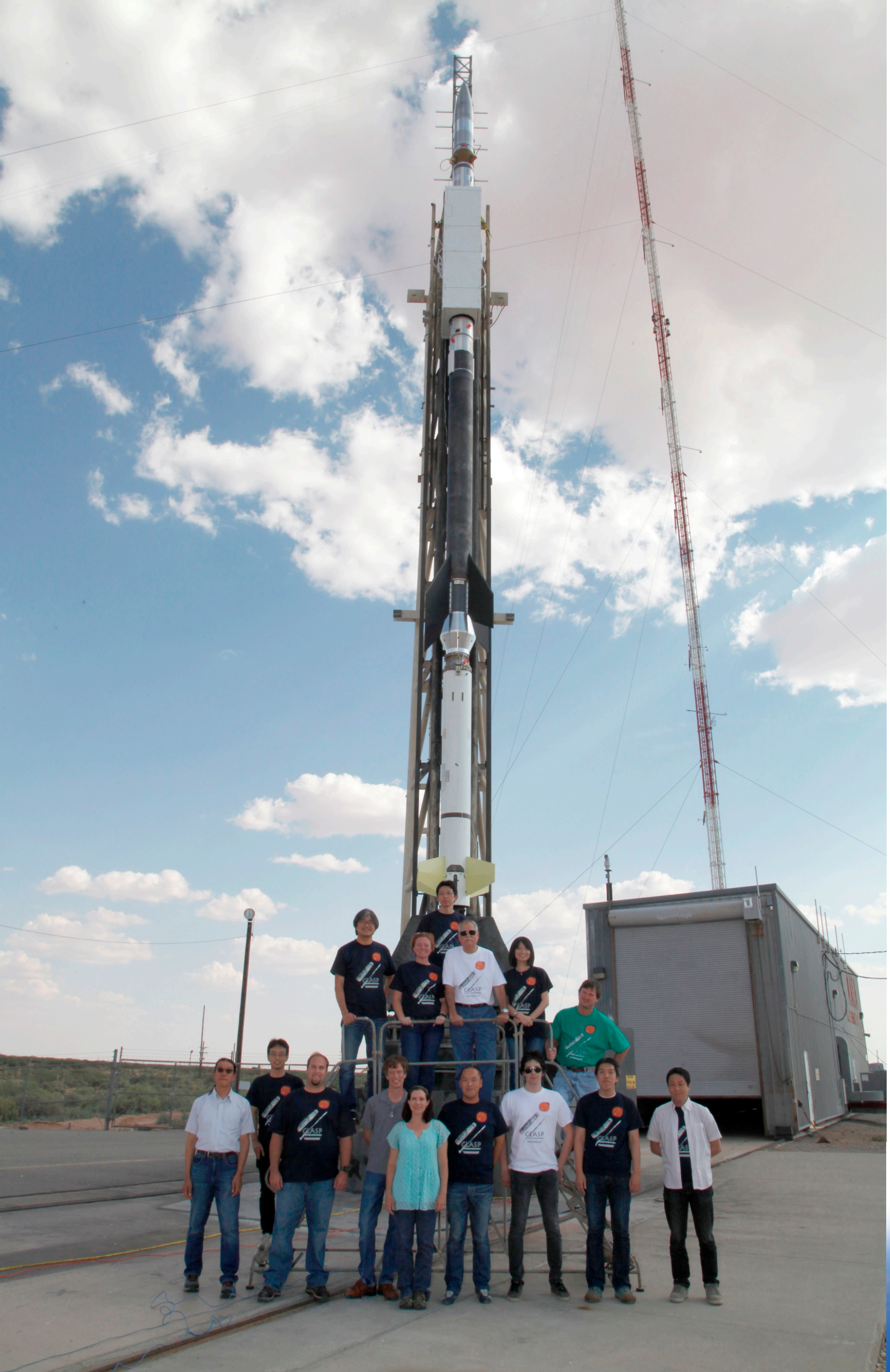
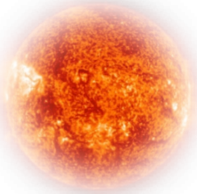


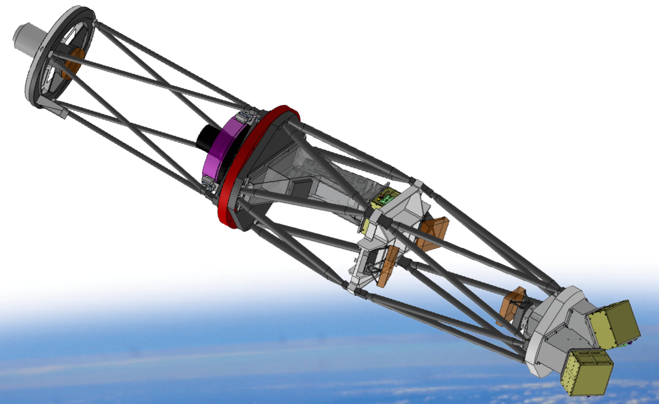
Science with CLASP 1 & 2

Javier Trujillo Bueno
(IAC; Tenerife; Spain)

