The Chromospheric LAyer Spectro-Polarimeter (CLASP2) Sounding Rocket Mission: First Results

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CLASP2: Exploring the magnetic chromosphere

CLASP Chromospheric Layer Spectro Polarimeter April 2019

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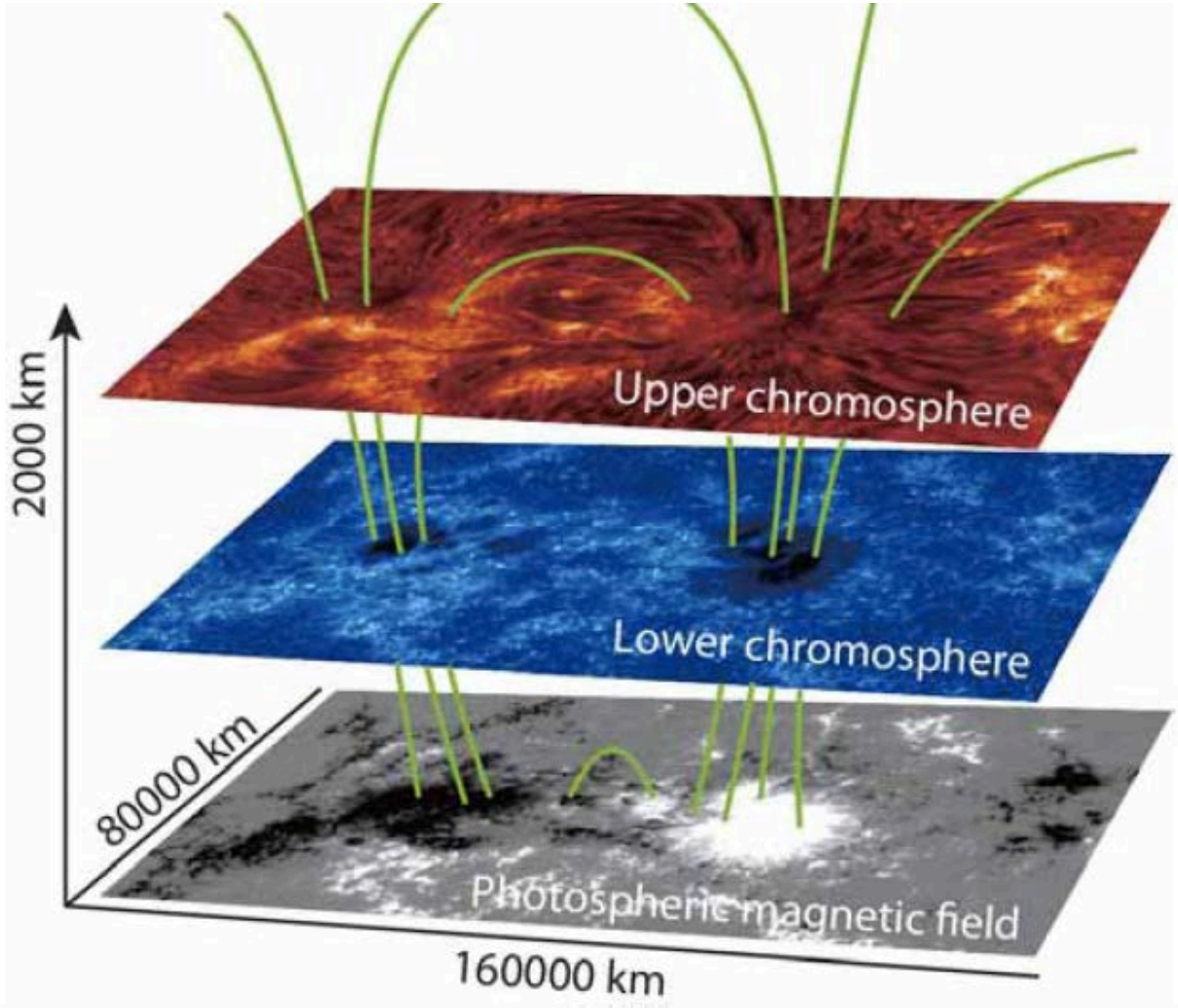
Anne Philippon (IAS)

CLASP/CLASP2 Scientific Objectives



CLASP/CLASP2 Scientific Objectives

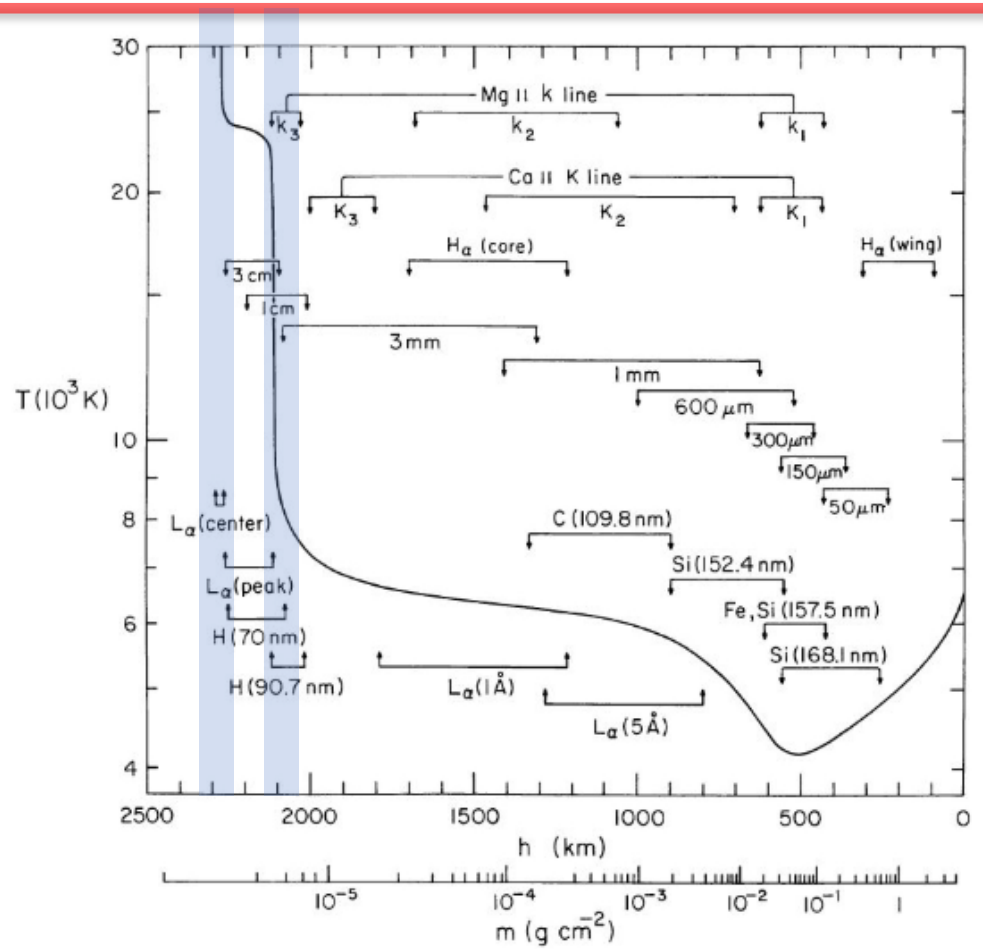
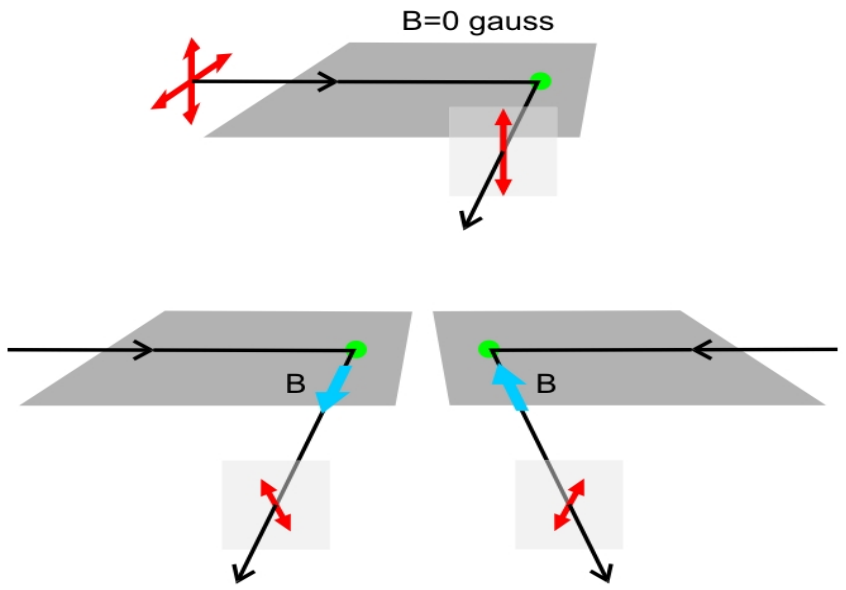


FIG. 1.—The average quiet-Sun temperature distribution derived from the EUV continuum, the Lα line, and other observations. The approximate depths where the various continua and lines originate are indicated.

Vernazza J.E., Avrett E.H., and Loeser R. The Solar Chromosphere. III. Models of the EUV Brightness Components of the Quiet Sun. The Astrophysical Journal Supplement Series, 45:635-725, 1981 April.

CLASP/CLASP2 Scientific Objectives

Understanding scattering experiments in the absence and in the presence of a magnetic field → the Hanle effect



Critical Hanle field?

