral lines
- Schwartz, Heinzel at al.

Total mass of prominences

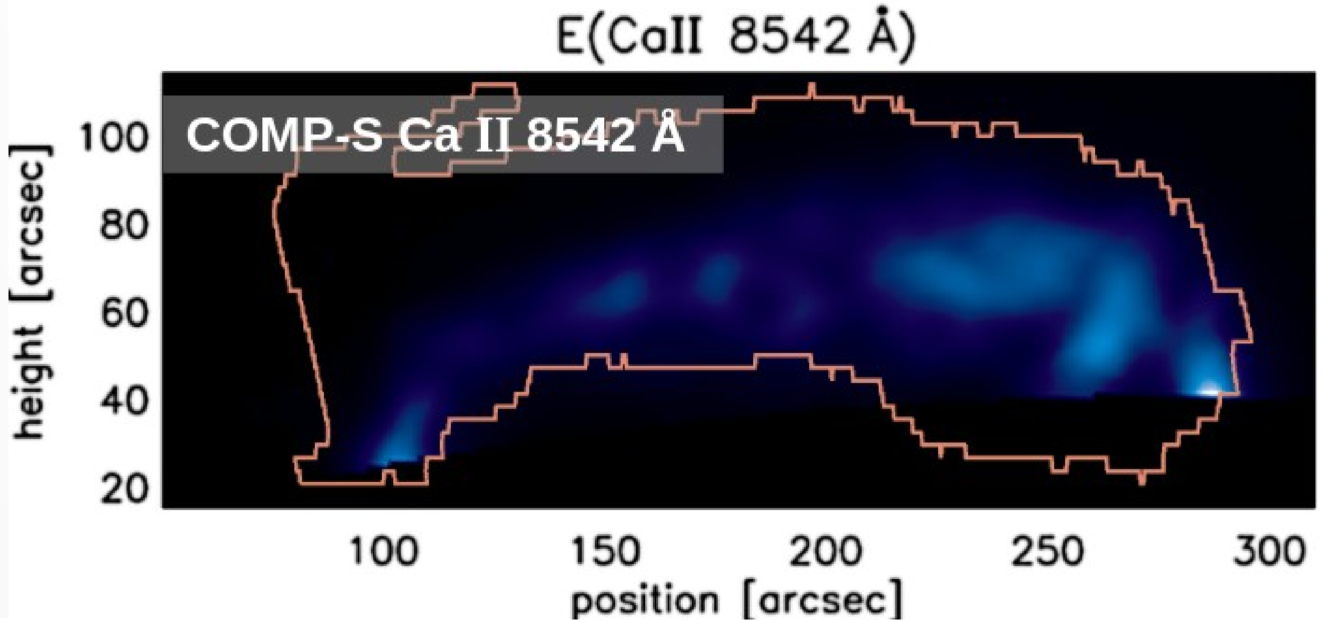


Total mass of prominences





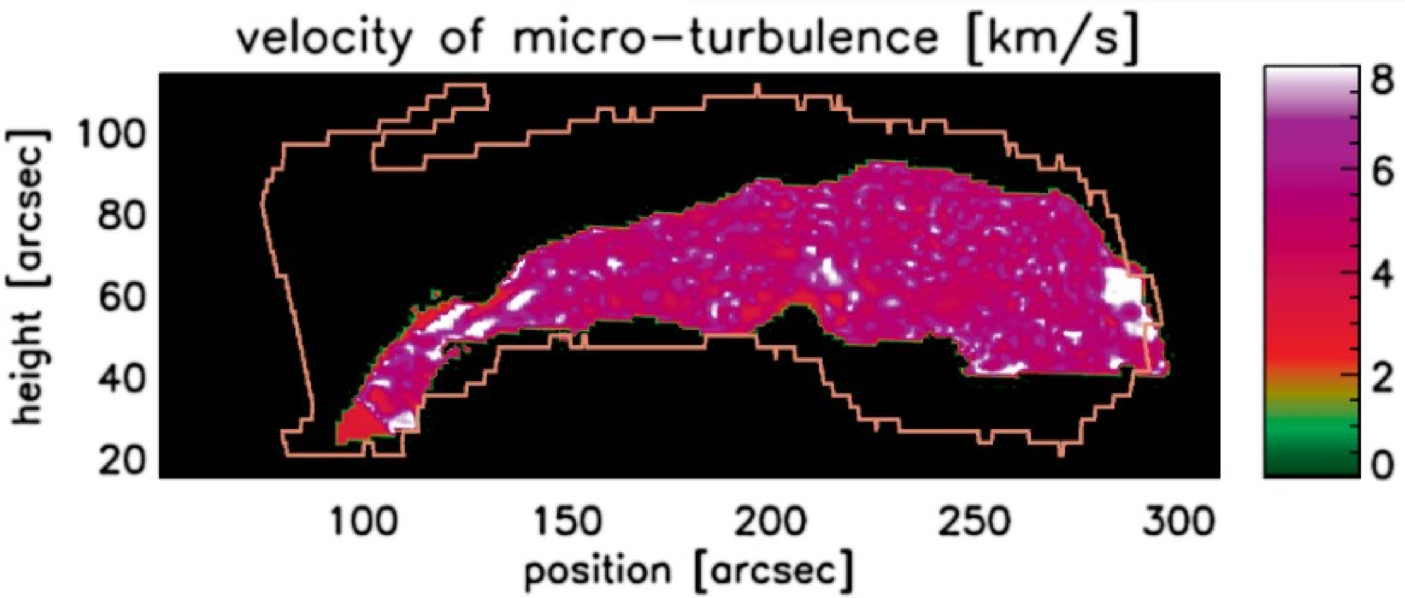
11:45 UT

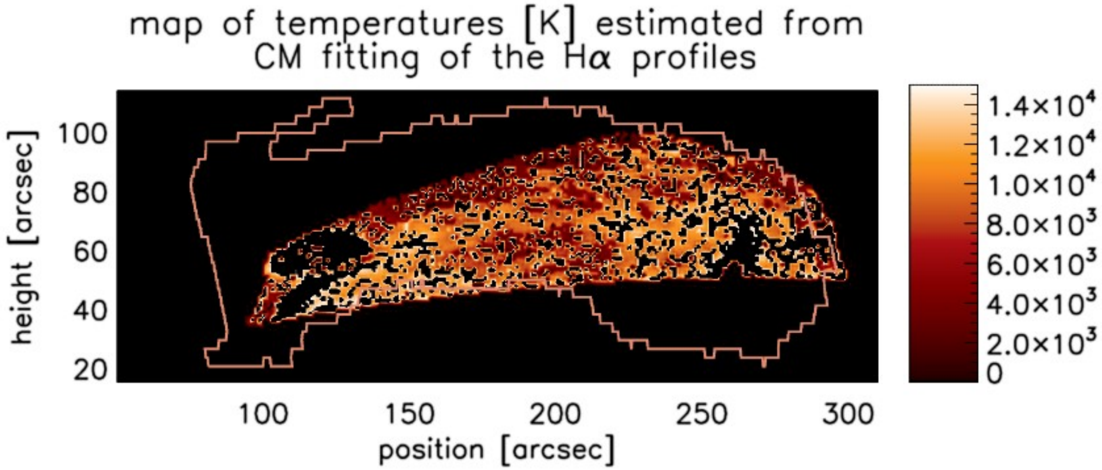


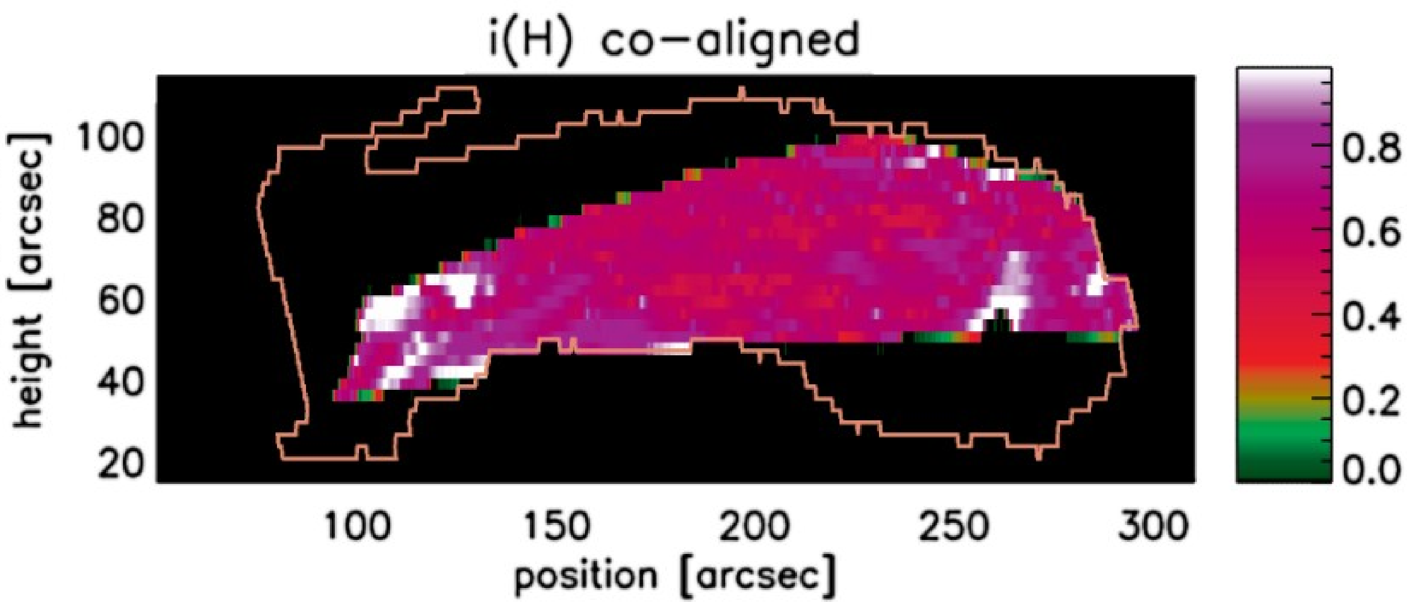
11:41 UT

Total mass of prominences

- The cloud-model fitting of the Hα and Ca II spectral lines and estimation of the ionization degree of hydrogen (Schwartz, P., Heinzel, P., Kotrč, P., Fárník, F., Kuprzakov, Yu. A. et al.: 2015a, A&A 574, A62)
- M=2.09×10^12 kg with uncertainties of ± 19%







Coronal rain

AISAS/LSO CoMP-S Observing Program Proposal

period: 2022/01-12

Principal Investigator: Zurab Vashalomidze (vashalomidze@astro.sk), AISAS

Co–Investigators(s): Jan Rybak (rybak@astro.sk), AISAS
Teimuraz Zaqarashvili (teimuraz.zaqarashvili@uni-graz.at), Uni Graz. Austria
Peter Gomory (gomory@astro.sk), AISAS

