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8. LMSAL, 9. HAO, 10. IRSOL, 11. ASCR, 12. Univ. of Oslo



# CLASP Launch Succeeded on Sep. 3<sup>rd</sup>, 2015



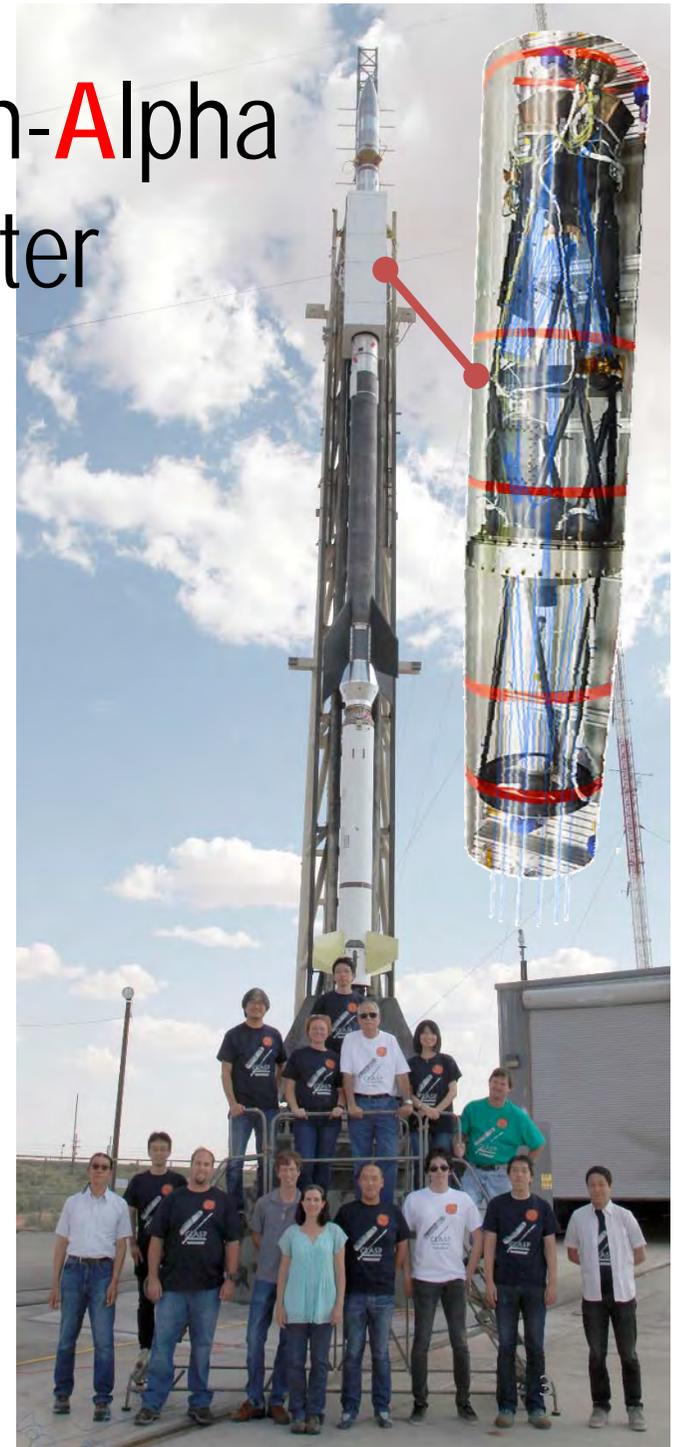


# Chromospheric Lyman-Alpha Spectro-Polarimeter

- **High-precision** ( $<0.1\%$ ) **spectro-polarimetry** in **VUV**.
- **First detection** of scattering polarization in the **Ly $\alpha$  line** (121.6 nm).
- **Exploration** of **magnetic fields** in **the upper chromosphere** and **the transition region** via the Hanle effect.

2015/09/17

Hinode 9





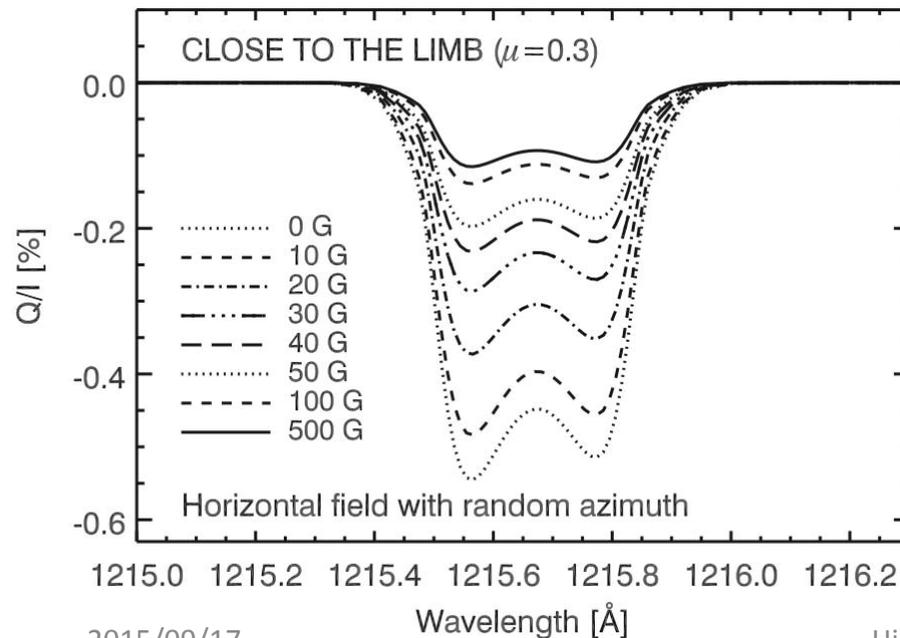
# Hanle effect in Ly $\alpha$ line

Line core:

- atomic polarization + Hanle effect
- sensitive to 5 - 50 G

Line wing:

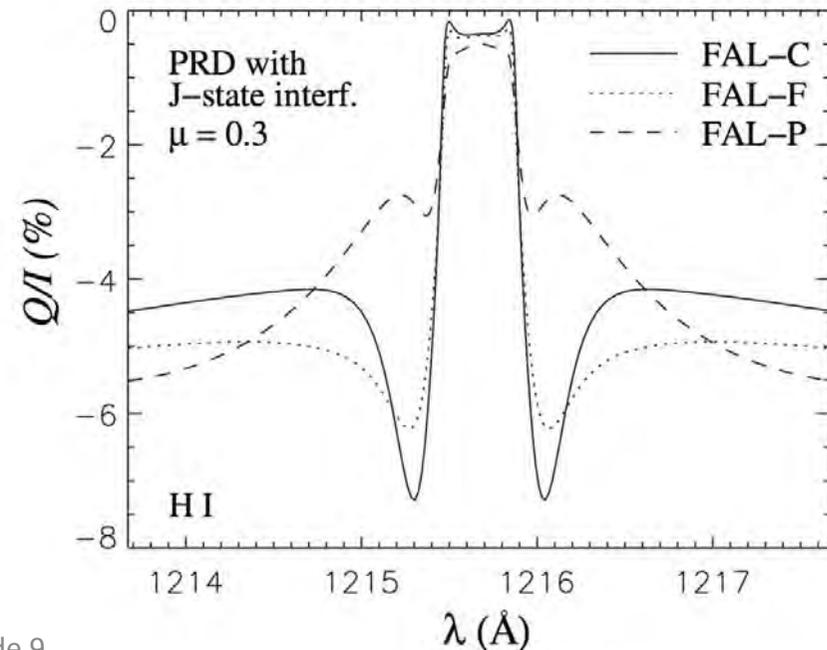
- atomic polarization ONLY
- sensitive to temperature structure



