Initial Results of Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP)

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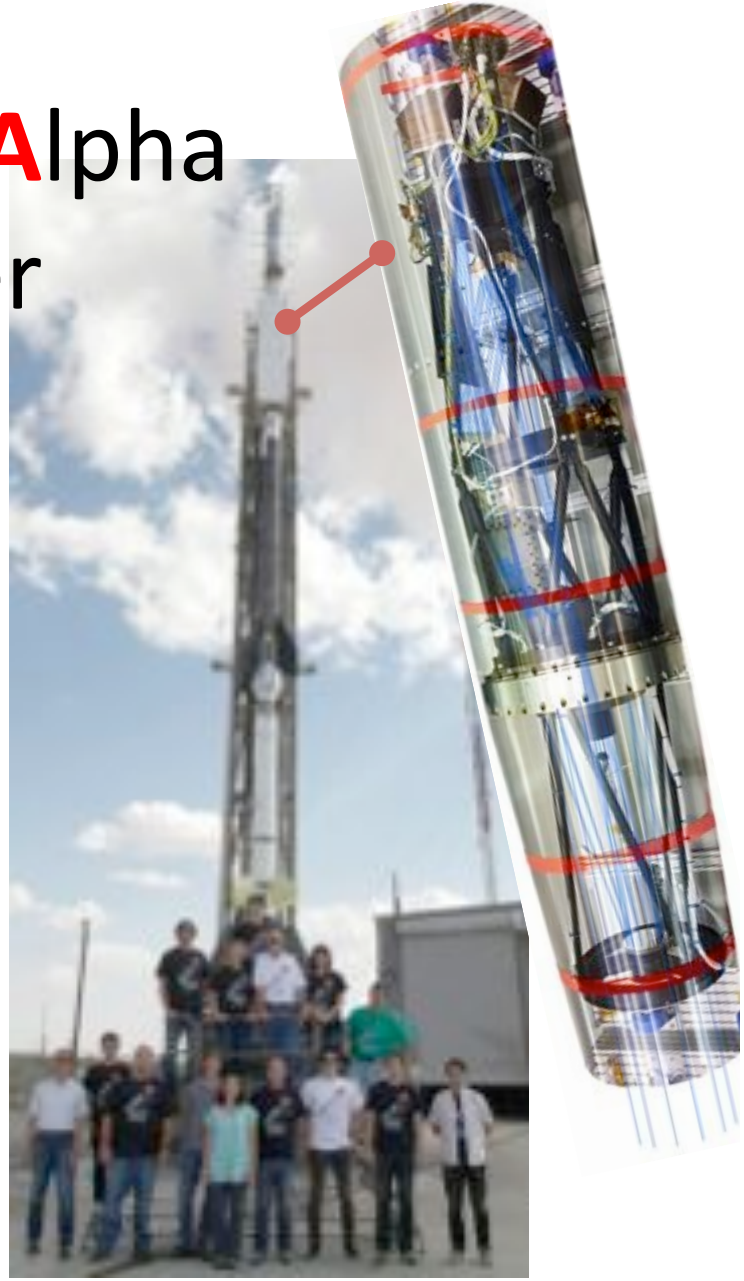
Launch on September 3rd 2015

@ White Sands Missile Range (USA)

NASA's sounding rocket experiment

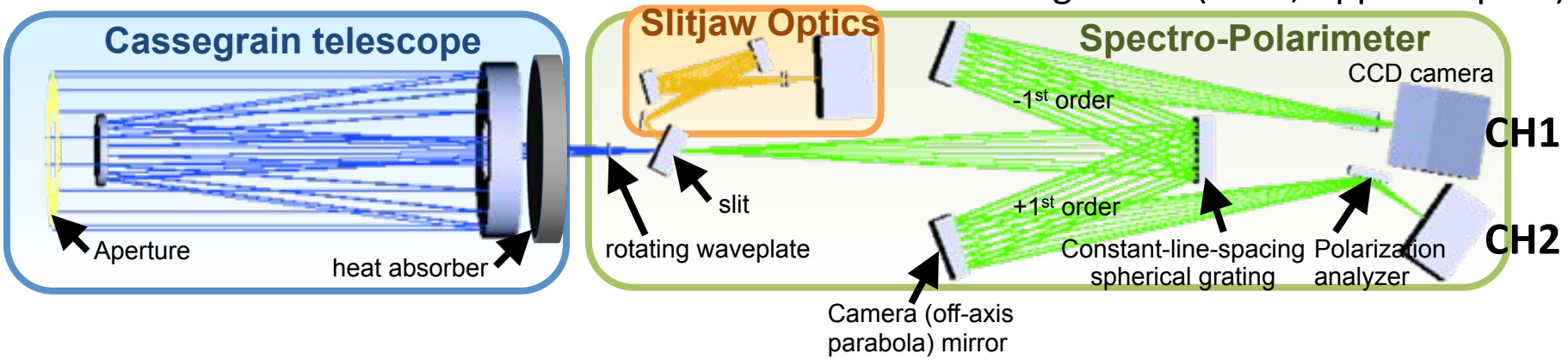
Chromospheric Lyman-Alpha Spectro-Polarimeter

- **Perform high-precision** (<0.1%) spectro-polarimetery in VUV (Vacuum Ultra Violet)
- **Detect** the scattering polarization and Hanle effect in the Lyα line (121.6 nm)
- **Explore** the magnetic fields in the upper chromosphere and the transition region



CLASP instrument

Narukage et al. (2014, Applied Optics)



- Two symmetric channels: **CH1 & CH2**
  - **Simultaneously** measure **orthogonal polarization** states
- Realize **high throughput** in **VUV**
  - Minimize the number of optical components
  - Apply high-reflectivity coating to all optical components

CLASP instrument

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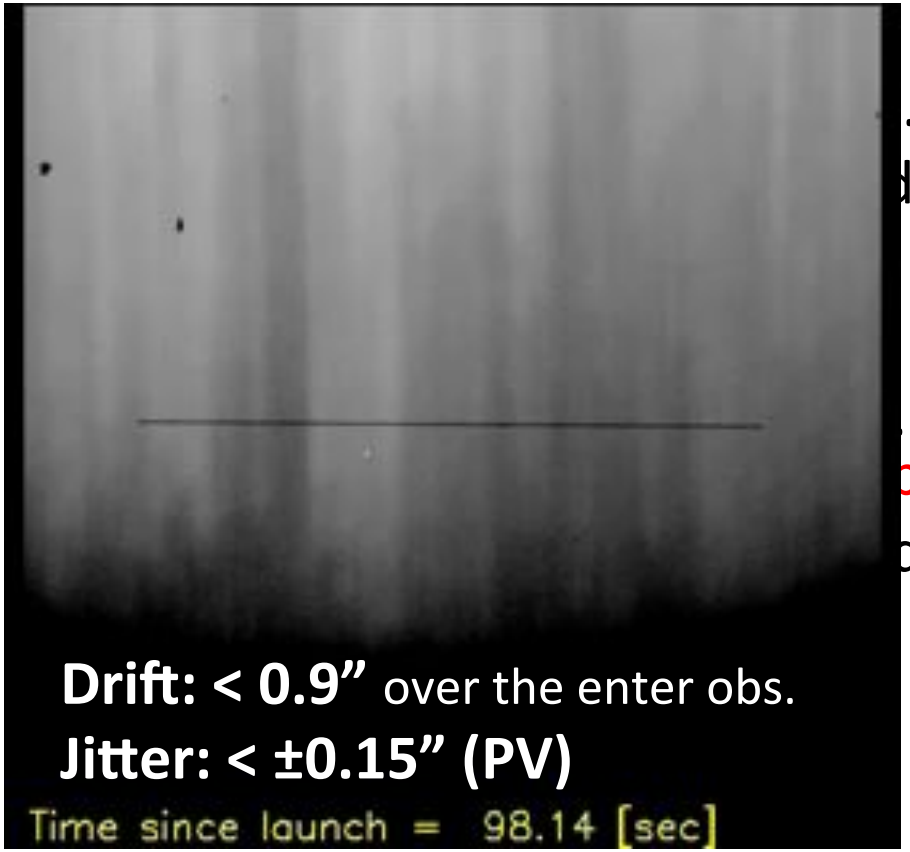
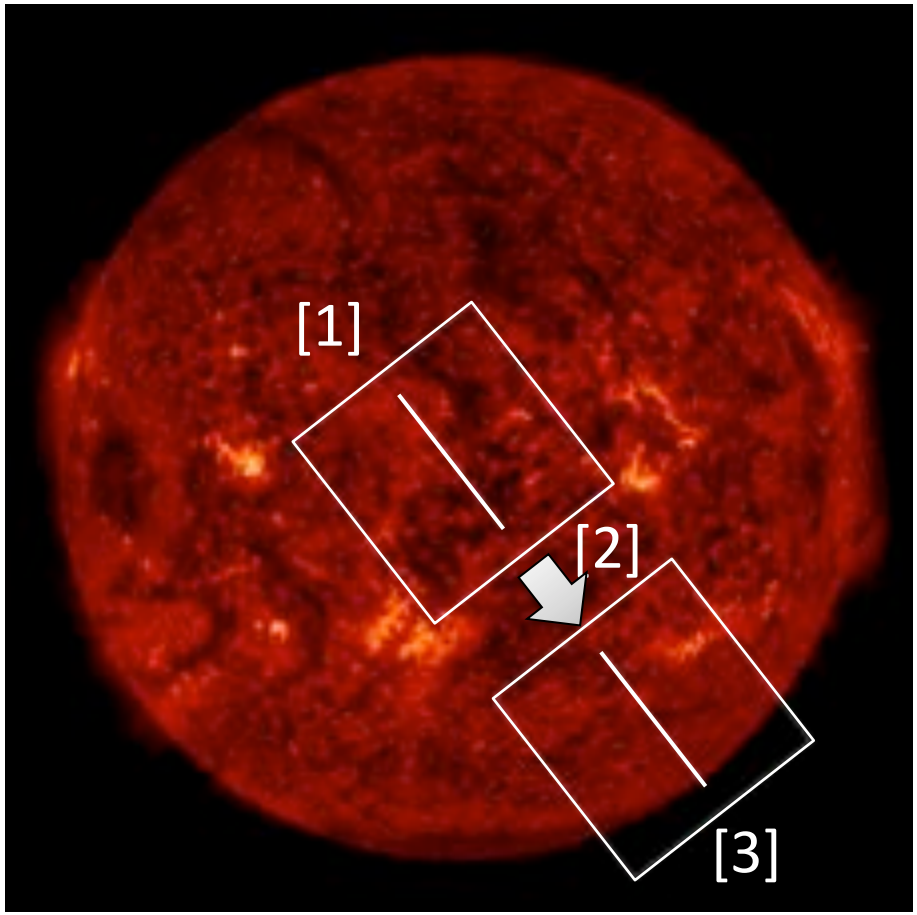
CLASP observation

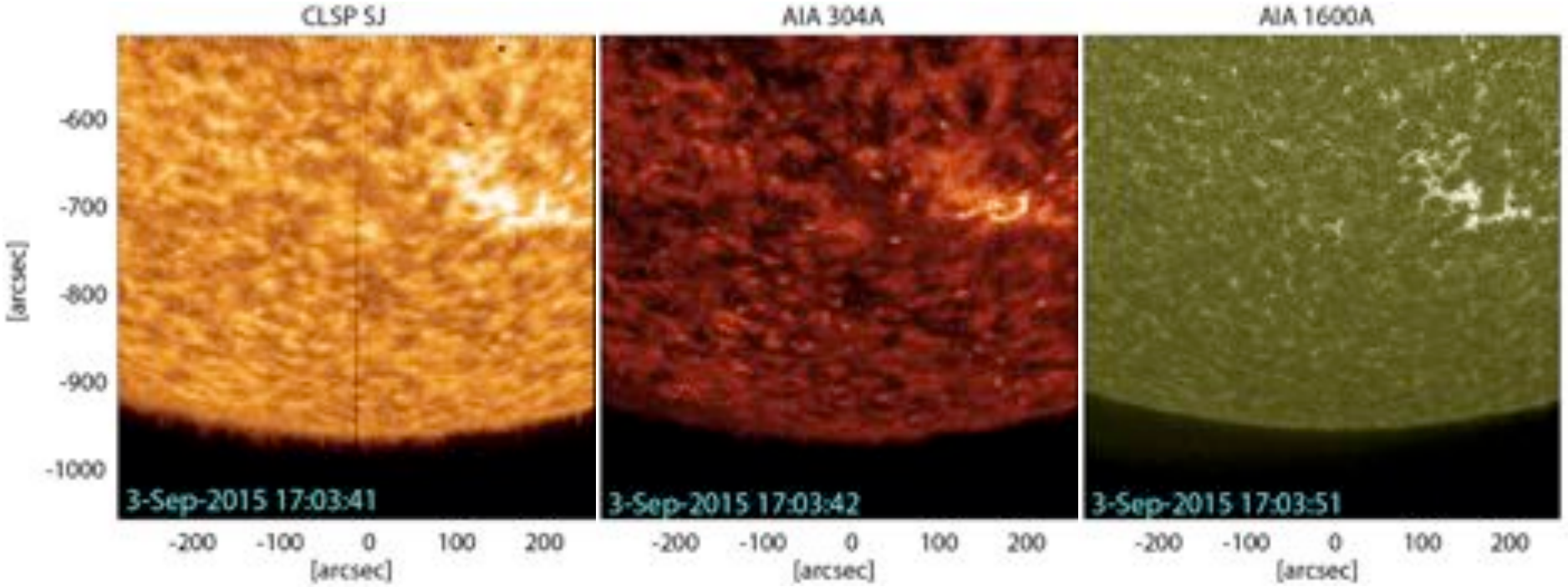
[1] Initial ~ 10 sec

CLASP Slitjaw (SJ) movie





Observation of CLASP Slit-jaw (SJ)



