

First Detection of Lyman-Alpha Scattering Polarization in Off-Limb Spicules and Its Constraint on Their Magnetic Field

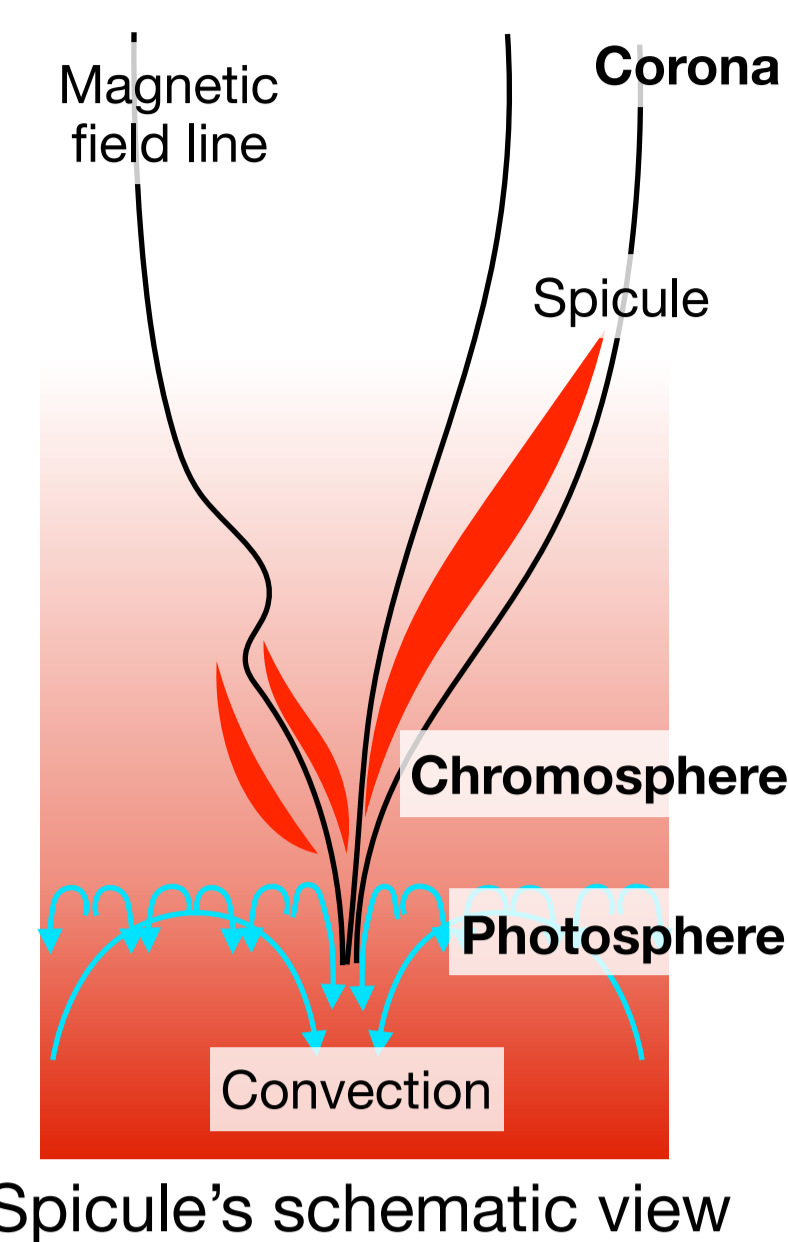
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1. Introduction

In the Solar chromosphere, “**Spicules**” (jet-like structures) are observed everywhere.

** We do not know how spicules are formed and how they affect the corona. **



Spicule's schematic view

Magnetic field measurement is critical for understanding the formation mechanism of spicule and its influence on the corona.

Final Goal: Derive spicule magnetic field

There are few studies deriving spicule magnetic field.