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Trujillo Bueno et al. (2011)

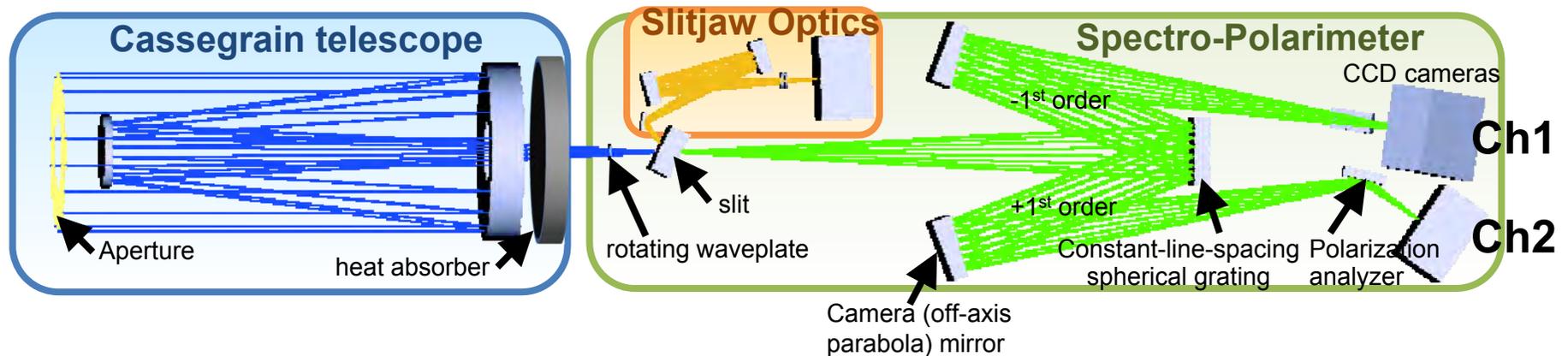


Belluzzi et al. (2012)



# CLASP Instrument

Narukage et al. (2015, Applied Optics)

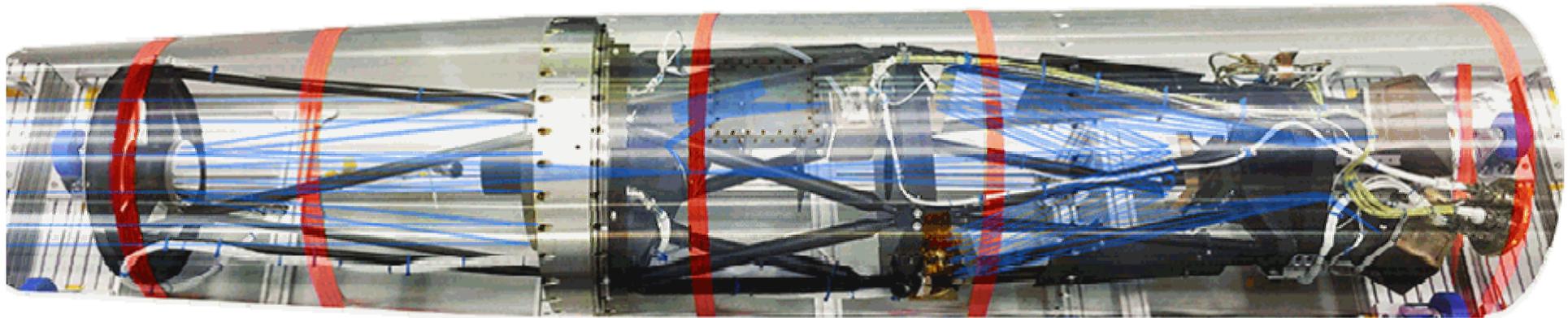


- Two symmetric channels: **Ch1 & Ch2**
  - ▶ Simultaneously measure **orthogonal polarization** states
- Realize high throughput in VUV
  - ◀ Minimize the number of optical components
  - ◀ Apply high-reflectivity coating to all optical components



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# Observing procedure

Peak height was  $\sim 278$  km.

## [1] Initial $\sim 10$ sec

**Disk center** for the on-flight polarization calibration.

- SJ:  $>16$  images with 0.6s cad.
- SP:  $>33$  images with 0.3s cad.

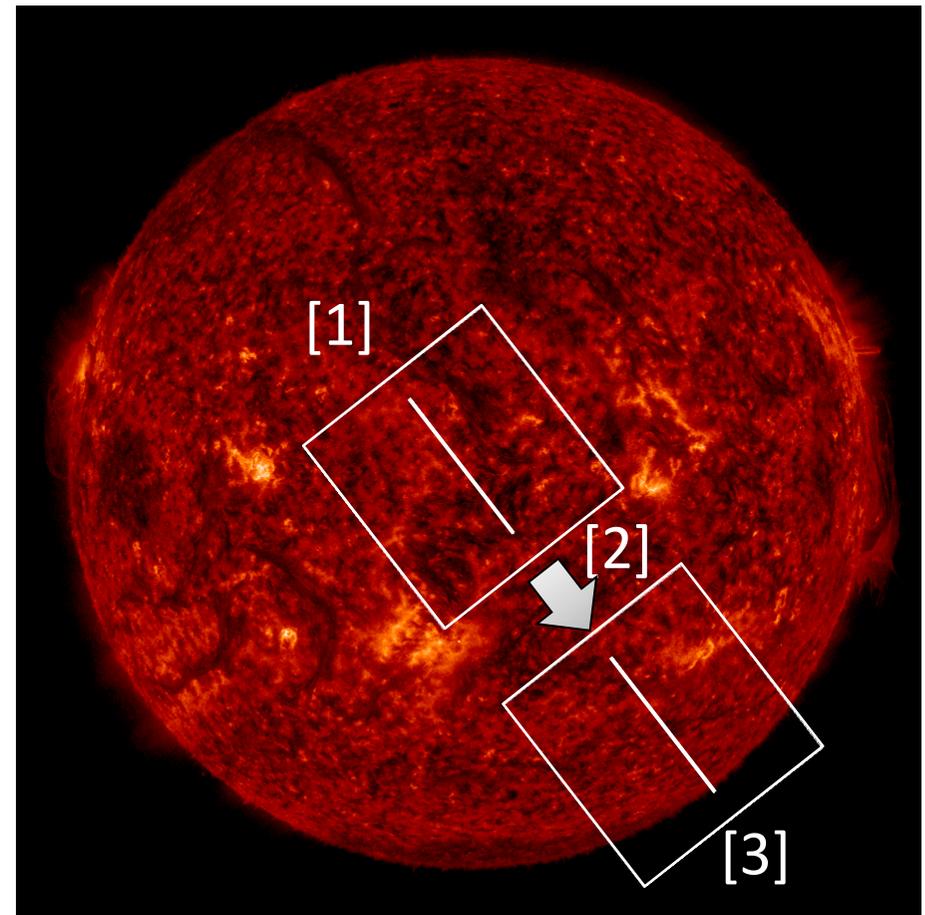
## [2] $\sim 30$ sec for repointing.

## [3] Remaining $\sim 240$ sec

**Sit & stare** in **QS** near SW limb.

Slit is **perpendicular to the limb**.

- SJ:  $> 466$  images with 0.6 cad.
- SP:  $> 933$  images with 0.3s cad.