with the CLASP teams



Suborbital experiments
to explore the
POLARIZATION of
ultraviolet spectral lines



IRIS-9, Göttingen, 25-29 June 2018

Invited Talk

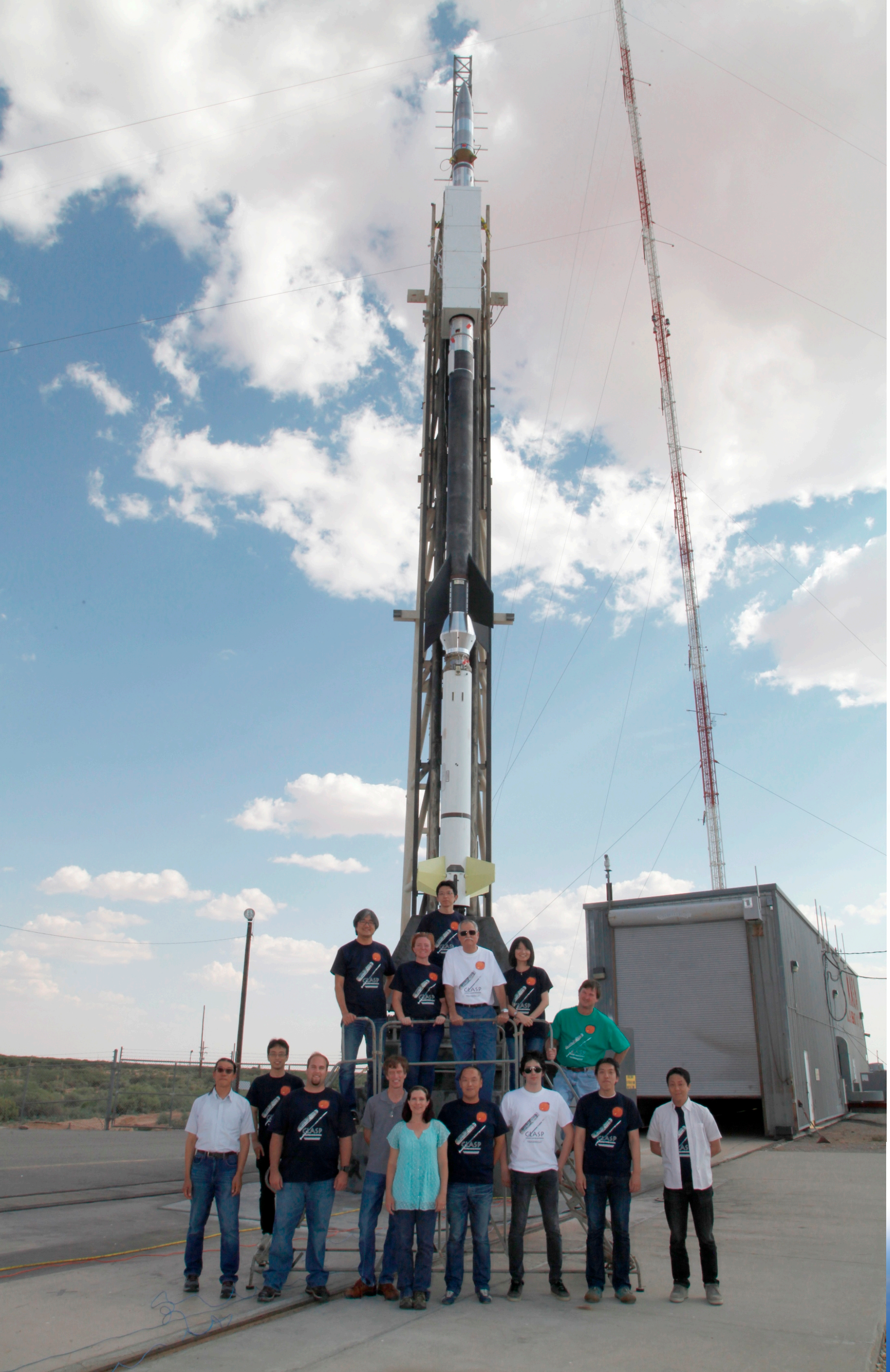
6. Science together with future facilities

Science with CLASP 1 & 2

Javier Trujillo Bueno and the CLASP team[1]

[1] *Instituto de Astrofísica de Canarias (IAC), Tenerife, Spain*

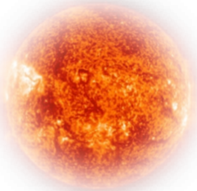
Spectroscopic observations with IRIS of the radiation intensity in ultraviolet (UV) spectral lines have led to very important advances in our empirical understanding of the thermal structure and dynamic behavior of the interface region between the chromosphere and corona of the Sun. Yet, to quantitatively explore the magnetic field of the upper solar chromosphere and the transition region requires spectropolarimetry in magnetically sensitive UV spectral lines, such as hydrogen Lyman-α and the Mg II h & k lines. The sensitivity to the presence of magnetic fields in the upper solar chromosphere is caused mainly by the Hanle effect, which operates in the core of the linear polarization profiles produced by scattering processes, but recently we have learned that in such strong resonance lines the Zeeman effect can also introduce magnetic sensitivity in the wings of their linear polarization profiles. The observation and modeling of the polarization produced in UV lines by the joint action of scattering processes and the Hanle and Zeeman effects are not easy, but solar physics has always benefited when new diagnostic windows are pursued and eventually opened. On 3rd September 2015 an international team of scientists from USA, Japan and Europe carried out a challenging experiment with the Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), a vacuum UV telescope with a spectropolarimeter launched by a NASA suborbital rocket. Here we provide an overview of this successful mission that has allowed us to observe for the first time the linear polarization produced by scattering processes in the hydrogen Lyman-α line of the solar disk radiation. We also inform about the second flight of CLASP, planned for 2019, which will hopefully measure the linear and circular polarization across the Mg II h & k lines. The emphasis of this lecture will be on the scientific aspects of both sounding rocket experiments.



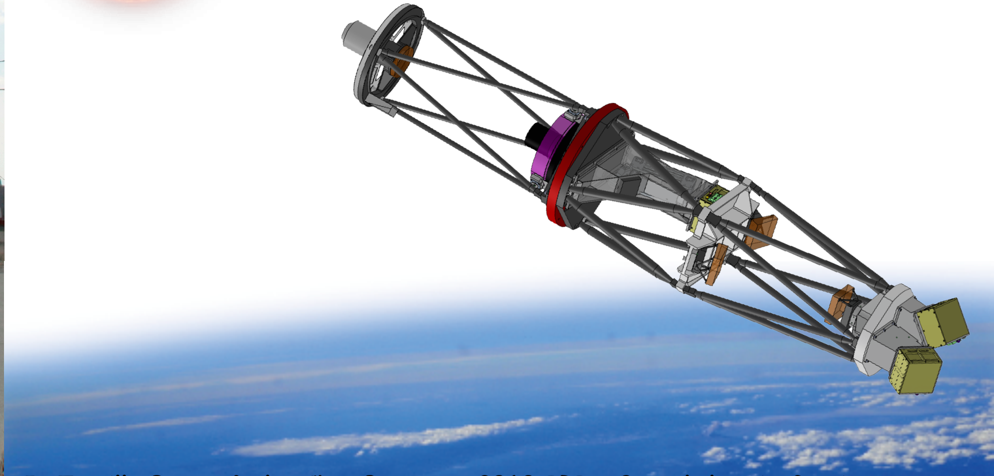
Science with CLASP 1 & 2

Javier Trujillo Bueno
(IAC; Tenerife; Spain)