Cross correlation with CLASP/SJ

	Full FOV	Quiet Sun
AIA 1600A (Lower chromosphere)	0.78	0.43
AIA 304A (Transition region)	0.92	0.86

CLASP/SJ → Middle or upper chromosphere

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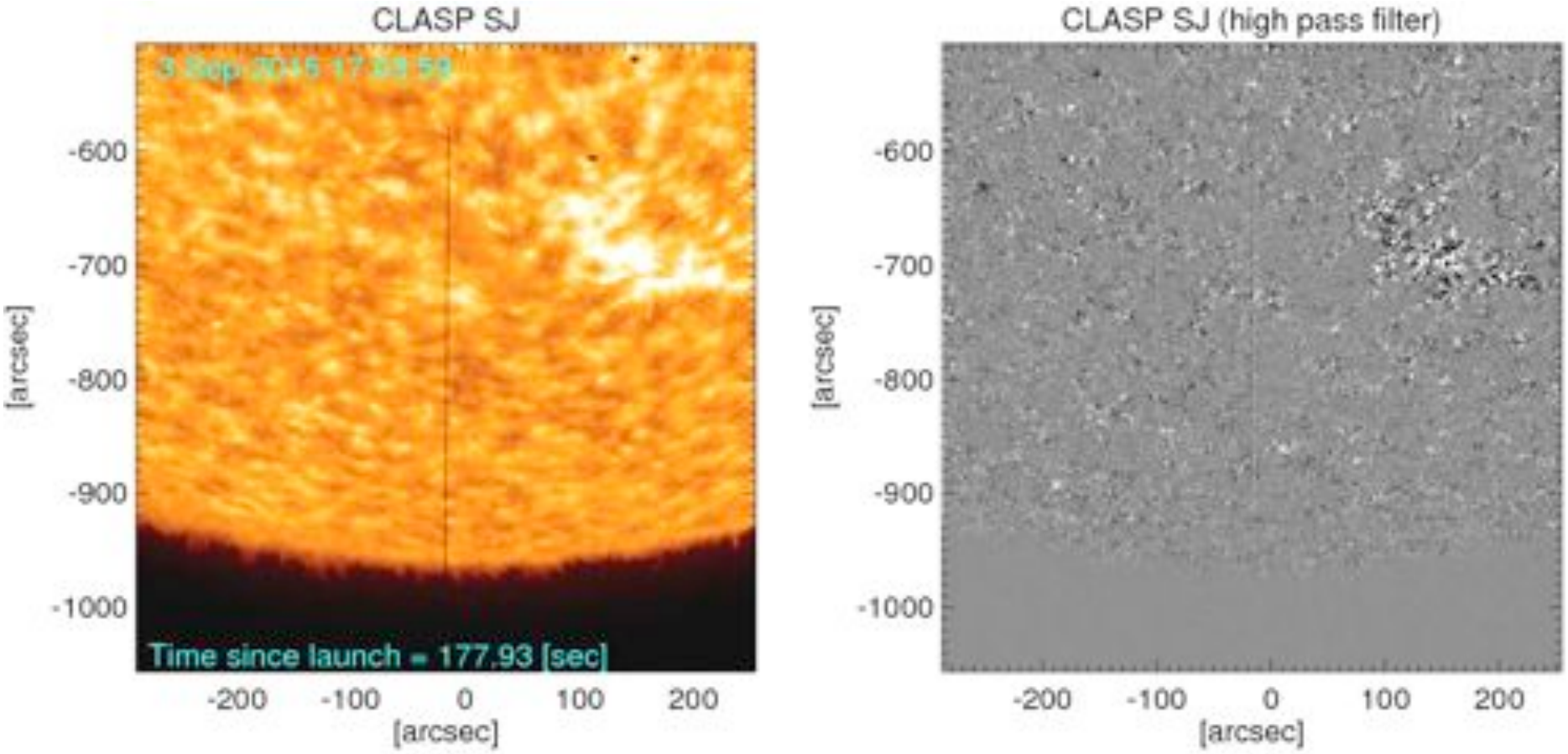
CLASP/SJ images with high pass filter



- Ubiquitous fast intensity fluctuations in active region and the quiet Sun.

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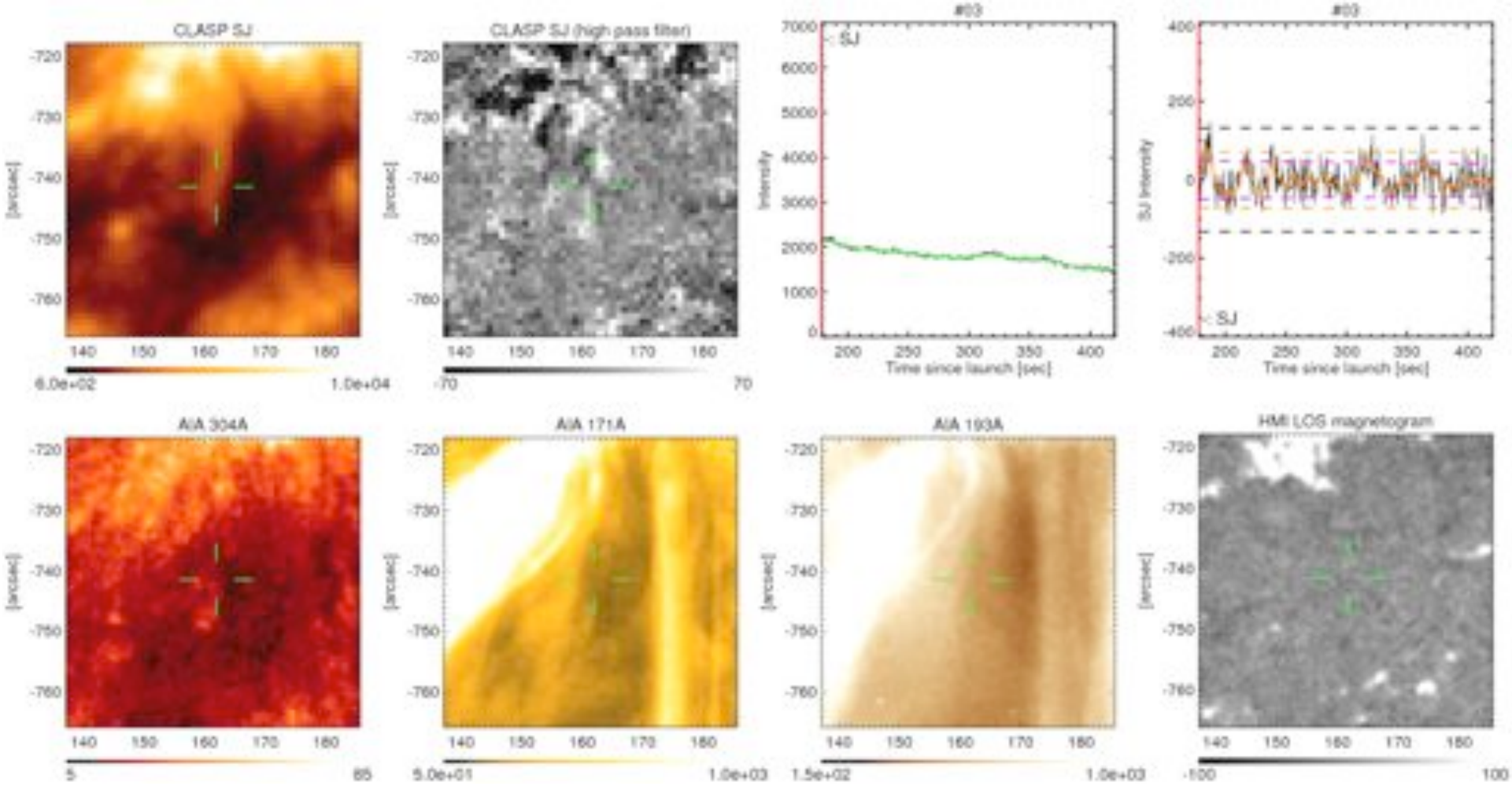
Propagating disturbance at AR edge



- Intensity fluctuations propagate along the elongated bright structure

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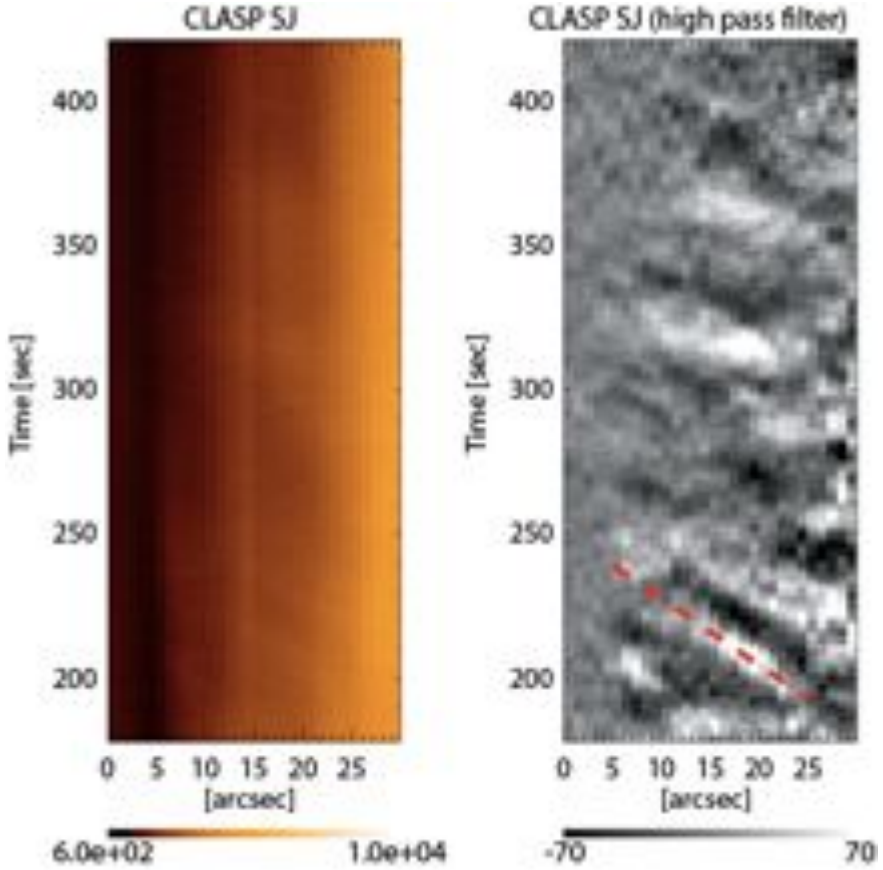
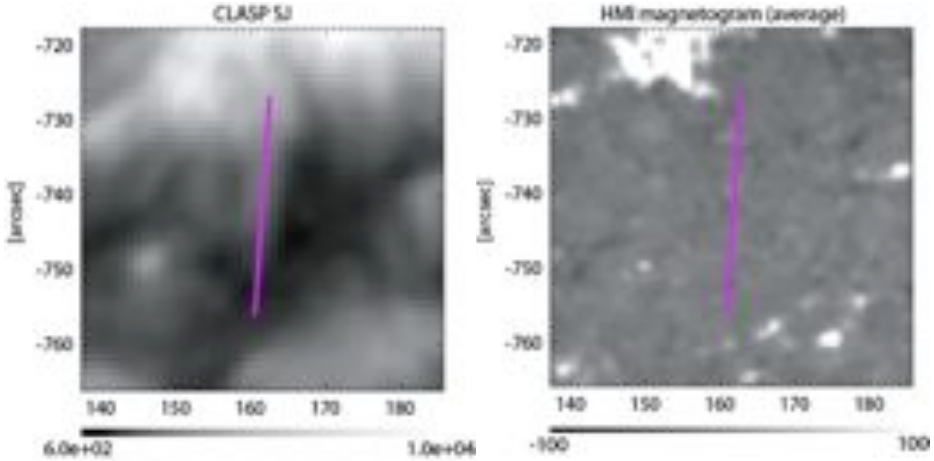
Space-time plot





- White/dark patterns (quasi-)periodically appear and move away from the AR at ~325 km/sec (>normal sound speed)
- Period is shorter than 1 min
- No counterparts in high pass filtered AIA images