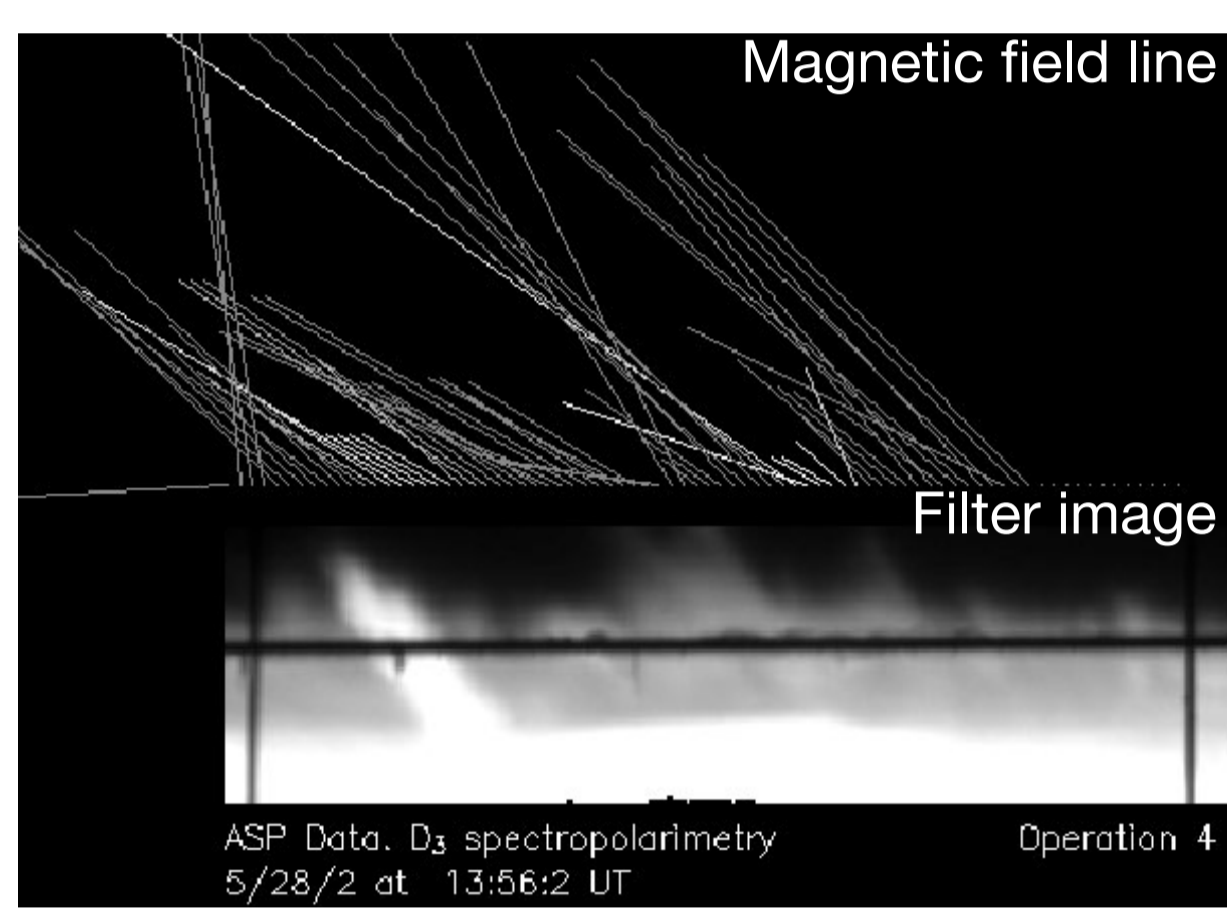
All of these measurements performed by ground-based telescope.

Trujillo Bueno et al. 2005 (He I 1083.0 nm): Spicule magnetic field is ~10G.

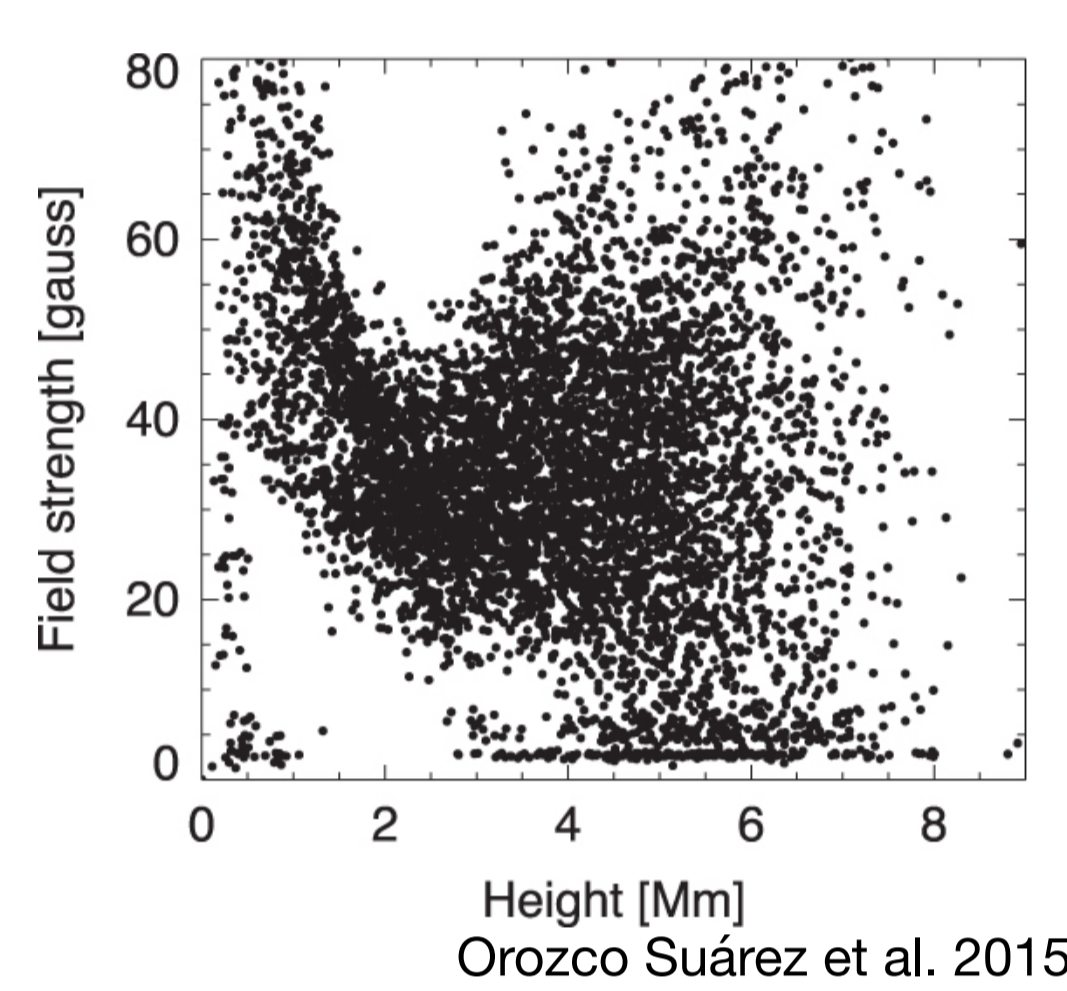
López Ariste and Casini 2005 (He I D3 587.6 nm): Spicules are aligned with the magnetic field line.