$8.79 \times 10^6 \, g_L$ B(gauss) ~ 1/Lifetime

Physical mechanisms affecting polarization in spectral lines:

1) The Zeeman effect

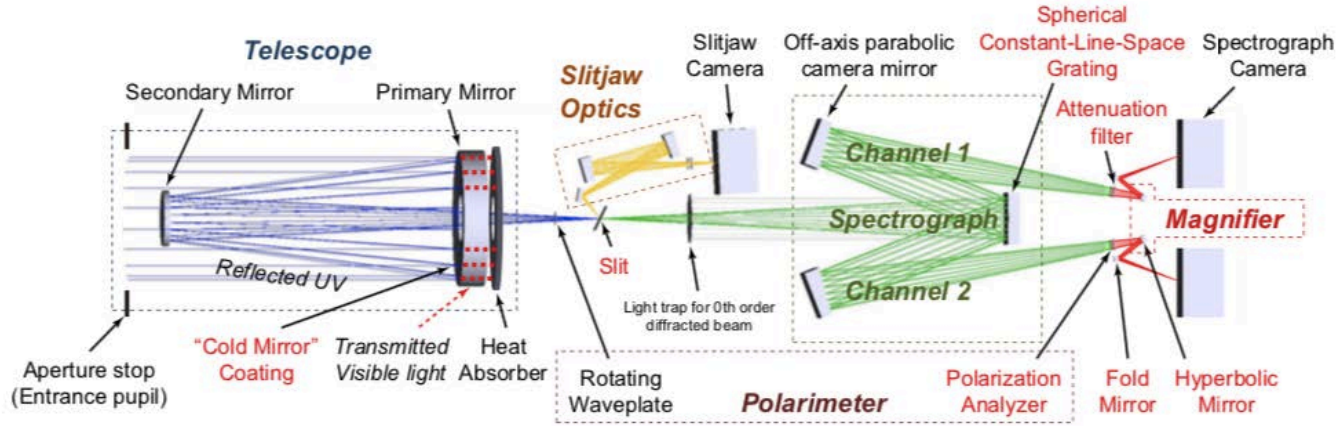
2) The scattering of anisotropic radiation

3) The Hanle effect

4) Magneto-Optical (MO) effects in the wings of strong resonance lines

CLASP/CLASP2 Functional Principles

- "Cold mirror" coating selects the range of wavelengths to be fed into the spectrograph.
- A rotating waveplate varies the polarization angle of light seen by the spectro-polarimeter (SP).
- Polarization analyzers in front of the SP cameras determine the intensity of light that falls upon the detectors.
- Slitjaw imager (SJ) provides context imaging and pointing feedback.



Yoshida et al. (2018, SPIE)
Song et al. (2018, SPIE)
Tsuzuki et al., in prep.

CLASP-1 Findings

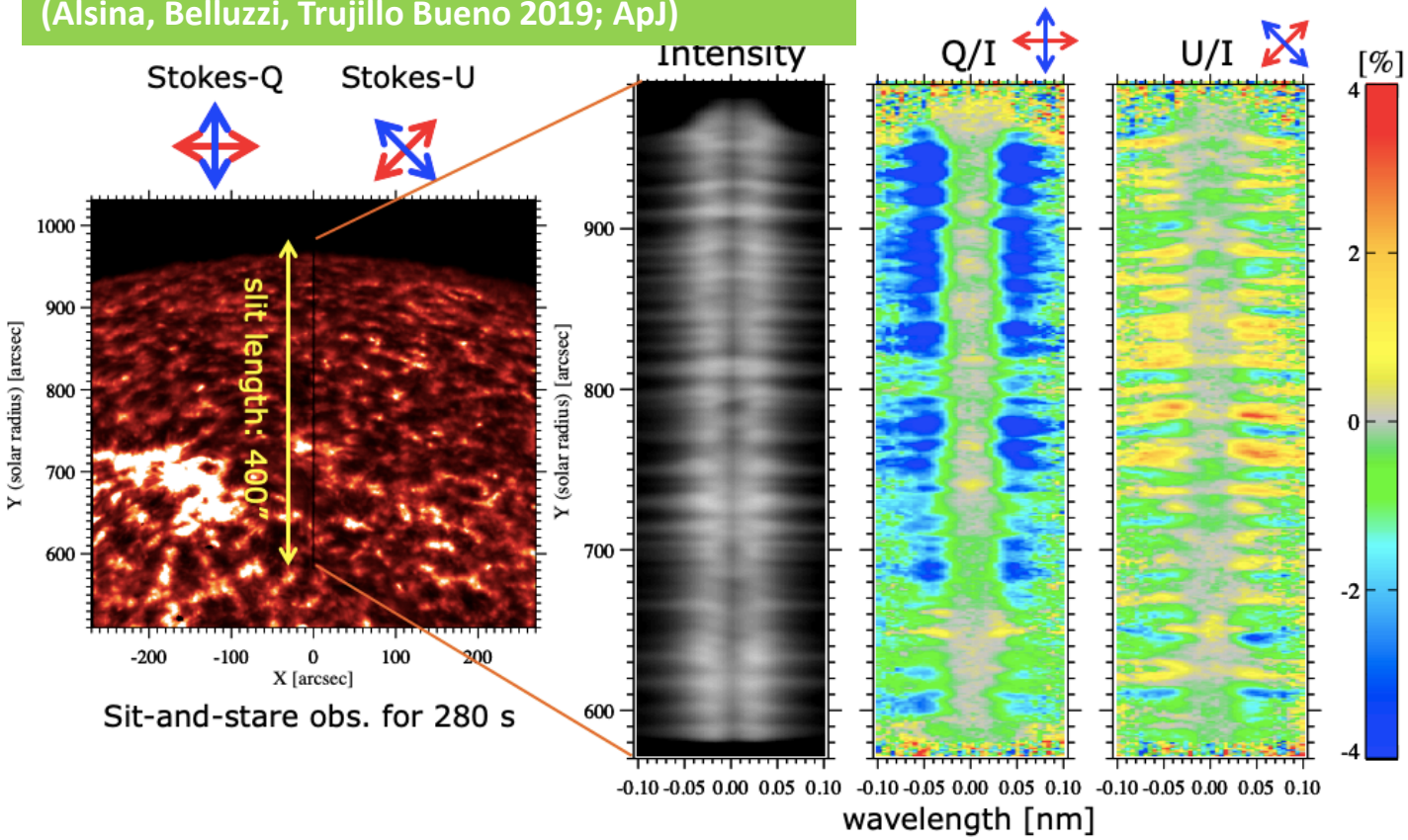
CLASP Science Highlights (Polarimetry)

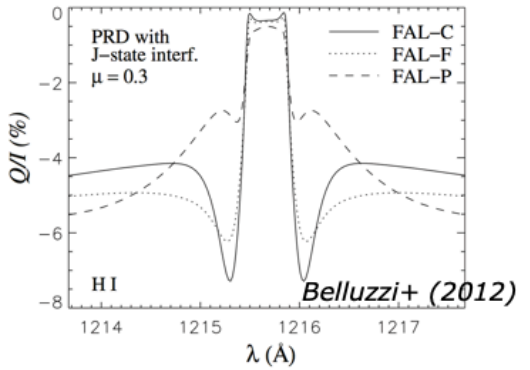
First Detection of Scattering Pol. in VUV

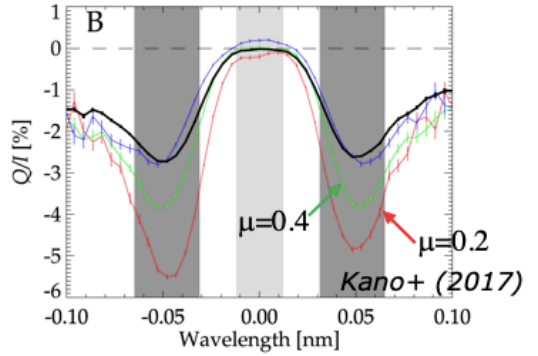
Kano+ (2017)

H I Ly-alpha wings
Scattering + magnetic sensitivity due to MO effects
(Alsina, Belluzzi, Trujillo Bueno 2019; ApJ)

Clear center-to-limb variation up to 6% in Q/I
Fluctuating at a few% at ~10″ both in Q/I and U/I







