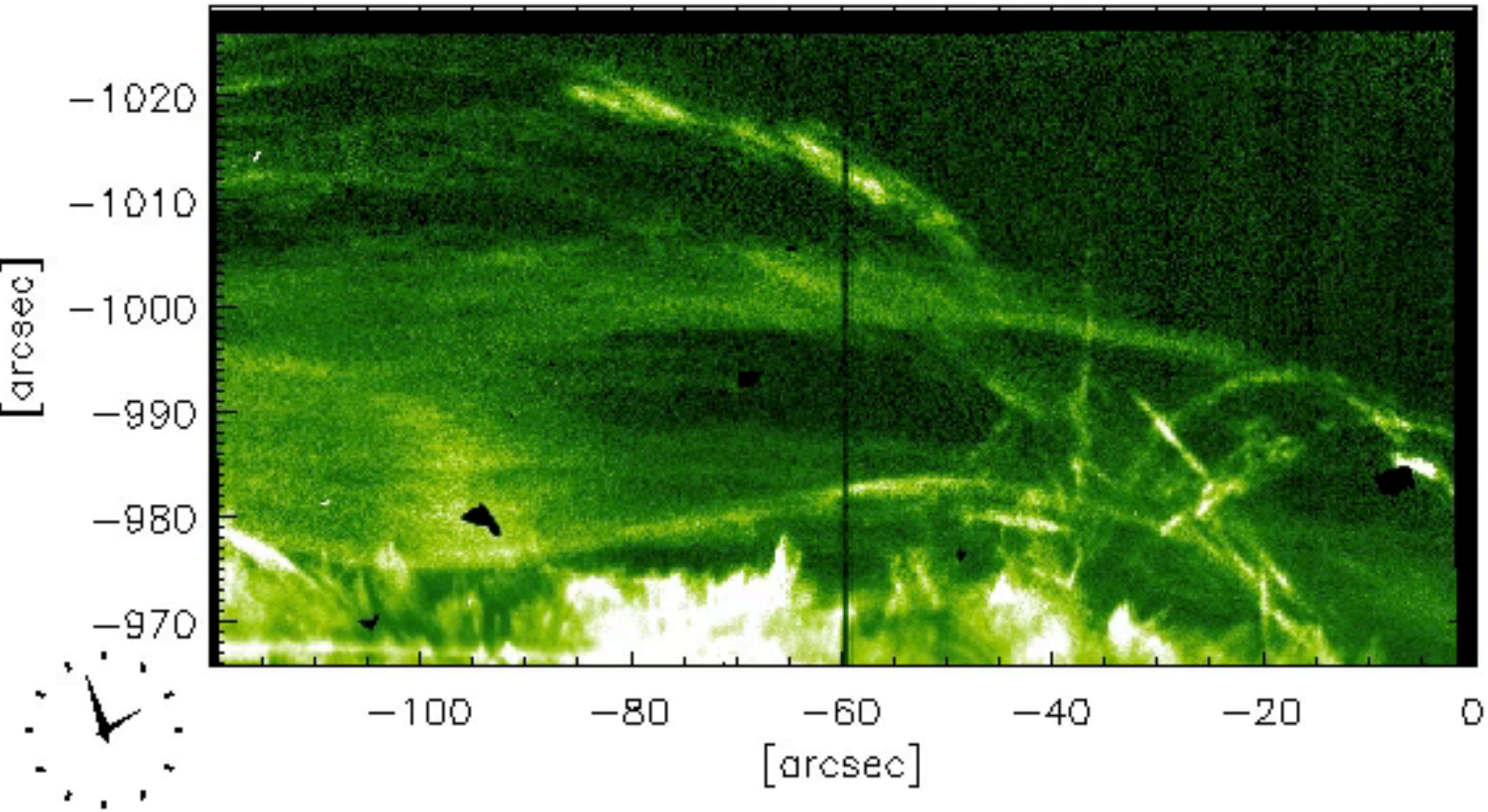
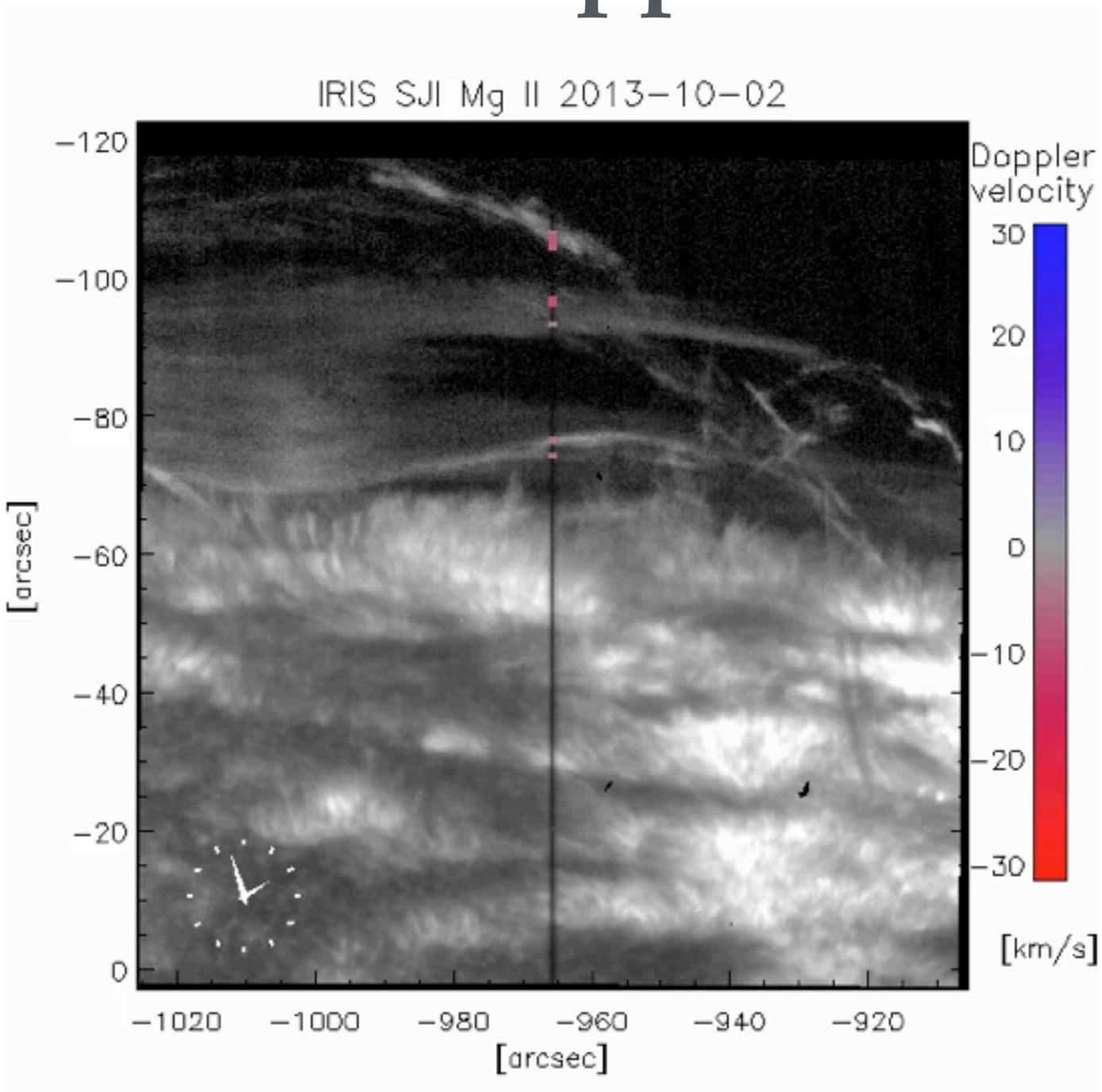
Non-thermal line broadening measurements at high resolution through coronal rain observations

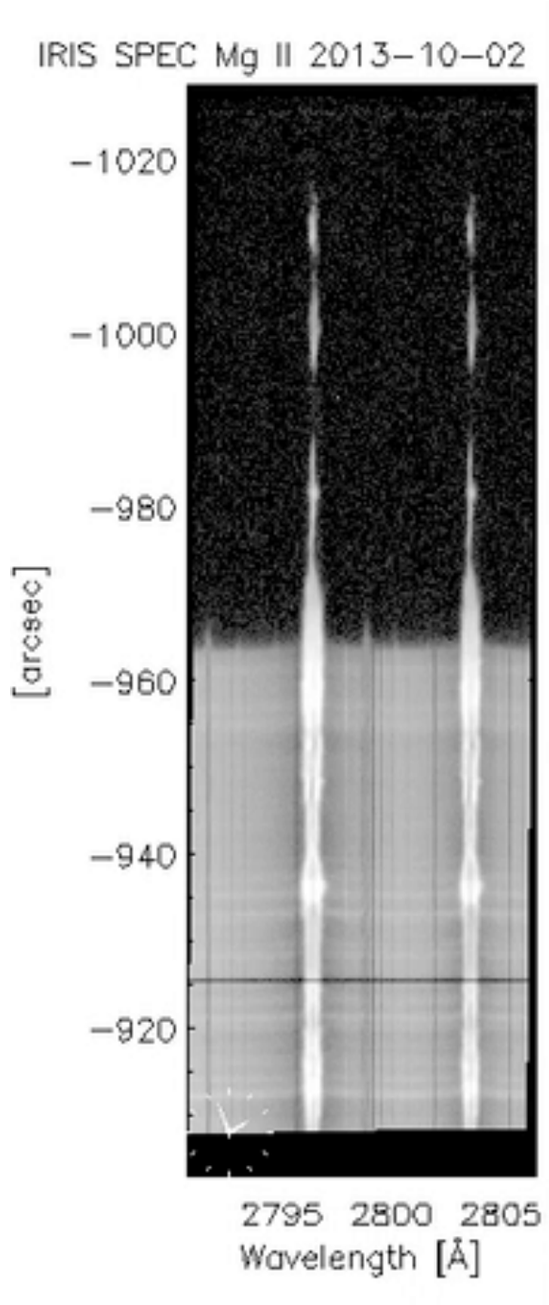
Patrick Antolin

University of St Andrews


IRIS SJI CII 2013-10-02
-1020
-1010
-1000
-990
-980
-970
[arcsec]
-100
-80
-60
-40
-20
0
[arcsec]