Orozco Suárez et al. 2015 (He I 1083.0 nm): Magnetic field strength decrease with spicule height from 80 G to 30 G

Spicule magnetic field is not studied well.



López Ariste and Casini 2005



Orozco Suárez et al. 2015

• To measure magnetic field of spicule, we use “**Ly α line (121.56 nm)**” polarization observed by “**CLASP.**”

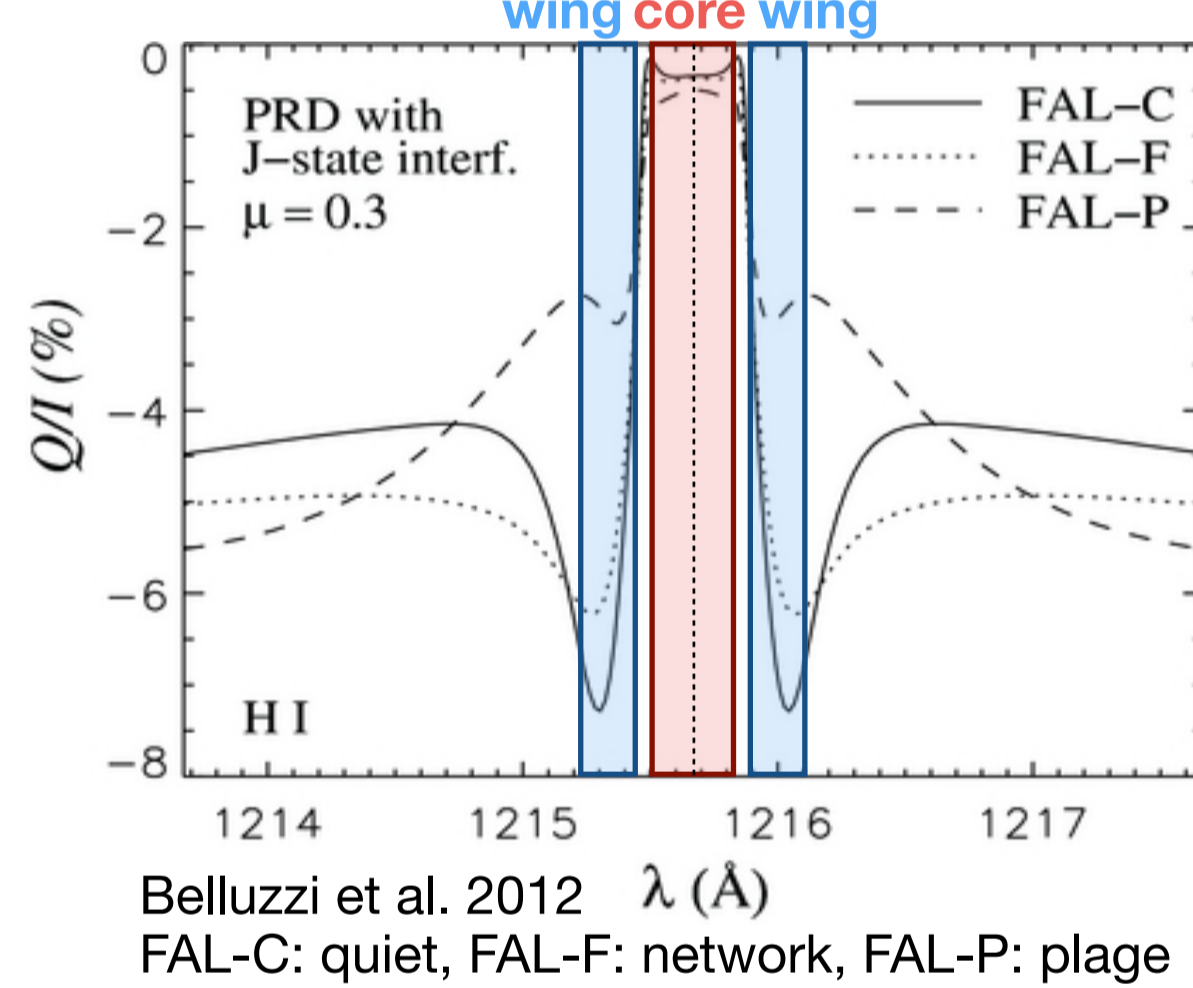
• Ly α line is an optically thick and it is sensitive to high temperature.

• Ly α line is well suited to investigate how spicules affect corona.

• Hanle effective field strength of Ly α line: $B_H \sim 10\text{--}100\text{G}$
• It is comparable with spicule's typical field strength about 10–80G; Trujillo Bueno et al. 2005; Orozco Suárez et al. 2015.

• Strategy to derive magnetic field

1. Investigate polarization in Ly α spicule (temporal & spatial variation).
2. Compare polarization degree of **Ly α core** (scattering polarization & Hanle effect) with **Ly α wing** (scattering polarization).
3. Constrain magnetic field parameters using Hanle diagram.