CLASP-1 Findings

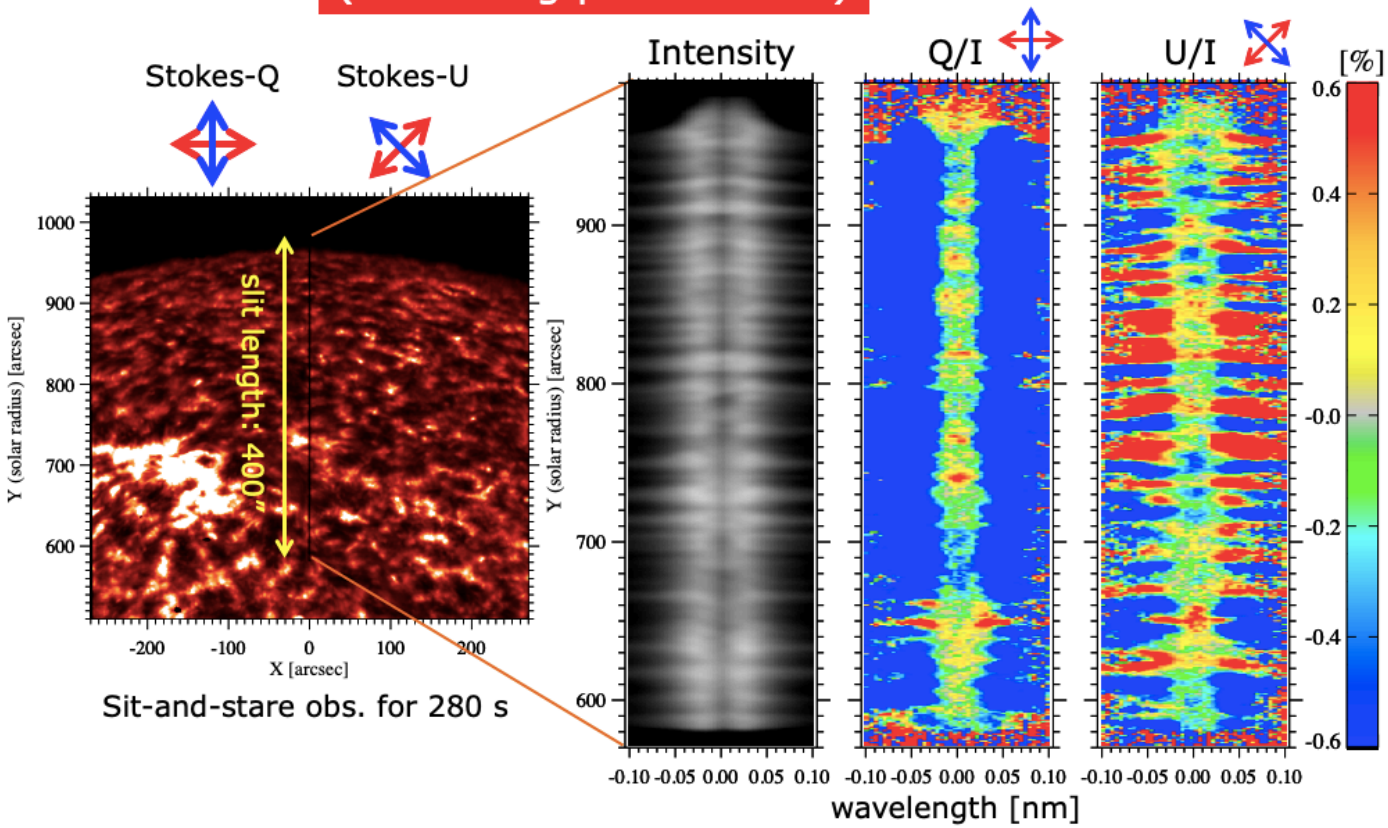
CLASP Science Highlights (Polarimetry)

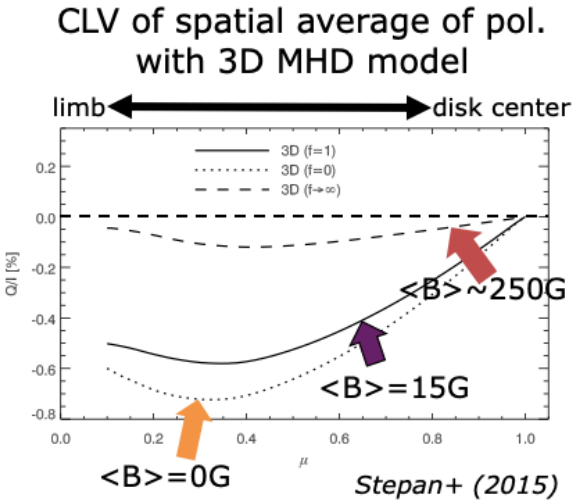
First Detection of Scattering Pol. in VUV

Kano+ (2017)

H I Lya core (scattering pol. & Hanle)

No clear center-to-limb variation (CLV) in Q/I
Fluctuating at a few of 0.1% both in Q/I and U/I





CLASP-1 Findings

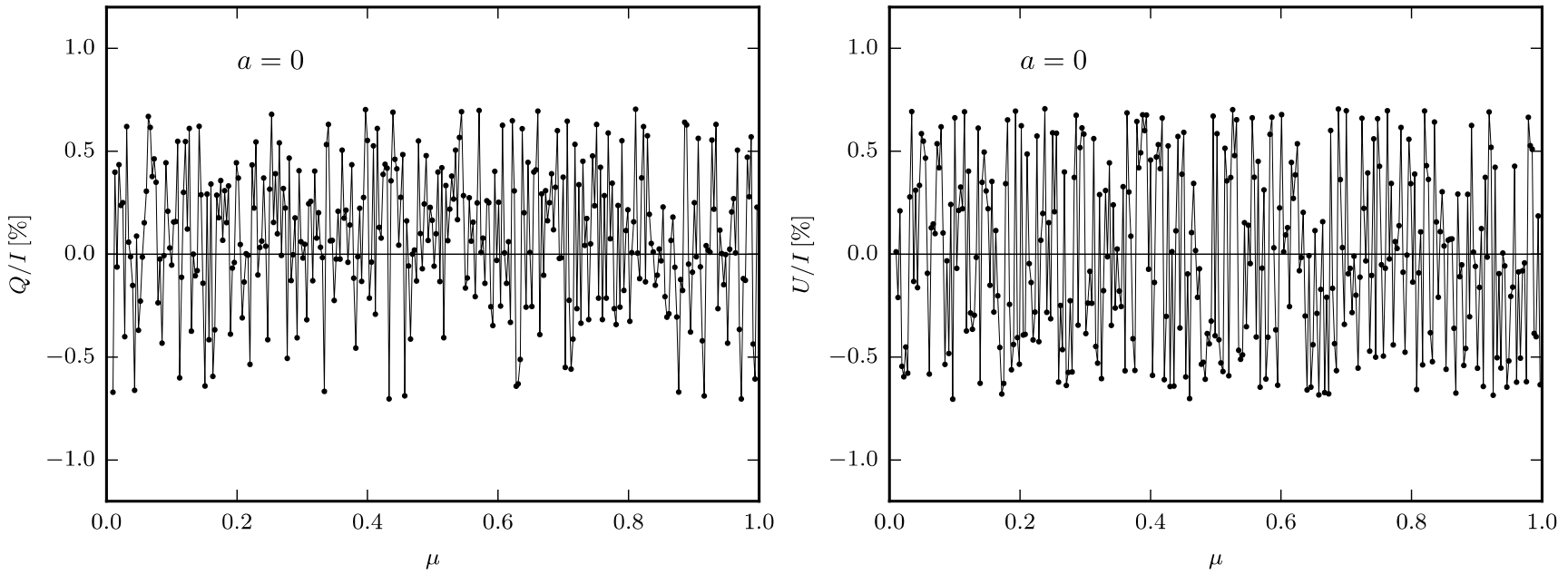
Explanation of an interesting surprise revealed by CLASP

CLASP revealed an interesting surprise: there is no CLV at the center of Q/I

EXPLANATION: the TR surface is extremely corrugated

The amplitude of the Q/I and U/I fluctuations (see figure) is sensitive to B in the TR !

For a model with very corrugated TR:



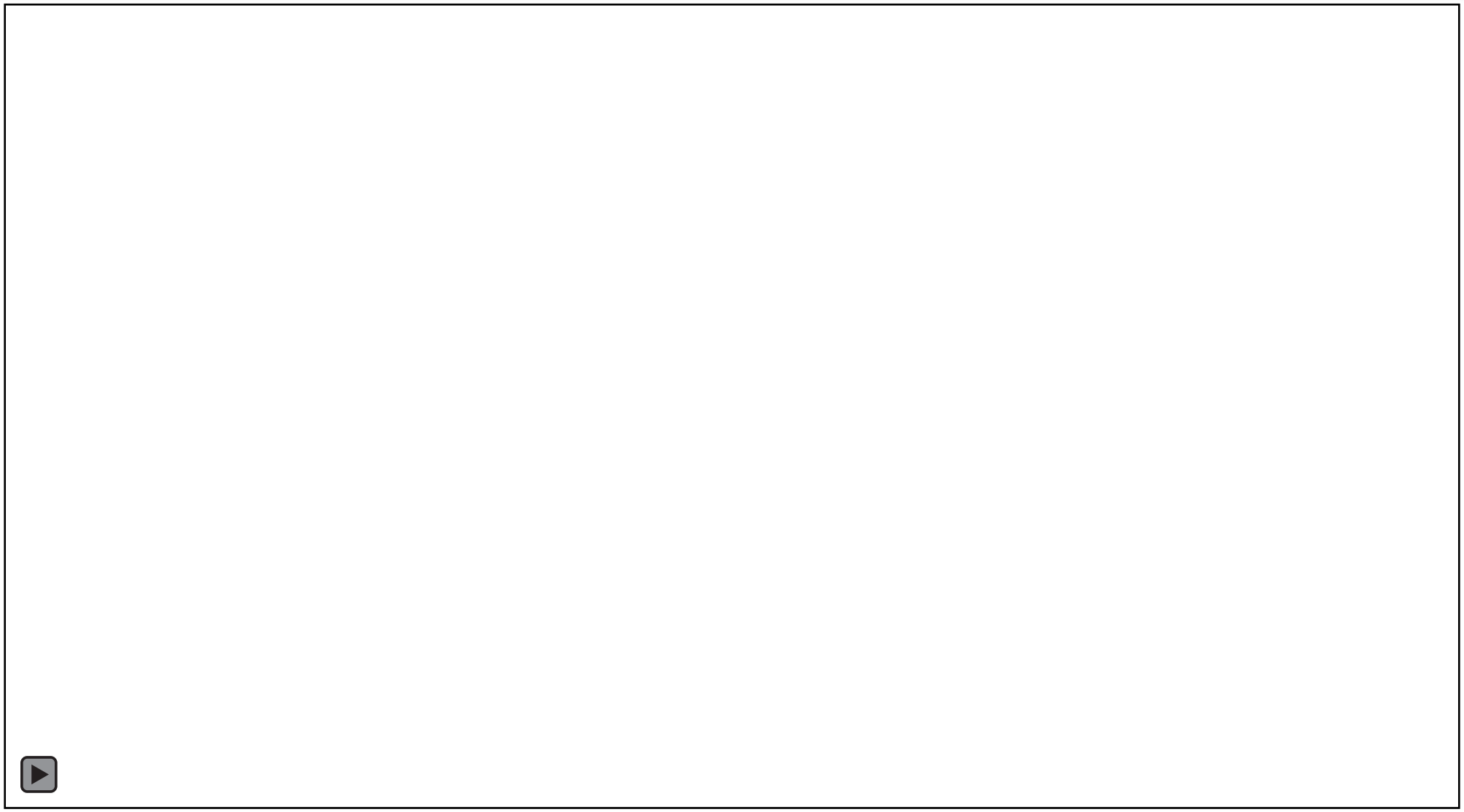
Trujillo Bueno et al. (ApJ Letters, 2018)