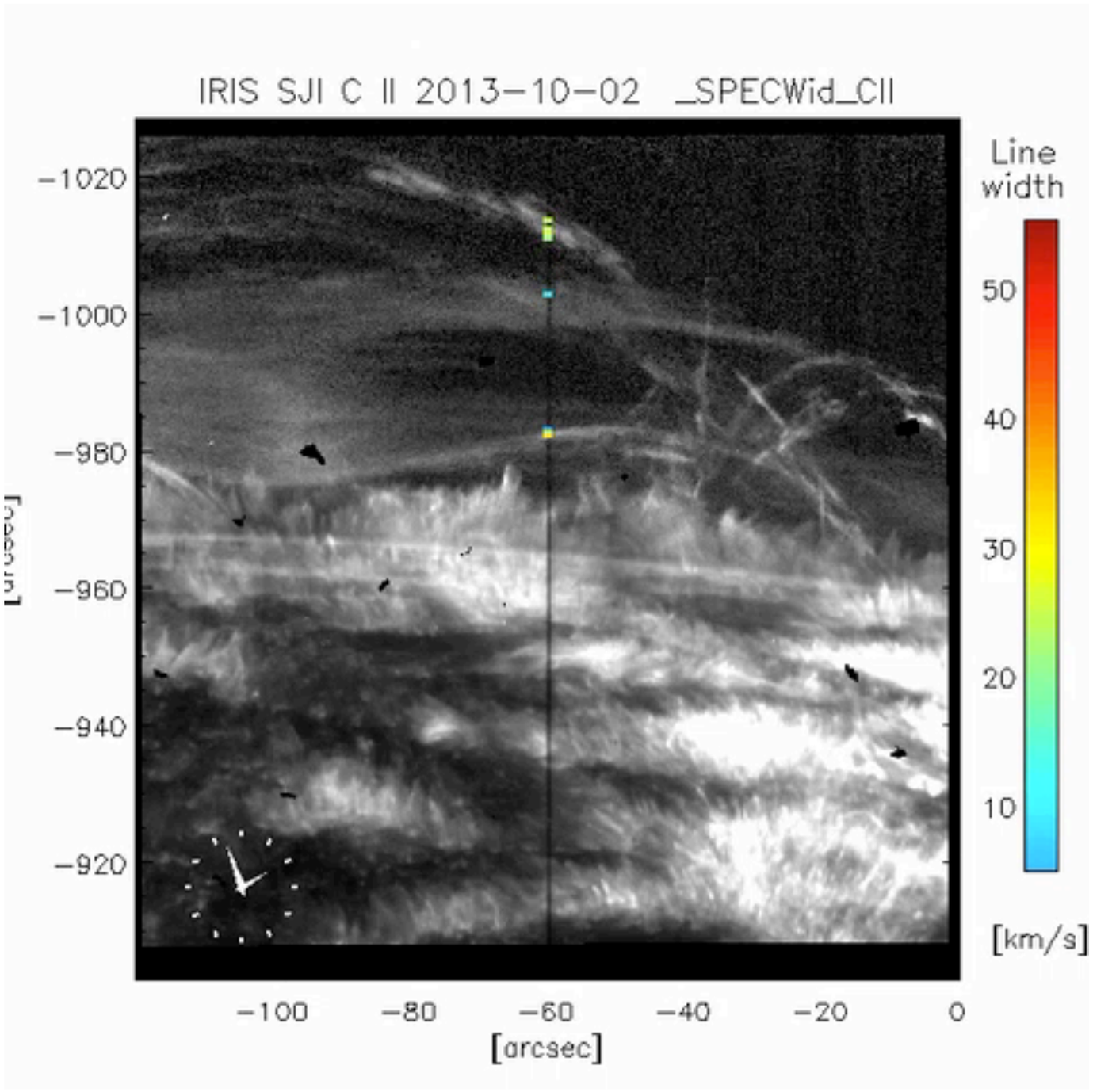
Doppler velocities

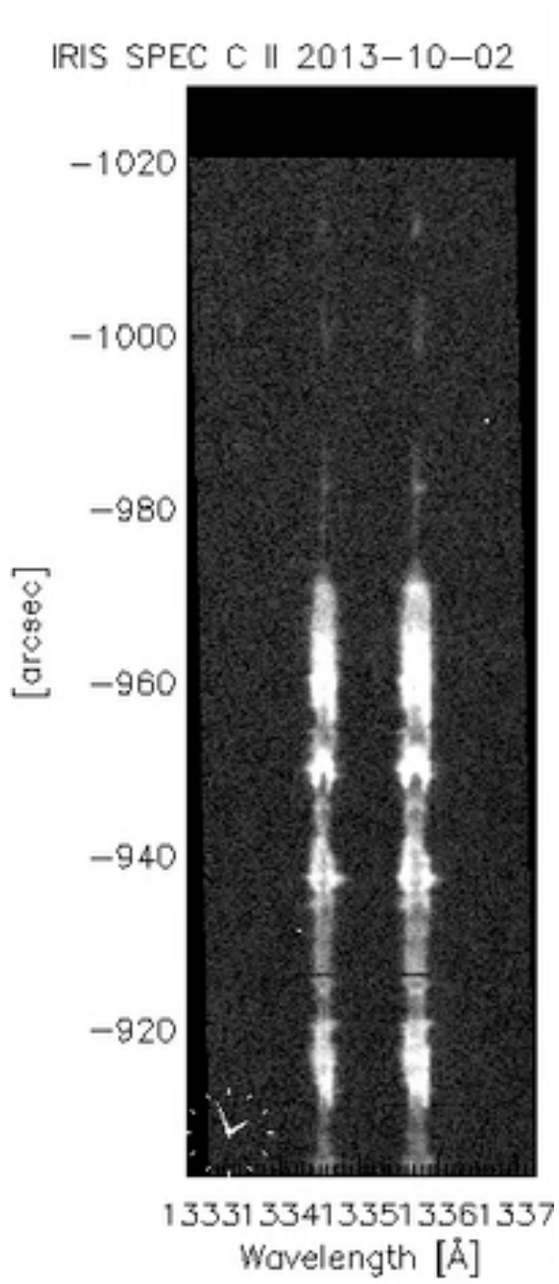




Semi-automatic detection of rain (variable intensity, clumpy)/prominence (continuous flow, constant intensity) for statistical analysis

Estimates of non-thermal line width





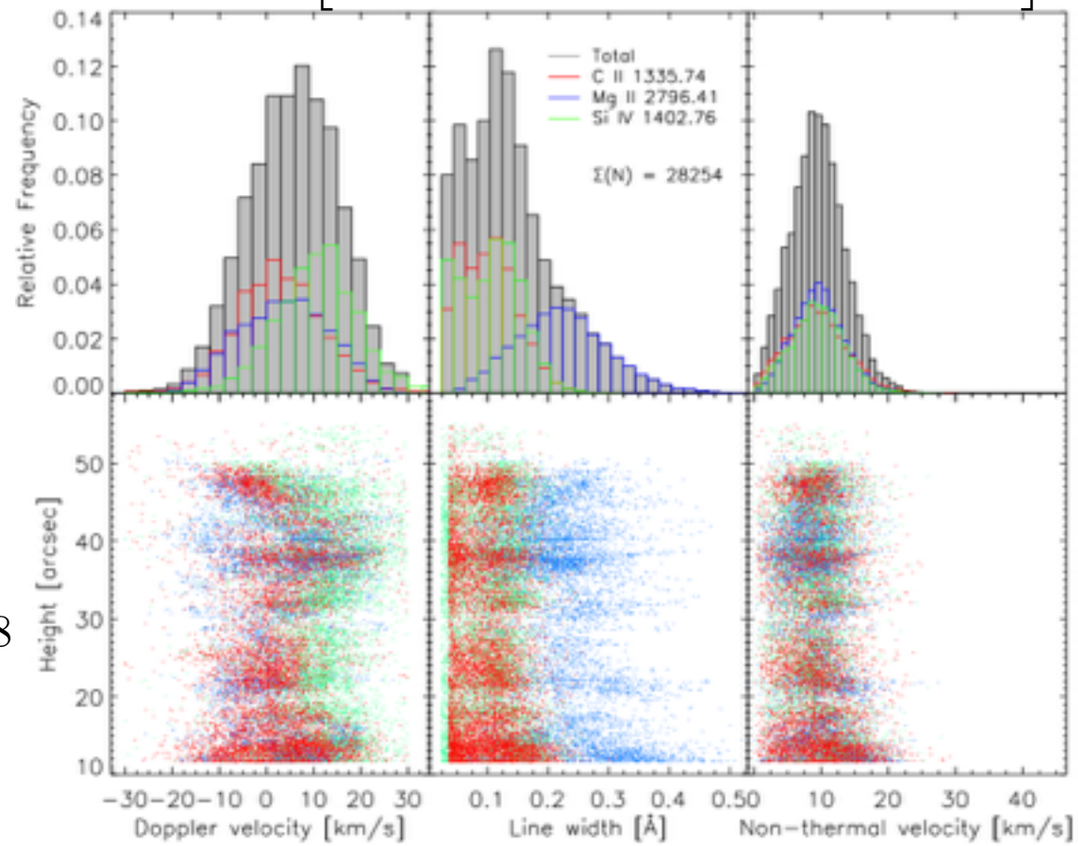
Semi-automatic detection of rain (variable intensity, clumpy)/prominence (continuous flow, constant intensity) for statistical analysis

Estimates of non-thermal line broadening

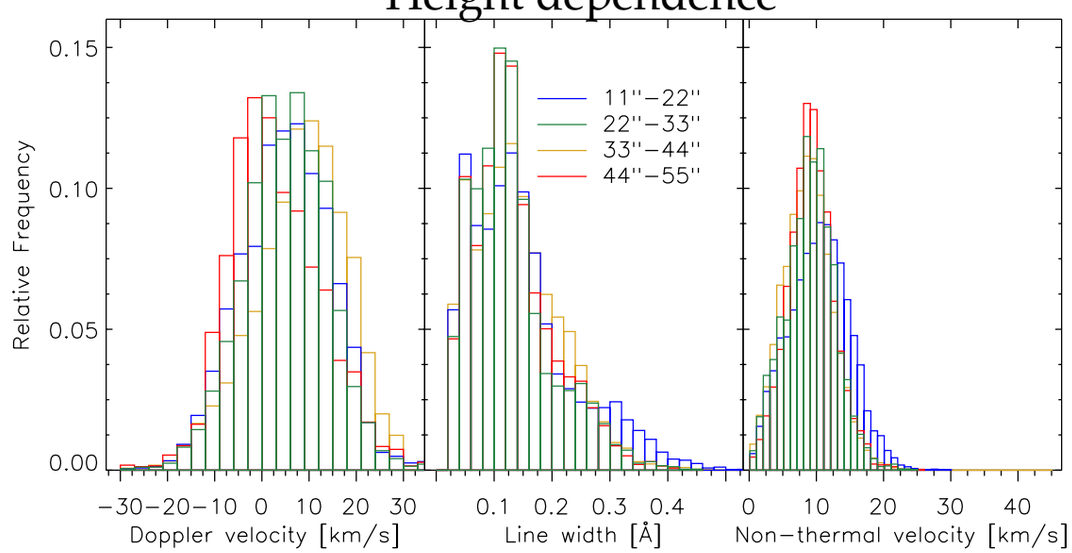
$$\mathrm{FWHM} = \left[\left(2\sqrt{2\log 2}\frac{\lambda_0}{c}\right)^2\left(\frac{2k_BT}{m}+\xi_{\mathrm{nth}}^2\right)+\xi_{\mathrm{inst}}^2\right]^{\frac{1}{2}}$$

- Mostly single emission peaks
- Gaussian-like. $v_{NT} < 25$ km/s and a peak ≲10 km/s
- Similar to previously reported for prominences (Parenti & Vial 2007) despite much higher resolution. LOS effects? (De Pontieu+2014)
- No clear height dependence

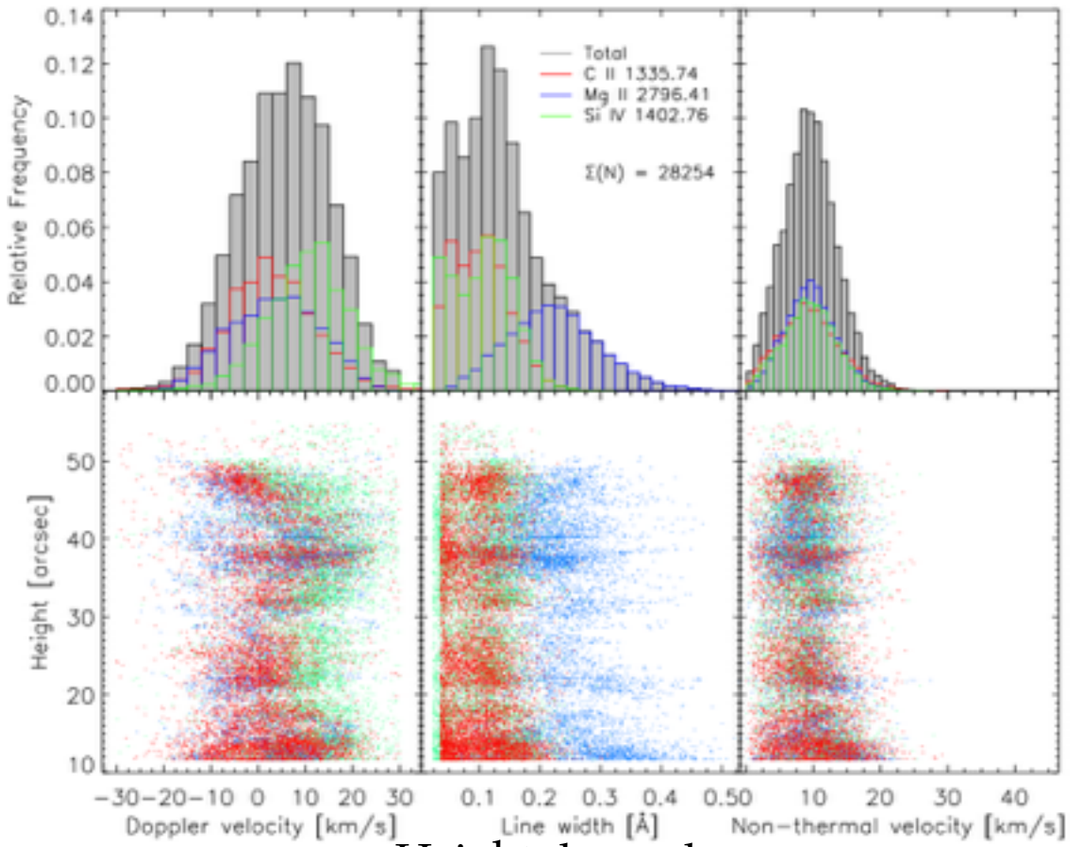
$\log(T_{\mathrm{Si\ IV}}) = 4.8$
$\log(T_{\mathrm{C\ II}}) = 4.3$
$\log(T_{\mathrm{Mg\ II}}) = 4.$