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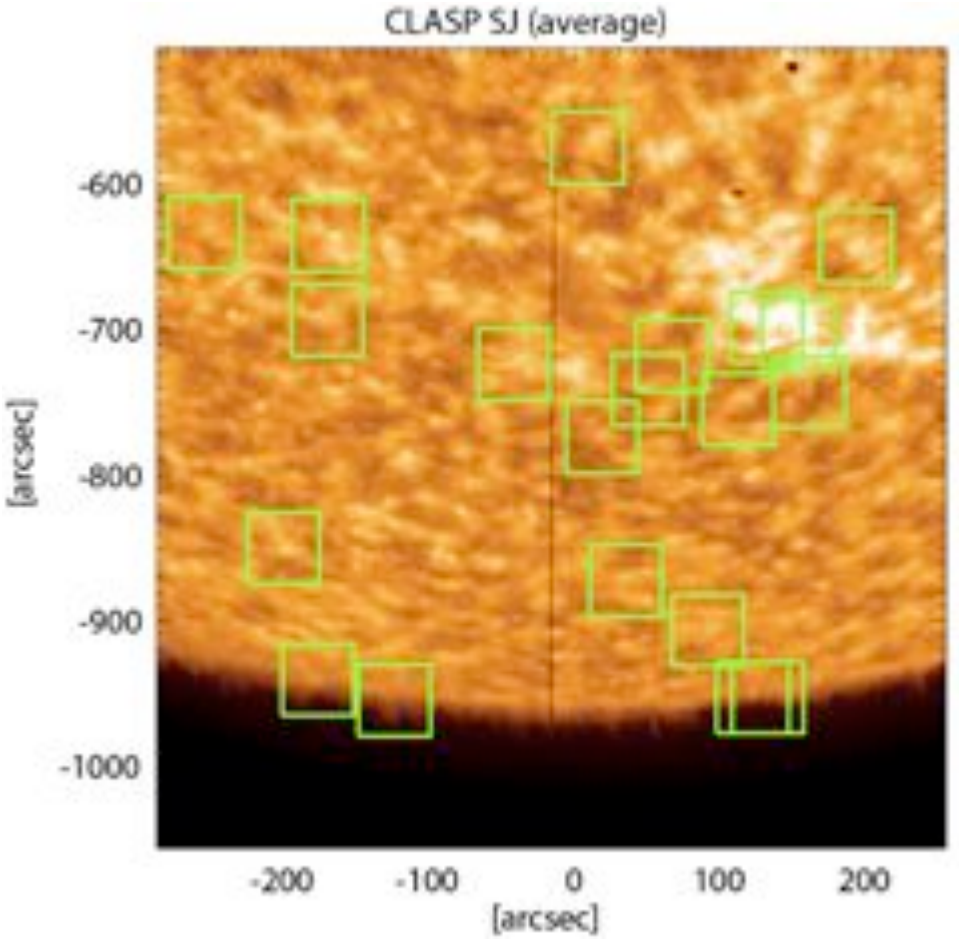
Quasi-periodic motions with unprecedentedly short lifetime



Clear quasi-periodic propagating disturbances are observed in at least 20 areas.

- Area: QS, AR, limb
- Period: < 1 min
- Amplitude: < 2 - 3%
- Speed: 150 km/s – 400 km/s
- Distance: < 10”
- Direction: Away from magnetic islands (not all)
- Relations with AIA 304A images: Sometimes

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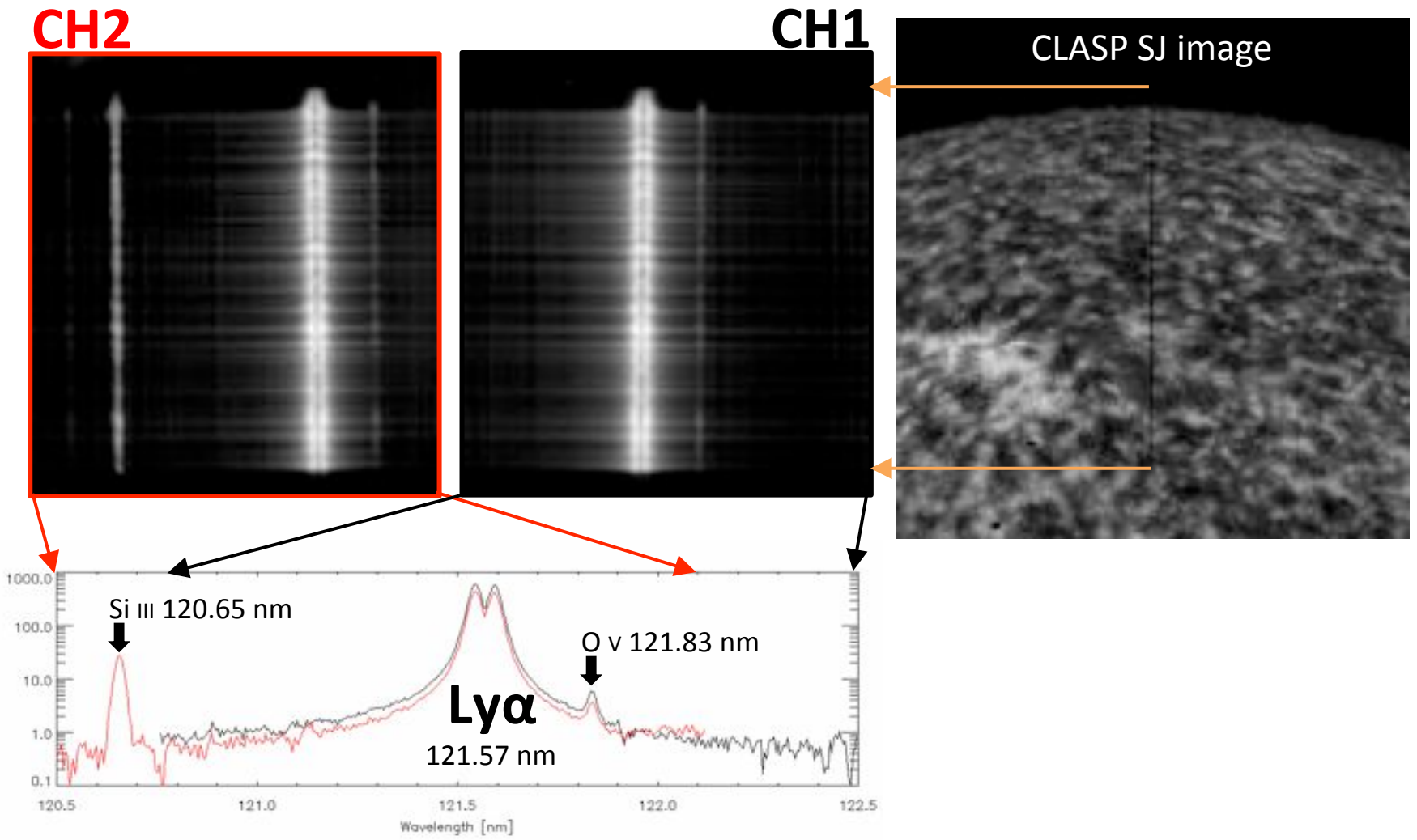
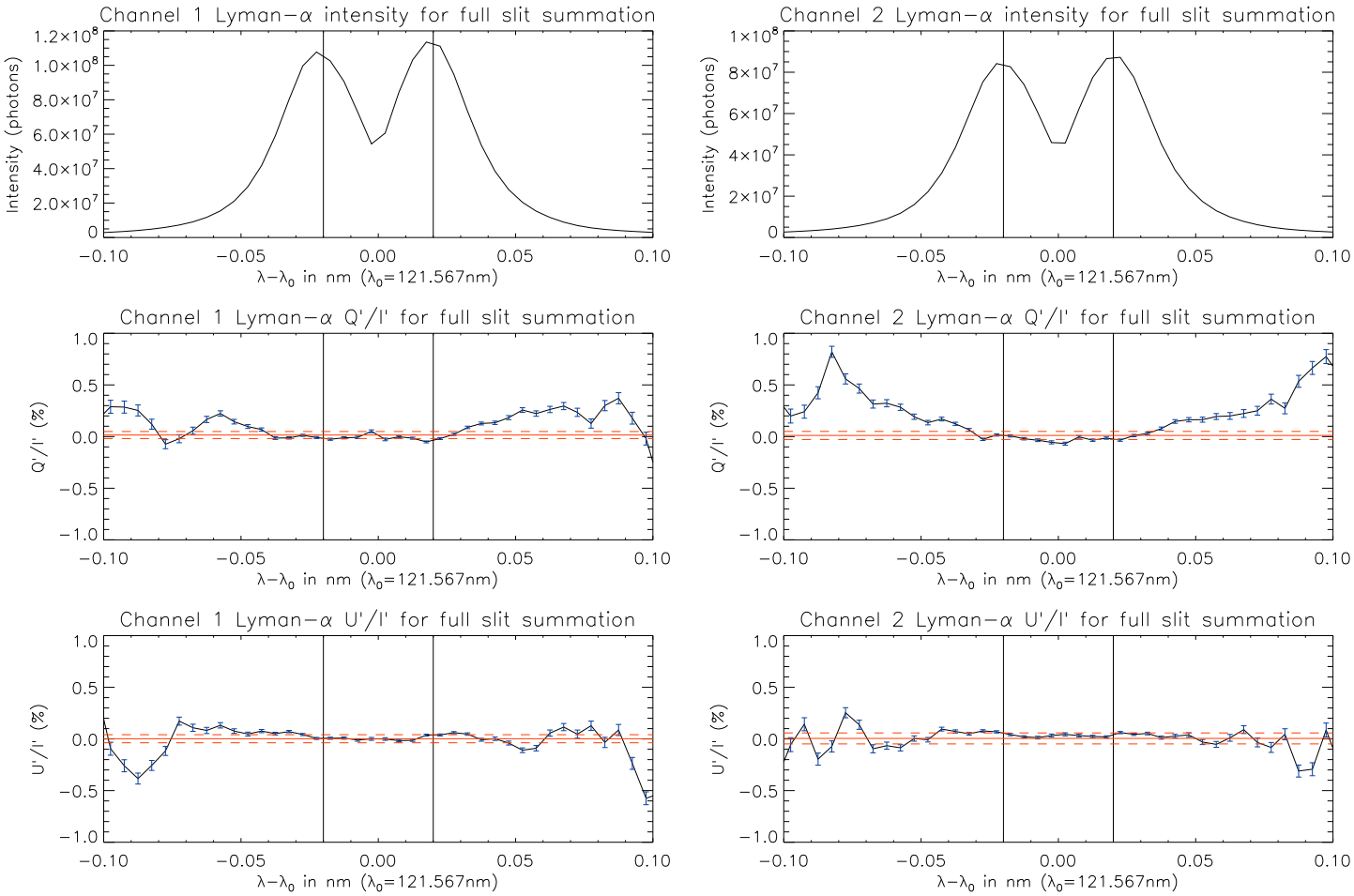
Spectrum taken with Spectro-Polarimeter (SP)



Disk center observation by CLASP Spectro-Polarimeter (SP)



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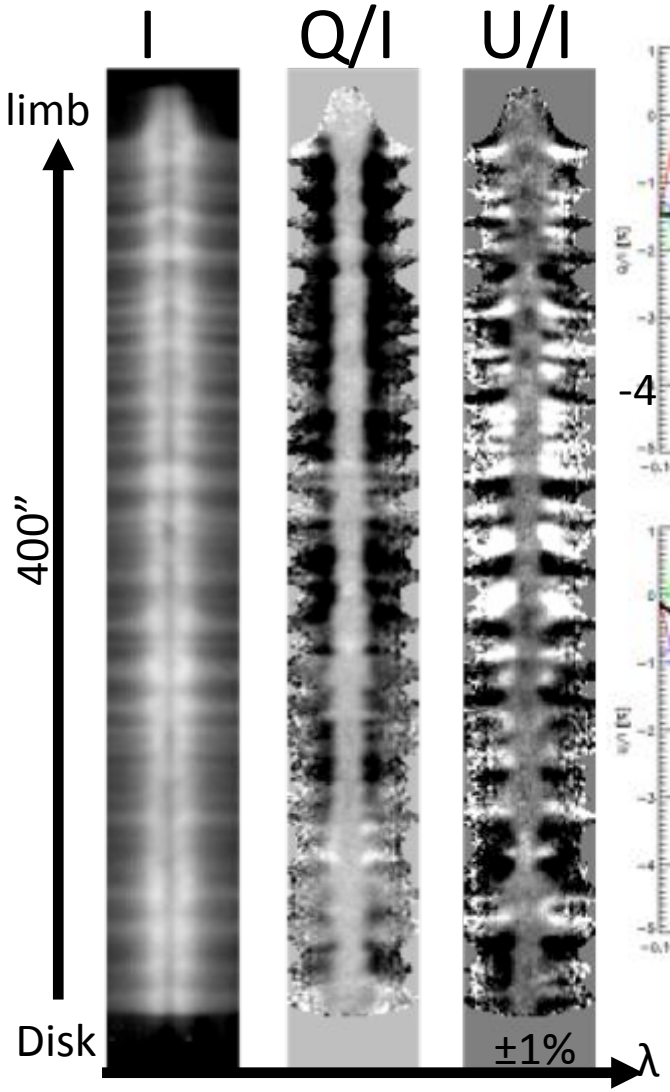
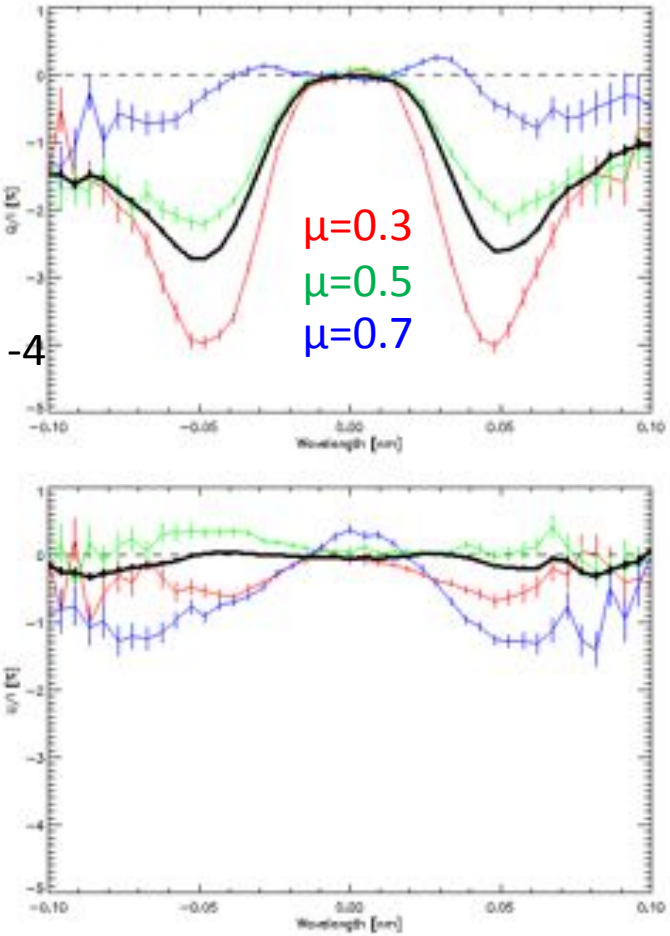
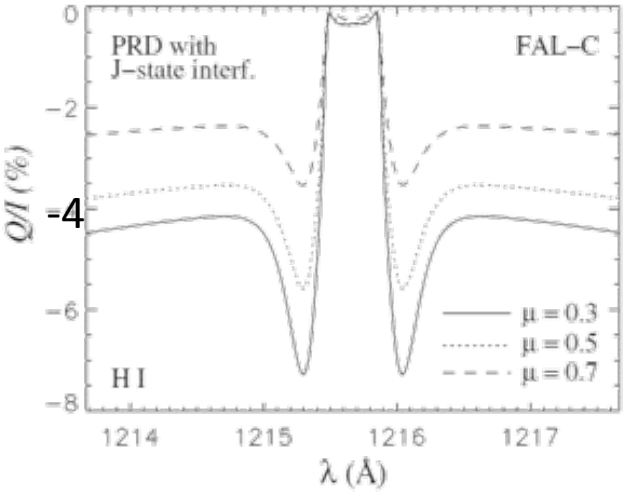
Polarization @ Lya wing