CLASP2 Vital Statistics

“JUST OFF THE PAD”

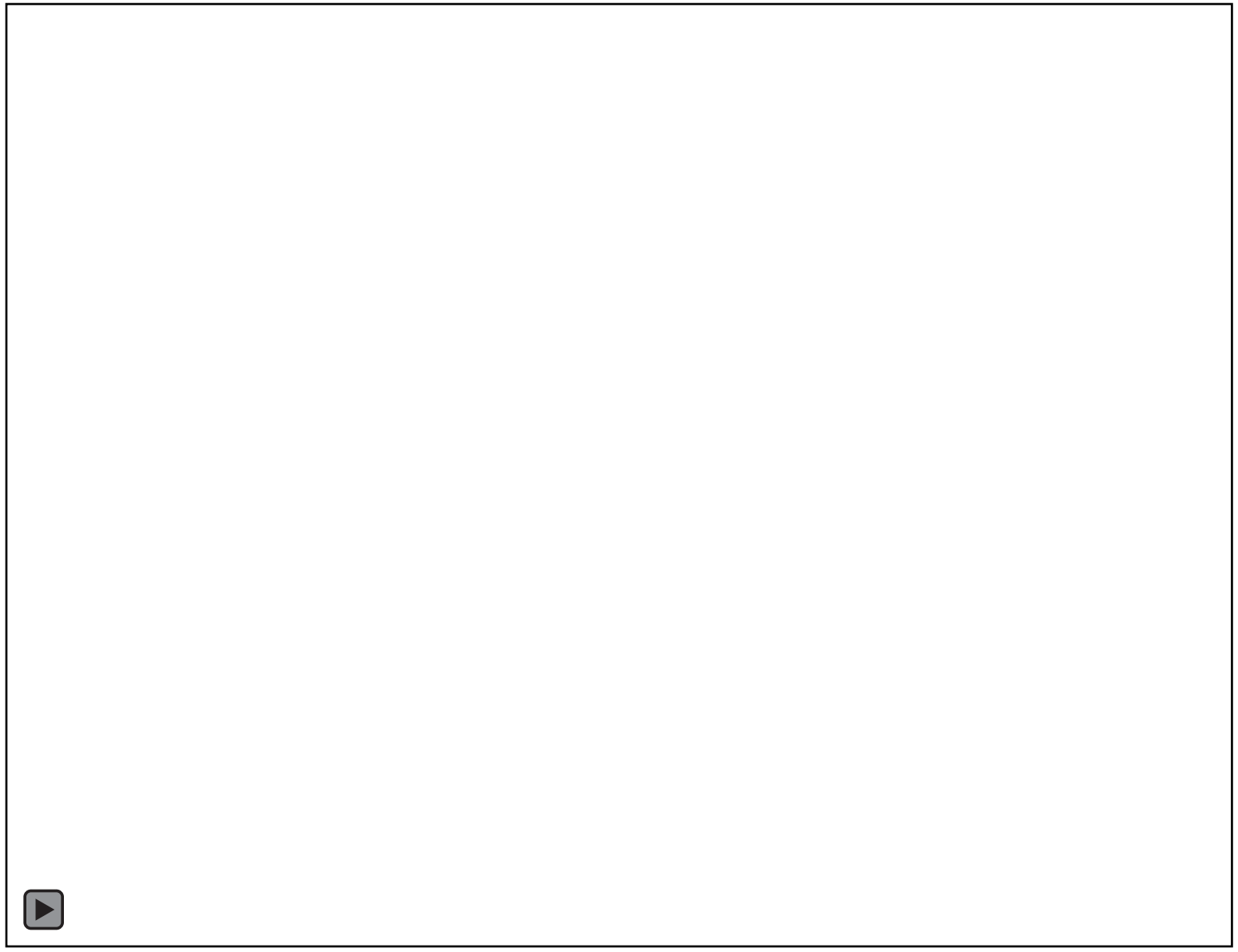
DATE LAUNCHED April 11, 2019
TIME: 10:51:00 MT
TYPE OF ROCKET: Black Brant IX Mk 4
FLIGHT NO: 36.332
LAUNCH SITE: White Sands Missile Range, NM
ALTITUDE PREDICTED: 269.0 km
ACTUAL ALTITUDE: 274.1 km
PAYLOAD WEIGHT: 1244 lbs (564 kg)
ACS SYSTEM: SPARCS
RECOVERY SYSTEM: 1250# NFORSe
EXPERIMENT: Good target, good data, good science.
REMARKS: All payload systems appeared to function nominally
MISSION MANAGER: Rick Weaver/NSROC/Northrop Grumman
SRPO MANAGER: Nathan Empson

CLASP2 Launch!



CLASP2 Targets

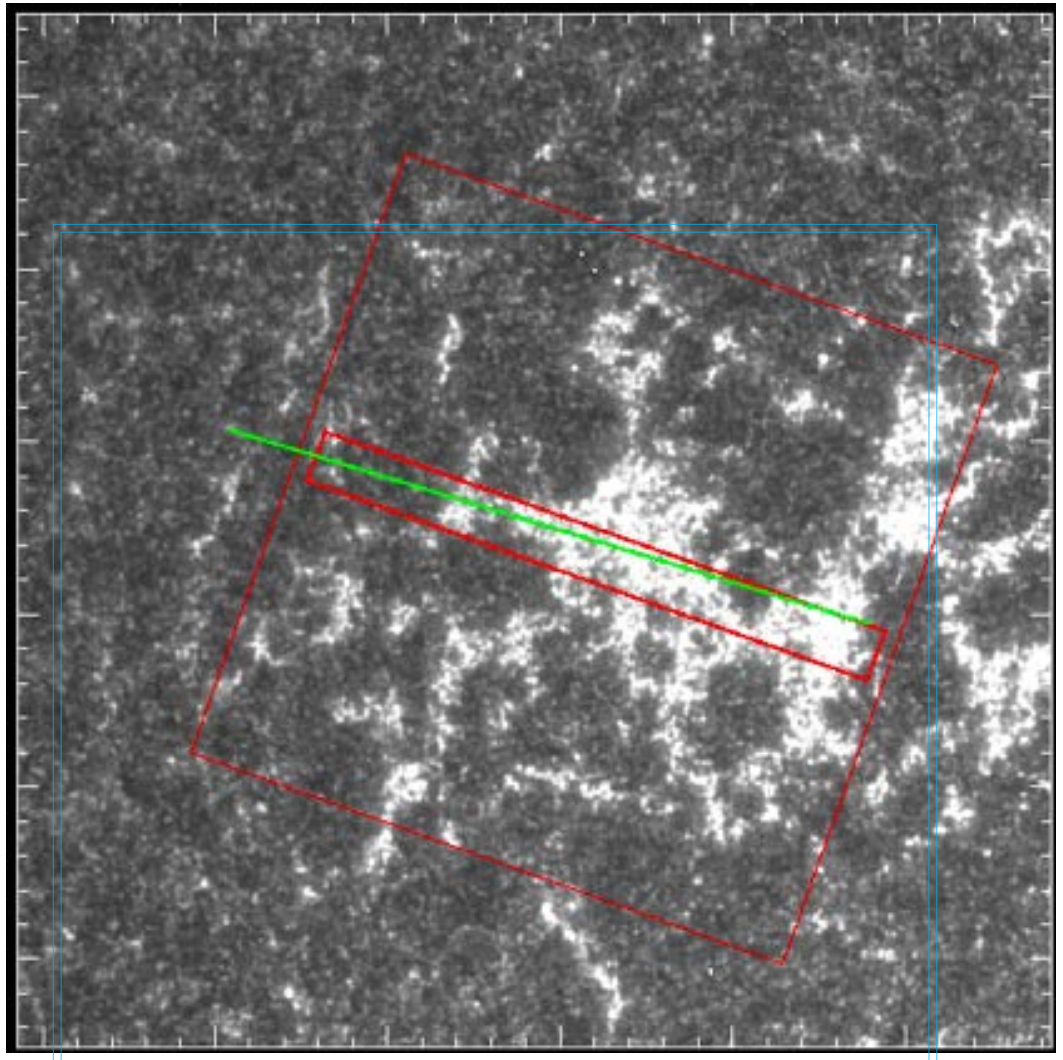
- Disk center for calibration (13s)
- Active region plage (157s)
- Quiet Sun near the limb (142s)



CLASP2 Co-observations

Plage target was simultaneously observed by IRIS, Hinode, and IBIS at NSO/Sac Peak. The result is a combination of imaging, spectroscopy, and polarimetry in NIR, visible, UV, EUV, and soft X-rays.