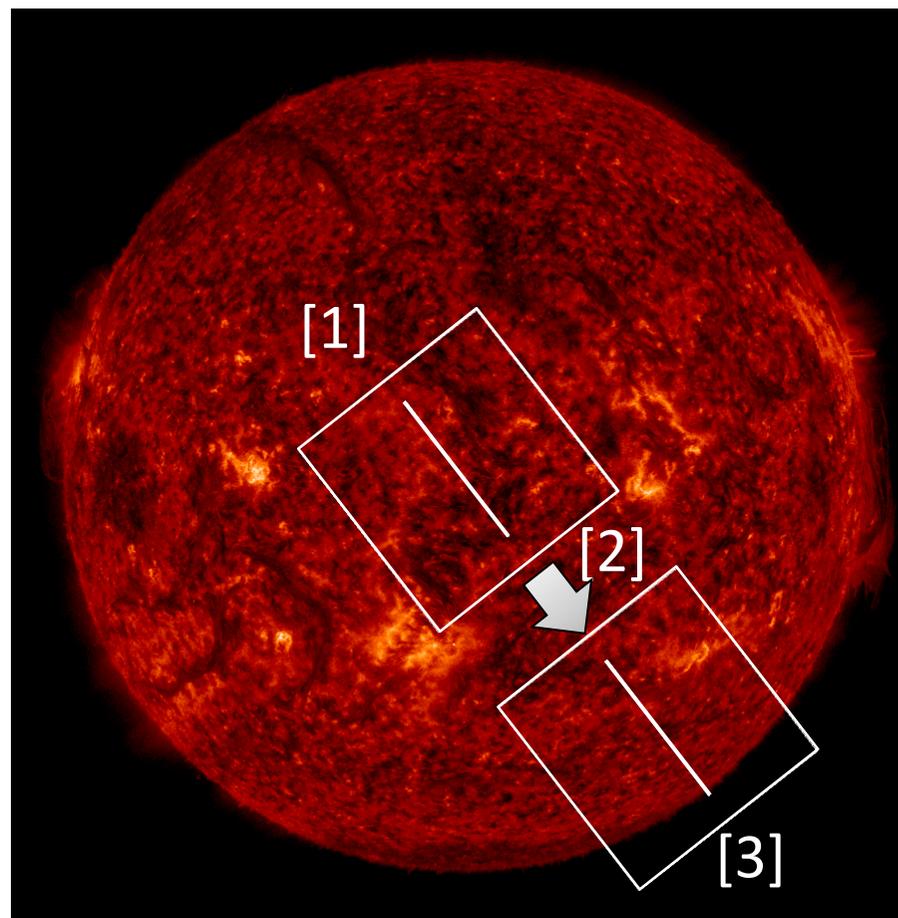
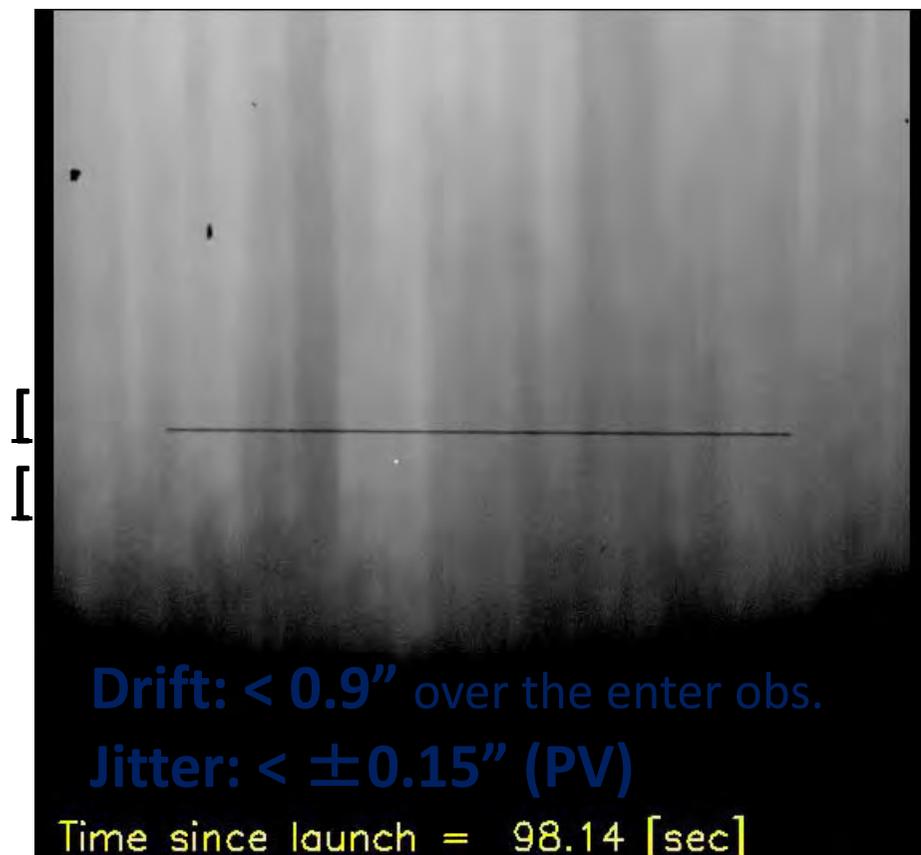