Title of program: Statistical study of behaviour of the prominences on the solar limb in relation to the stability of prominence and their possible subsequent eruption

Coronal rain

Scientific objectives:

In our recent article, based on spacecraft observational data, we studied observational evidence of coronal rain's impact on the stability of prominence and subsequent eruption (Vashalomidze et al., 2022, A&A, 658, A18, https://doi.org/10.1051/0004-6361/202040233). We analysed three solar prominences using simultaneous observations of SDO and STEREO spacecraft, which gave us the possibility to follow evolution and dynamics of the objects in detail. The massive coronal rain blobs started to flow from the prominence main bodies. Assuming the symmetric mass flux along both legs, the estimations showed that the prominences became unstable after the loss of 40% of their masses via coronal rain. The time intervals between the start of coronal rain and the final destabilisation of the prominence were estimated as one day. Therefore, if the coronal rain leads to the final destabilisation of many prominences, one can predict CMEs one day before their eruptions. If future analysis shows similar behaviour for many prominences, this will lead to considerable improvement in space weather predictions. This requires a detailed statistical study of the prominences from different ground-based and space mission observations.

Incorporation of the CoMP-S/LSO observations into the new data sets will allow gaining more information including the Doppler shifts of the prominence plasma which have not been included in our previous analysis. This could improve our work on the prominence dynamics and relation to possible subsequent eruptions.

Coronal waves