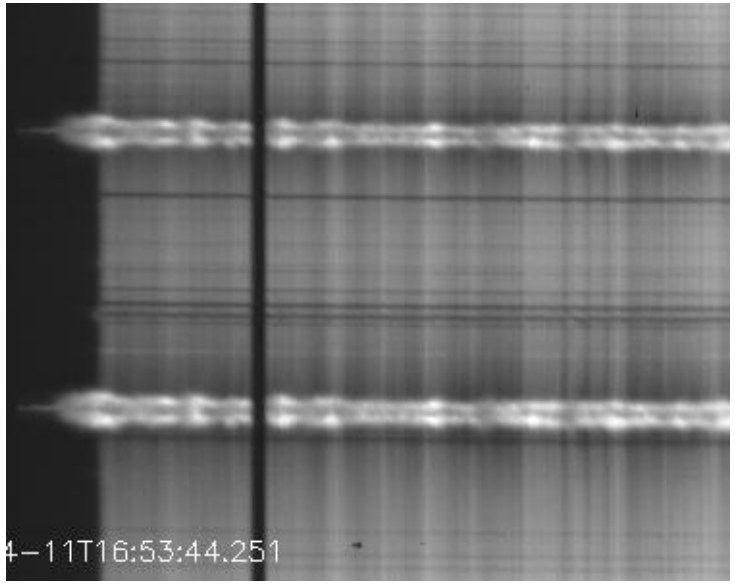
Limb target observed before/after by Hinode/EIS and IRIS.

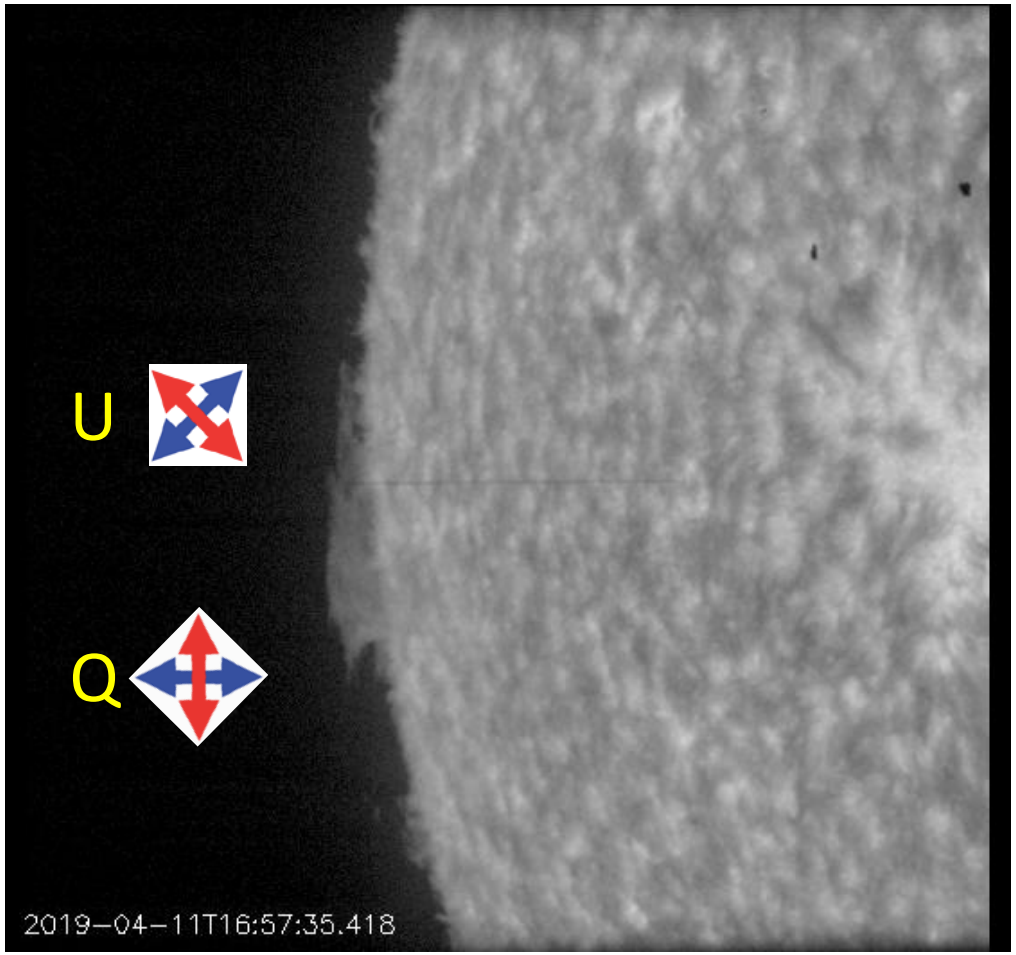


Green: CLASP2 slit
Red: IRIS raster area & slit-jaw FOV
Blue: XRT FOV

CLASP2 Preliminary Results

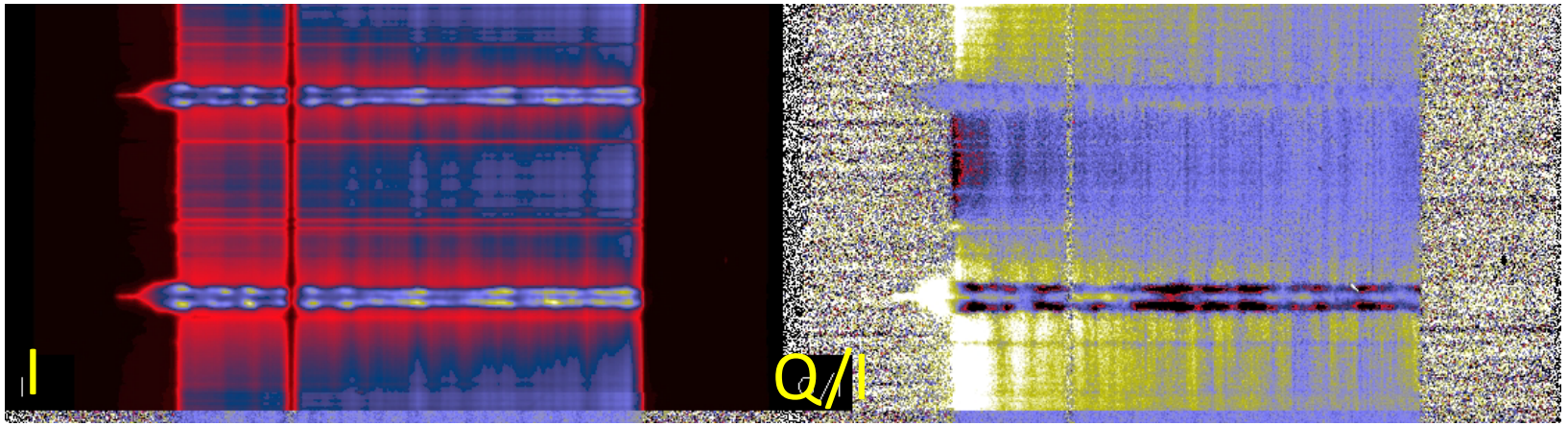
- Both the slitjaw (SJ) and spectro-polarimeter (SP) systems performed nominally.
- Acquired more than 500 SJ images in Ly-alpha, more than 3000 spectra near 280 nm.
- Both SP channels reduceable to I, Q, U, V profiles: >40 sets of Stokes *in each channel* at plage, *and* in QS near limb.
- Calibrations are in progress.