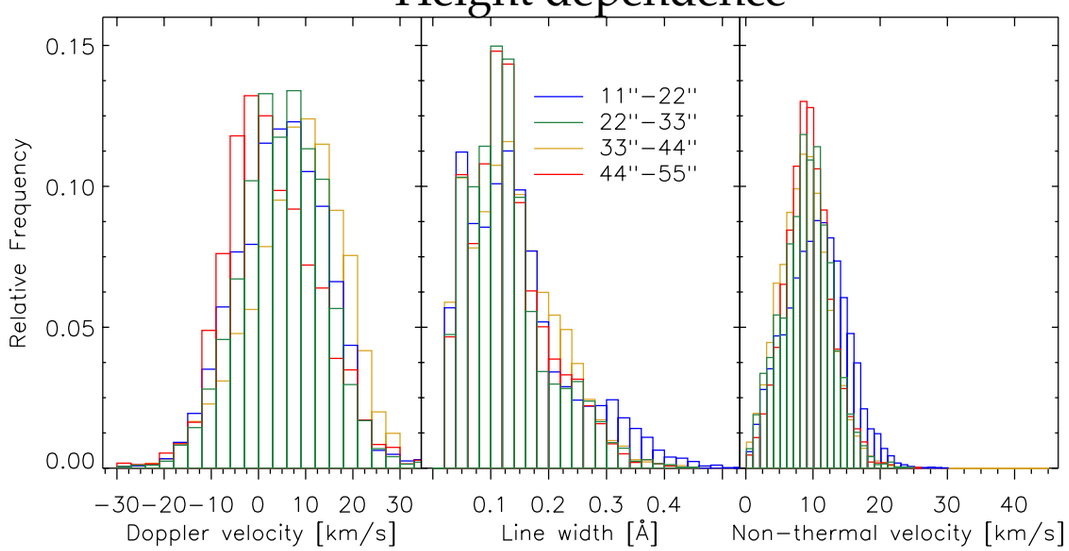
Height dependence



Coronal rain

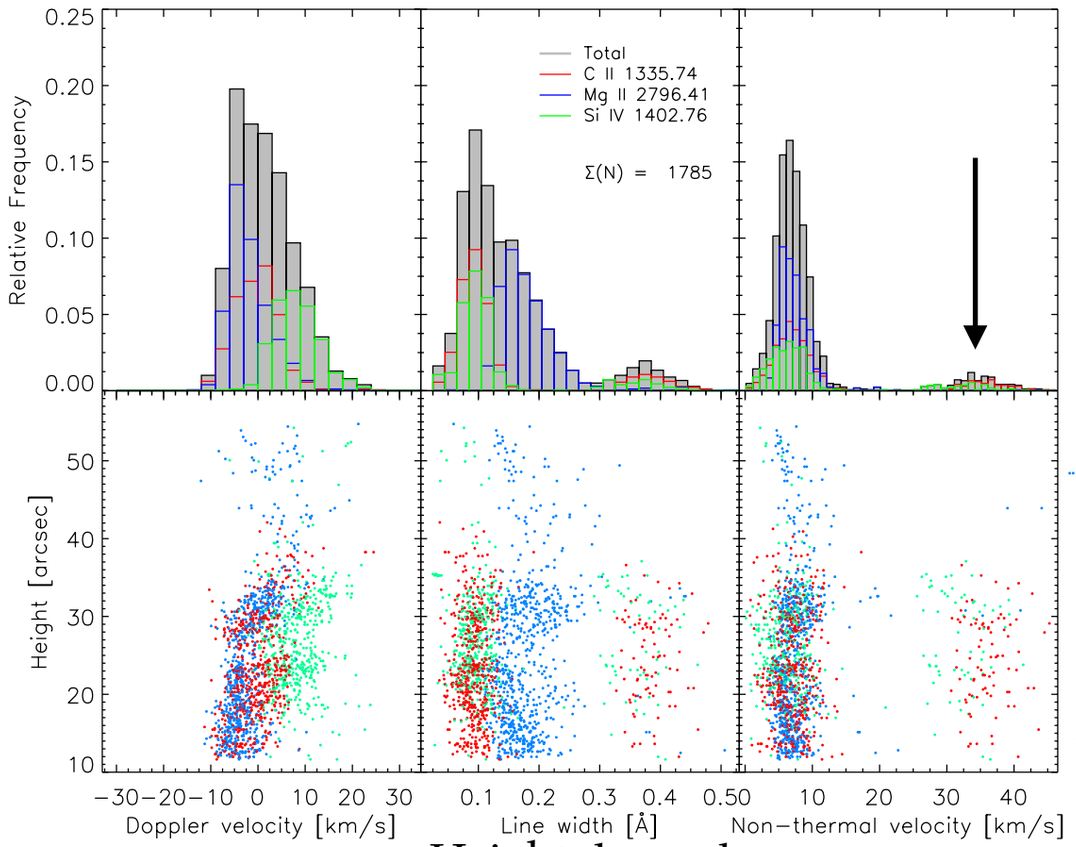


Height dependence

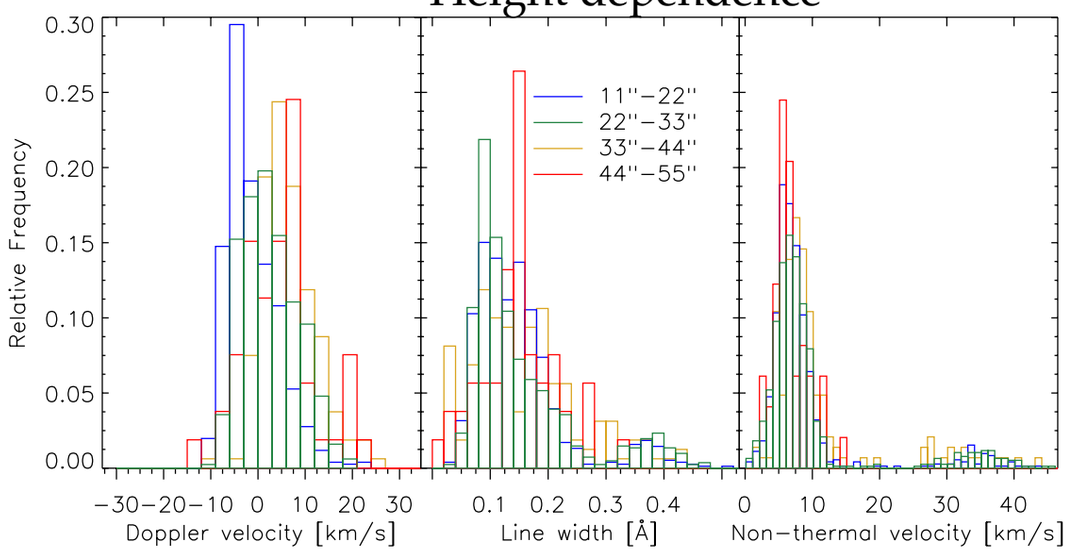


- Variable intensity (clumpy)

Prominence

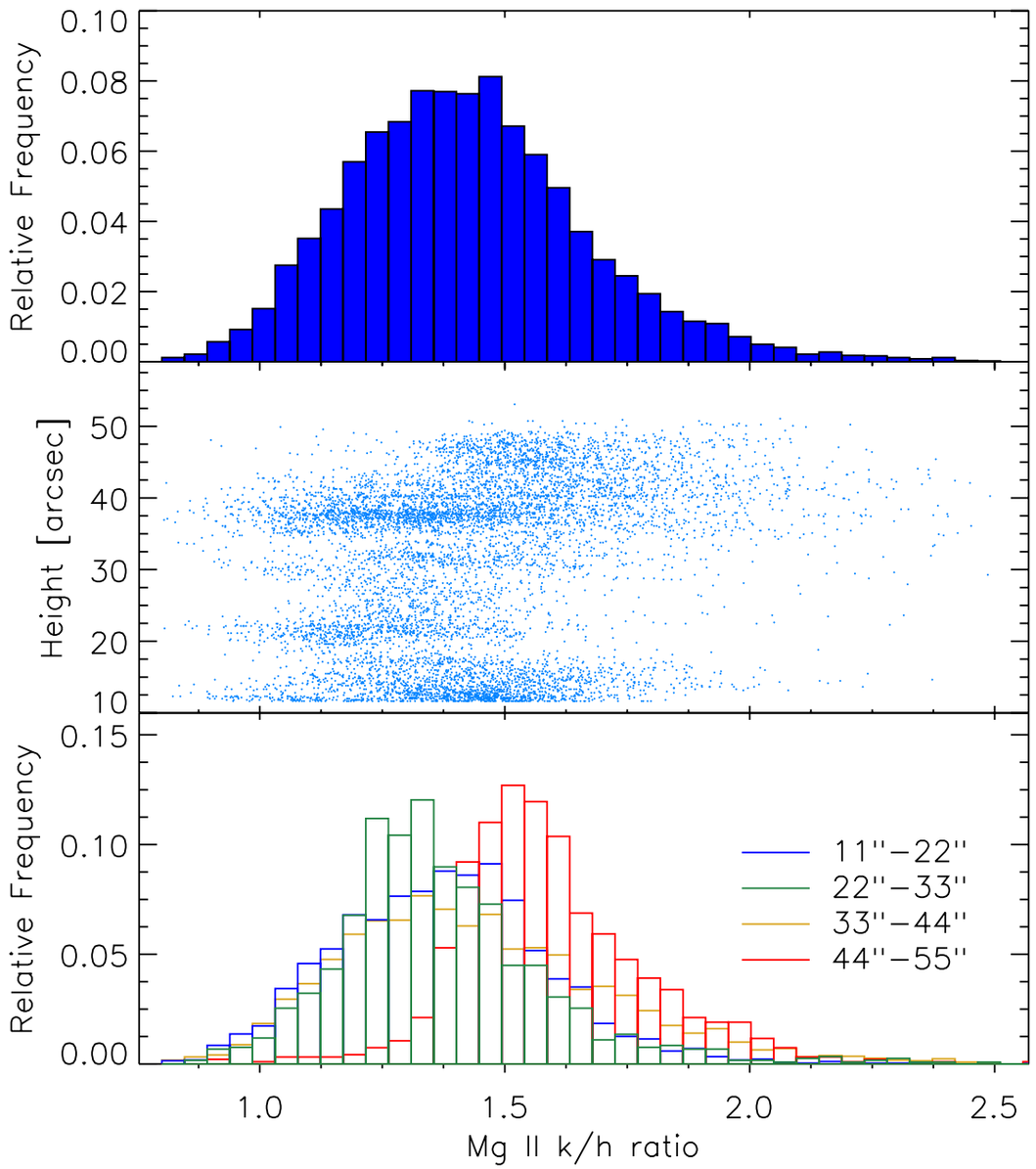


Height dependence

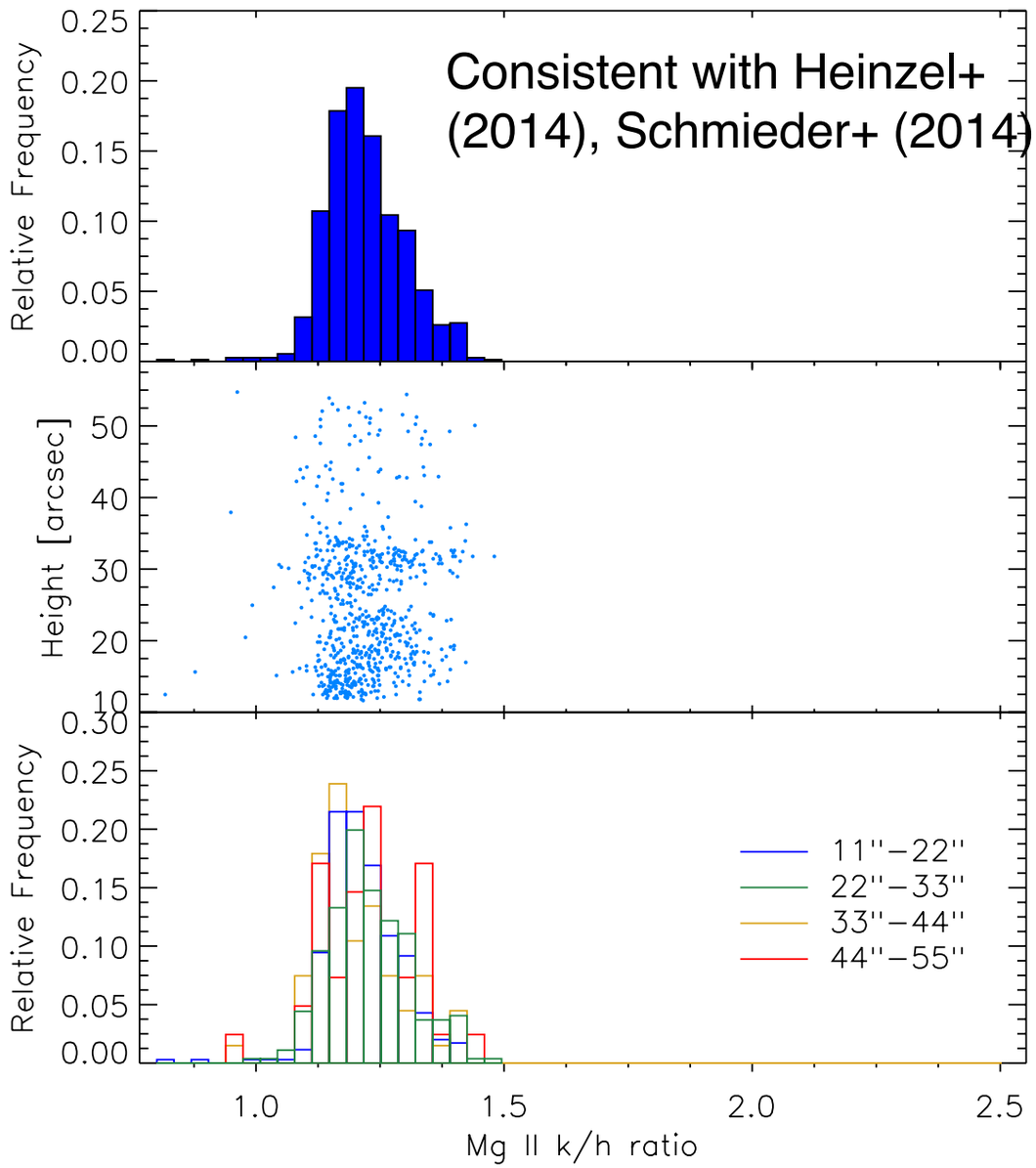


- Continuous flow (lower variability)