Observed Pol. Spectra



Model (Belluzzi+ 2012)



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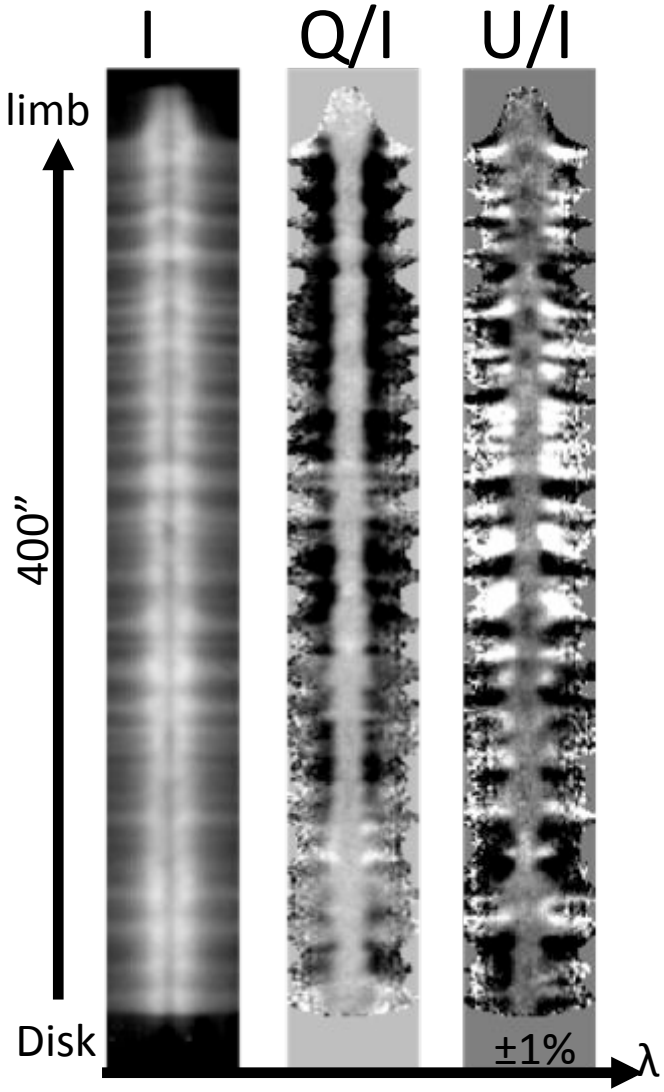
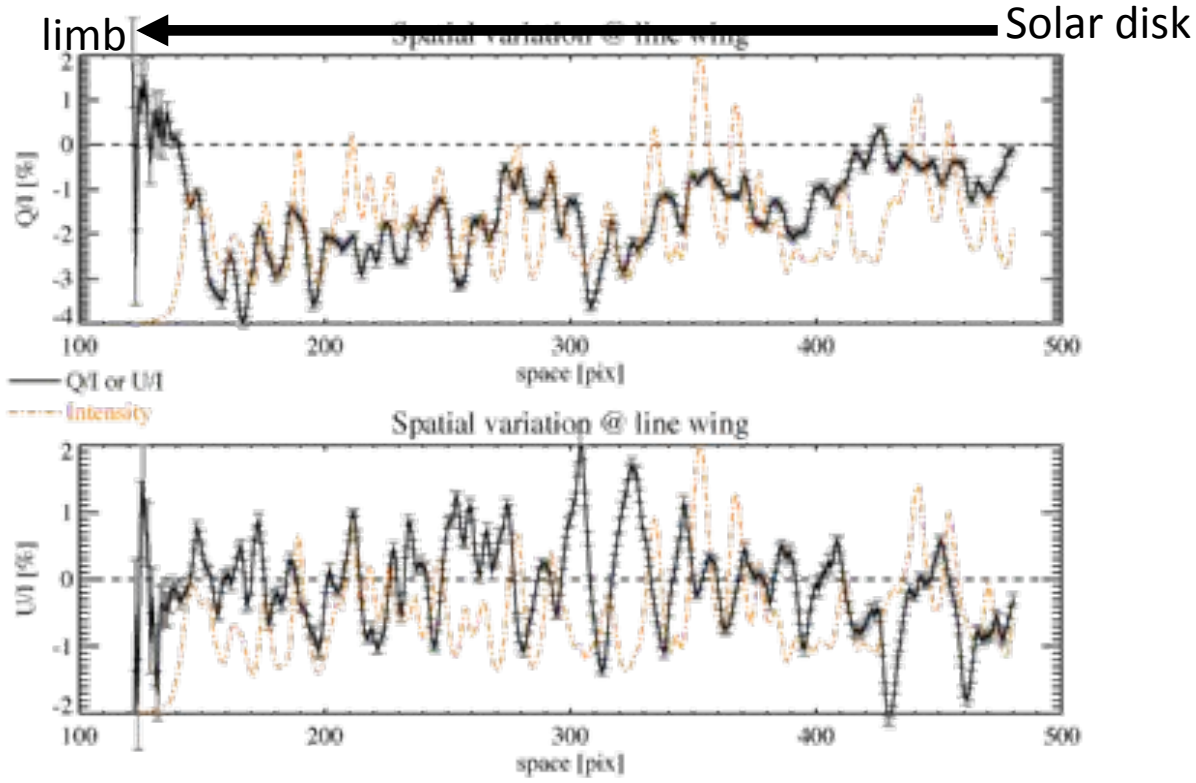
Polarization @ Lya wing





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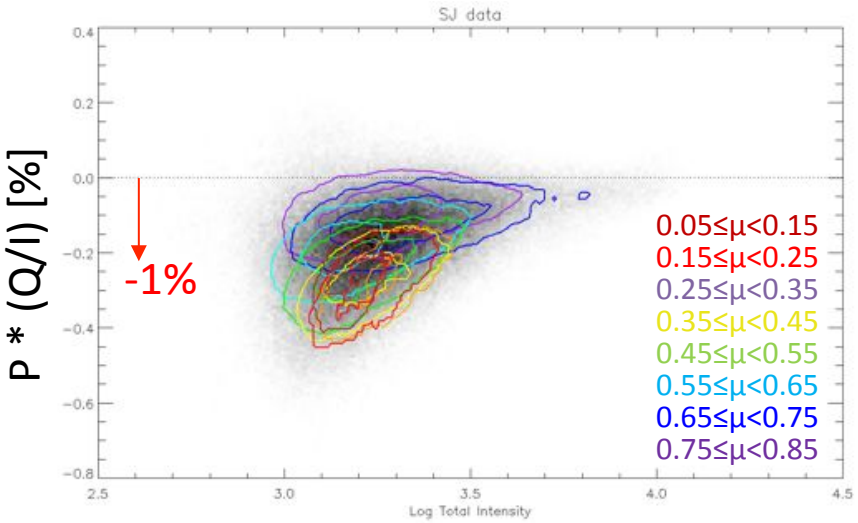
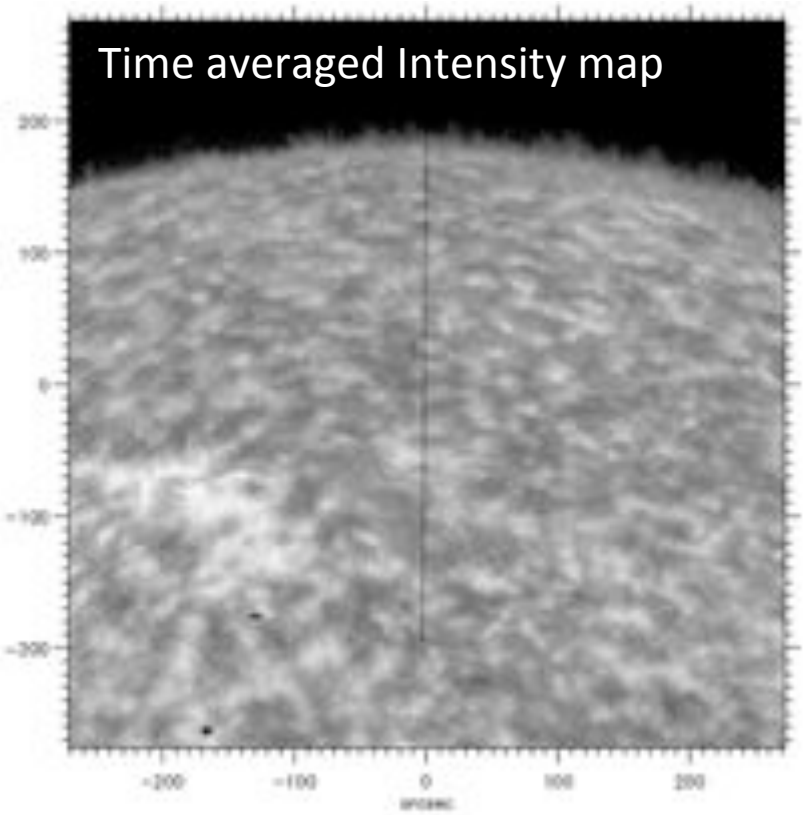
Spatial variation of wing polarization observed by CLASP/SJ

- The fold mirror in SJ is an imperfect polarizer.
  - Rp～39% & Rs～62%
  - P～0.22
- The exposure of 0.6s (twice of SP's) is fortunately(?) suitable for Q measurement.