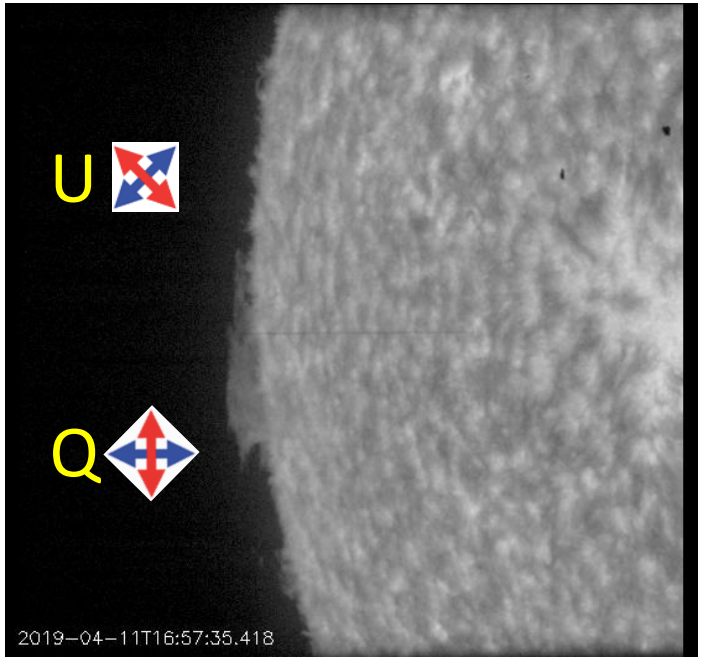


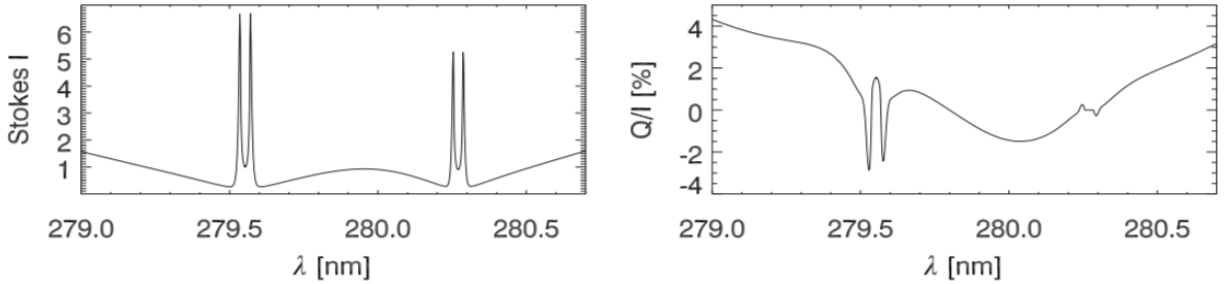


CLASP2 Preliminary Results: *Quiet Sun*

SP1 & SP2 coaligned and co-added, then temporally averaged

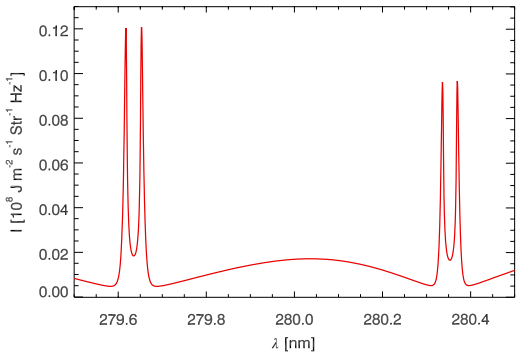




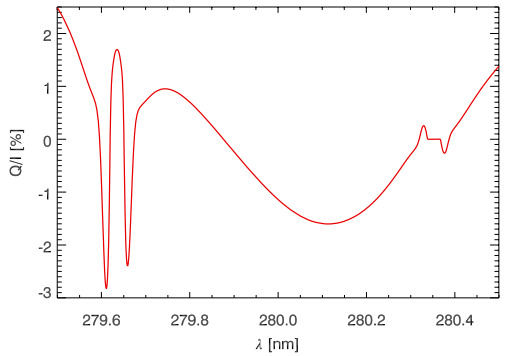


Model prediction (Belluzzi & Trujillo Bueno 2012, *ApJL*, vol. 750, L11), for quiet Sun, B=0, close to solar limb ($\mu = \cos\theta = 0.1$). Positive Stokes Q is parallel to the nearest limb. Strong scattering polarization in *k* line, zero polarization in center of *h* line.

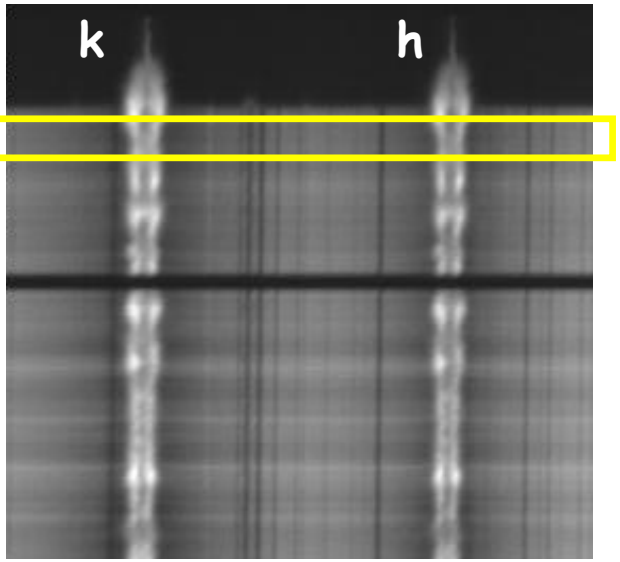
Belluzzi & Trujillo Bueno (2012)