Belluzzi et al. 2012 λ (Å)
FAL-C: quiet, FAL-F: network, FAL-P: plage

2. Observational result

• CLASP

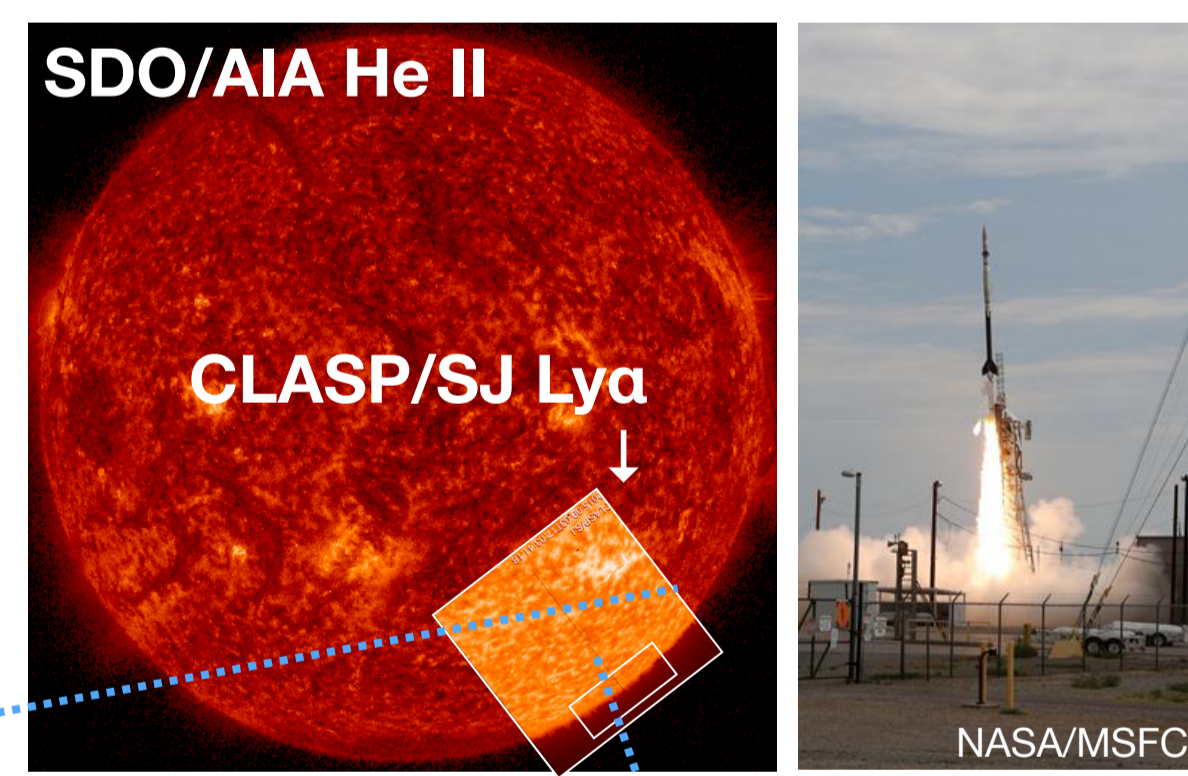
Rocket experiment (launched in Sep. 2015.)