About +/–3% in Q/I

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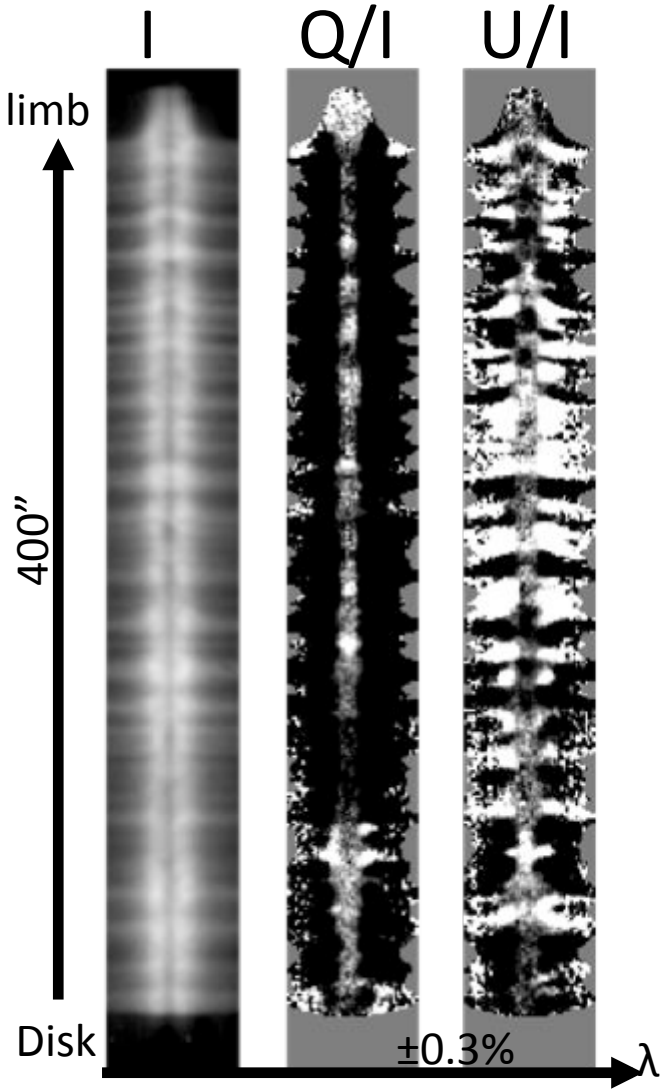
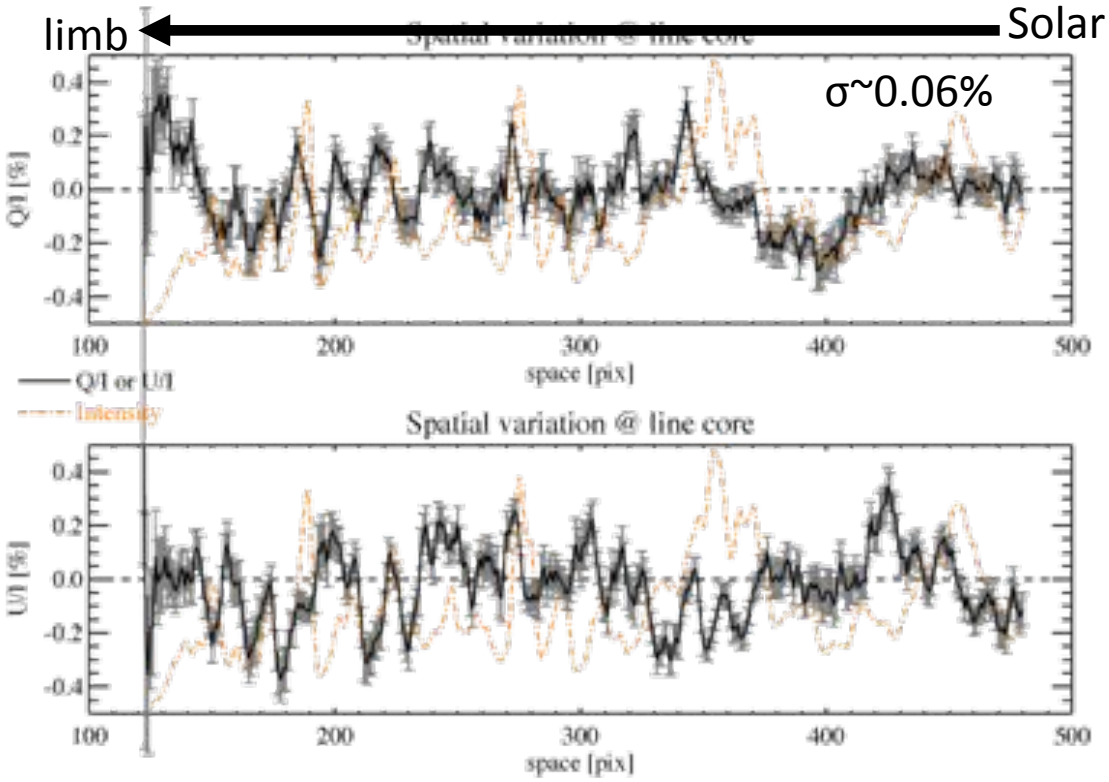
Polarization @ Lya core





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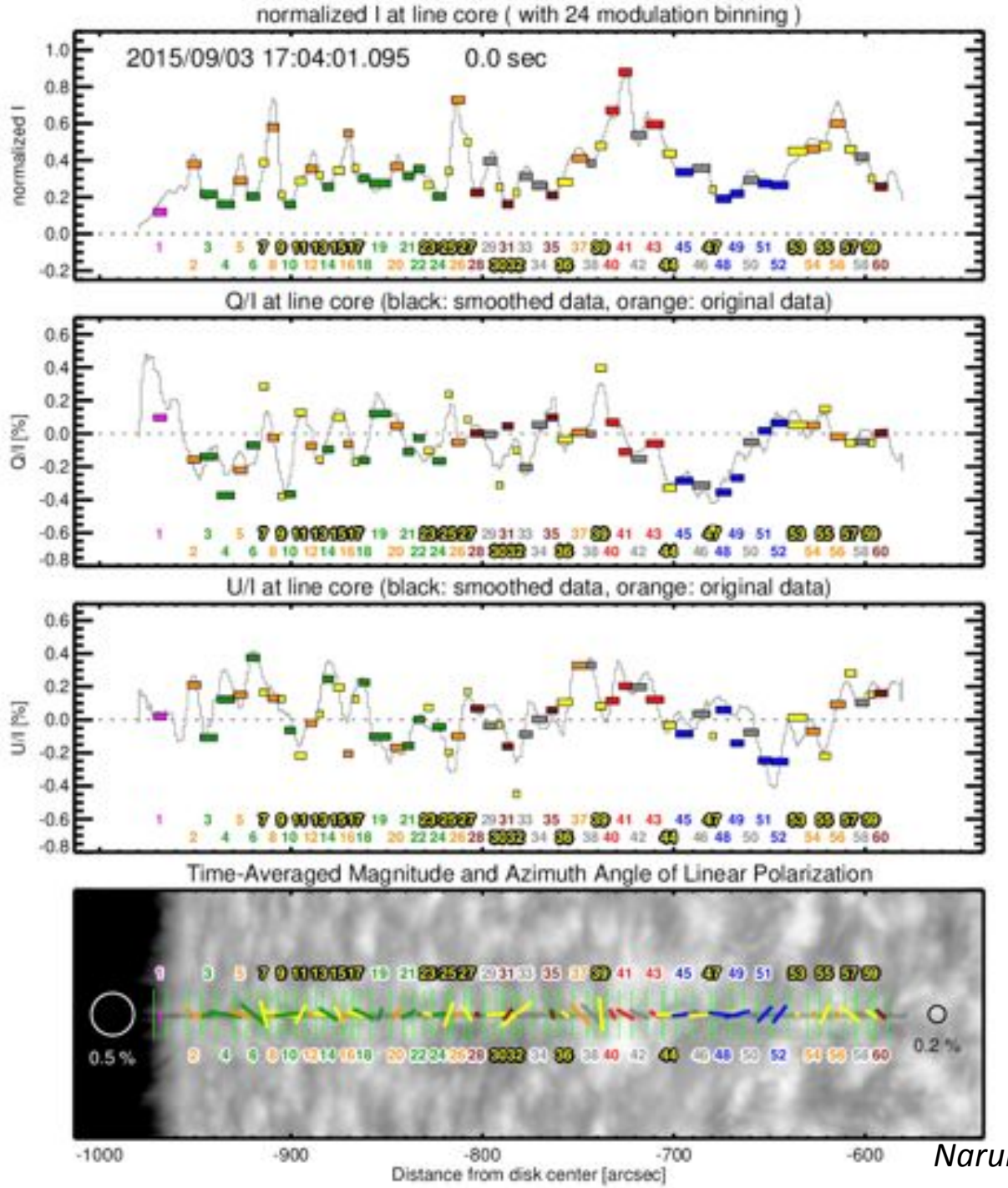
Time evolution of Lyα core polarization



"enhanced network", "network",
"inter network", "**boundary**",
"filament", "fibril", "intermed.",
"spicule"

Narukage et al. in prep

Comparison between Lyα core, wing and Si III

- Critical field strength: $B_H = \frac{1.137\times10^{-7}}{t_{life} g_j} = 1.137\times10^{-7}\frac{A}{g_j}$

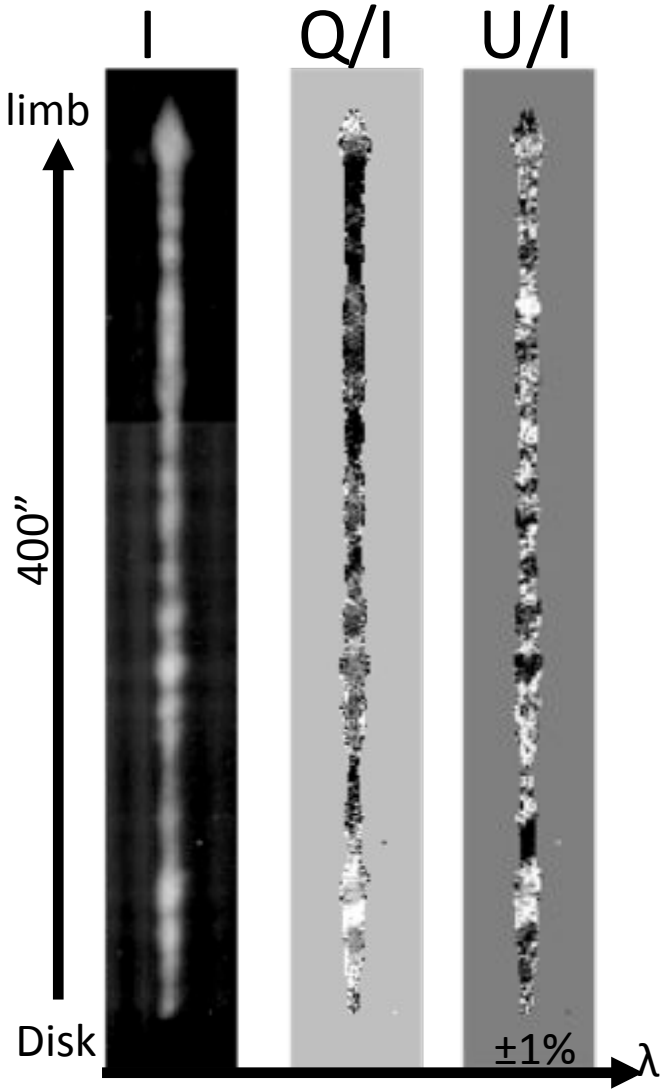
- Lya core
  B_H = **54** G
  (A = 6.27×10^8, g = 1.33)

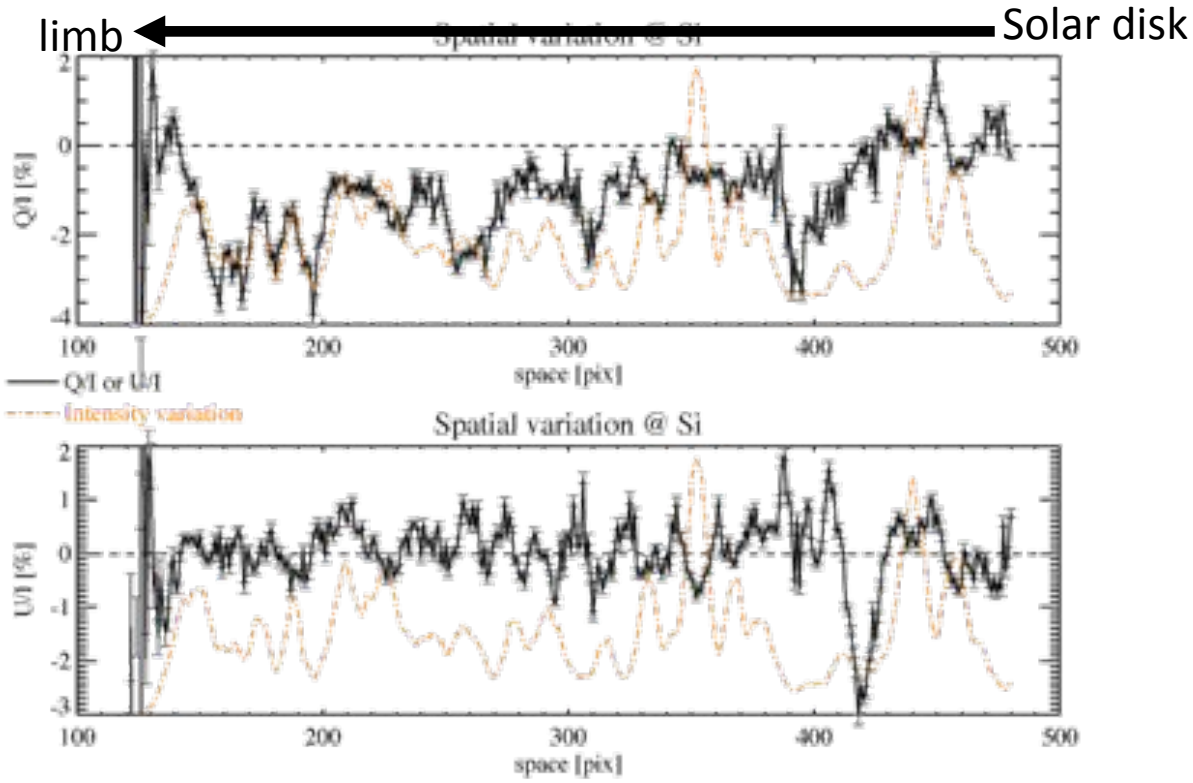
- Lya wing
  B_H = **∞**
  (not sensitive to B)