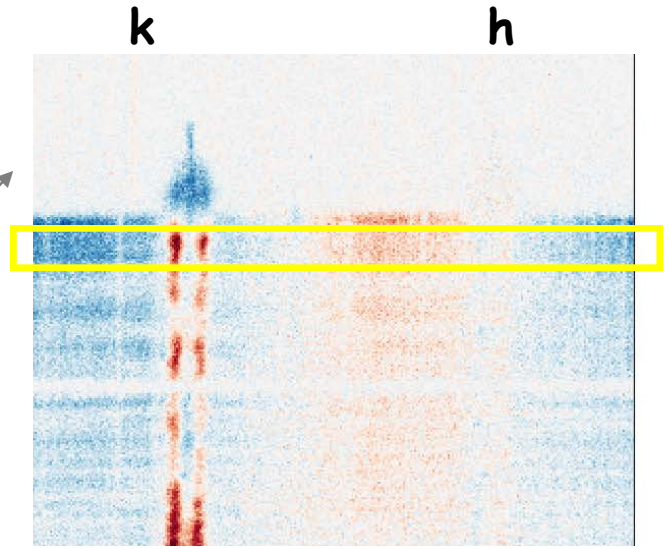
Theory

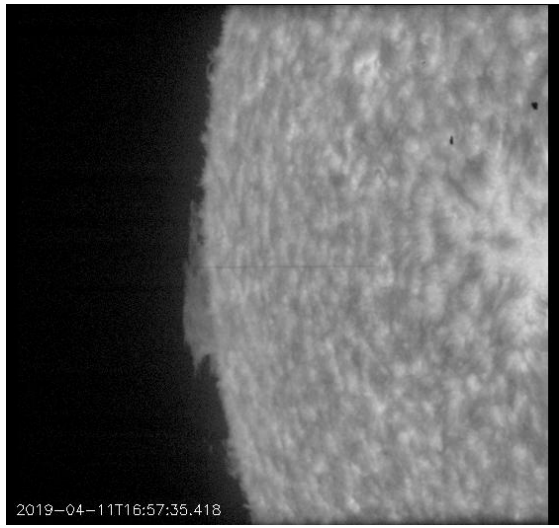


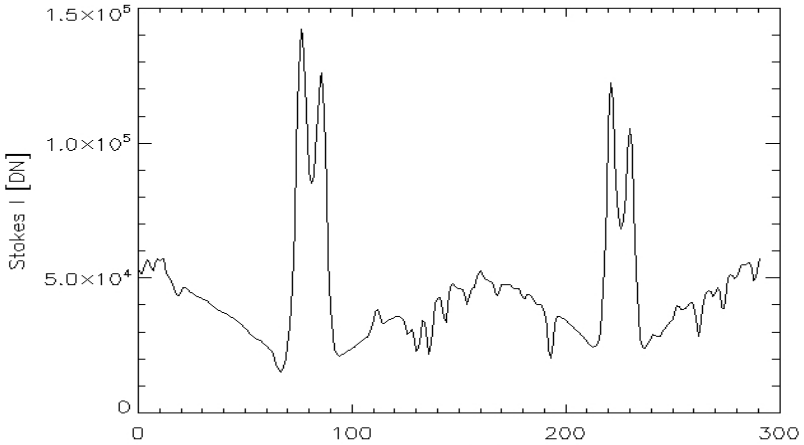
CLASP2 Preliminary Results: *Quiet Sun*

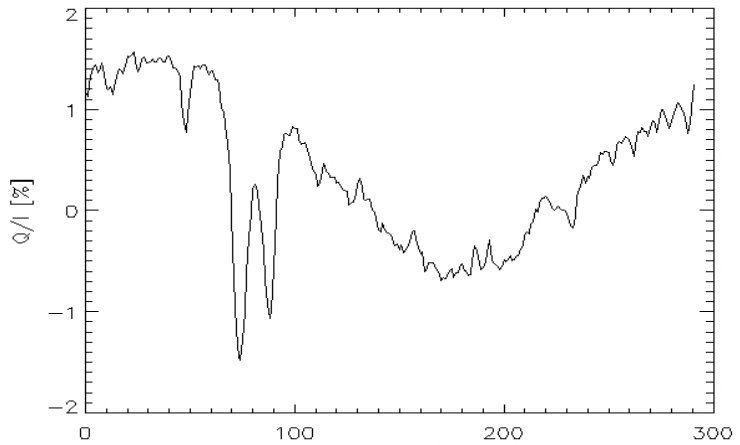


CLASP2

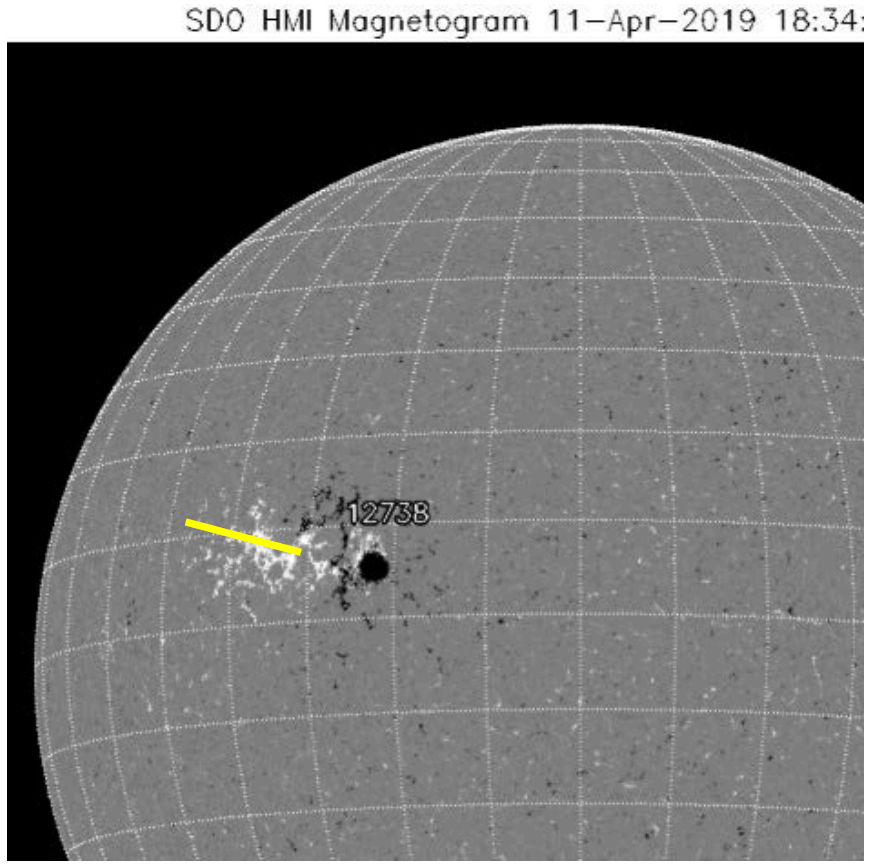




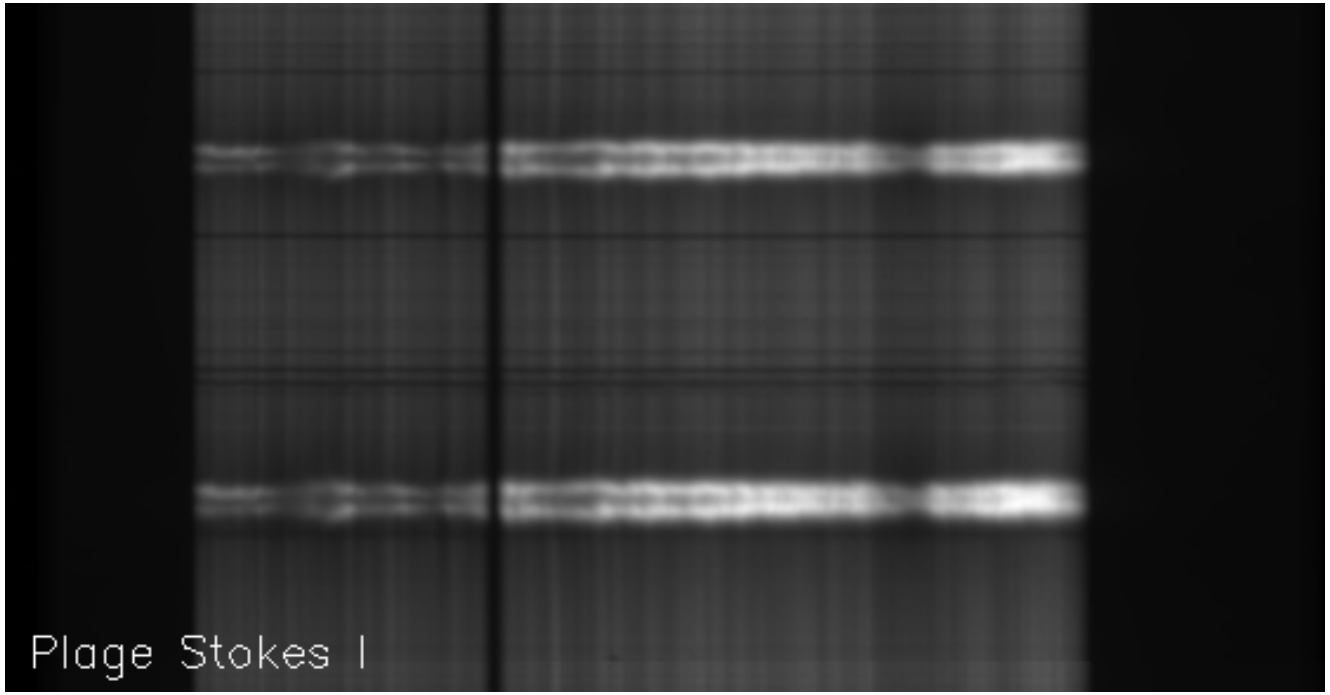




CLASP2 Preliminary Results: *Plage*



SP1 & SP2 coaligned and co-added, then temporally averaged



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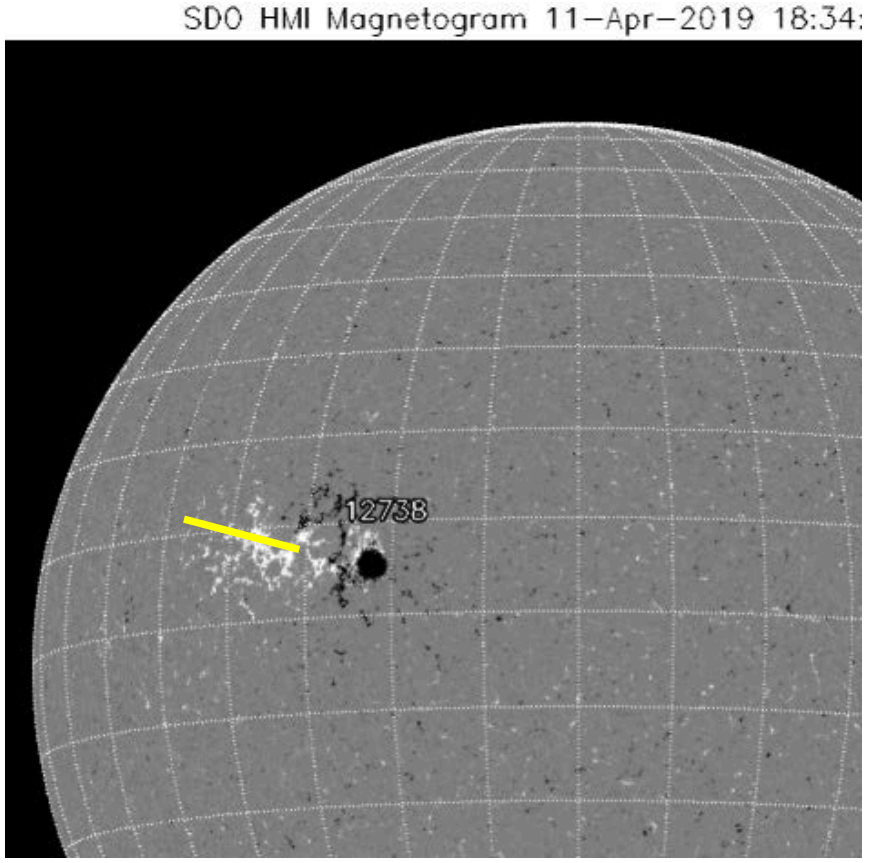
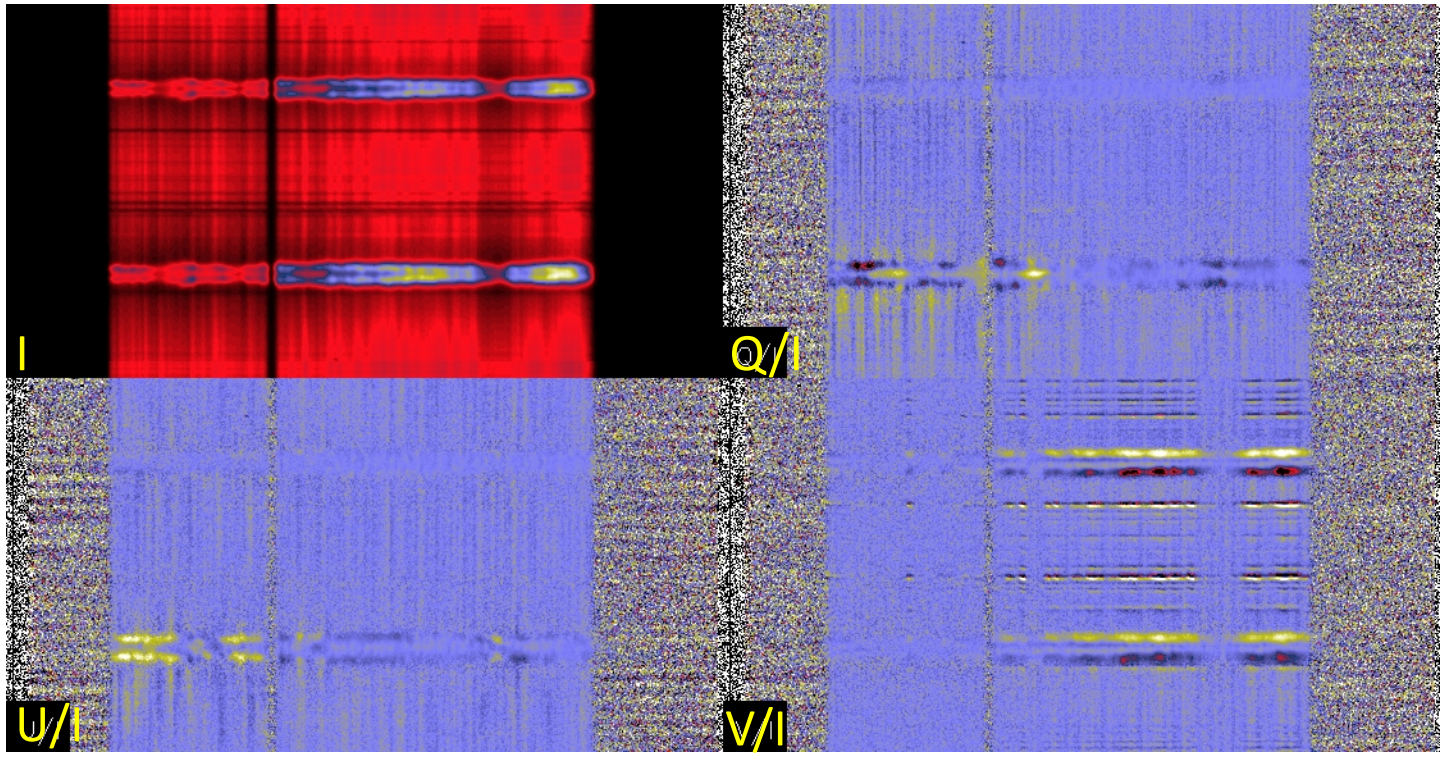
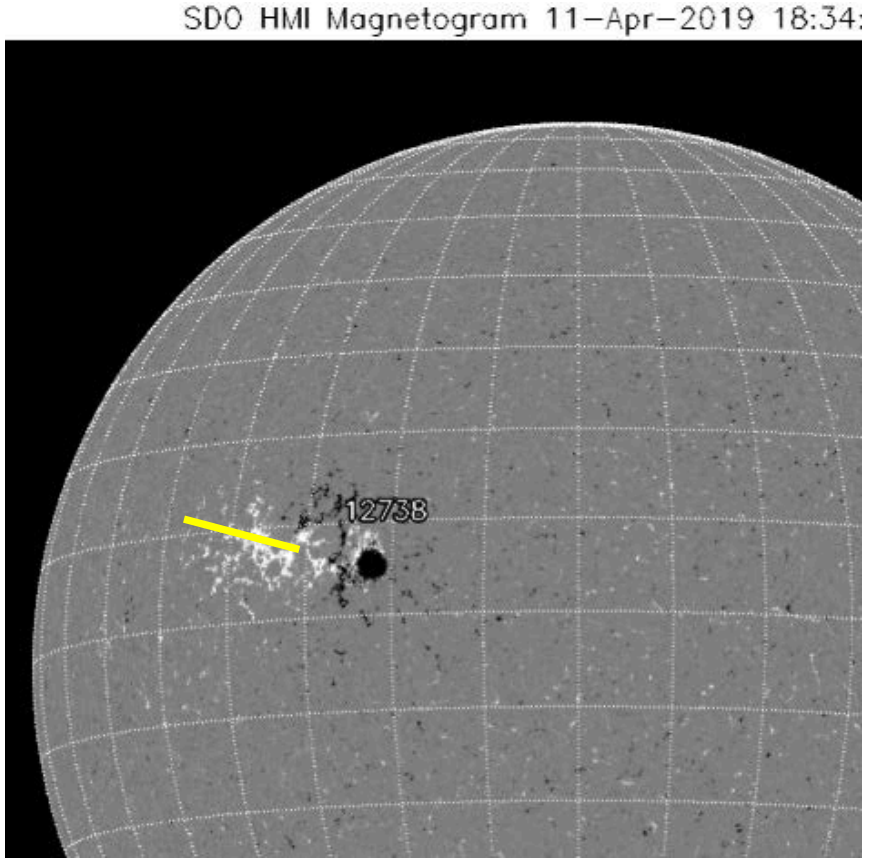