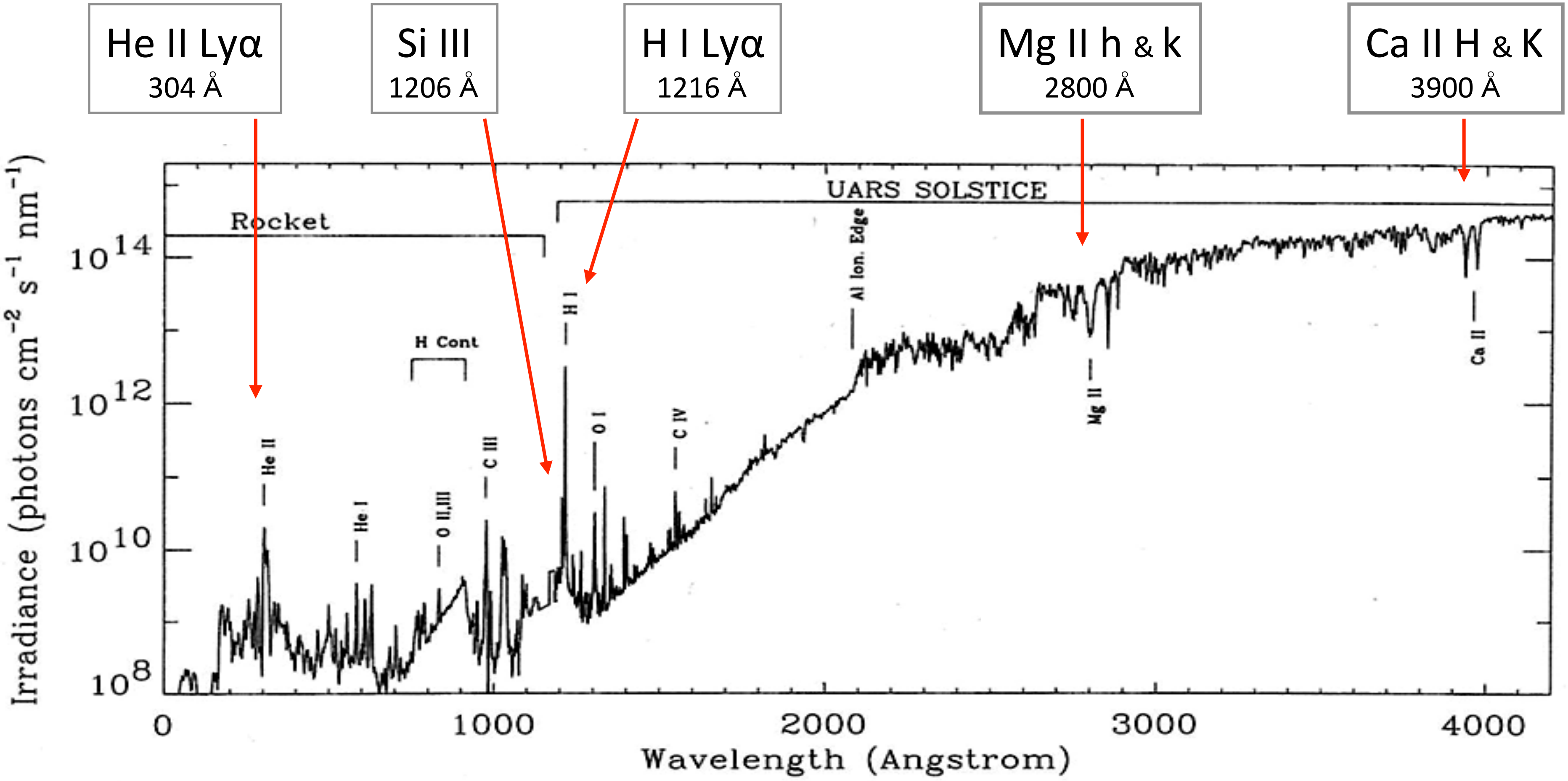
with the CLASP teams



Suborbital experiments
to explore the
POLARIZATION of
ultraviolet spectral lines



The primary emission of the upper chromosphere, TR and corona is in the UV, EUV and X-ray spectral regions