Coronal rain



Prominence



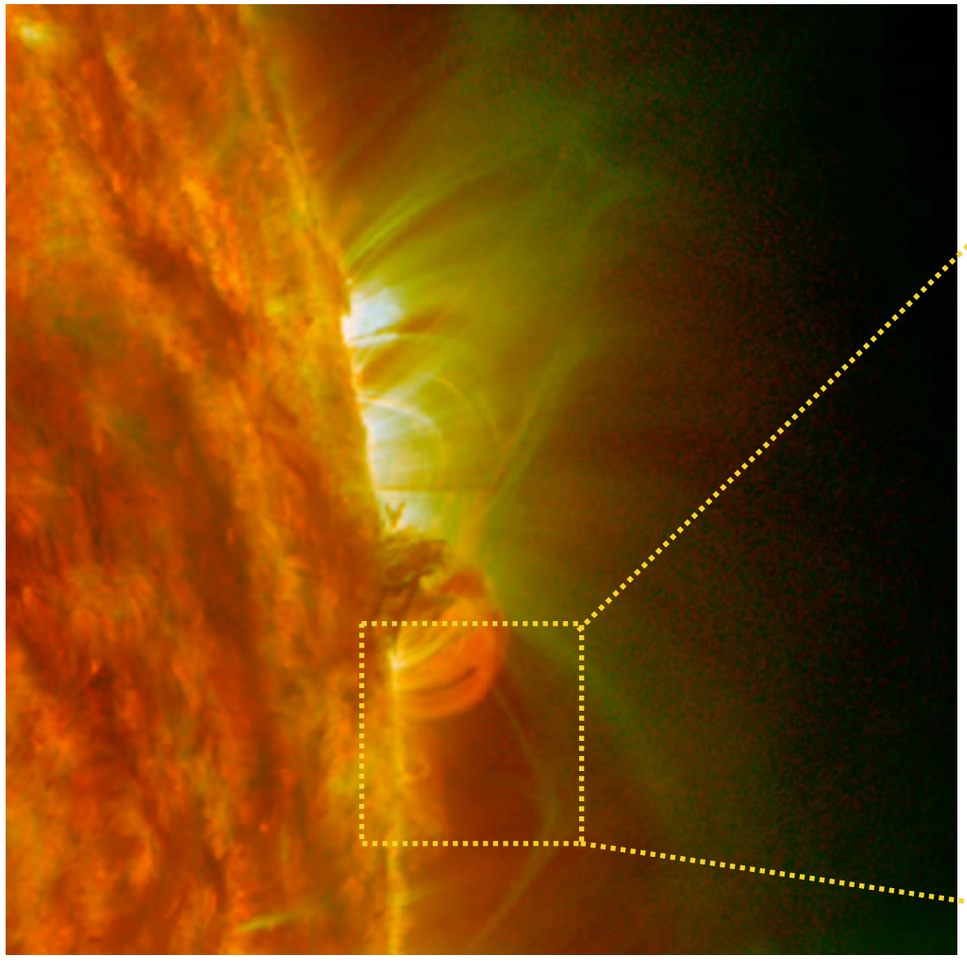
k/h ratio increases with height for coronal rain:

- Doppler dimming effect (Liu+2015)?
- Transition to optically thick state (Antolin+2015)?
- Internal pressure changes in loops? (Harra+ 2014)

Microjets in the solar corona

Coronal rain and prominence eruption

SDO/AIA

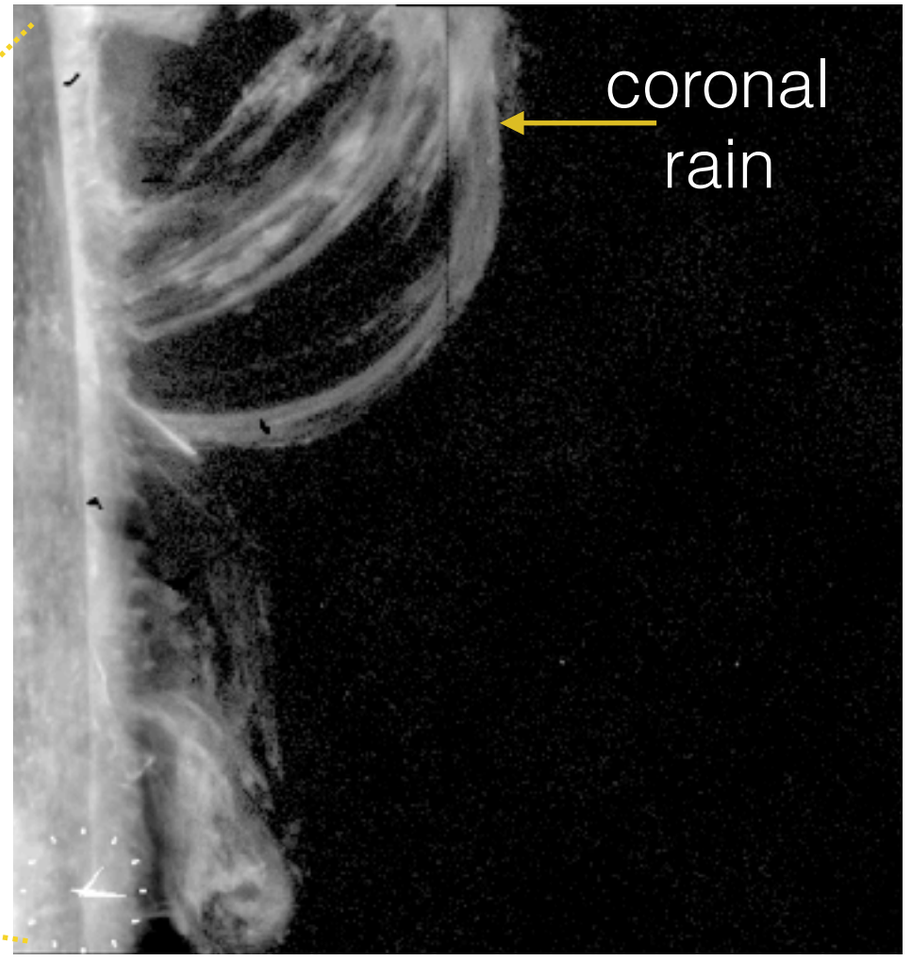


SDO/AIA 171 Å
10^6 K hot plasma
(corona)

+

SDO/AIA 304 Å
10^5 K plasma
(transition region)

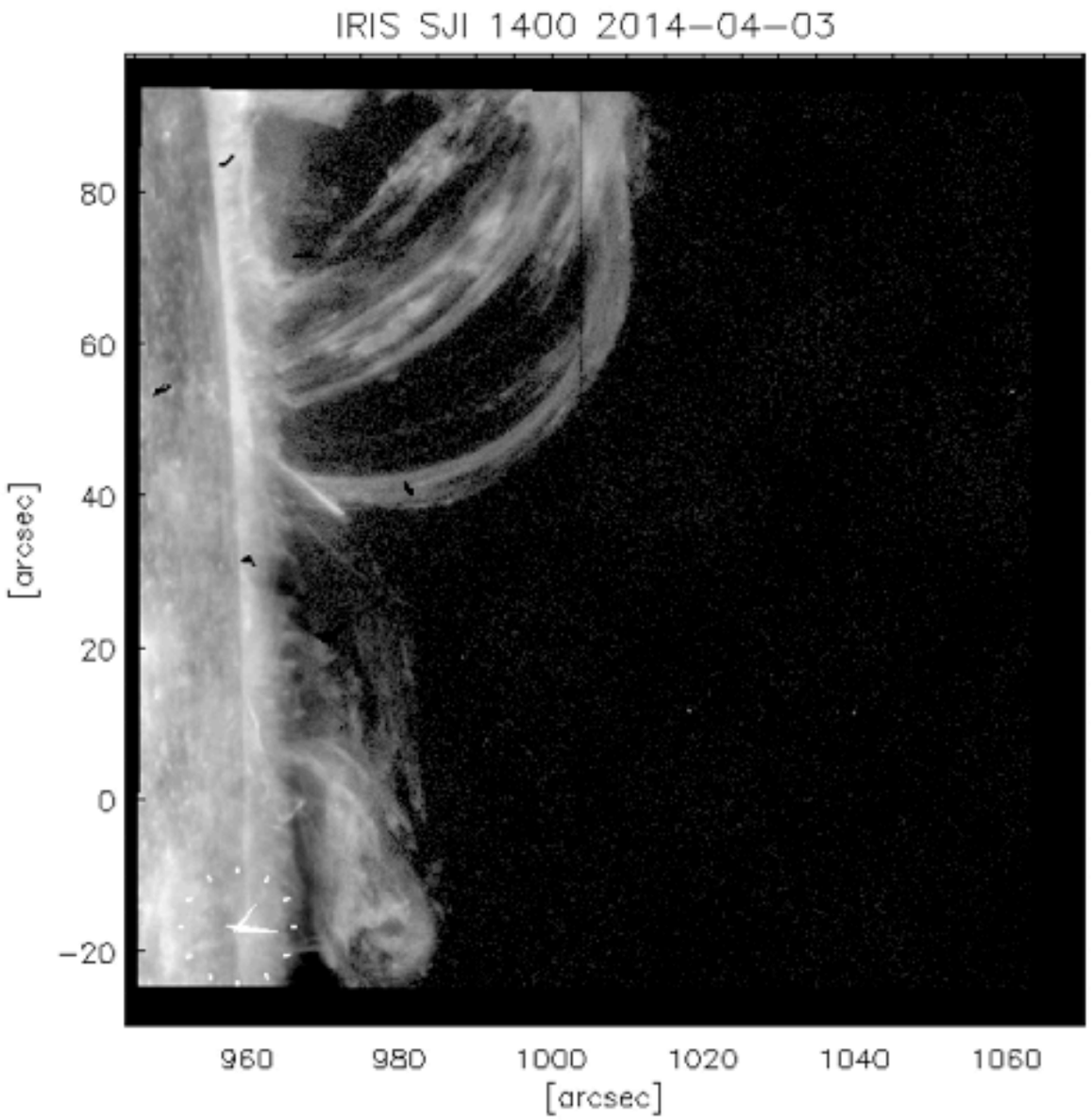
IRIS 1400 Å
10^5 K plasma（transition to corona)