Only 5 mins. observation time

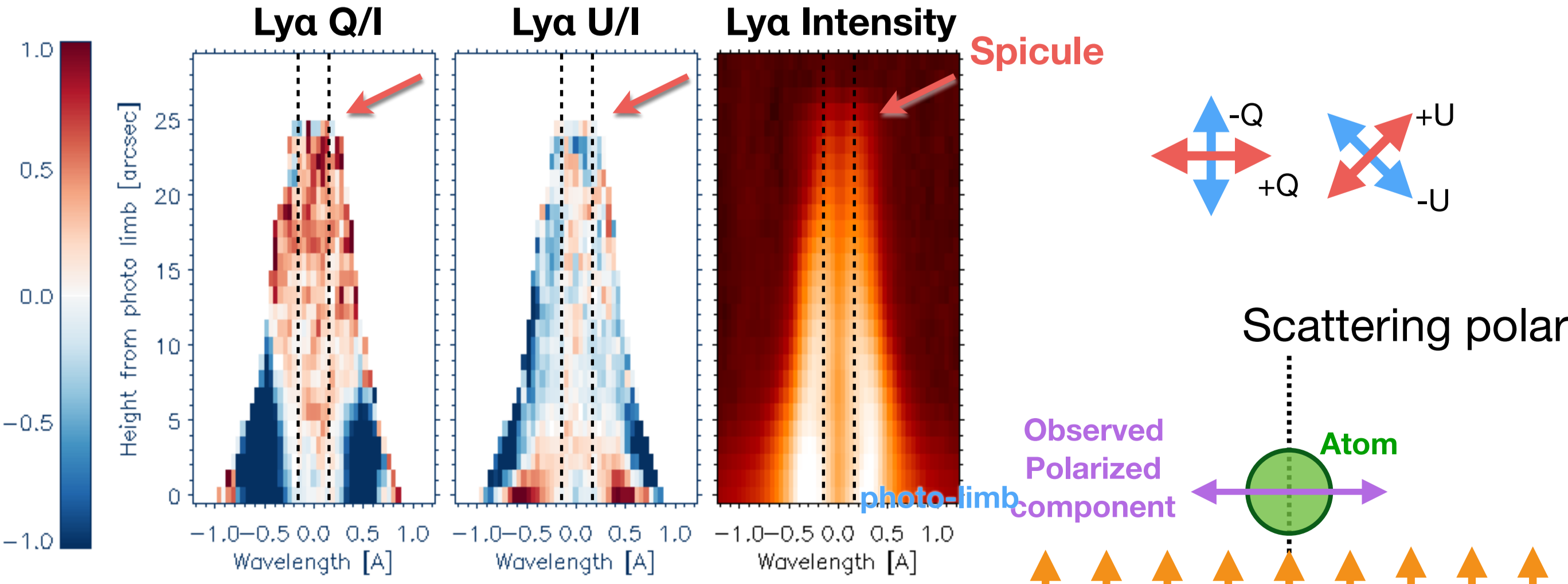
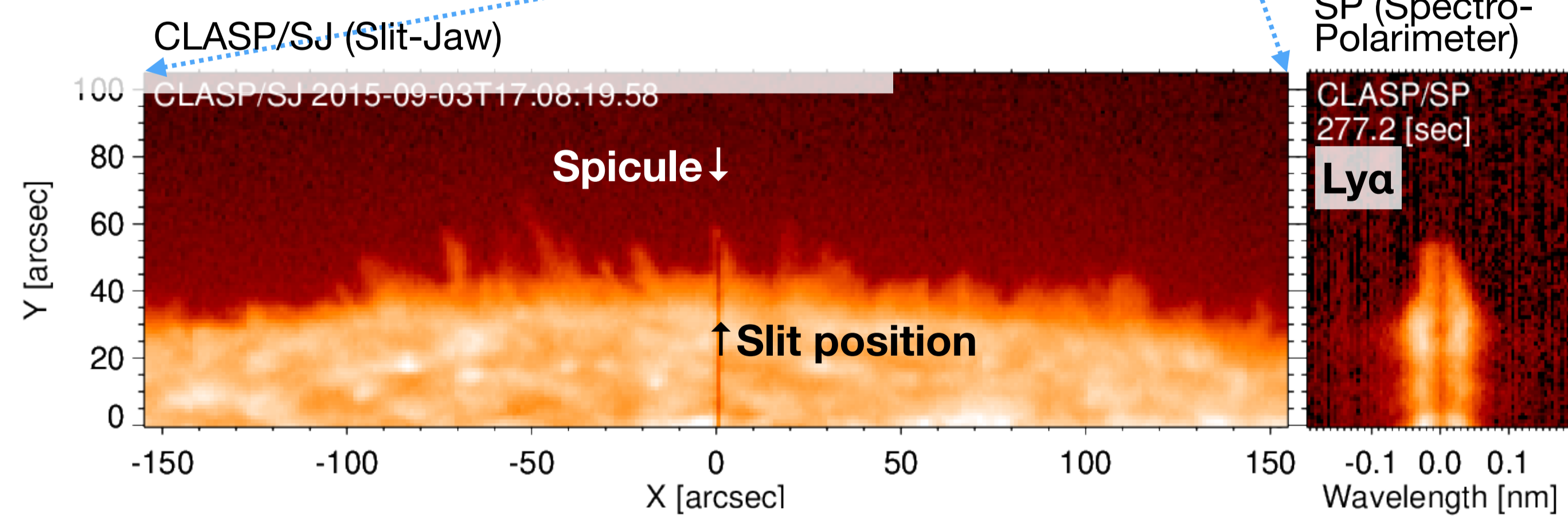
High cadence observation!

(SP: 0.3 sec, SJ: 0.6 sec)

• CLASP/SP succeeded in observing Ly α spectra along a spicule.



NASA/MSFC



Temporally averaged (277sec) spicule.

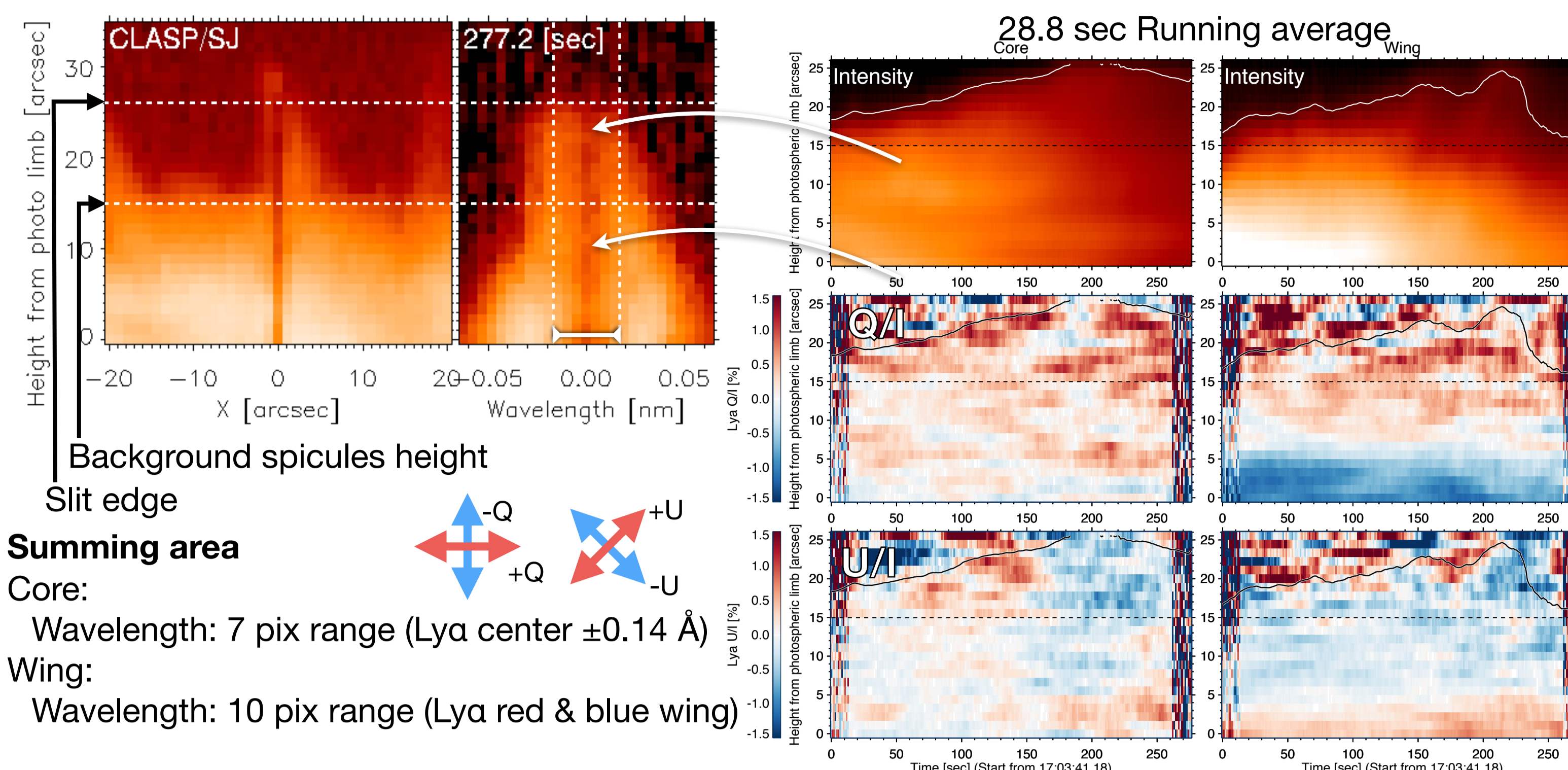
Ly α core:

Q/I: +0.5%, U/I: 0.0%

-> Scattering polarization is dominant.

Axisymmetric radiation field

Hinode13 meeting @Tokyo, Japan, 2019/09/02-06



• **Summing area**

• Core:

• Wavelength: 7 pix range (Ly α center ± 0.14 Å)

• Wing:

• Wavelength: 10 pix range (Ly α red & blue wing)

• Core

• Both Q/I & U/I are high in upper spicule part.

• (Higher than the background spicule height.)

• Upper part:

• Q/I is positive.

• U/I changes in time from positive to negative.

• Wing

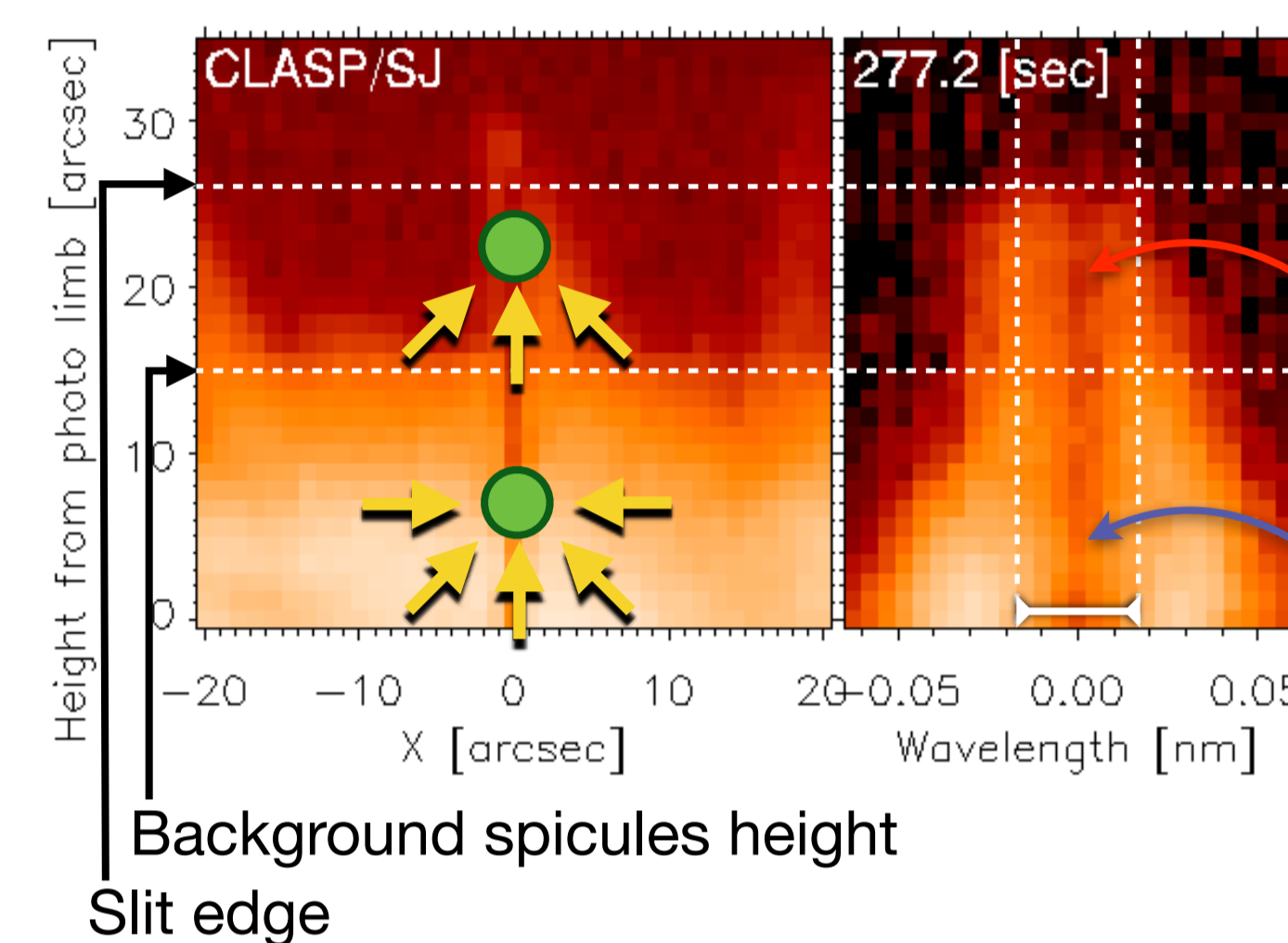
• Upper part:

• Q/I is positive.