# Observing procedure

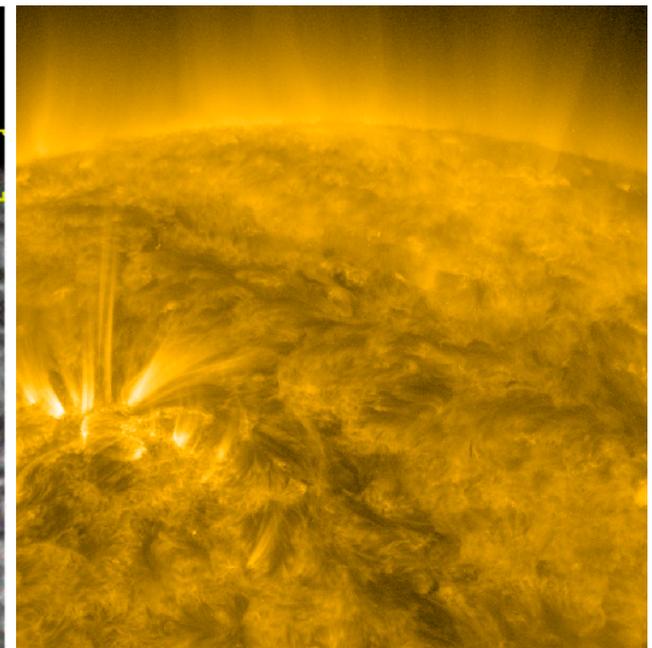
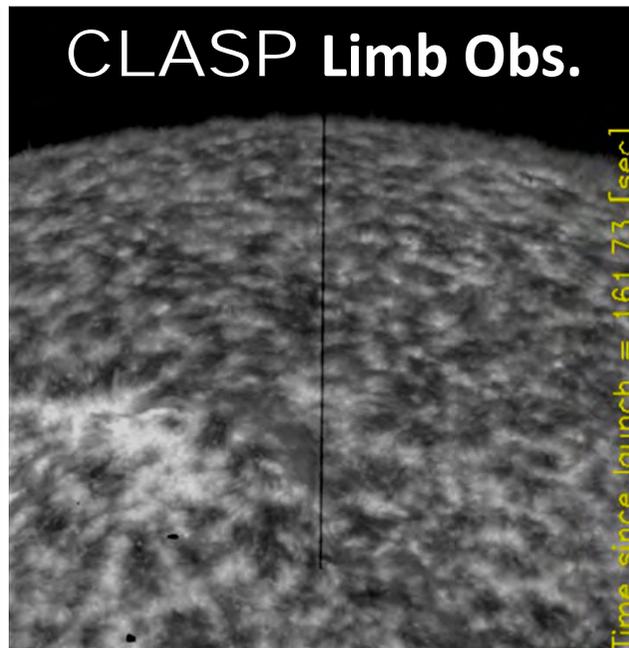
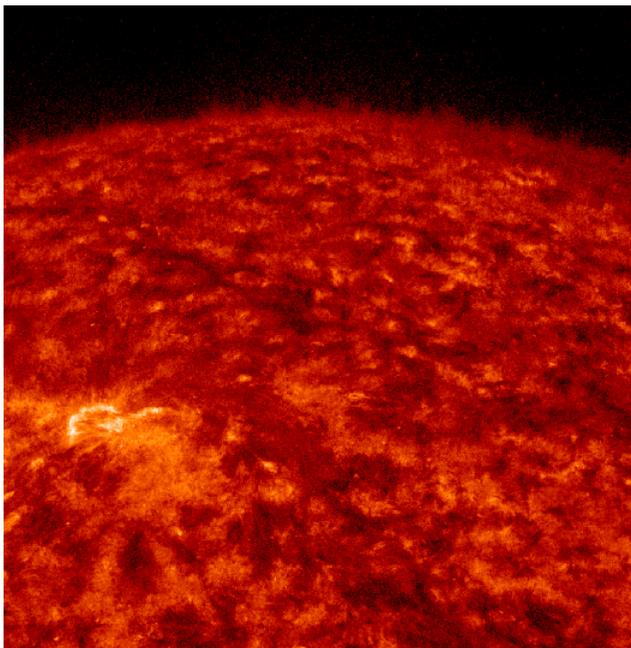
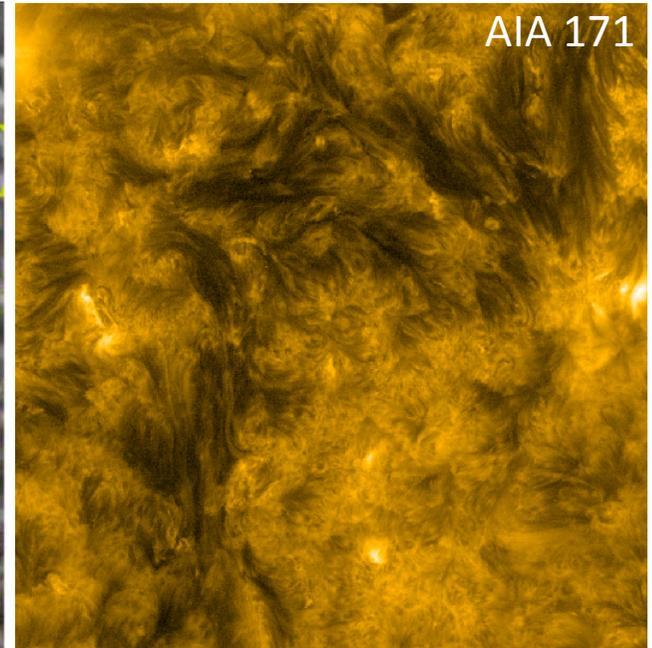
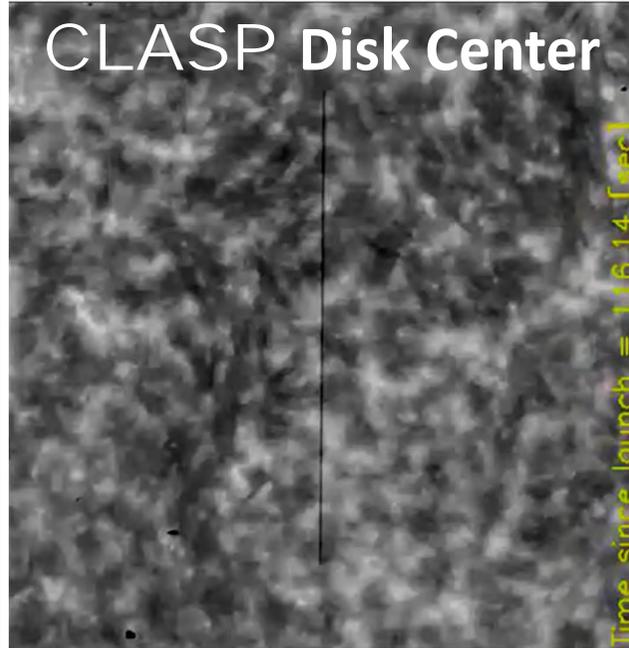
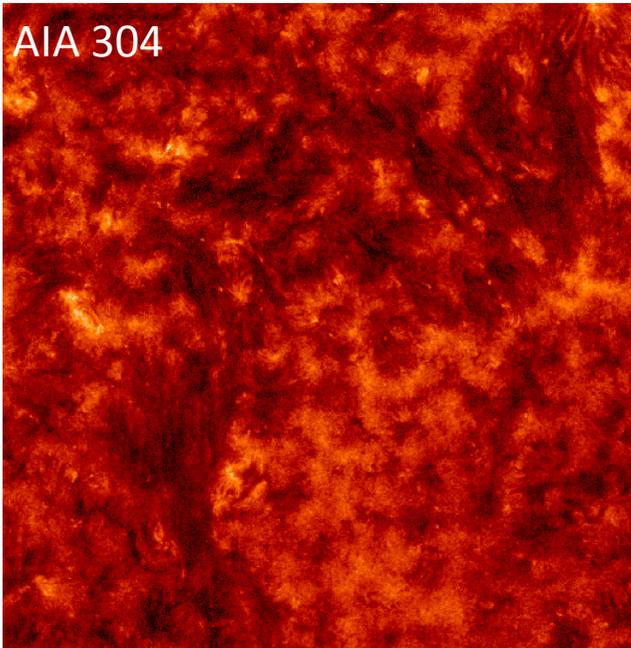
Peak height was  $\sim 278$  km.