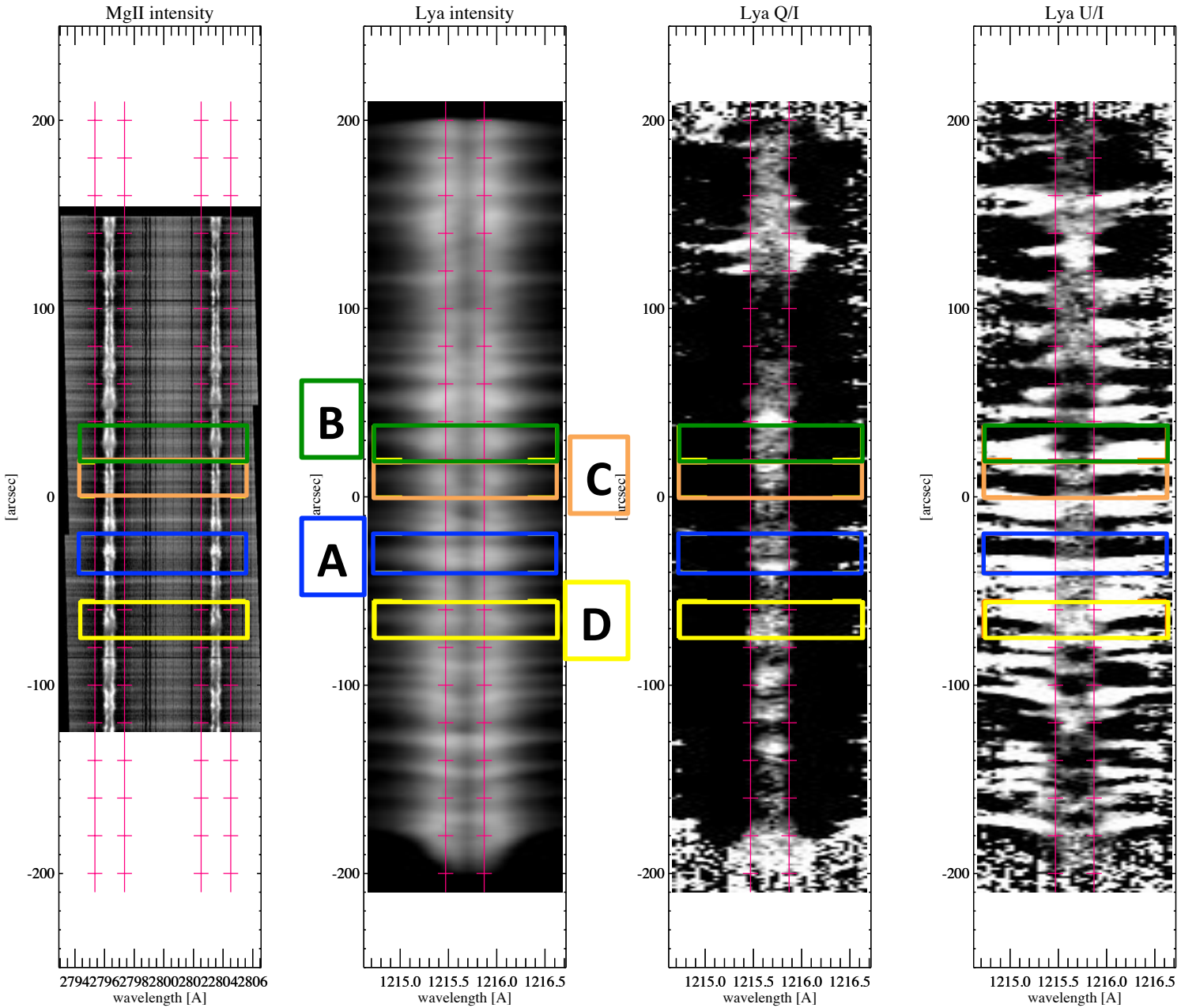
- Si III (J_l=0, J_u=1)
  B_H = **290** G
  (A = 2.55×10^9, g = 1)

- Difference in Q/I & U/I can be explained by the operation of the Hanle effect (differential Hanle effect)
  - if the anisotropic radiation field is similar among three lines

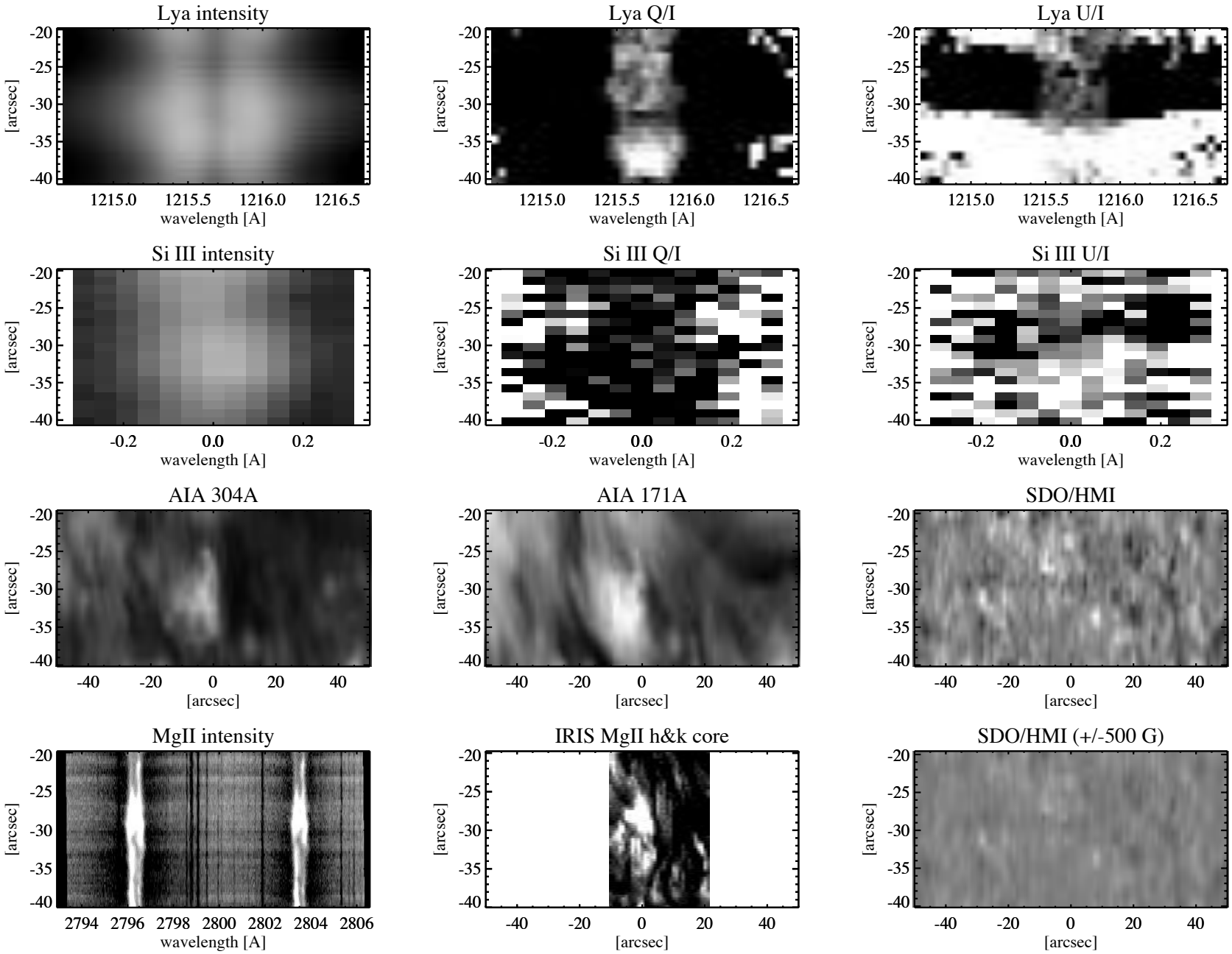
Polarization @ Si III



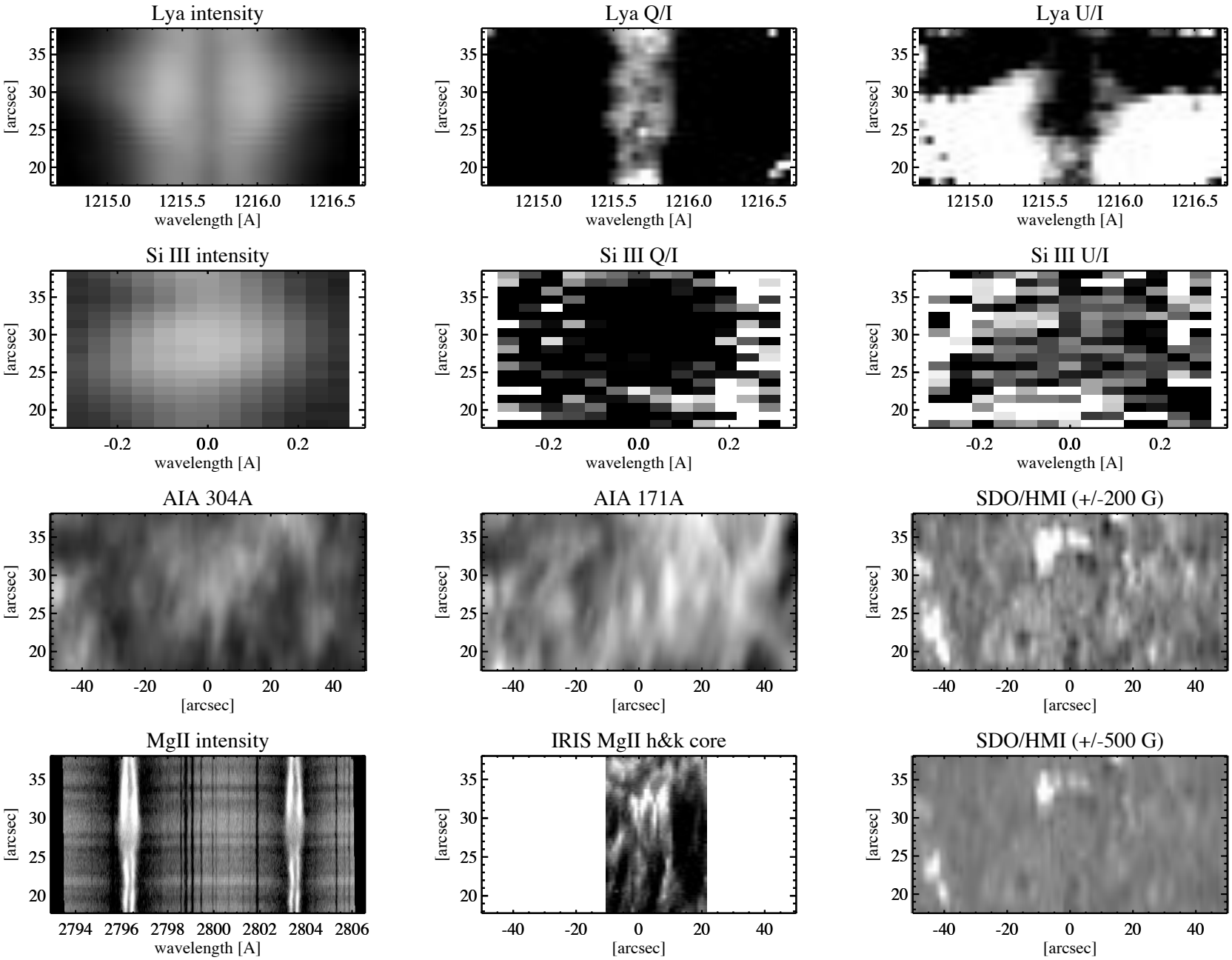



MgII intensity
Lya intensity
Lya Q/I
Lya U/I
200
100
0
-100
-200
[arcsec]
B
A
C
D
2794279627982800280228042806
1215.0 1215.5 1216.0 1216.5
wavelength [A]

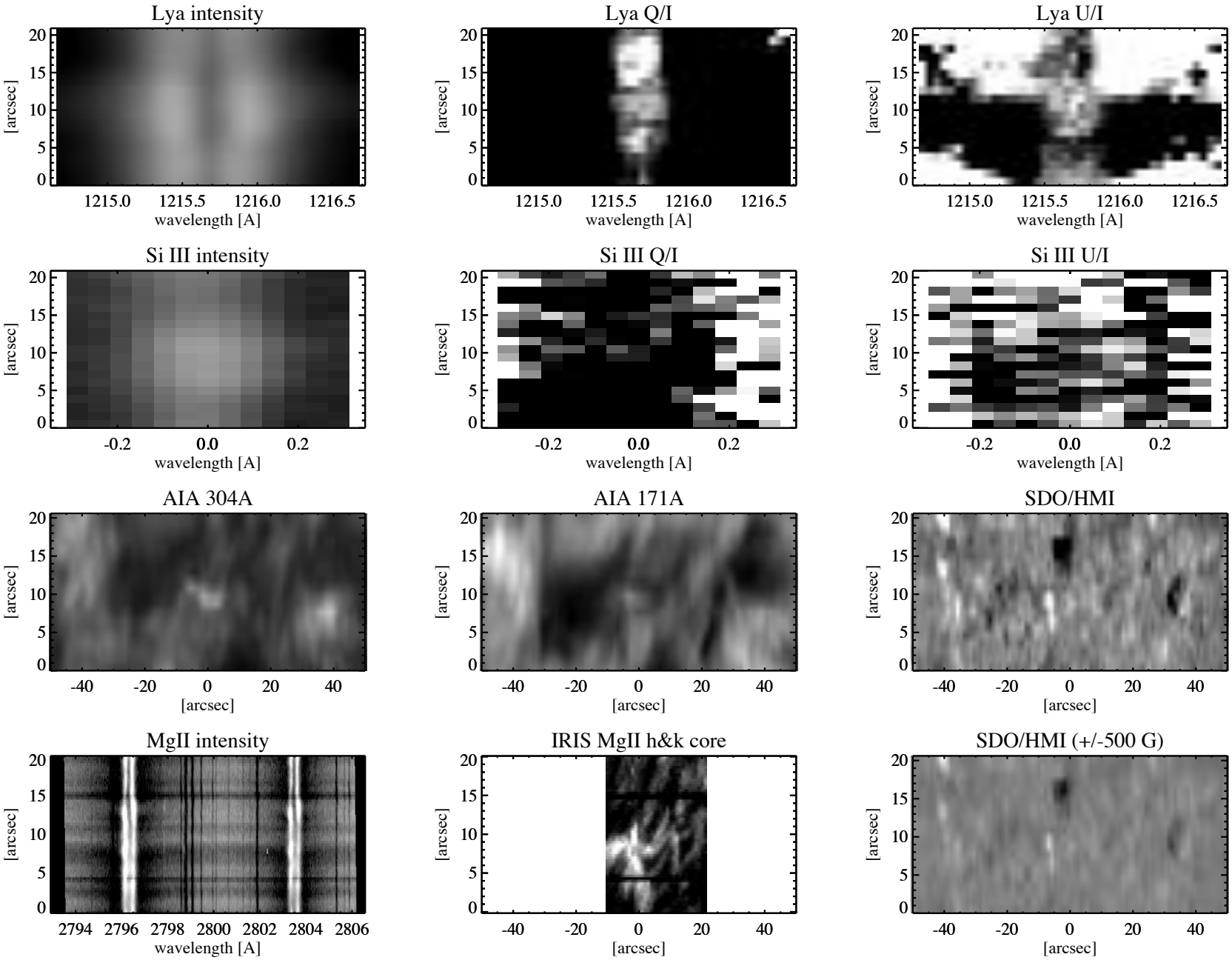
Region A


Lya intensity
Lya Q/I
Lya U/I
Si III intensity
Si III Q/I
Si III U/I
AIA 304A
AIA 171A
SDO/HMI
MgII intensity
IRIS MgII h&k core
SDO/HMI (+/-500 G)
[arcsec]
wavelength [A]
-20
-25
-30
-35
-40
1215.0
1215.5
1216.0
1216.5
-0.2
0.0
0.2
2794
2796
2798
2800
2802
2804
2806