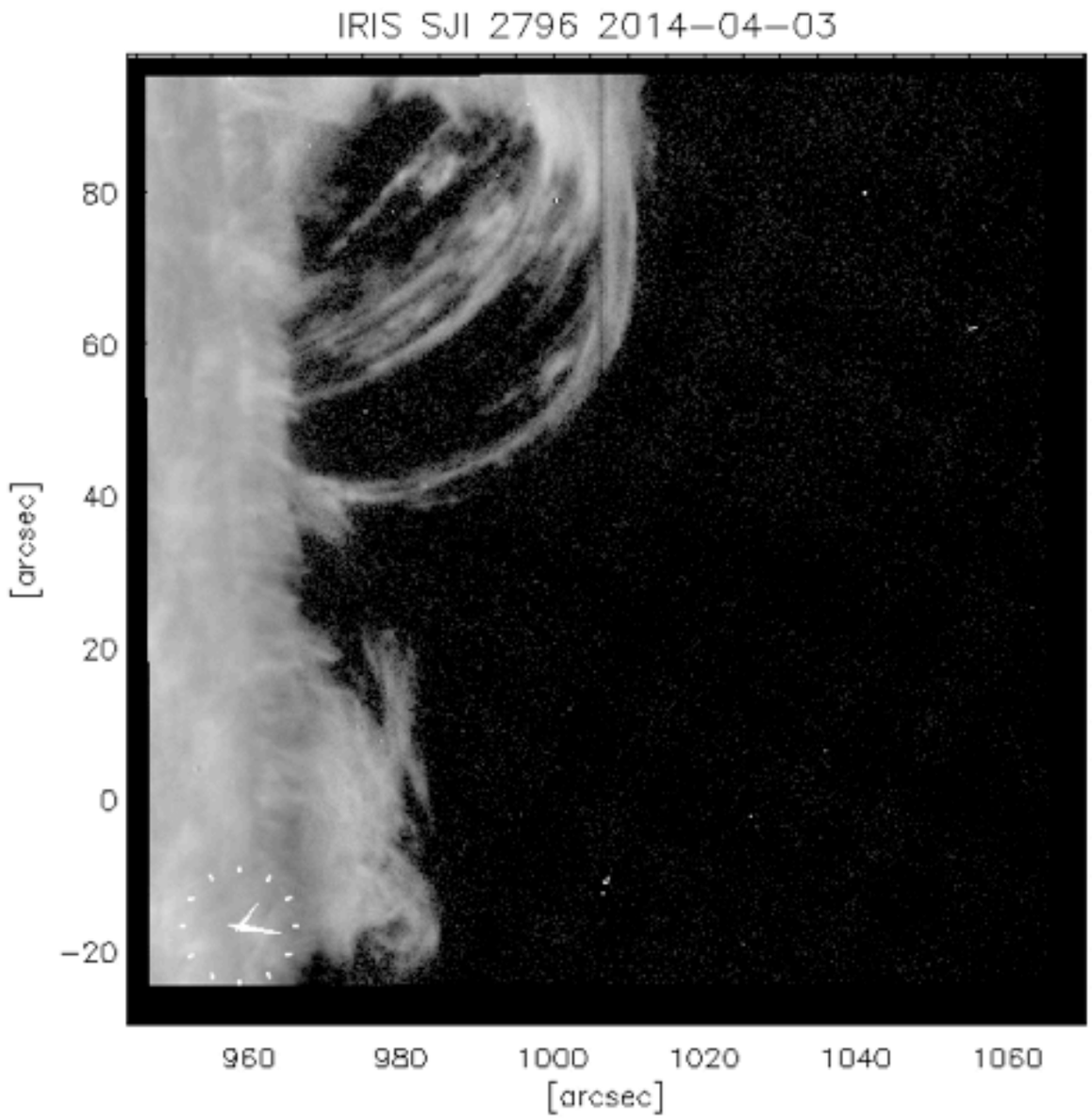


86,000 km

86,000 km

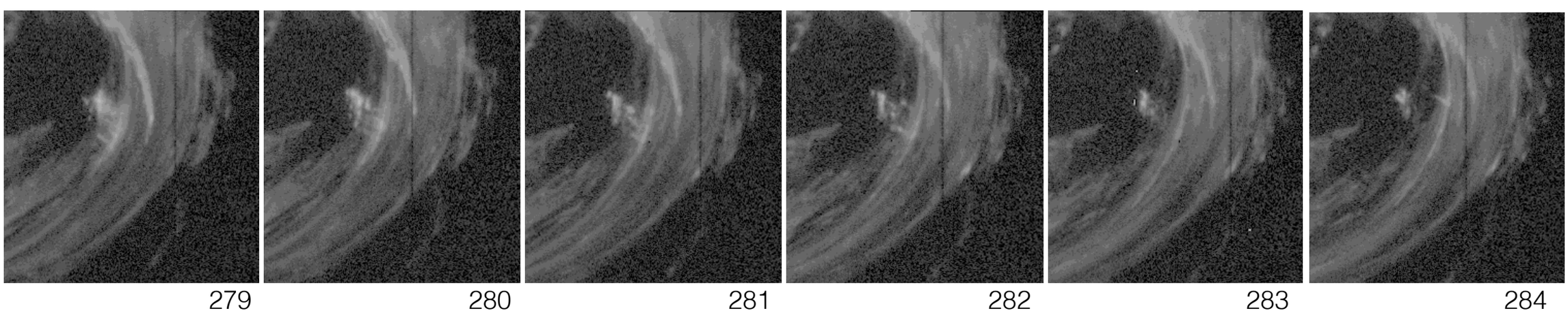
Coronal rain and prominence eruption

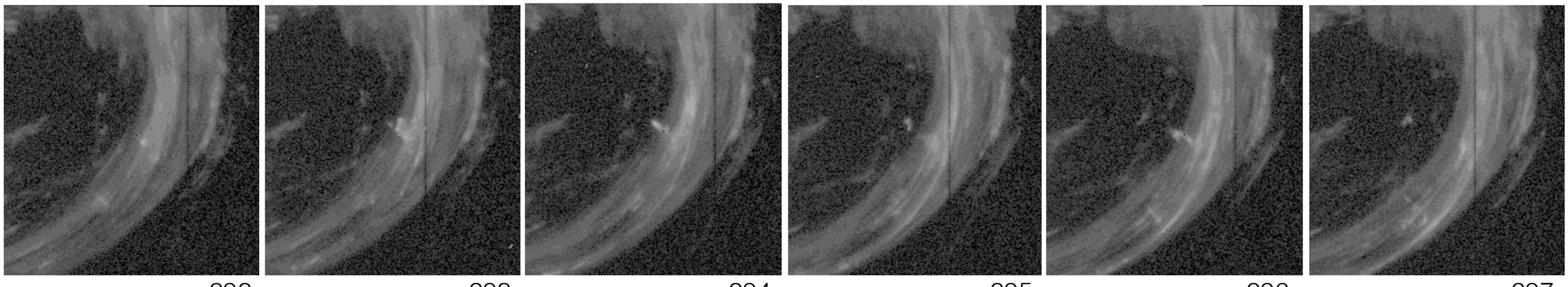




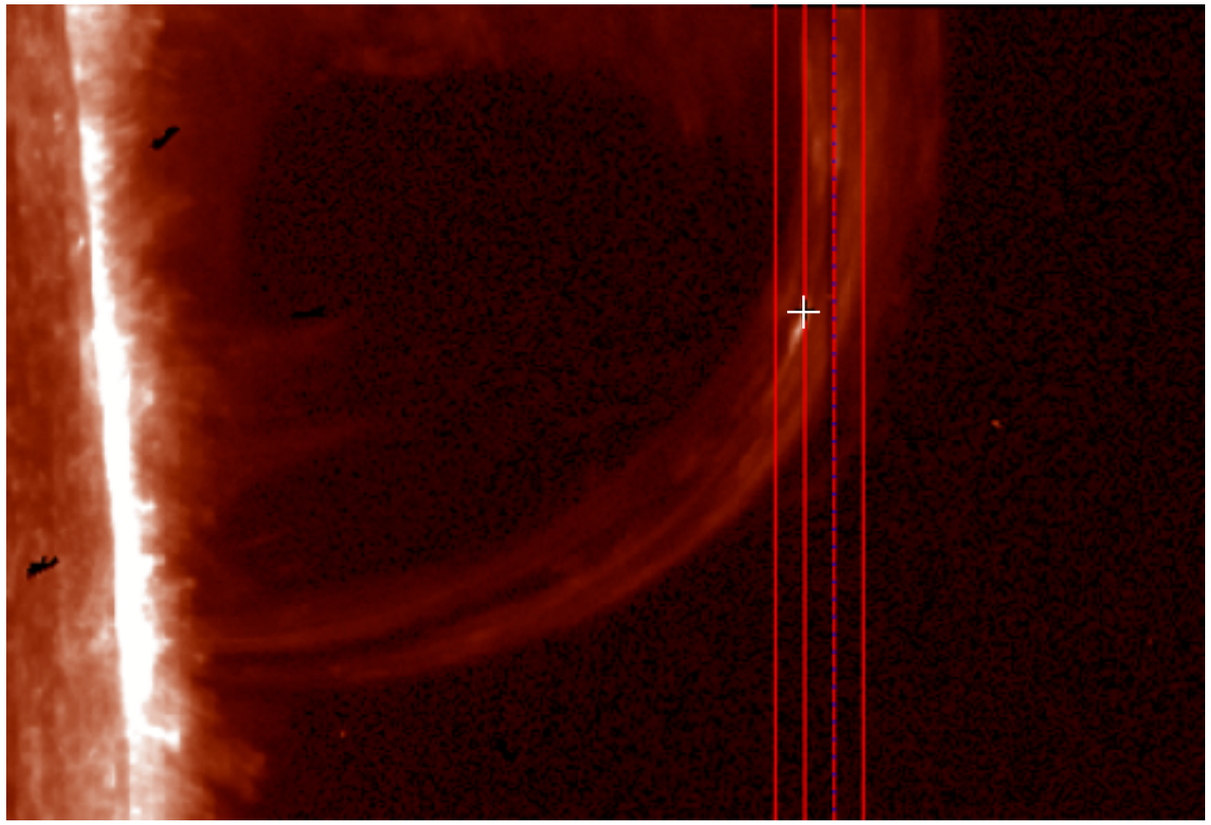
Microjets prior to eruption

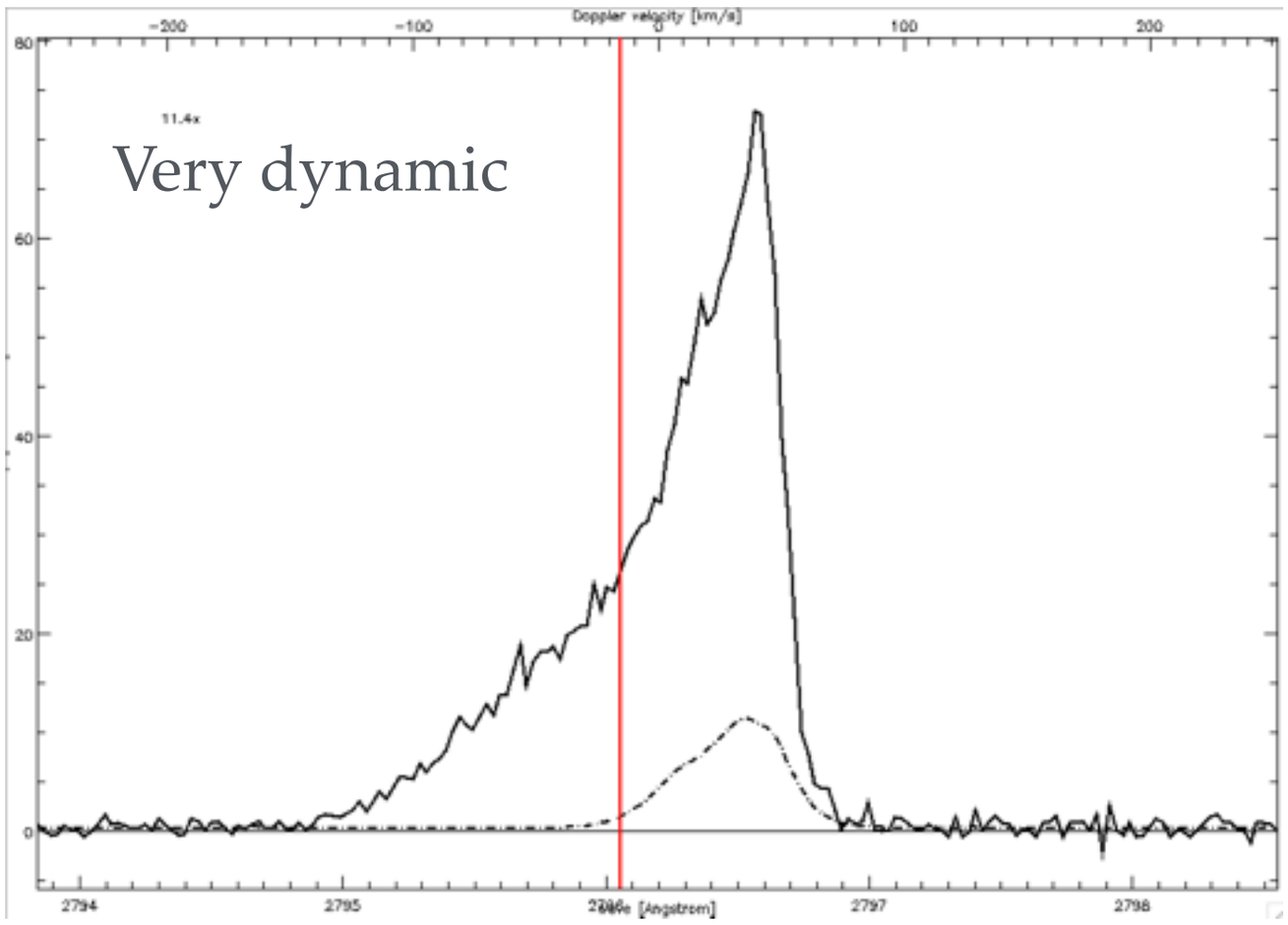
Δt = 18 sec

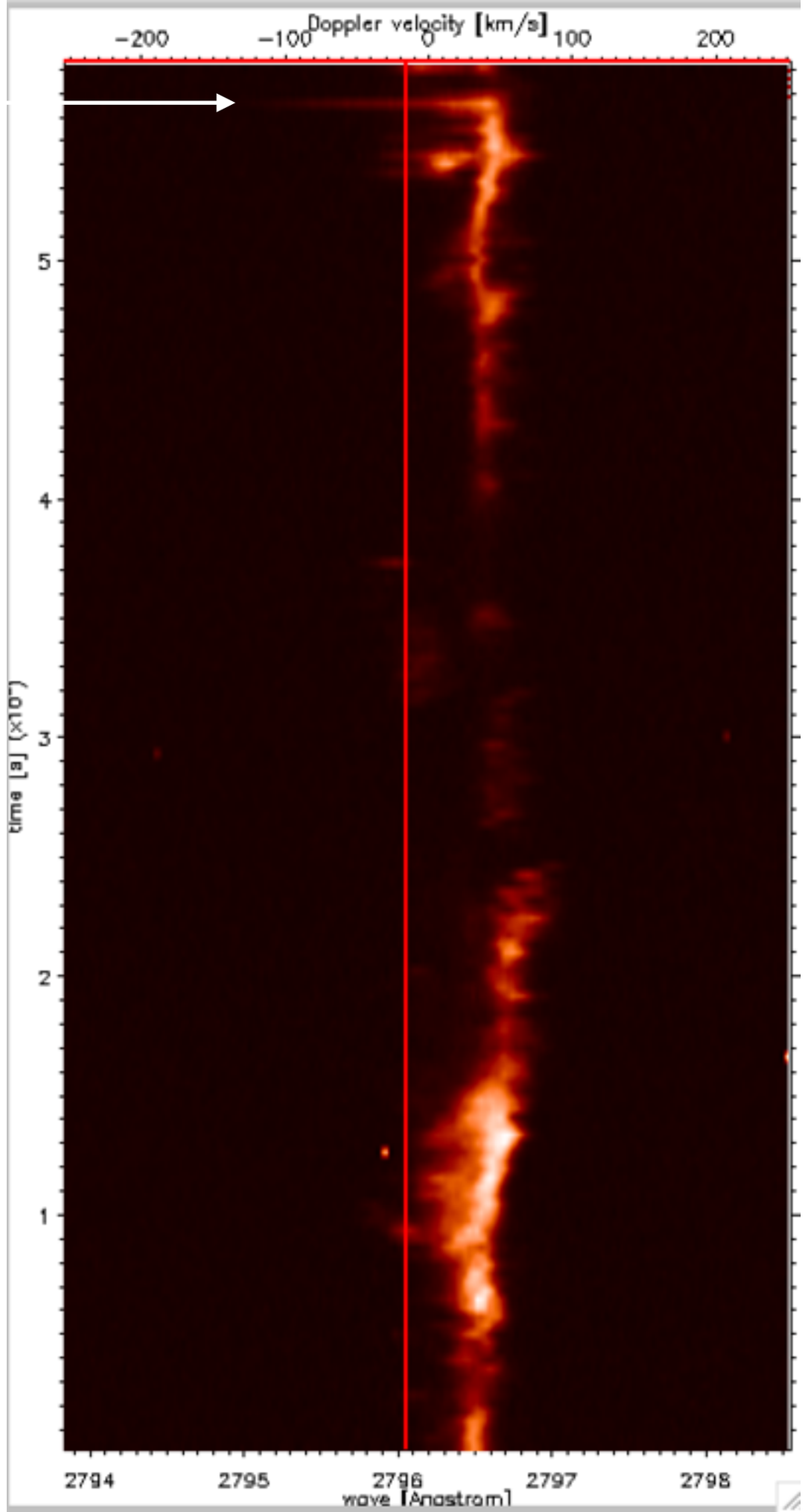




Very short lived (< Δt)