He II Lyα
304 Å

Si III
1206 Å

H I Lyα
1216 Å

Mg II h & k
2800 Å

Ca II H & K
3900 Å

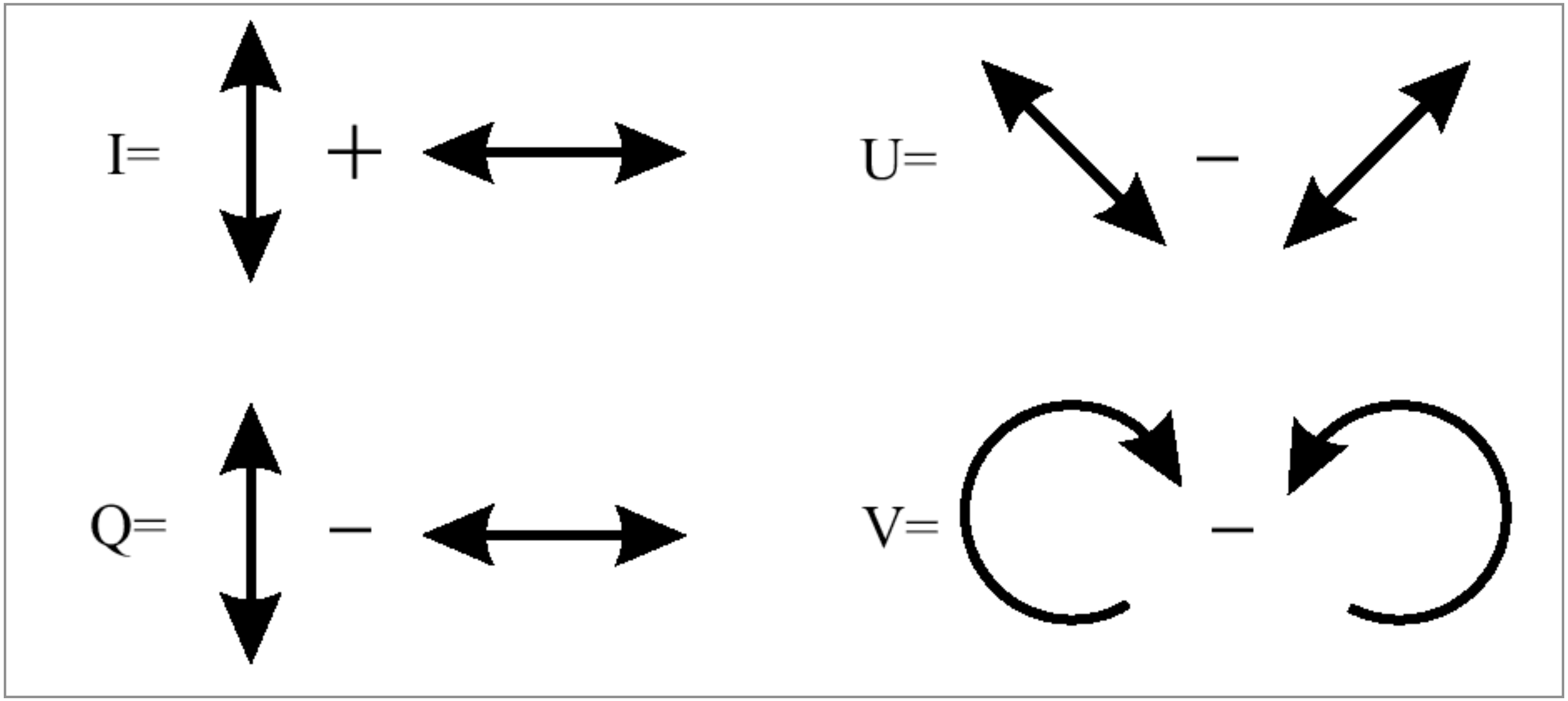
J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

IRIS spectroscopy: only the intensity (Stokes I)

High temporal and spatial resolution

VIDEO

The Stokes parameters



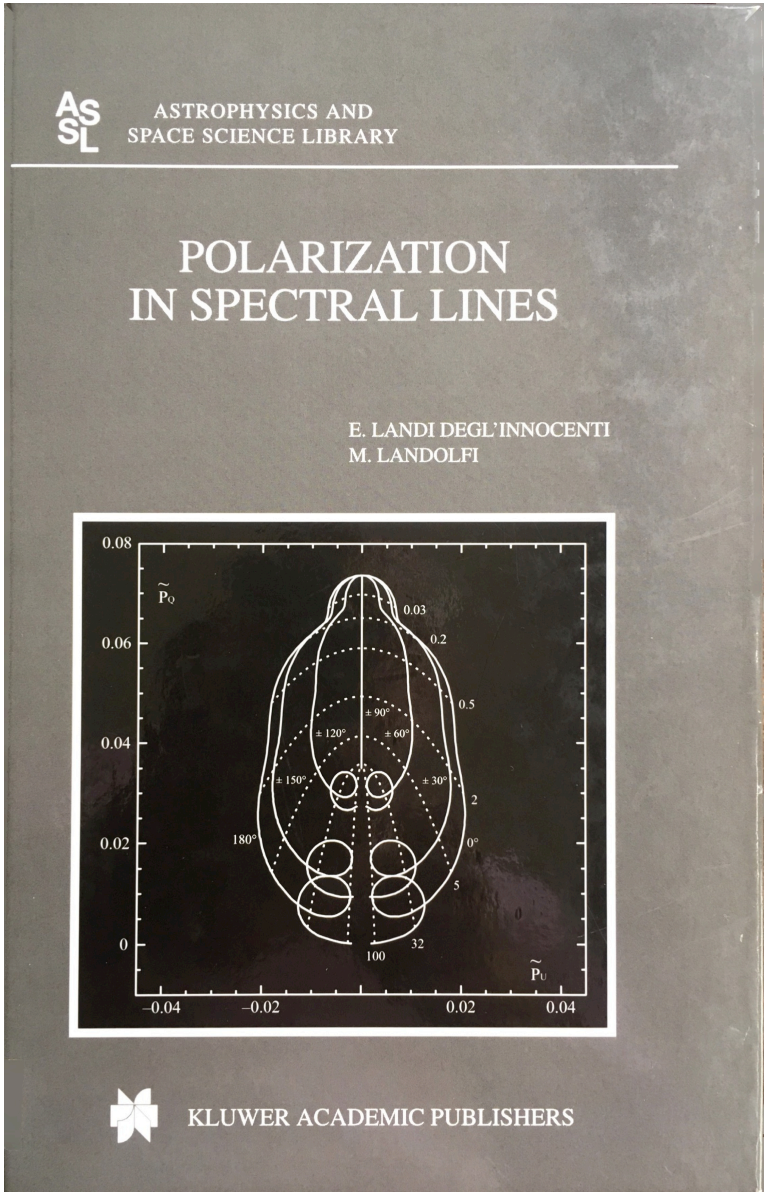
CLASP spectro-polarimetry: I, Q, U, V

Lower temporal and spatial resolution

VIDEO

The Quantum Theory of Polarization in Spectral Lines

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen



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POLARIZATION
IN SPECTRAL LINES