## I CLASP Slitjaw(SJ) movie



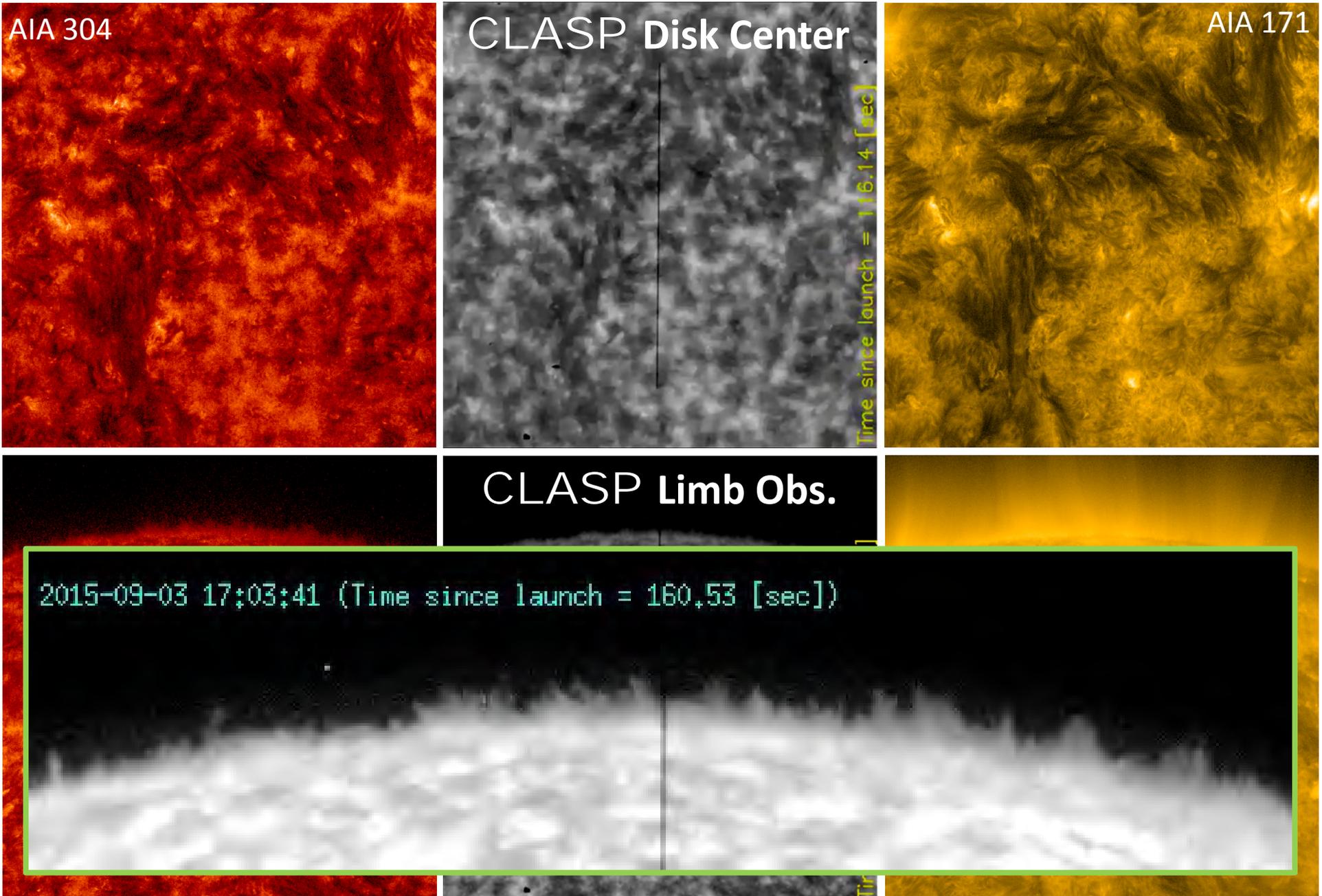


# Slitjaw Movies! -- 0.6s cadence





# Slitjaw Movies! -- 0.6s cadence





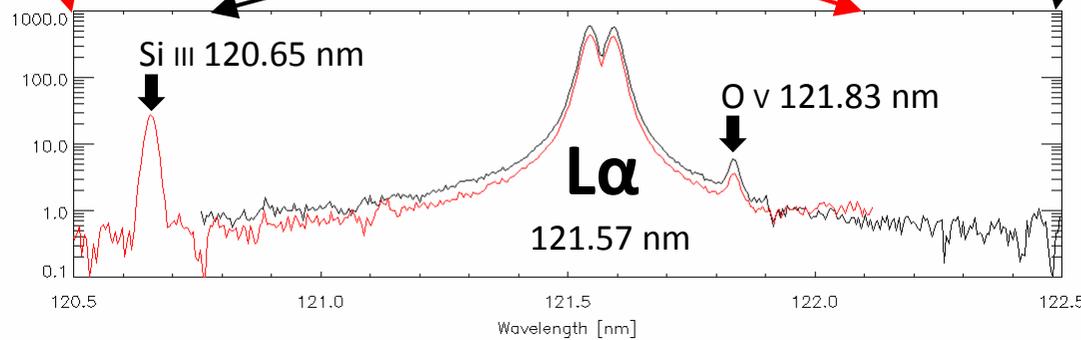
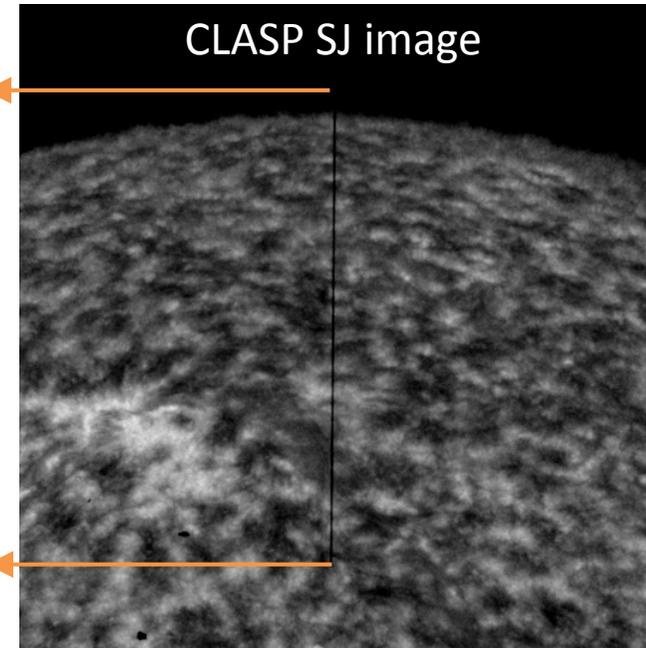
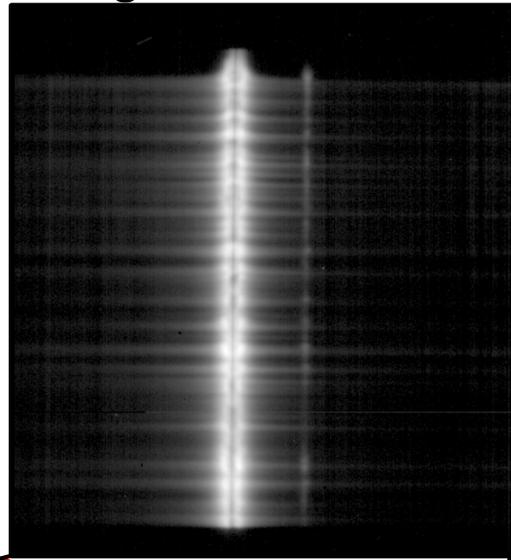
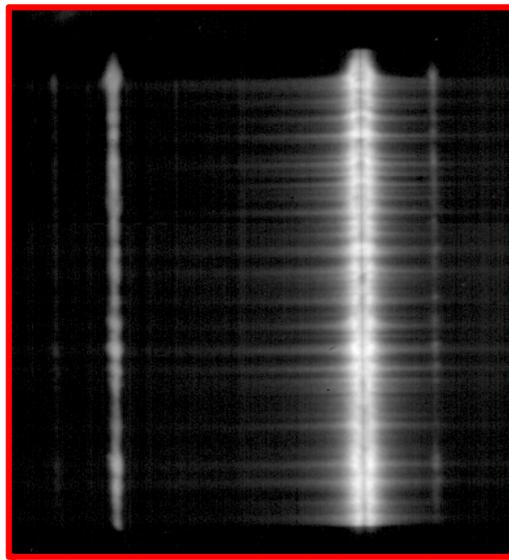
# Lyman- $\alpha$ Spectrum taken with Spectro-Polarimeter (SP)

**Ch2**

CLASP SP images

**Ch1**

CLASP SJ image





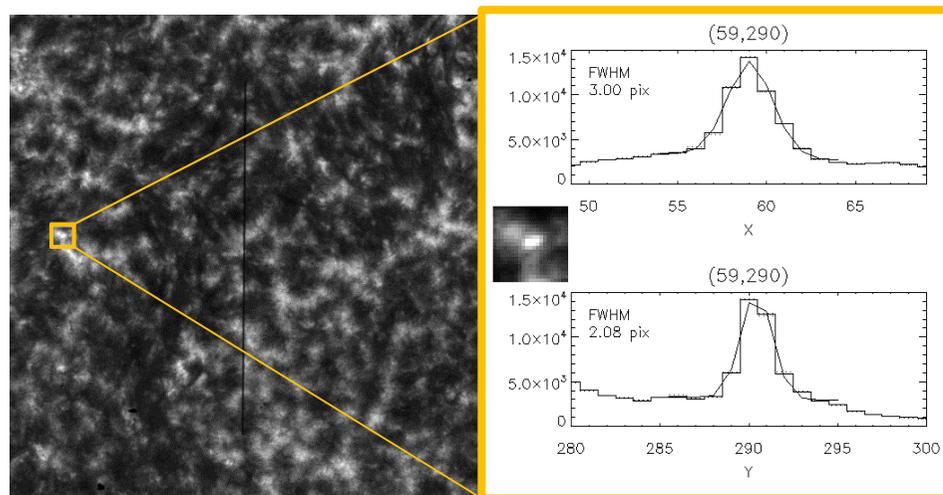
# Image Quality

## Spatial resolution

- Fitting of a bright point in SJ image.
    - FWHM < 2.1" (2.08 pix)
- (The SJ pixel size is 1.03".)