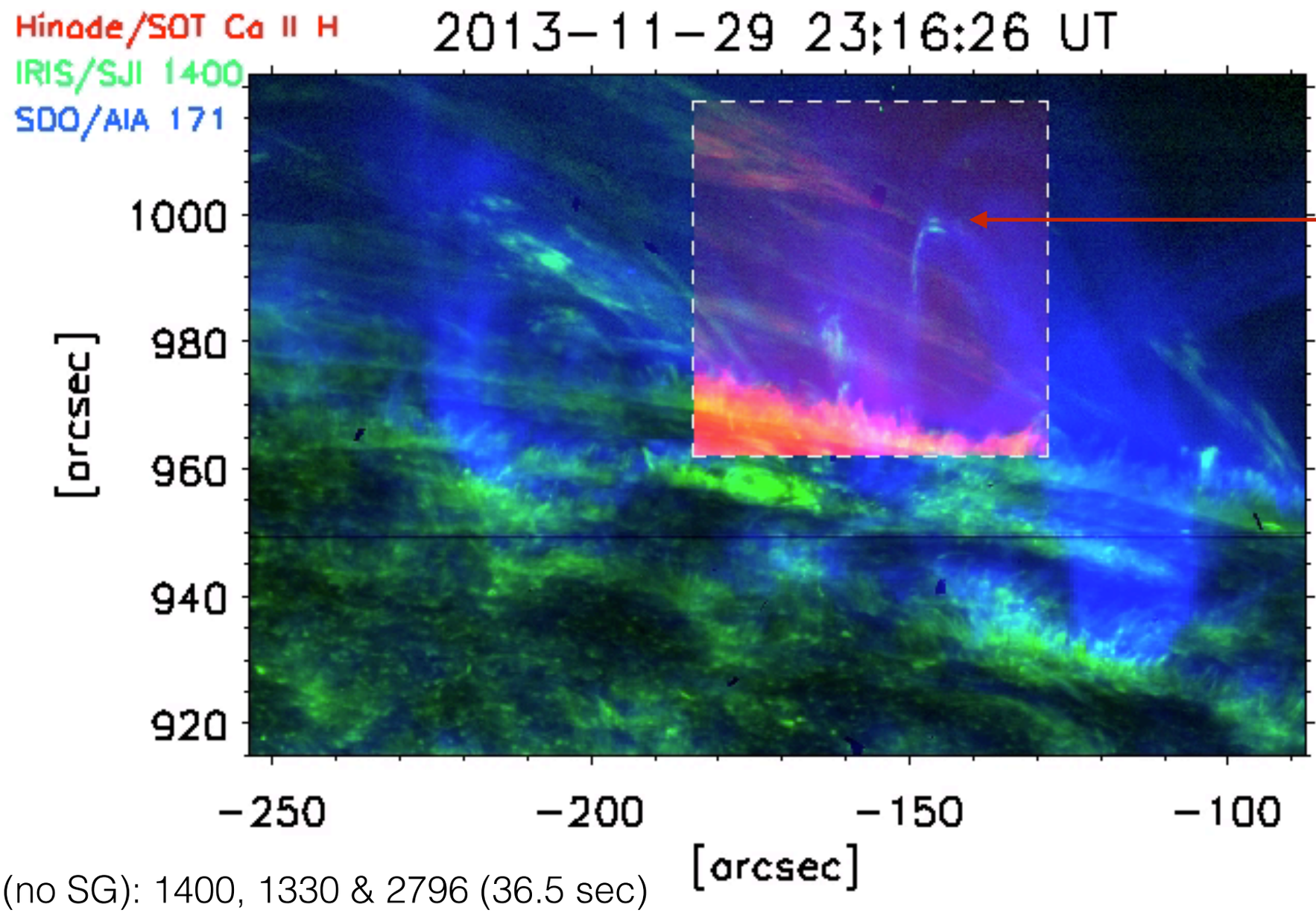

Doppler velocity [km/s]
−200
−100
0
100
200
11.4x
Very dynamic
80
60
40
20
0
2794
2795
2796
2797
2798
wave [Angstrom]


Doppler velocity [km/s]
−200
−100
0
100
200
5
4
3
2
1
time [s] (x10^)
2794
2795
2796
2797
2798
wave [Anastrom]