SP1 & SP2 coaligned and co-added, then temporally averaged

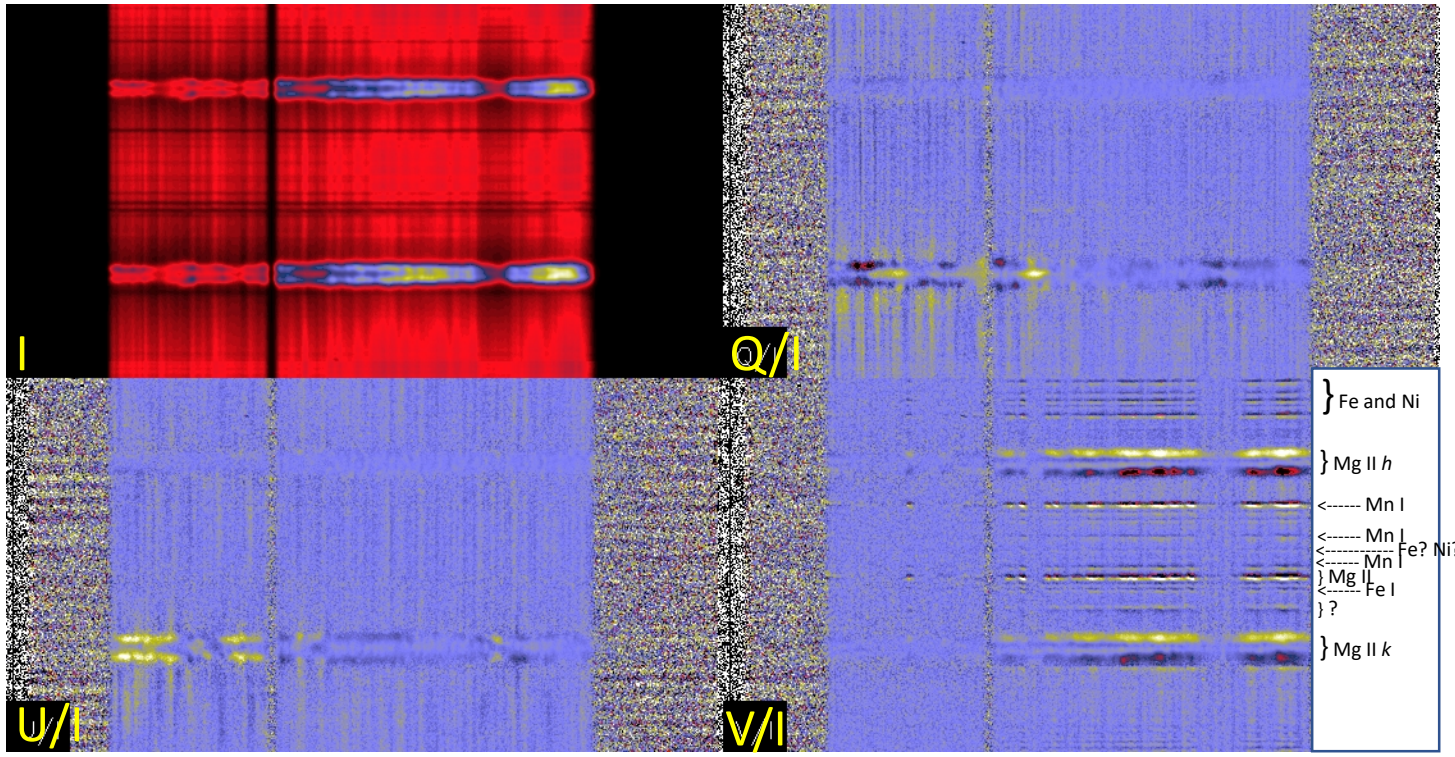


Strong Stokes V/I in plage, presumed due to Zeeman effect. *First observation in chromospheric UV.* And so many lines!

CLASP2 Preliminary Results: *Plage*

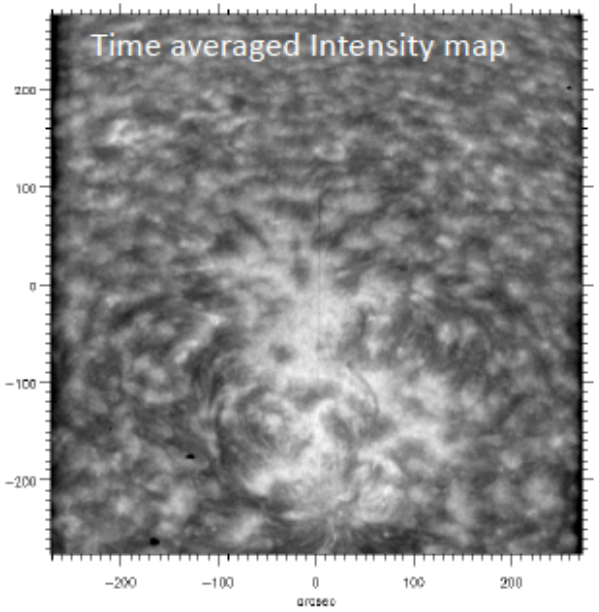


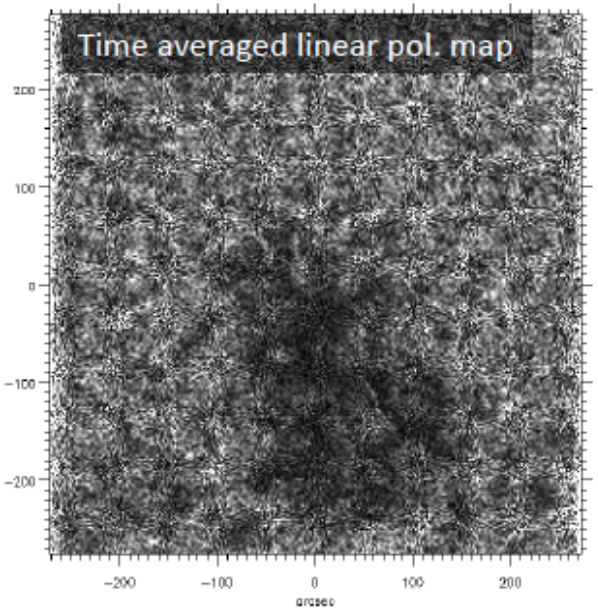
SP1 & SP2 coaligned and co-added, then temporally averaged



Strong Stokes V/I in plage, presumed due to Zeeman effect. *First observation in chromospheric UV.* And so many lines!

CLASP2 Preliminary Results: *Filtergram polarimetry*





We succeeded to obtain both Stokes-Q/I and U/I broad-band images.
A preliminary analysis suggests the followings:

- In quiet regions, the total linear polarization can be up to a few %.
- Anti-correlation between the intensity and the total linear polarization.
- Almost no polarization in the active region.

← These CLASP2/SJ results are consistent with those obtained with CLASP/SJ.

Kano et al., 2019 AAS/SPD, publication in prep.

Moving ahead

- Some remaining calibrations, we're in good shape.
- Data will be published on VSO. Anticipate releasing:
  - Demodulated Stokes I, Q, U, V
  - Full-cadence intensity spectra
  - Instructions/procedures for aligning with co-observations