E. LANDI DEGL'INNOCENTI
M. LANDOLFI

KLUWER ACADEMIC PUBLISHERS

Physical mechanisms responsible of the Polarization in Spectral Lines

1) The Zeeman effect

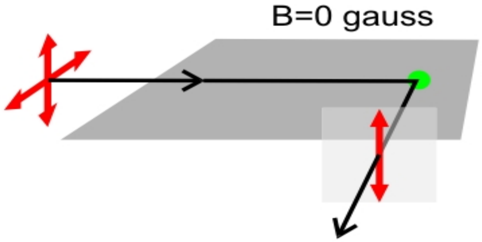
2) Scattering processes

3) The Hanle effect

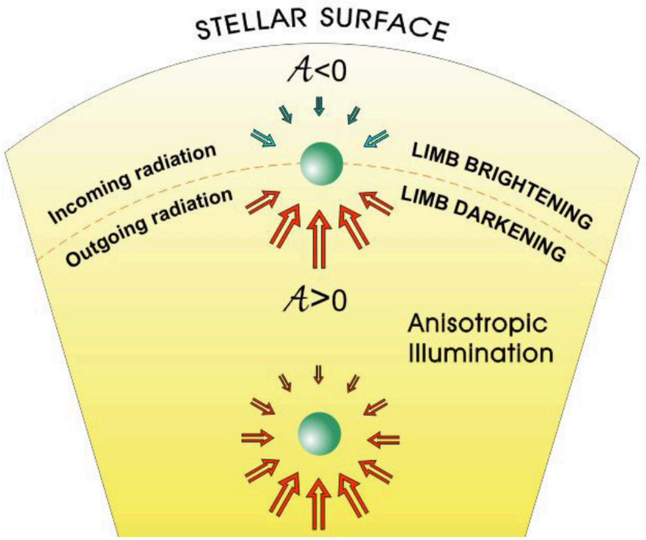
4) Magneto-Optical (MO) effects in the wings of strong resonance lines

(2) Scattering line polarization

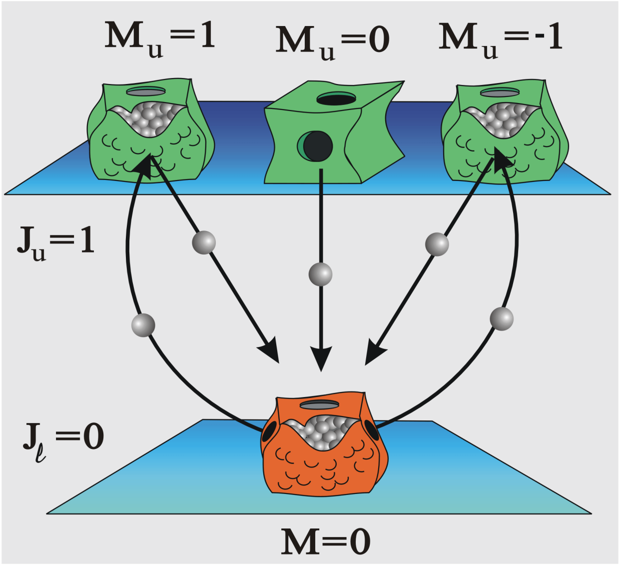
ANISOTROPIC RADIATION → ATOMIC POLARIZATION → LINEAR POLARIZATION produced



Anisotropic Radiation

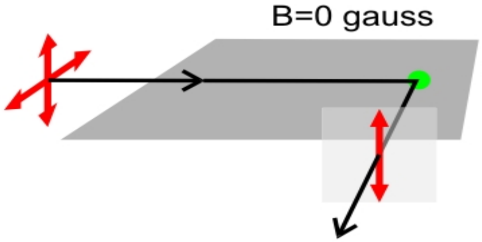


Atomic Polarization



(2) Scattering line polarization

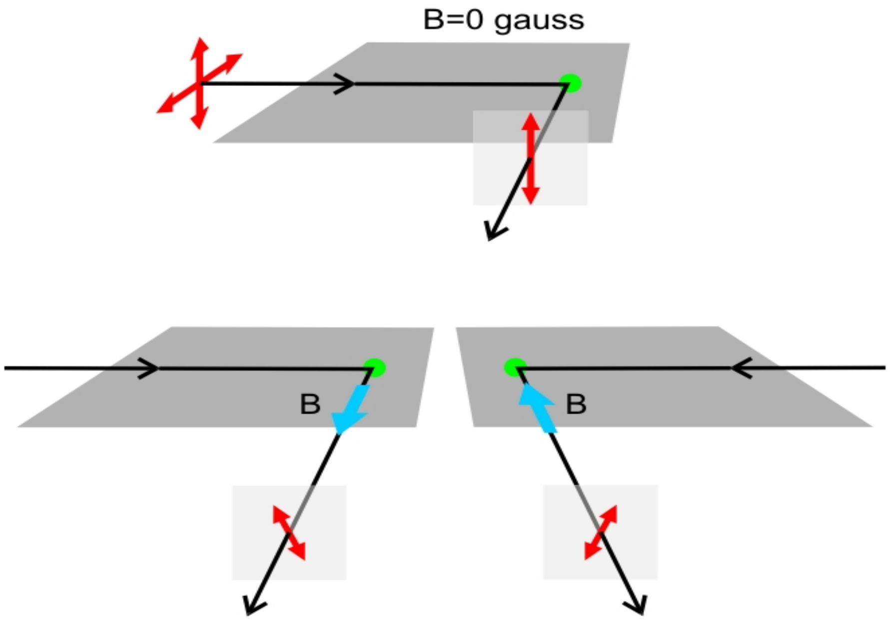
ANISOTROPIC RADIATION ⟶ ATOMIC POLARIZATION ⟶ LINEAR POLARIZATION produced



It does NOT need a magnetic field !