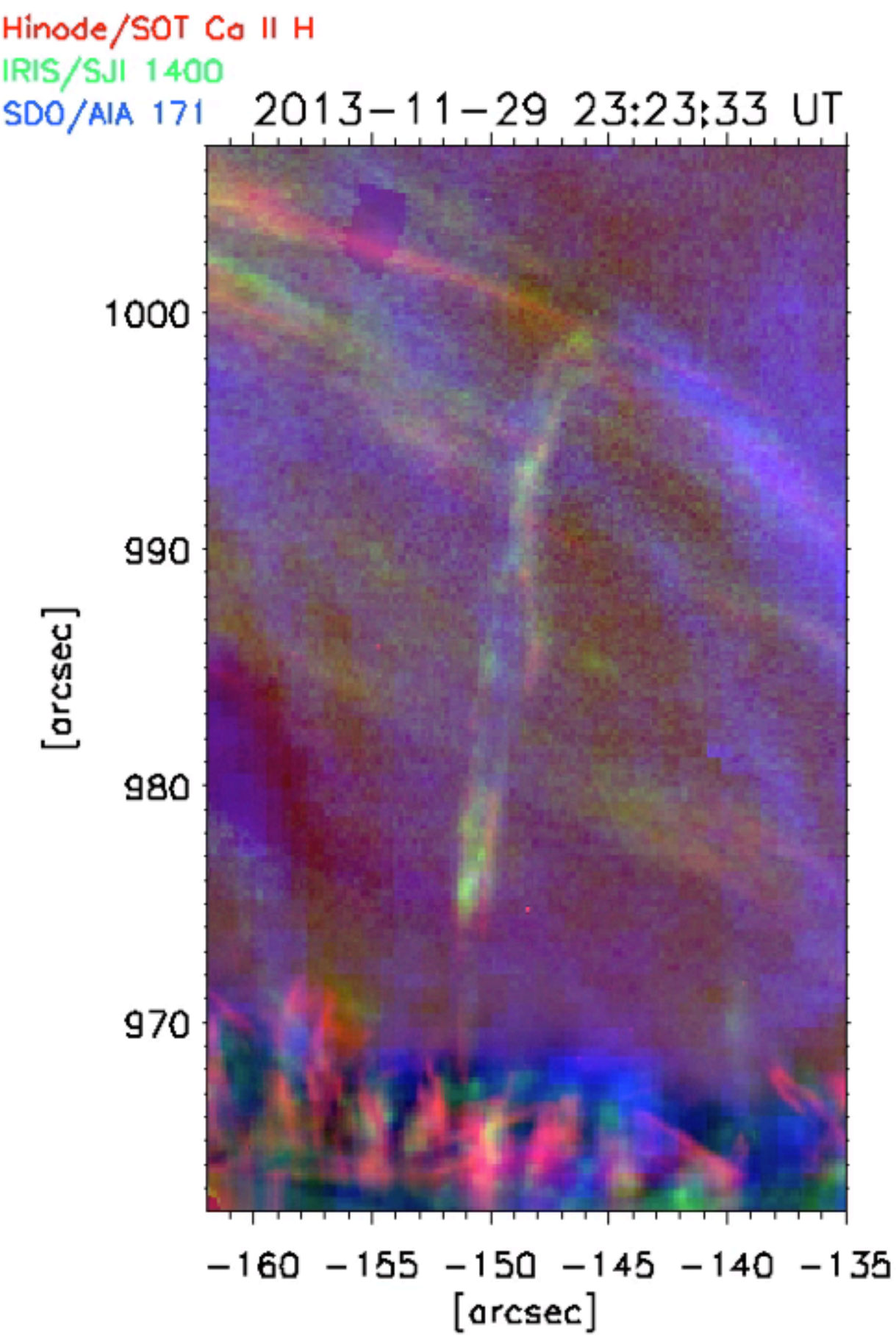
A peculiar coronal rain event

Patrick Antolin

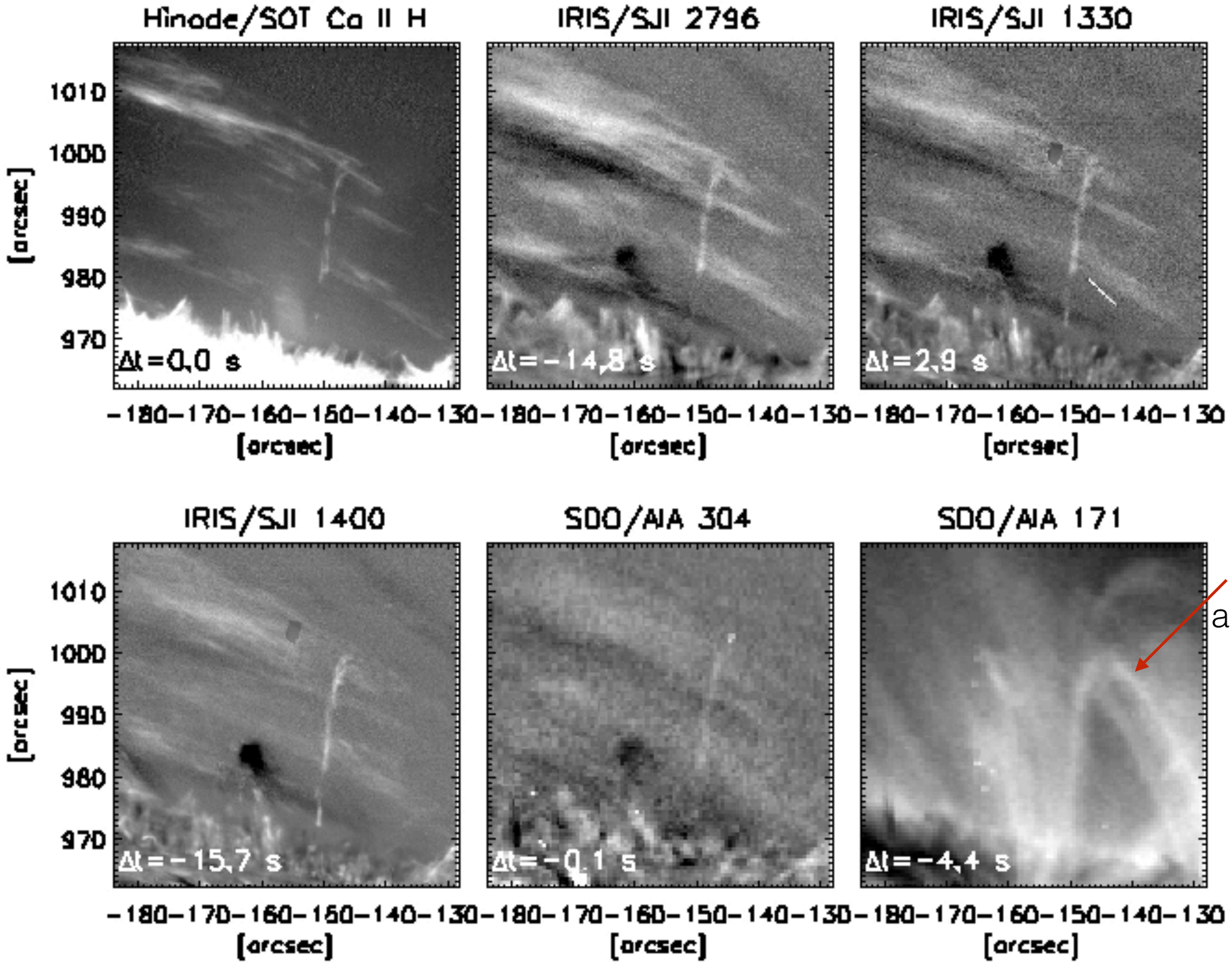
Hinode-IRIS co-observation



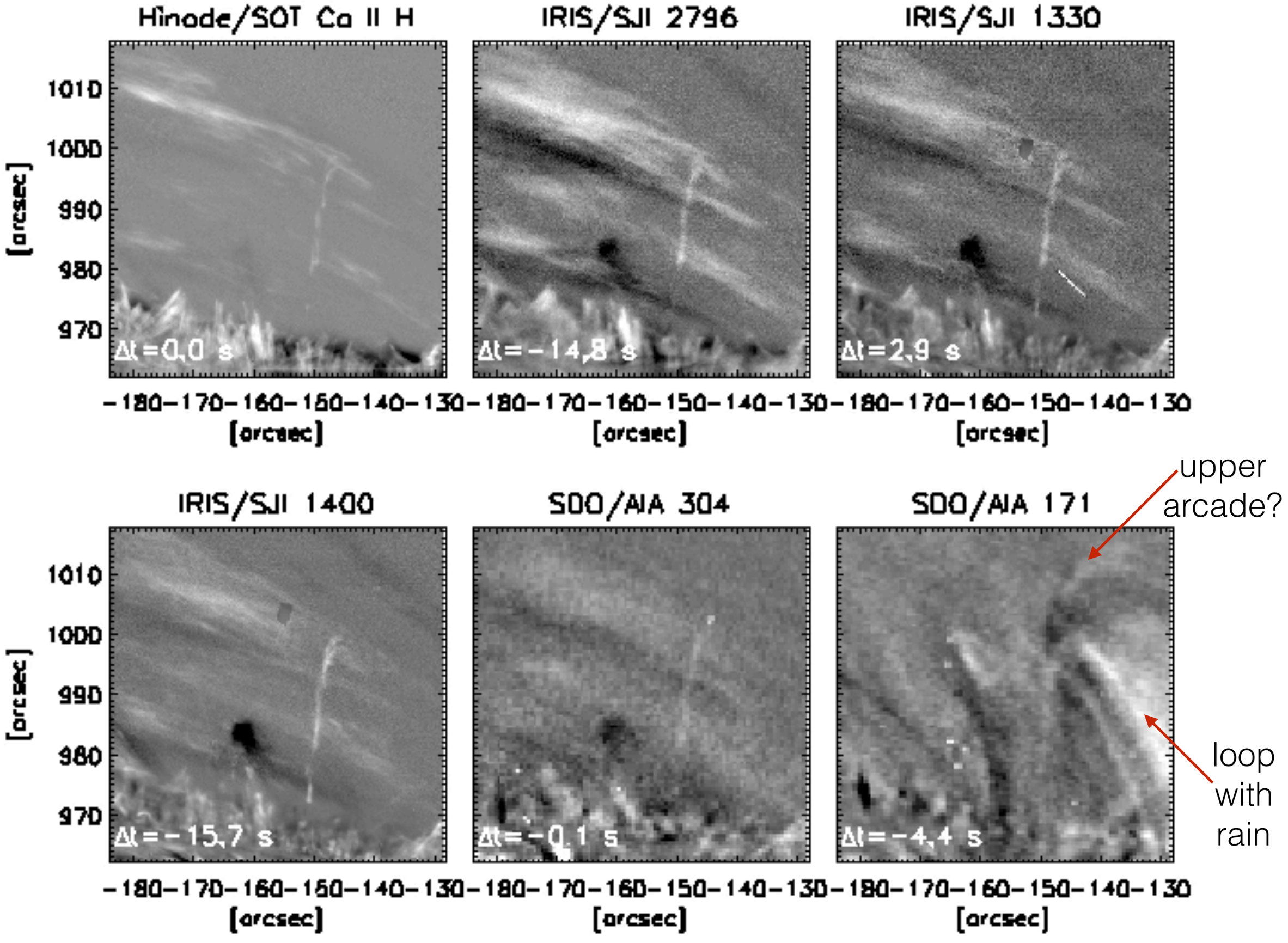
- Iris/SJI (no SG): 1400, 1330 & 2796 (36.5 sec)
- SDO AIA: 304 & 171 (12 sec)
- Hinode/SOT (4.8 sec)


Hinode/SOT Ca II H
IRIS/SJI 1400
SDO/AIA 171
2013-11-29 23:23:33 UT
1000
990
980
970
[arcsec]
-160
-155
-150
-145
-140
-135
[arcsec]

2013-11-29 23:20:54 UT



2013-11-29 23:20:54 UT



2013−11−29 23:25:28 UT

Hinode/SOT Ca II H

IRIS/SJI 2796

IRIS/SJI 1330

IRIS/SJI 1400

SDO/AIA 304

SDO/AIA 171

[arcsec]

1010
1000
990
980
970

−180 −170 −160 −150 −140 −130

[arcsec]

Δt=0.0 s

Δt=2.5 s

Δt=−16.4 s

Δt=1.6 s

Δt=−3.0 s

Δt=4.8 s

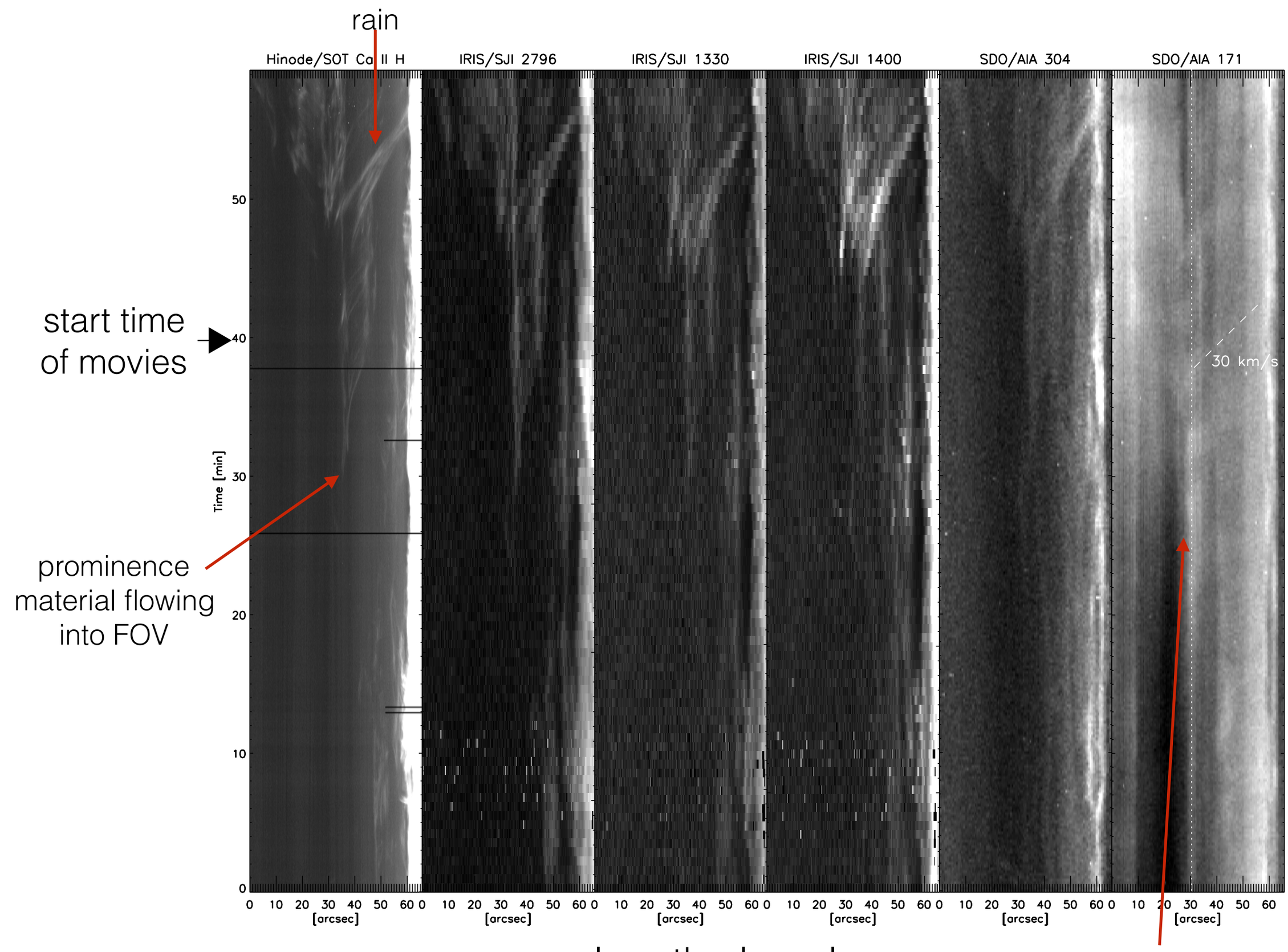
upper arcade

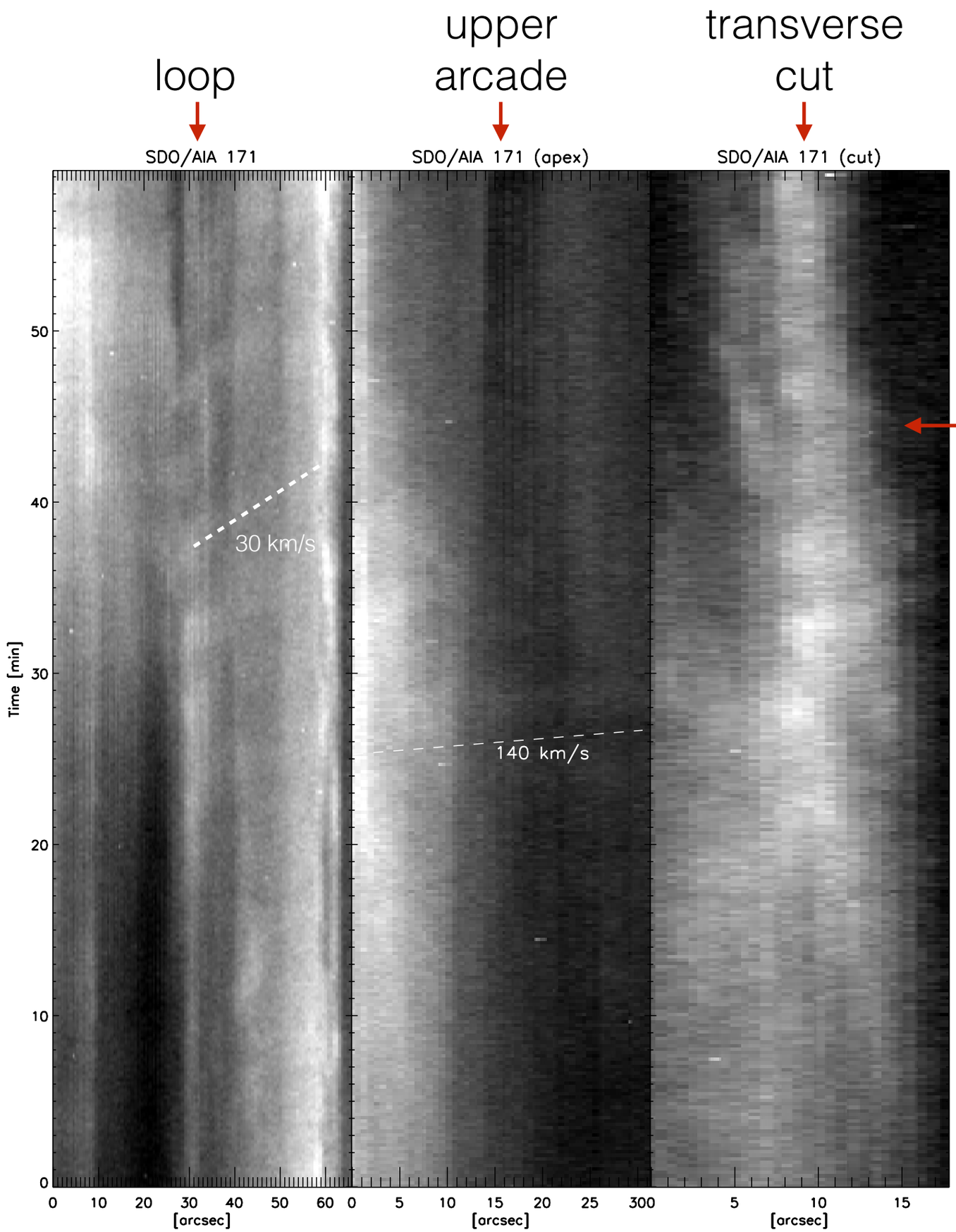
region A

A

transverse cut

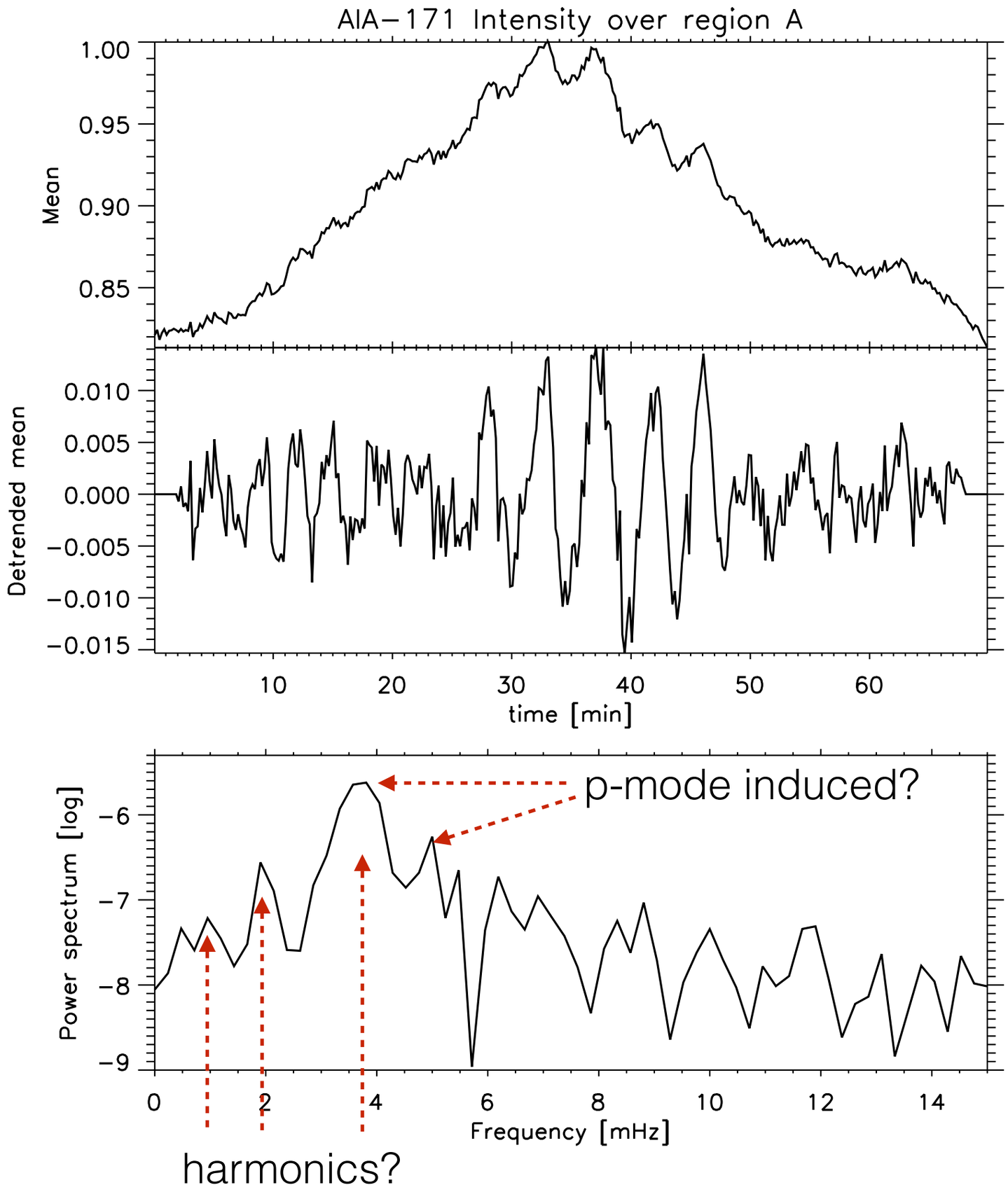
loop with rain


rain
Hinode/SOT Ca II H
IRIS/SJI 2796
IRIS/SJI 1330
IRIS/SJI 1400
SDO/AIA 304
SDO/AIA 171
start time of movies
prominence material flowing into FOV
Time [min]
50
40
30
20
10
0
30 km/s
0 10 20 30 40 50 60
[arcsec]
length along loop
periodic intensity variations at apex, with propagating patterns