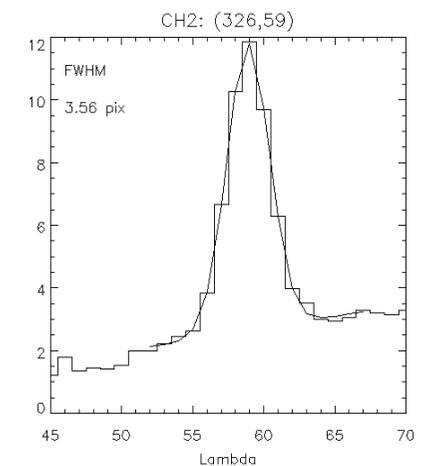
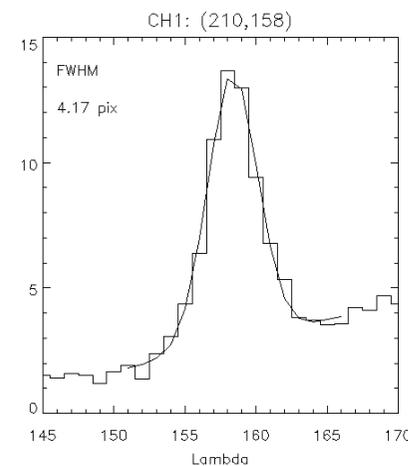
## Wavelength resolution

- Fitting of a Ov line.
    - FWHM < 0.017nm (3.56 pix)
- (The SP pixel size is 0.0048nm and 1.11".)



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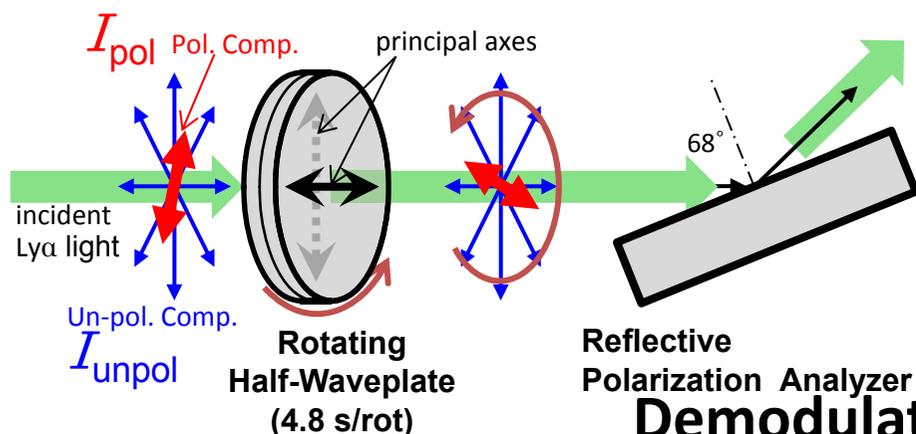
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# Modulation & Demodulation

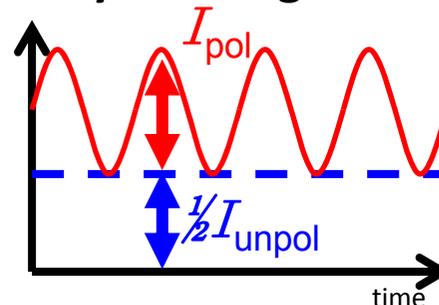
- CLASP is optimized for linear polarization, because  $V/I$  is expected to be too small ( $\sim 0.005\%$  @10G in the Ly-alpha by Zeeman effect).

## CLASP Polarimeter

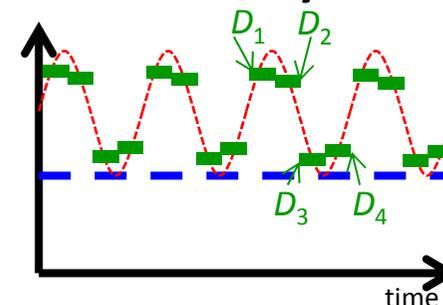


## Modulation

by rotating WP



detected by CCD



## Demodulation from CCD exposures

$$Q = aK\{(D_1 - D_2 - D_3 + D_4) + \dots\}$$

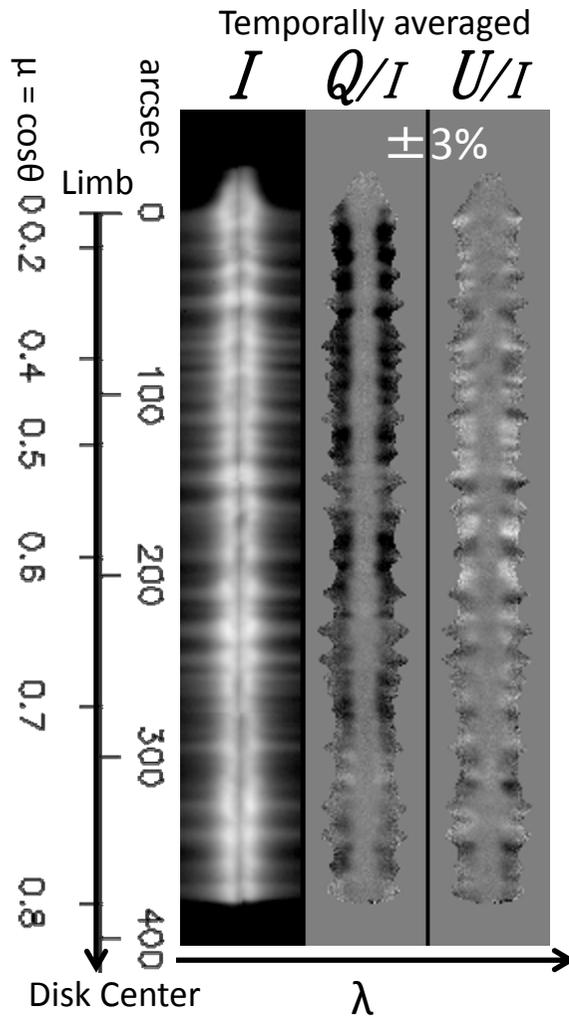
$$U = aK\{(D_2 - D_3 - D_4 + D_5) + \dots\}$$