• U/I is negative.

• In the lower part, CLV of Q/I still exists.

3. Discussion



• **Upper part of the spicule**

=> The polarization degree is large.

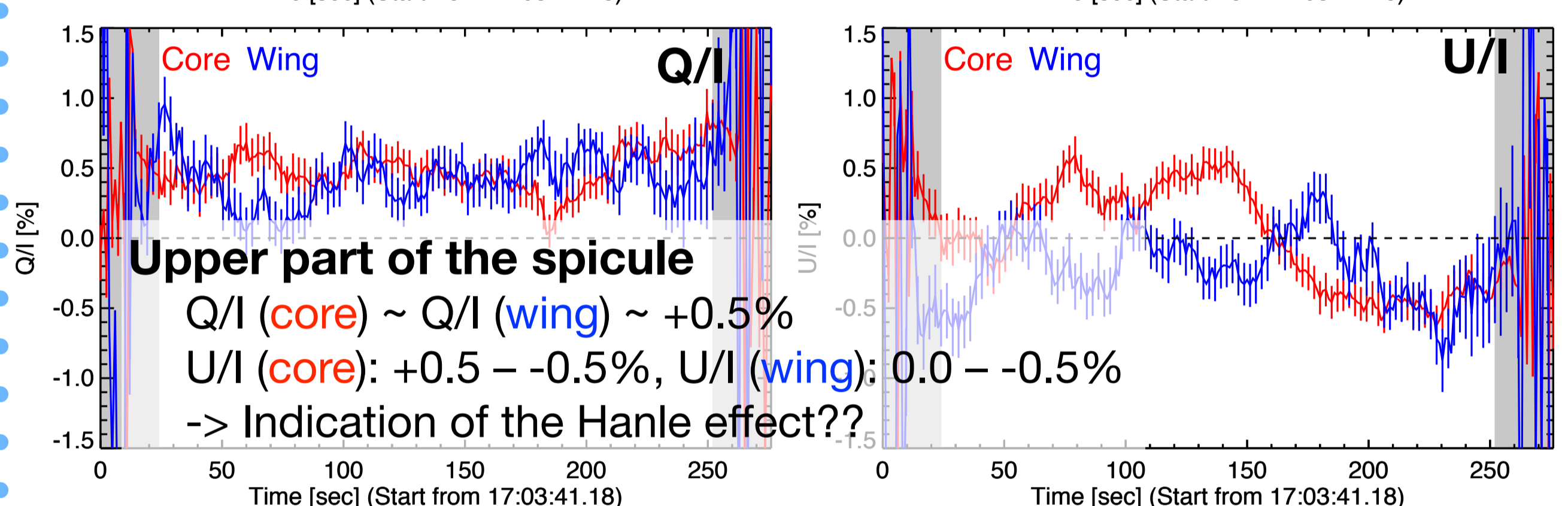
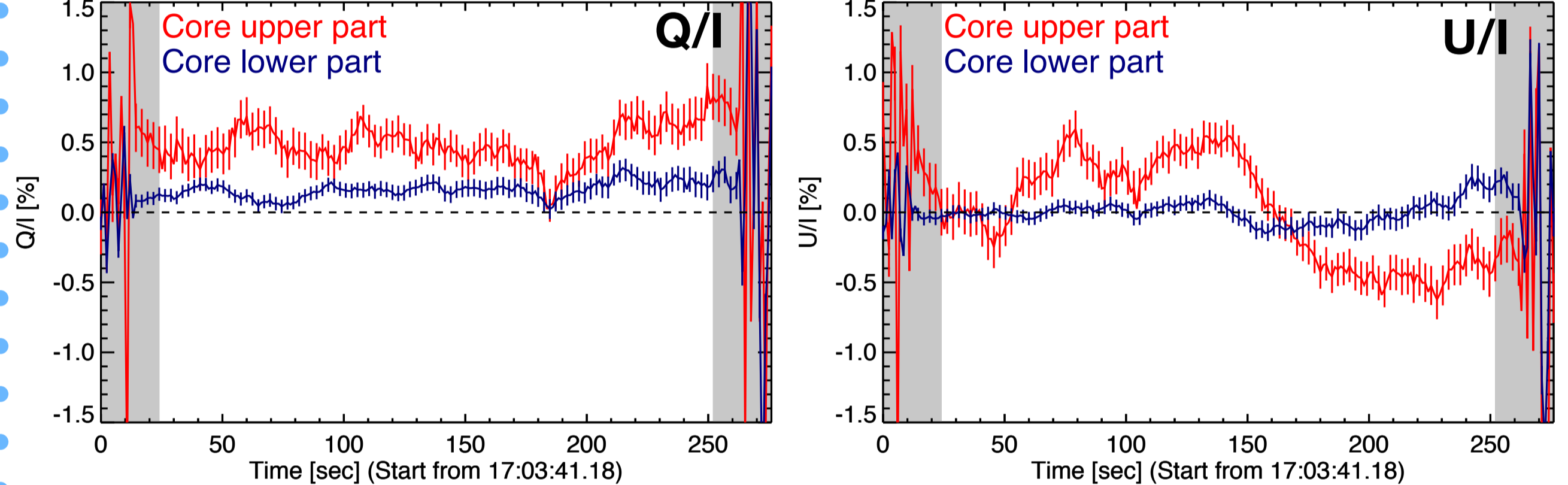
Due to the low denseness of the structures, the spicule's plasmas mainly illuminated from vertical direction.