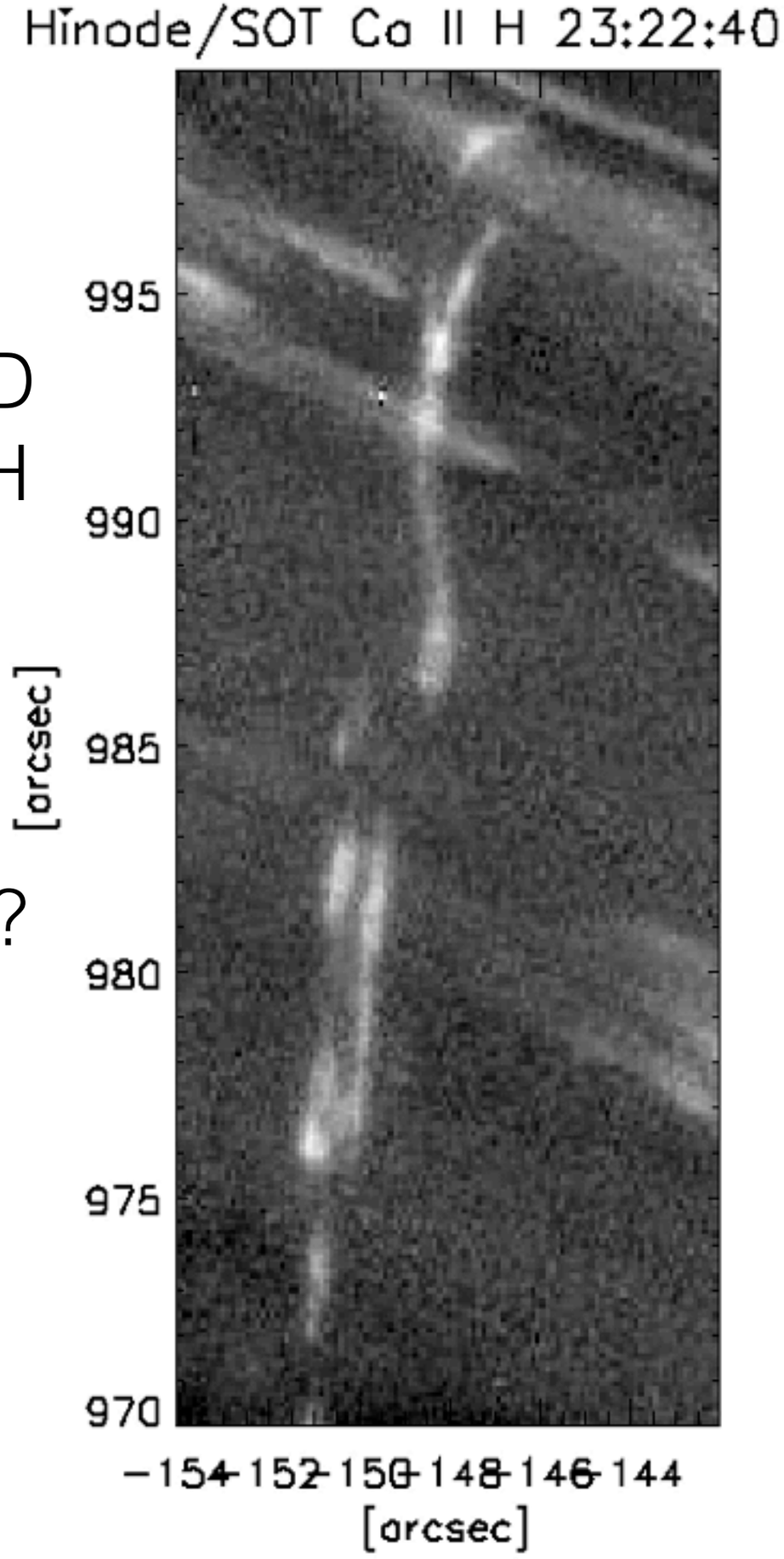
Transverse MHD waves in phase with intensity variation

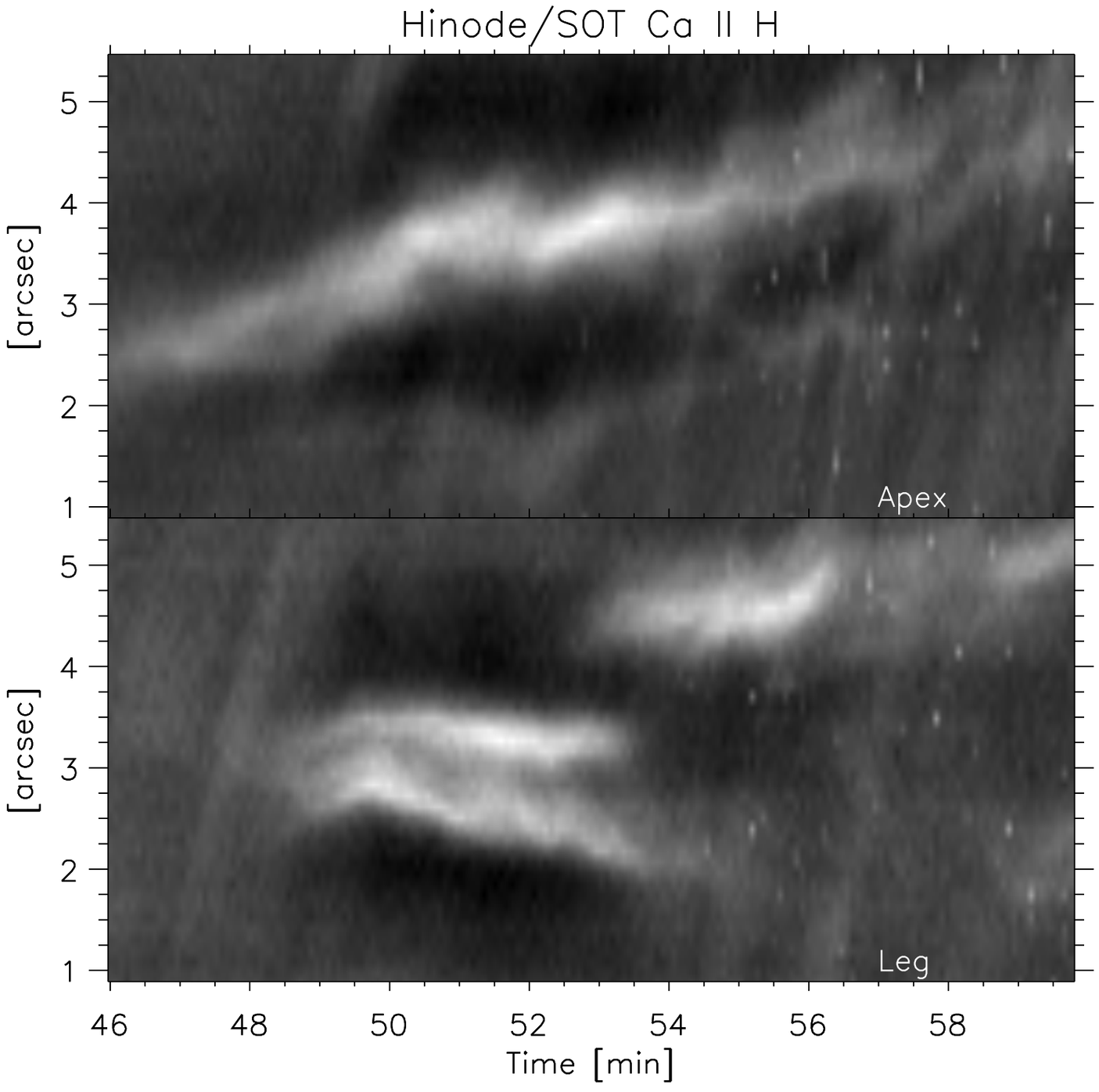
- 4-5 min period
- signatures of damping


AIA−171 Intensity over region A
Mean
1.00
0.95
0.90
0.85
Detrended mean
0.010
0.005
0.000
−0.005
−0.010
−0.015
10
20
30
40
50
60
time [min]
Power spectrum [log]
−6
−7
−8
−9
0
2
4
6
8
10
12
14
Frequency [mHz]
p-mode induced?
harmonics?

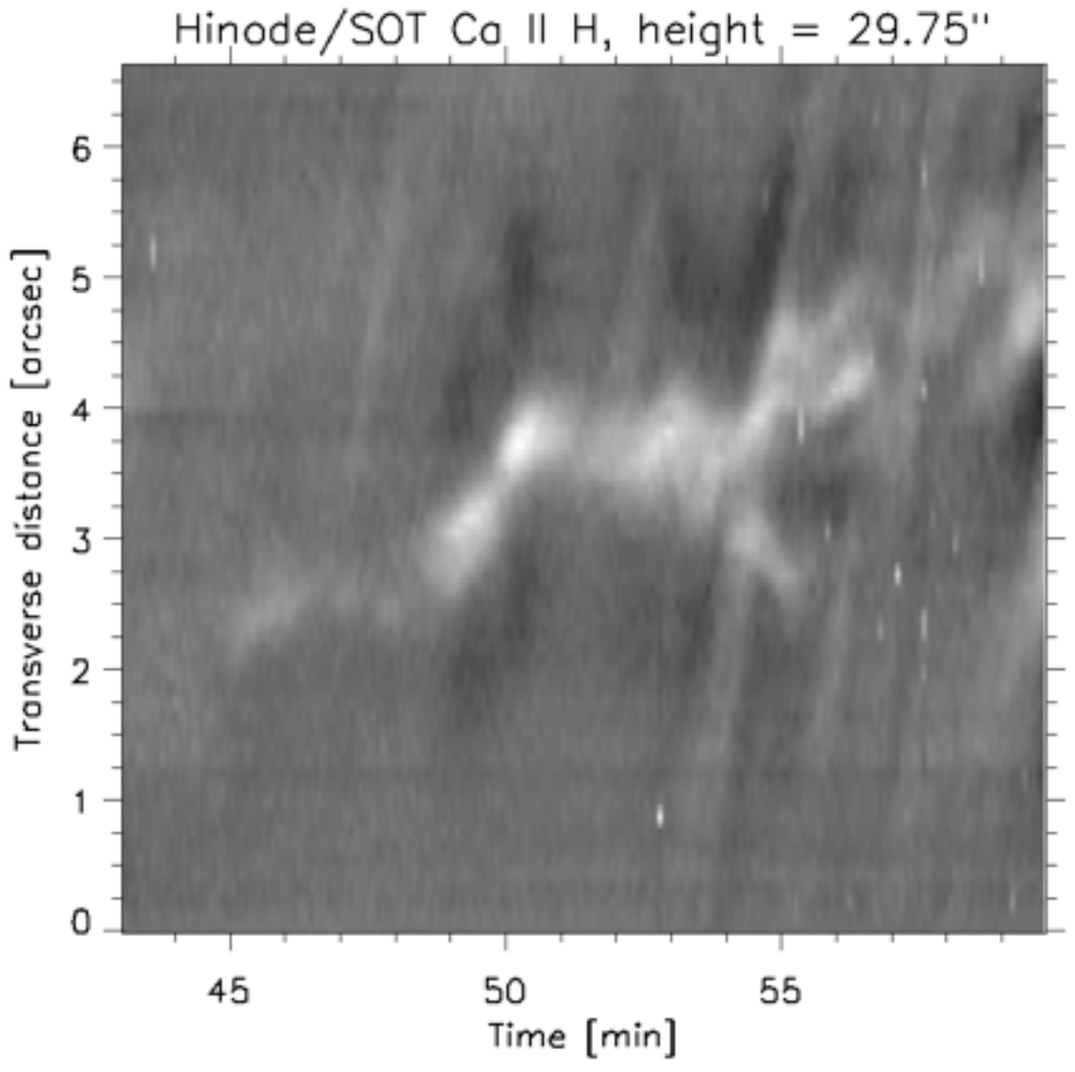
Transverse MHD waves in Ca II H

more complex, multiple period?





movie of xt transverse cuts with height



Transverse MHD waves can be seen, but apparently different (smaller) periods