(3) The Hanle effect of a magnetic field

Magnetic Field → HANLE effect → LINEAR POLARIZATION modified



$B_H = 850$ G

He II 304 Å

$B_H = 290$ G

Si III 1206 Å

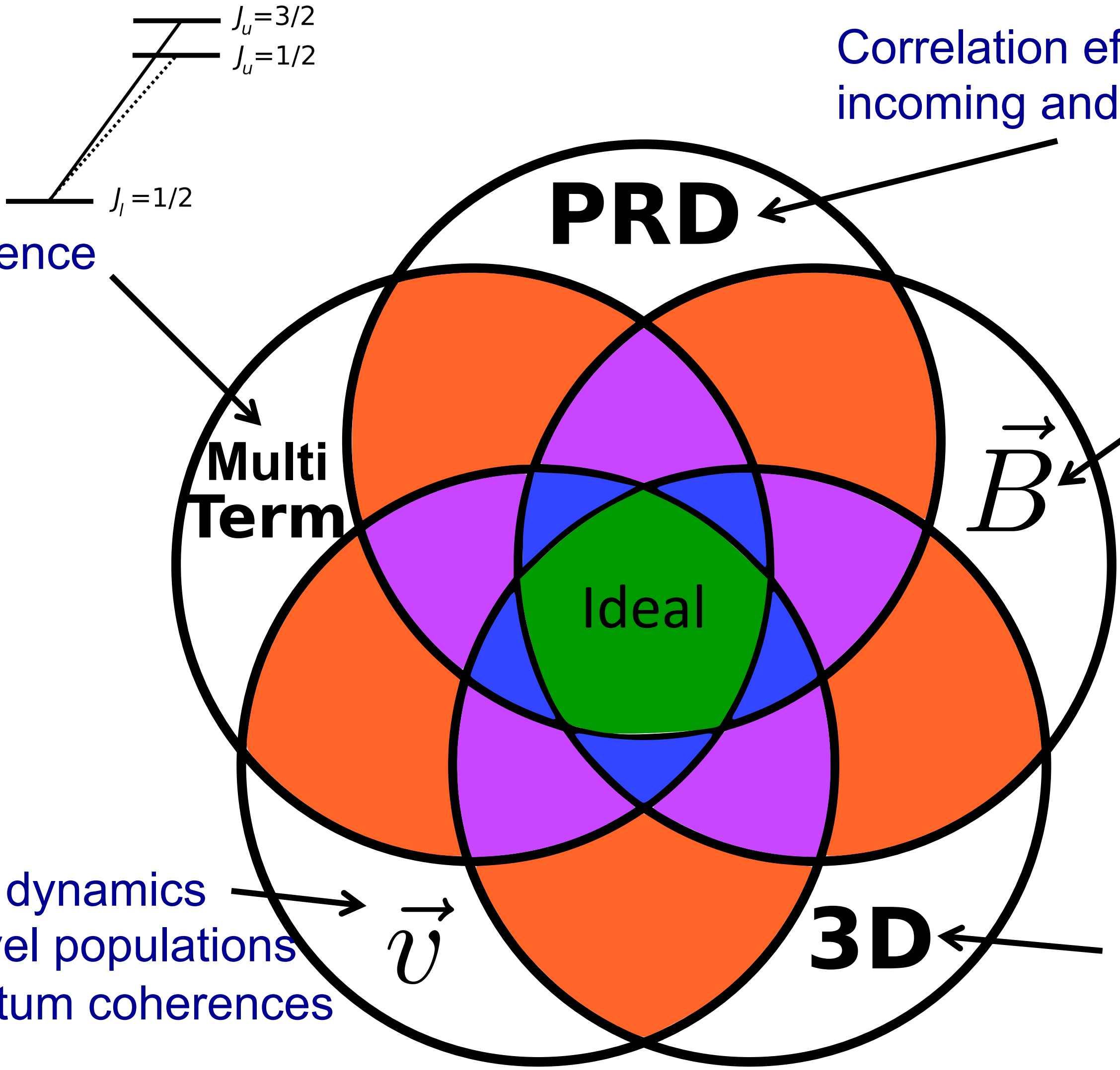
$B_H = 53$ G

Ly-alpha of H I

$B_H = 20$ G

k-line of Mg II

The generation and transfer of spectral line polarization



J-state interference

Correlation effects between incoming and outgoing photons

Hanle and Zeeman effects

Impact of dynamics on the level populations and quantum coherences

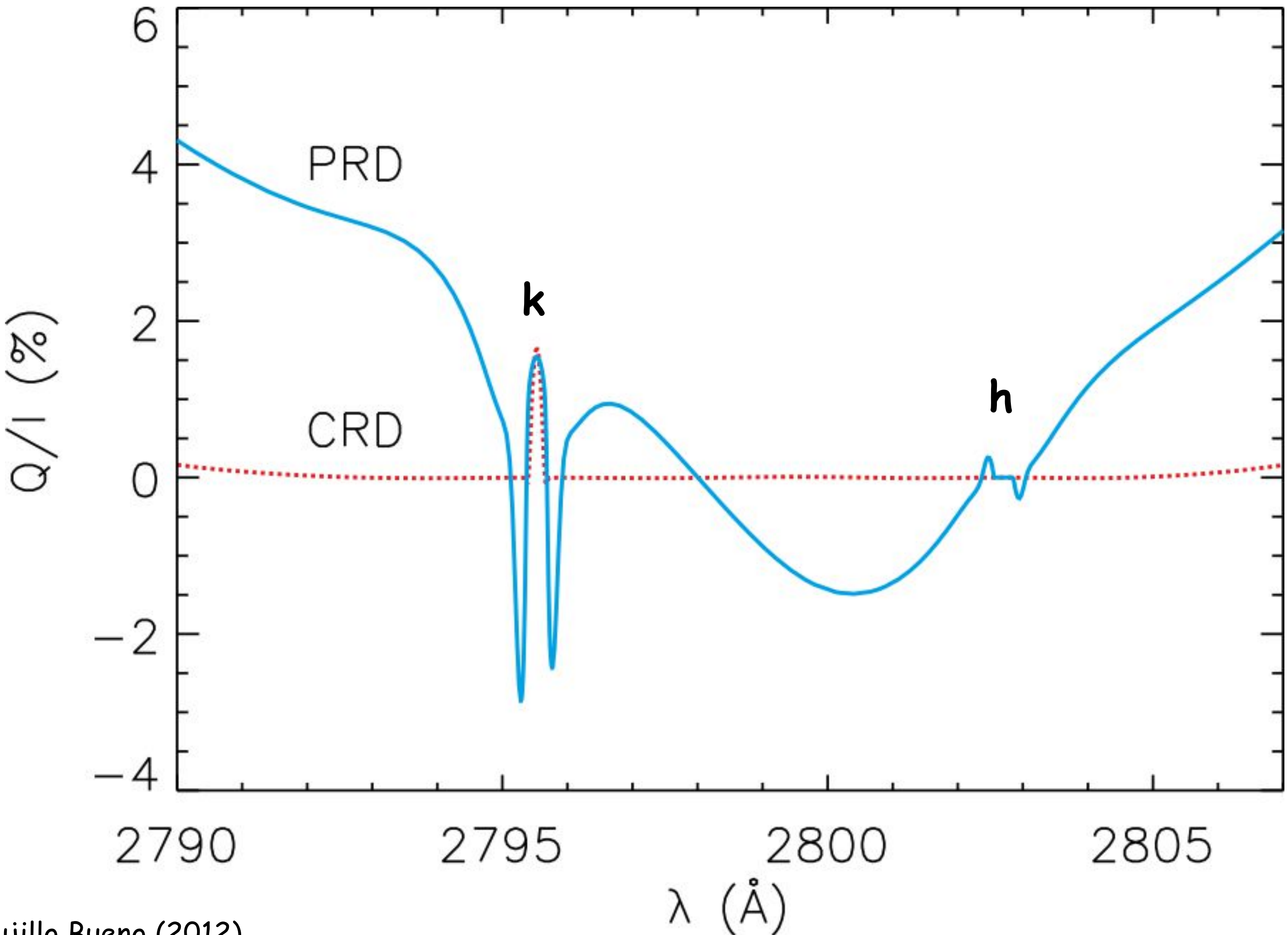
Symmetry breaking caused by horizontal atmospheric inhomogeneities

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The Linear Polarization of Mg II h & k

PRD: correlation effects YES

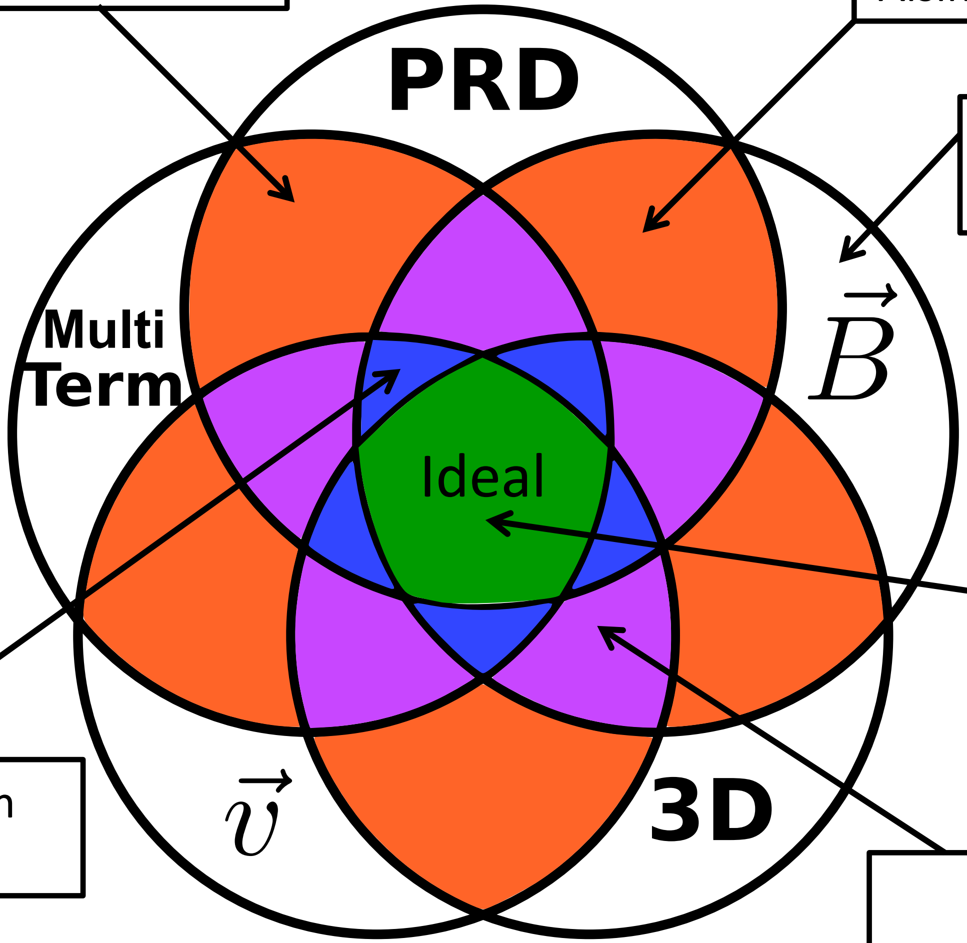
CRD: correlation effects NO



Belluzzi & Trujillo Bueno (2012)

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The generation and transfer of spectral line polarization



Belluzzi & Trujillo Bueno (2012)

Alsina Ballester et al. (2016)

Manso Sainz &
Trujillo Bueno (2003)

POLMAG

del Pino Alemán
et al. (2016)

PORTA
Stepan & Trujillo Bueno (2013)

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The generation and transfer of spectral line polarization

Today we can do:

- **PRD in 1D with J-state interference**
- **CRD in 3D without J-state interference**

Predictions for hydrogen Ly-alpha

- Trujillo Bueno, Stepan, Casini (2011; ApJ)
- Belluzzi, Trujillo Bueno, Stepan (2012; ApJ)
- Stepan, Trujillo Bueno, Leenaarts, Carlsson (2015; ApJ)

Summary of our theoretical predictions for Ly-alpha at the spatial resolution (3”) of CLASP

Line CENTER:

Q/I and U/I amplitudes smaller than 1%, sensitive (via the Hanle effect) to 10 --- 100 G fields in the TR. With CLV in Q/I.