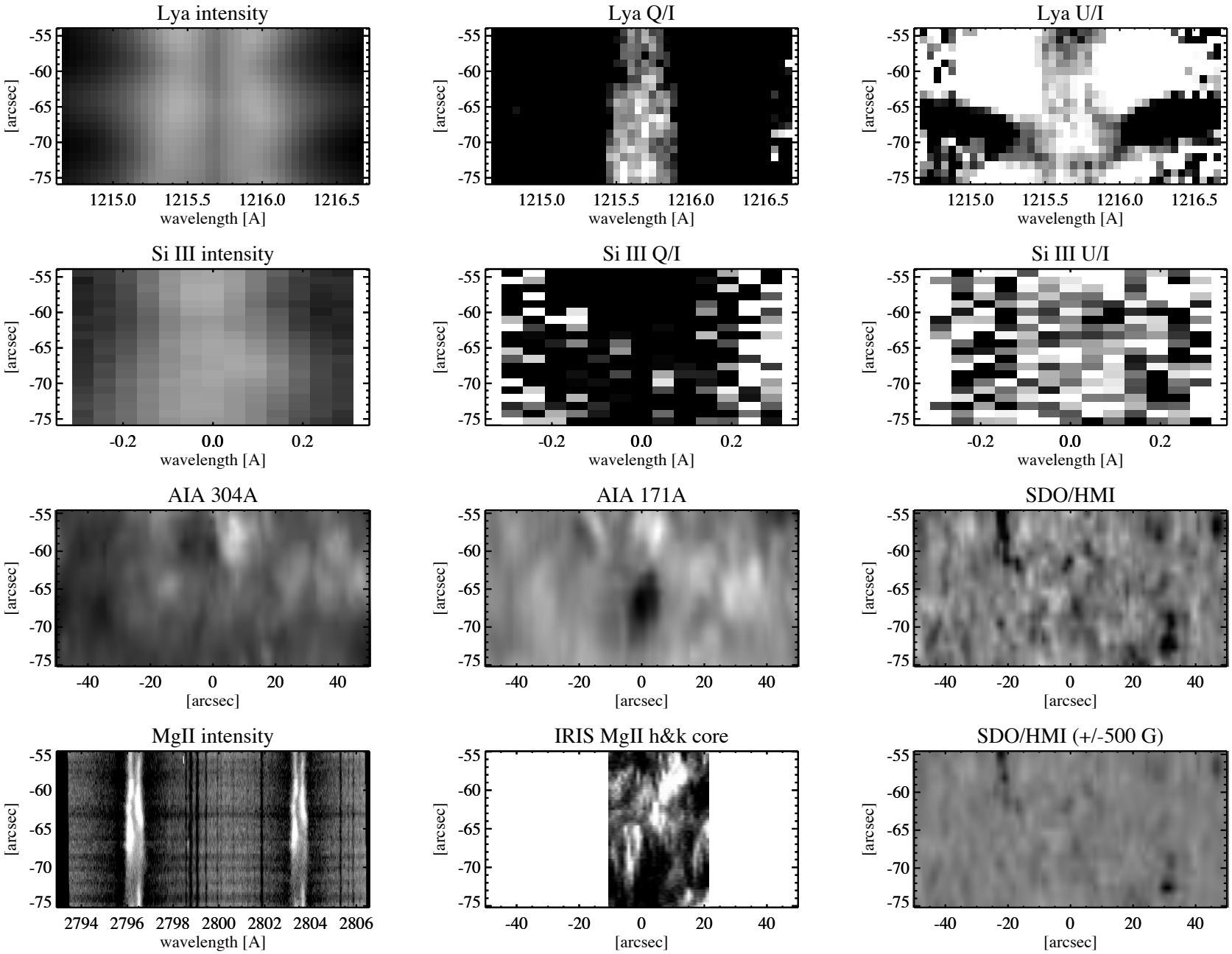
Region B


Lya intensity
Lya Q/I
Lya U/I
Si III intensity
Si III Q/I
Si III U/I
AIA 304A
AIA 171A
SDO/HMI (+/-200 G)
MgII intensity
IRIS MgII h&k core
SDO/HMI (+/-500 G)
[arcsec]
wavelength [A]
1215.0
1215.5
1216.0
1216.5
2794
2796
2798
2800
2802
2804
2806
-0.2
0.0
0.2
-40
-20
0
20
40
20
25
30
35

Region C


Lya intensity
Lya Q/I
Lya U/I
Si III intensity
Si III Q/I
Si III U/I
AIA 304A
AIA 171A
SDO/HMI
MgII intensity
IRIS MgII h&k core
SDO/HMI (+/-500 G)
[arcsec]
wavelength [A]
1215.0
1215.5
1216.0
1216.5
-0.2
0.0
0.2
2794
2796
2798
2800
2802
2804
2806
-40
-20
0
20
40
0
5
10
15
20

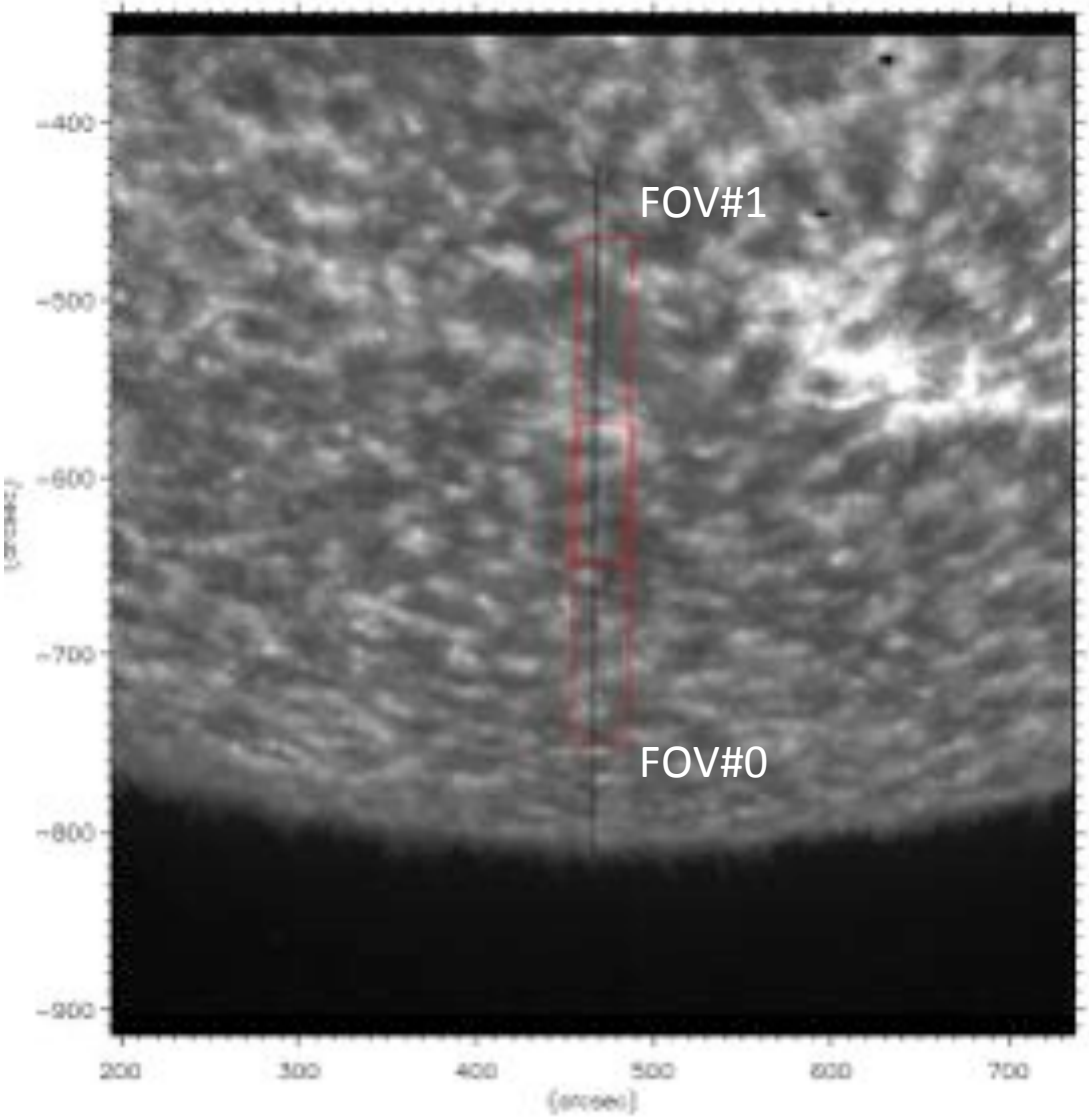
Region D

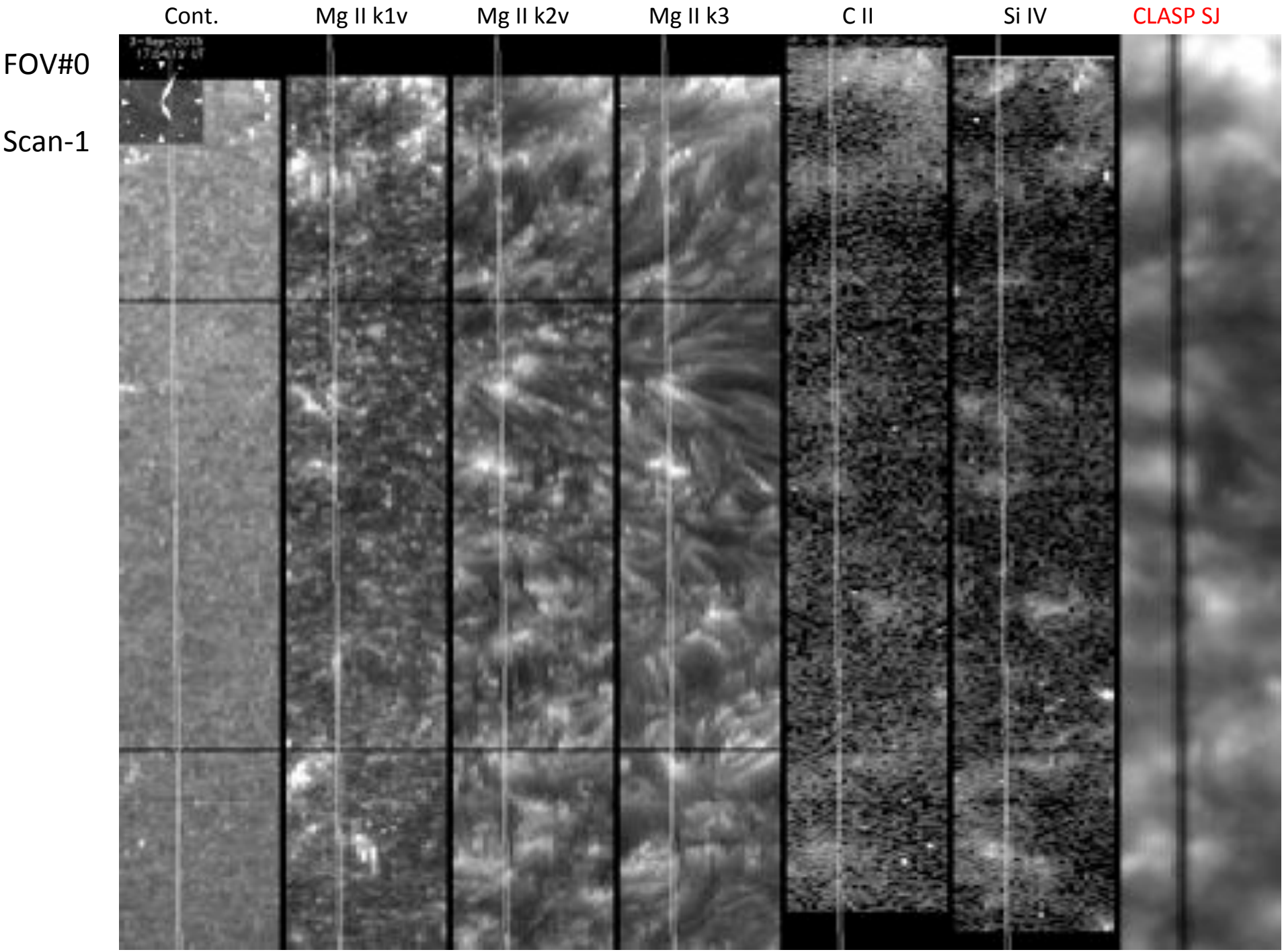

Lya intensity
Lya Q/I
Lya U/I
Si III intensity
Si III Q/I
Si III U/I
AIA 304A
AIA 171A
SDO/HMI
MgII intensity
IRIS MgII h&k core
SDO/HMI (+/-500 G)
[arcsec]
wavelength [A]
-55
-60
-65
-70
-75
1215.0
1215.5
1216.0
1216.5
-0.2
0.0
0.2
-40
-20
0
20
40
2794
2796
2798
2800
2802
2804
2806