$$I = K\{(D_1 + D_2 + D_3 + D_4) + \dots\}$$

a: modulation coefficient  
K: throughput value

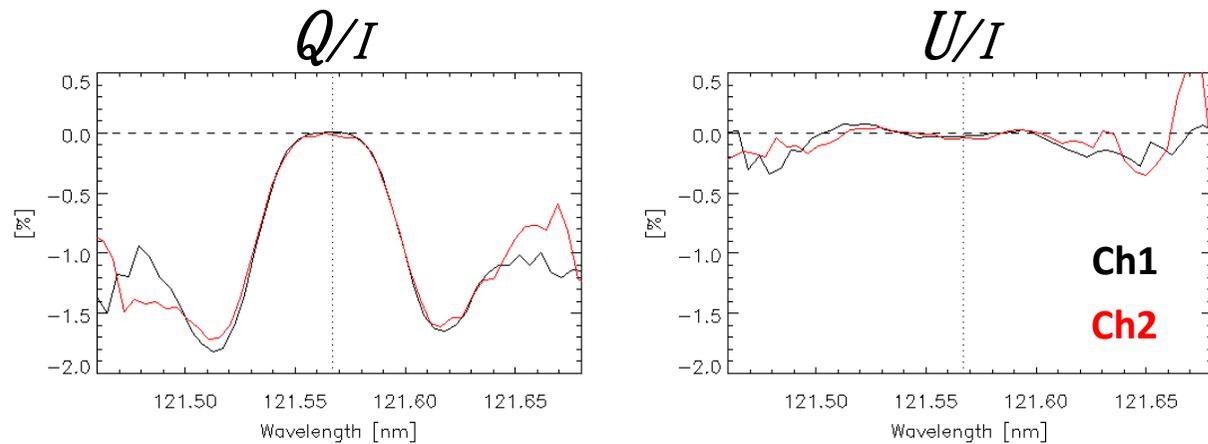


# Lyman- $\alpha$ Stokes-IQU



Further calibrations/investigations are required, but ...

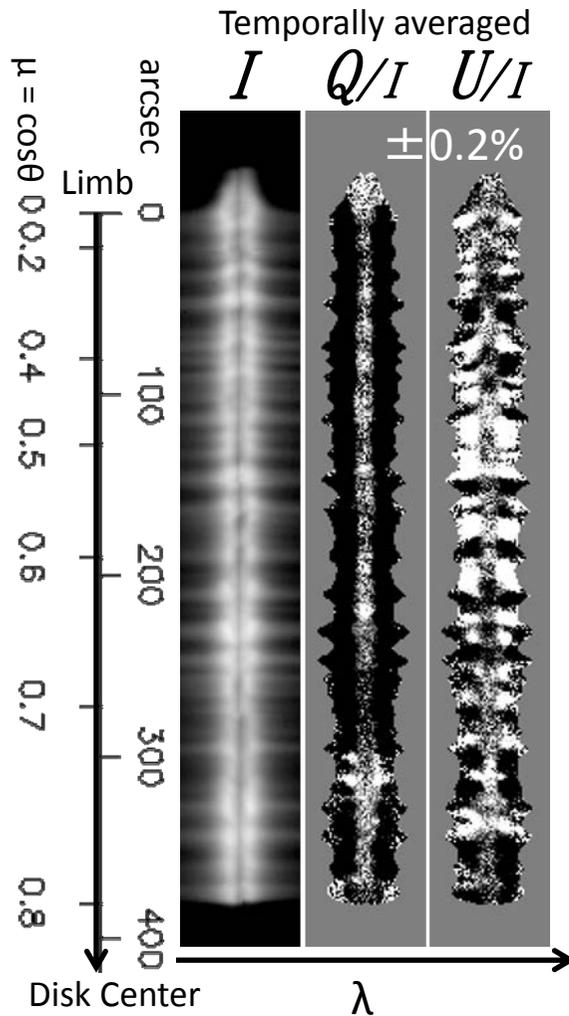
- **A few %** of polarization in the wing, and **a few of 0.1 %** in the core.
- A clear **C-to-L variation** in the wing of Q/I.
- Small-scale structures along the slit.
- Q/I profile is essentially **consistent with the model prediction**.



Spatially and temporally averaged

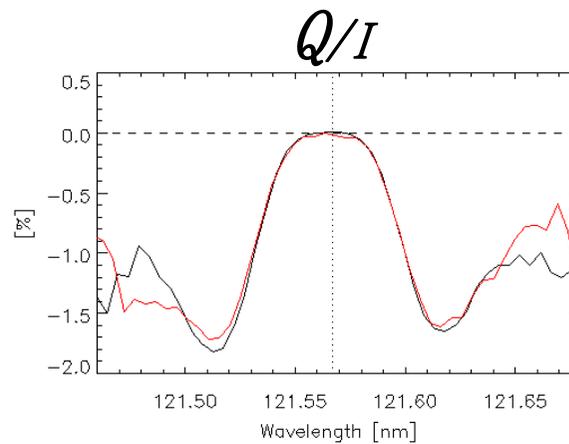


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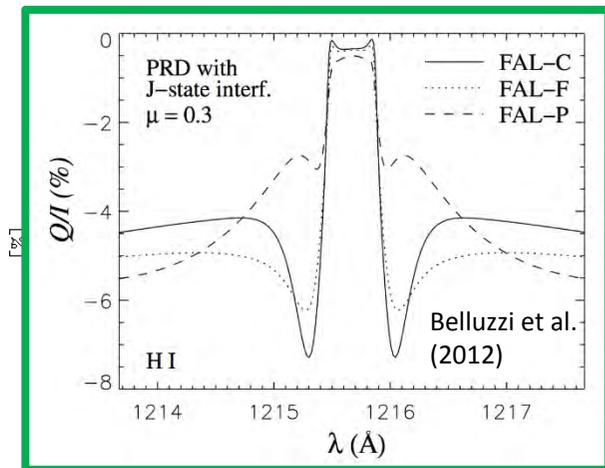


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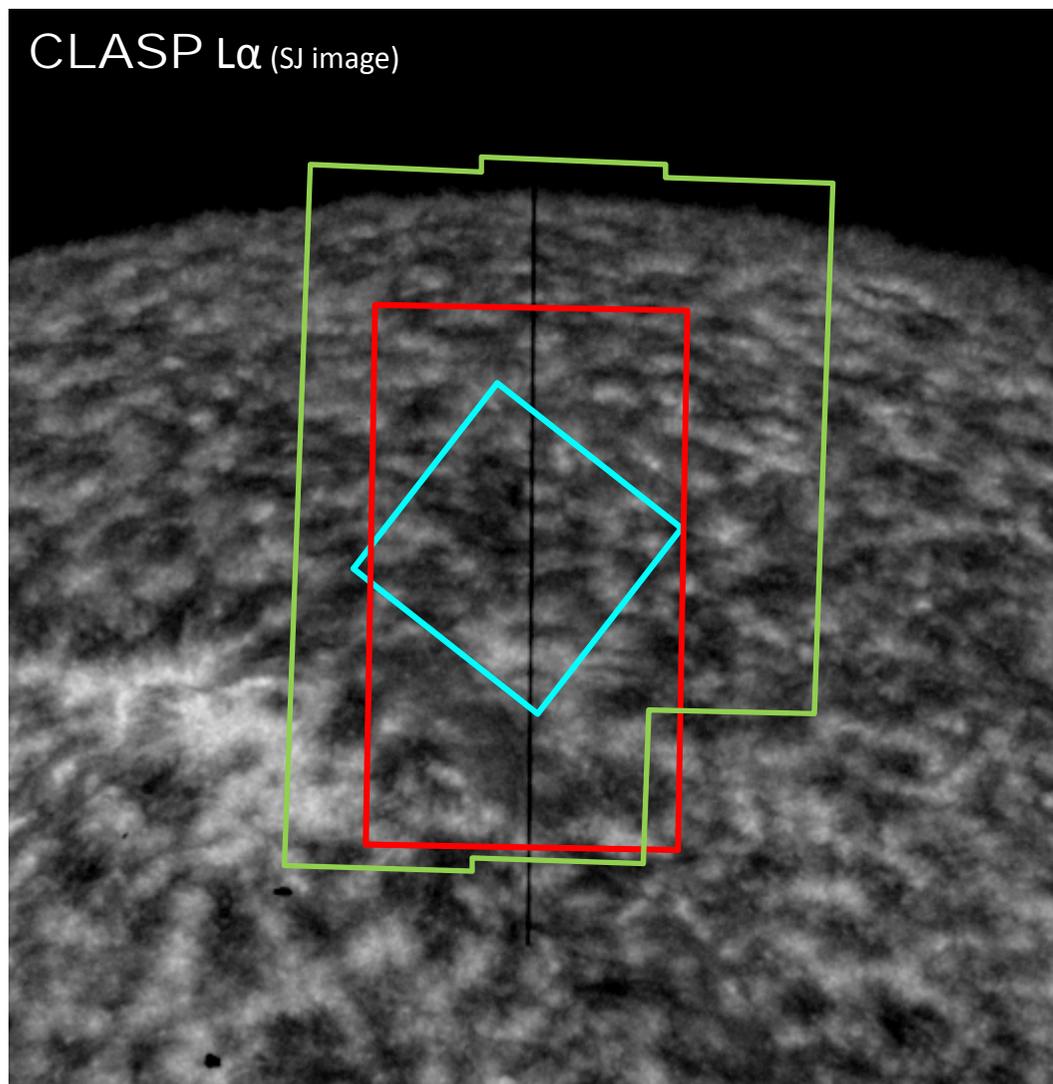
# Coordinated Observations