• **Lower part of the spicule**

=> The polarization degree is small.

Due to the high denseness of the structures, the spicule's plasmas illuminated from vertical and horizontal directions.

Error bar: photon noise & CCD readout noise

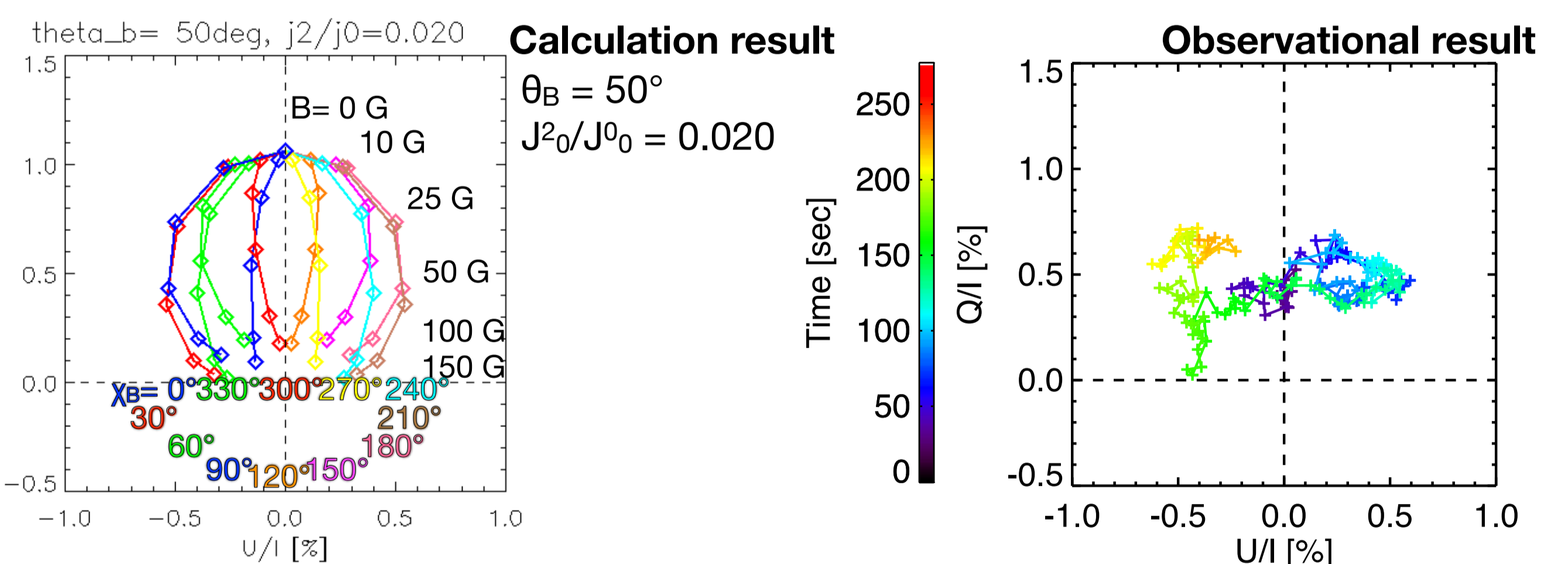


• **Upper part of the spicule**

Q/I (core) ~ Q/I (wing) ~ +0.5%

U/I (core): +0.5 - -0.5%, U/I (wing): 0.0 - -0.5%

-> Indication of the Hanle effect??



When $\theta_B = 50^\circ$ (or 130°) and $J^2_0/J^2_0 = 0.020$, $B \sim 50\text{G}$.

Changes of U/I (+0.5% to -0.5%)

can be explained by χ_B (azimuth) changes.

Magnitude and Inclination are consistent with previous studies.

10–80 G and 30–50° (or 130–150°)

; Trujillo Bueno et al. 2005; Orozco Suárez et al. 2015

As a final conclusion, we will assume **non-axisymmetric** radiation field.

Summary

• CLASP succeeded in observing Ly α linear polarization of spicules for the first time.

• We have found following things.

• Q/I of the off-limb spicule is positive.

• Scattering polarization

• Polarization degree is different between the upper part and lower part of the spicule.

• Polarization degree is higher in the upper part than the lower part.

• Due to the denseness of the structures depend on the spicule height, the spicule's plasmas in the upper part of the spicule mainly illuminated from vertical direction.

• U/I is different between Ly α core and wing.

• U/I (wing) is mainly negative. U/I (core) changed from positive to negative.

• Indication of the Hanle effect??

• $B \sim 50\text{G}$, $\theta_B \sim 50^\circ$ (or 130°), $J^2_0/J^2_0 \sim 0.020$, $\chi_B \sim 0^\circ\text{--}180^\circ$ (Assumption of axisymmetric radiation field)