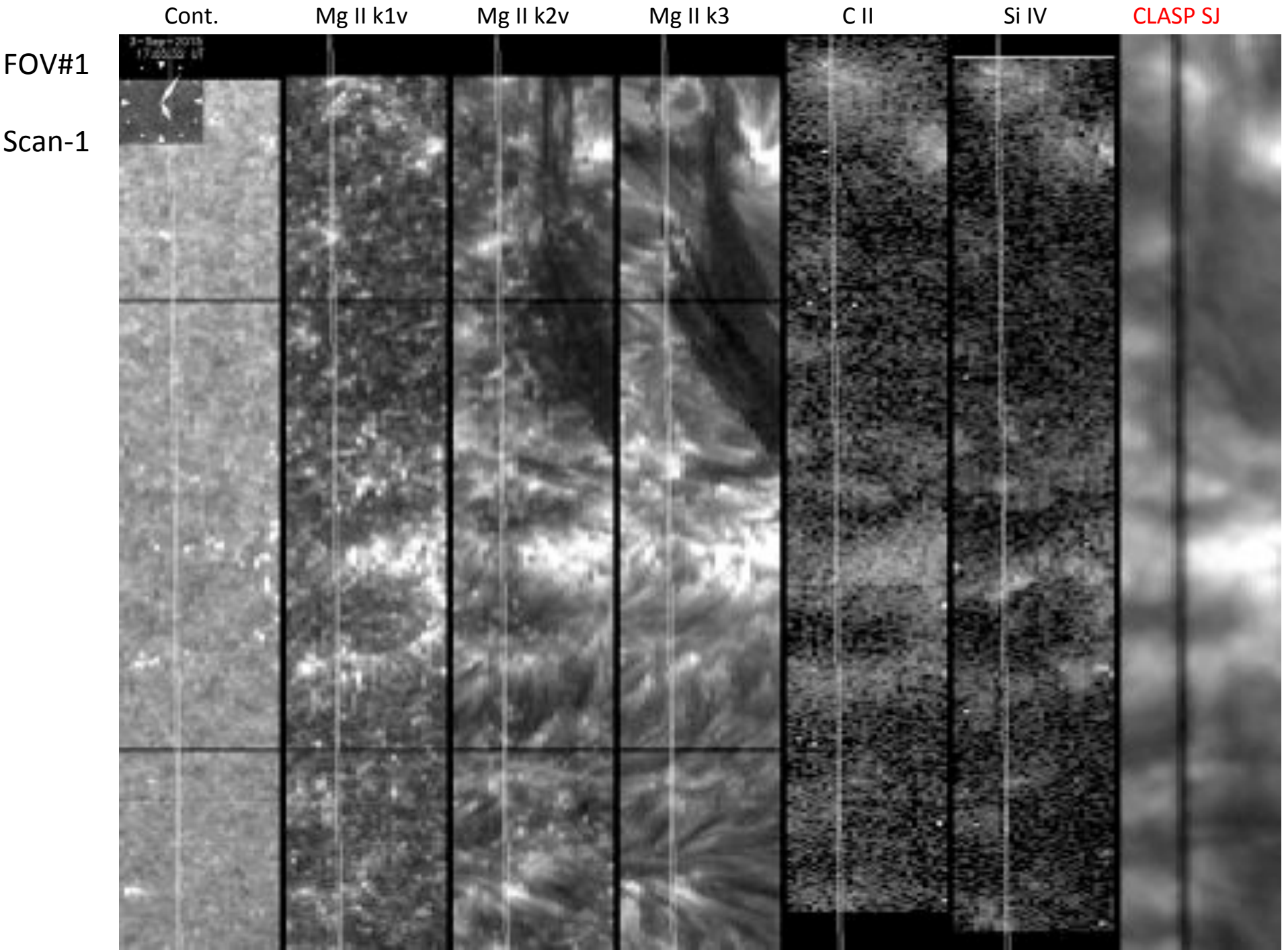
	Region A	Region B	Region C	Region D
sign of U/I @ Lya wing	+/-	+/-	+/-	+/-
sign of U/I @ Lya core	same as Lya wing	opposite to Lya wing	opposite to Lya wing	opposite to Lya wing
sign of U/I @ Si III	same as Lya wing	opposite to Lya wing	opposite to Lya wing	opposite to Lya wing
Photo. mag. in HMI	No signal	strong signal	strong signal	No signal
IRIS wing	brightening	brightening	brightening	No brightening
IRIS core (k2 & k3)	brightening	brightening	brightening	brightening

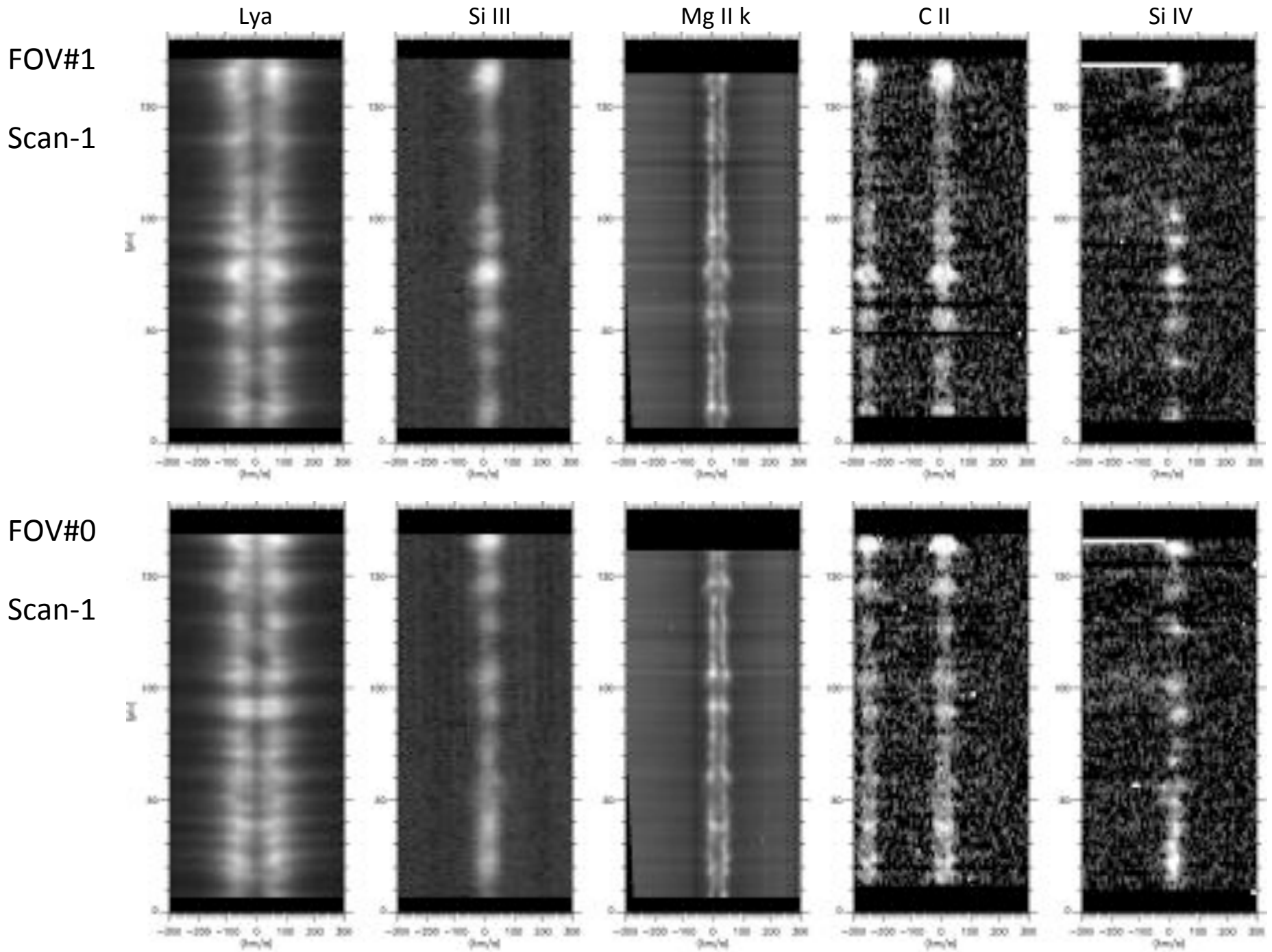
IRIS observation

- 32 step sparse raster
- 2 FOVs by M2 PZT
- Spat sampling: 1.0” x 0.33”
- FOV: 32”x 180” each
  (total: 32”x270”)
- ~ 1min / scan
- 2 raster scans at each FOV during the CLASP flight.




Cont.
Mg II k1v
Mg II k2v
Mg II k3
C II
Si IV
CLASP SJ
FOV#0
Scan-1


Cont.
Mg II k1v
Mg II k2v
Mg II k3
C II
Si IV
CLASP SJ
FOV#1
Scan-1

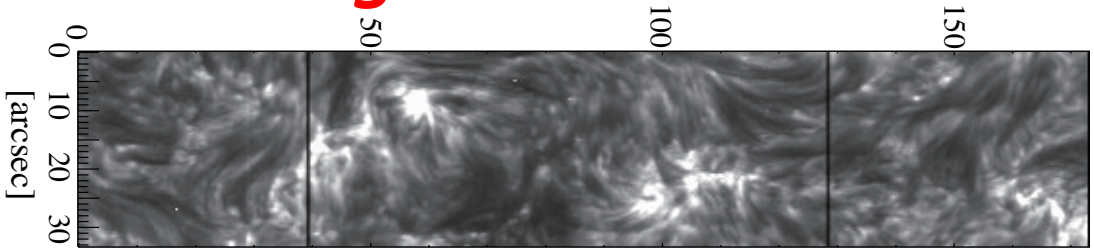

Lya
Si III
Mg II k
C II
Si IV
FOV#1
Scan-1
FOV#0
Scan-1

Summary

- **CLASP** was successfully launched on Sep.3, 2015, and made a high-precision (<0.1%) spectro-polarimetric observation in **VUV**.
  - Detected the **scattering polarization** in the Lyα and Si III lines for the first time
  - Now we have been working for the detection of the Hanle effect and exploration of the magnetic field in the upper chromosphere and transition region
    - Comparison between Lyα core, Lyα wing and Si III is critically important

What's next? CLASP2!

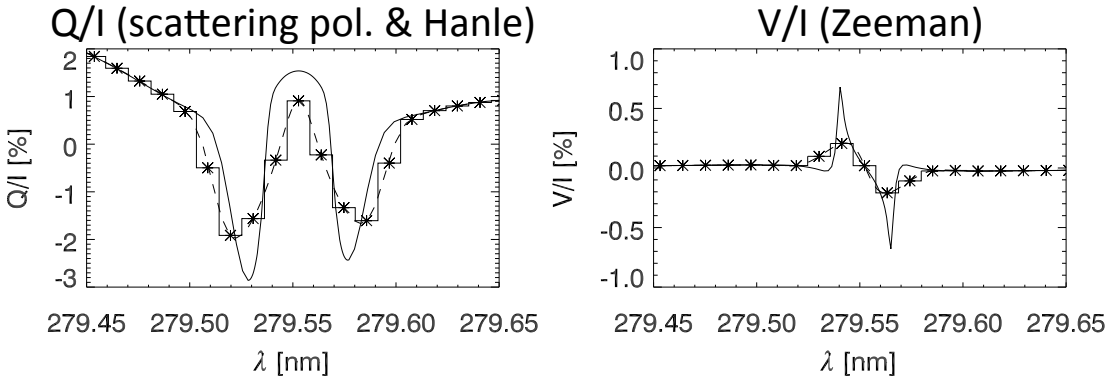
- The same optical design and structure, but for ***MgII h & k***



Mg II h& k line core image obtained by IRIS

Observing target: QS and plage (if available)

- Take ***Full Stokes (I, Q, U and V)***



Belluzzi & Trujillo Bueno (2012)

Measurement of ***circular*** as well as linear polarizations