- Hinode
  - SOT      SP:      Fe I 630nm, 5"(scan)x164"  
             BFI:      Ca II H 397nm, 111"x111"  
             NBI:      Na I D 589.6nm, 82"x164"
  - XRT      Al-poly., 768"x768", 30s-cad.
  - EIS      60"(scan)x512"
  
- IRIS      Mg II h&k, 30"(scan)x275"
  
- DST (partially clouded)
  - IBIS      H $\alpha$  656.3nm, 98"x98"-mosaic
  - ~~– FIRS      He I 1083nm, 60"(scan)x80"~~





# Coordinated Observations

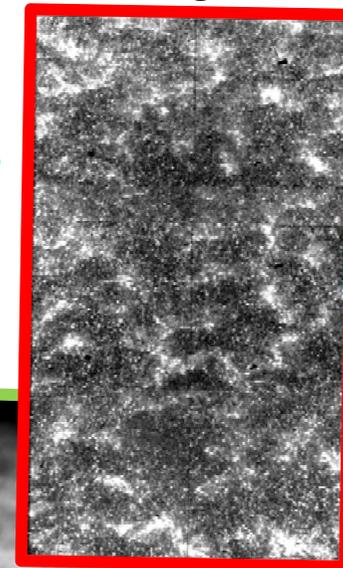


CLASP  $L\alpha$  (SJ image)

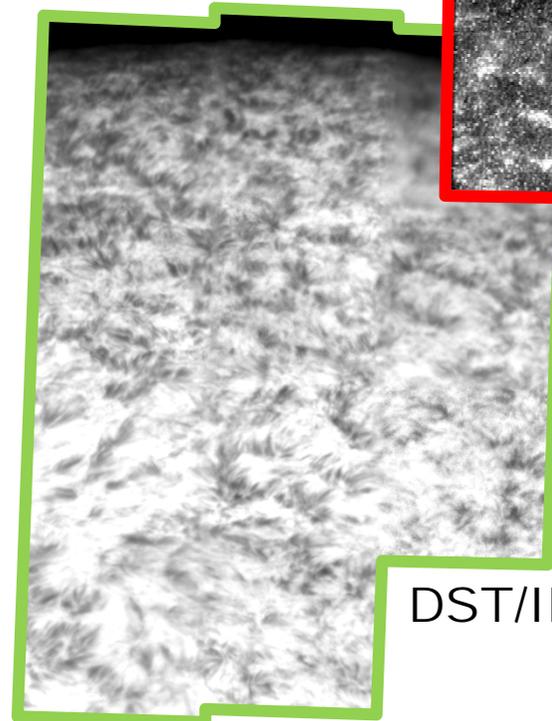
SOT Ca II H



IRIS Mg II (SJ image)



DST/IBIS  $H\alpha$



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# Analyses just started.

- Ly $\alpha$  polarization by SP
  - On-flight calibration of polarization by DC data.
  - Detailed investigation of the Stokes-Q and U spectra.
  - Infer the magnetic fields in the chromosphere and TR.
- Ly $\alpha$  spectra by SP with 0.3s cadence.
- Ly $\alpha$  Slitjaw images with 0.6s cadence.
  - High cadence observation will reveal tiny events in the chromosphere (e.g. nano-flares, waves ...).

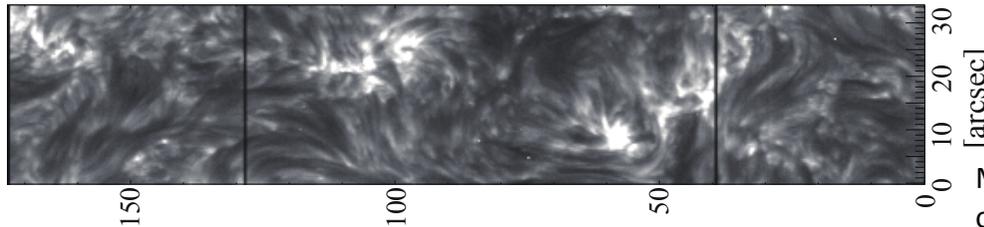
... and others.

**Visit e-Poster for the pre-flight calibration by G. Giono.**



# What's next? CLASP2

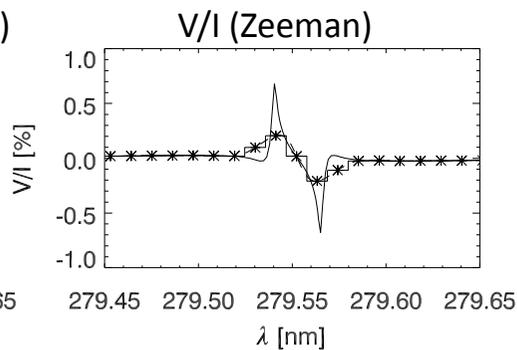
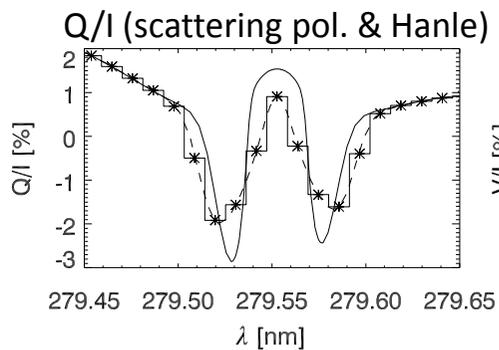
- The same optical design and structure, but for **Mg II h & k**.



Observing target: QS and plage (if available)

Mg II h&k line core image obtained by IRIS

- And take **Full Stokes**.



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

Belluzzi & Trujillo Bueno (2012; ApJ letters).

- Proposed to fly in 2018 Spring!







# Summary

- CLASP was **successfully** launched on Sep.3, 2015, and made a **perfect** Lyman- $\alpha$  spectro-polarimetric observation.
- **A few %** of polarization were observed in the Lyman- $\alpha$  wing, and **a few of 0.1 %** in the core. But, further investigations are required.
- The coordinated observations (IRIS, Hinode etc.) were also succeeded.
- CLASP2 for **MgII h&k** has already been proposed to NASA for the flight in 2018.