Line WINGS:

Negative (radial) Q/I signals with amplitudes larger than 1%, with a clear CLV.

And with Q/I and U/I spatial variations

CLASP 1

Chromospheric Lyman-Alpha SpectroPolarimeter

CLASP-1: measure I, Q, U of hydrogen Lyman-alpha with a vacuum UV telescope and a spectropolarimeter launched by a NASA sounding rocket

Rocket + CCD cameras

USA

A. Winebarger (MSFC. PI)
T. Holloway (MSFC)* - **PM**
K. Kobayashi - PS
J. Cirtain (MSFC)†
B. De Pontieu (LMSAL) *
R. Casini (HAO) †

France

F. Auchère (IAS, Co-PI) ‡ GRATING

Telescope + Polarimeter

Japan

R. Kano (NAOJ, Co-PI) ‡
S. Tsuneta (NAOJ)‡
N. Narukage (JAXA)‡ - **IS**
M. Kubo (NAOJ)‡
T. Sakao (JAXA) ‡
Y. Suematsu (NAOJ)‡
T. Shimizu (JAXA) ‡
T. Bando (NAOJ)‡ - **PM**
R. Ishikawa (NAOJ) ‡ - **PS**
Y. Katsukawa (NAOJ) ‡
H. Hara (NAOJ) ‡
K. Ichimoto (Kyoto) ‡
G. Ono (NAOJ)

Theory & Modeling

Spain

J. Trujillo Bueno (IAC, Co-PI)‡
R. Manso Sainz (IAC) ‡
L. Belluzzi (IAC) ‡
A. Asensio Ramos (IAC) ‡

Czech Republic

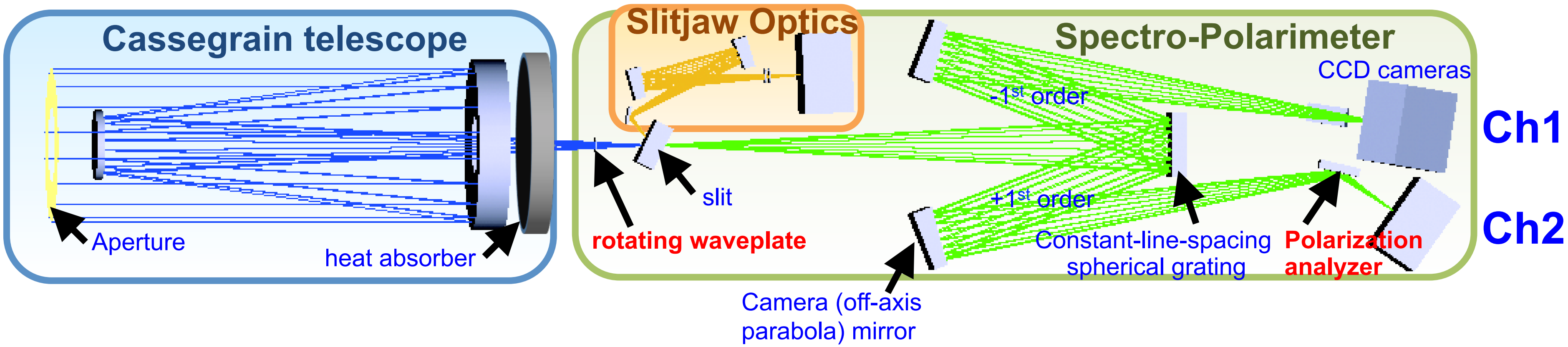
J. Stěpán (ASCR) ‡

Norway

M. Carlsson (Univ. of Oslo) ‡

The Chromospheric Ly-Alpha SpectroPolarimeter

(CLASP: a sounding rocket experiment by USA, Japan and Europe)



- Two symmetric channels: **Ch1 & Ch2**

  Simultaneously measure orthogonal polarization states

- High throughput in the UV:

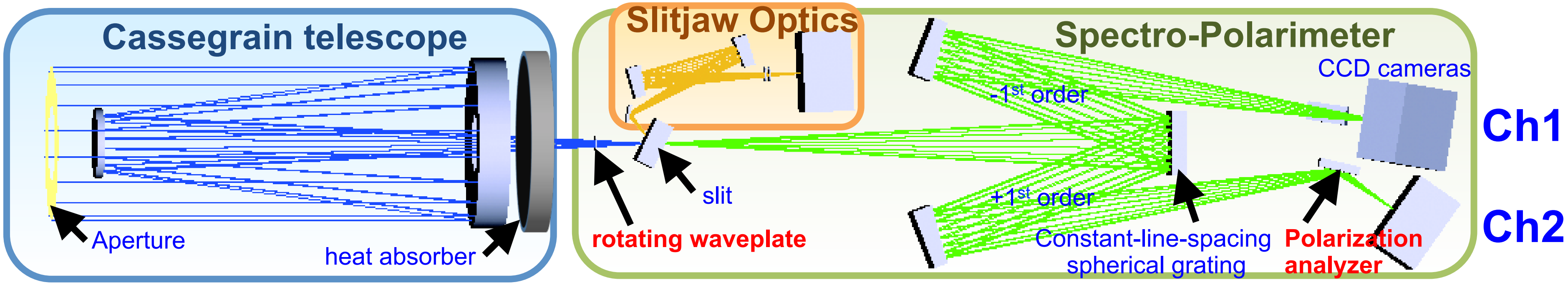
  Minimum number of optical components

  High-reflectivity coating in all optical components

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The Chromospheric Ly-Alpha SpectroPolarimeter

(CLASP: a sounding rocket experiment by USA, Japan and Europe)



Cassegrain Telescope	
Aperture	ϕ270.0 mm
Focal Length	2614 mm (F/9.68)
Visible light rejection	“Cold Mirror” coating on primary mirror

Slitjaw Optics	
Wavelength	121.567 nm (NB filter)
Plate scale	**1.03’’/pixel**
FoV	527’’×527’’

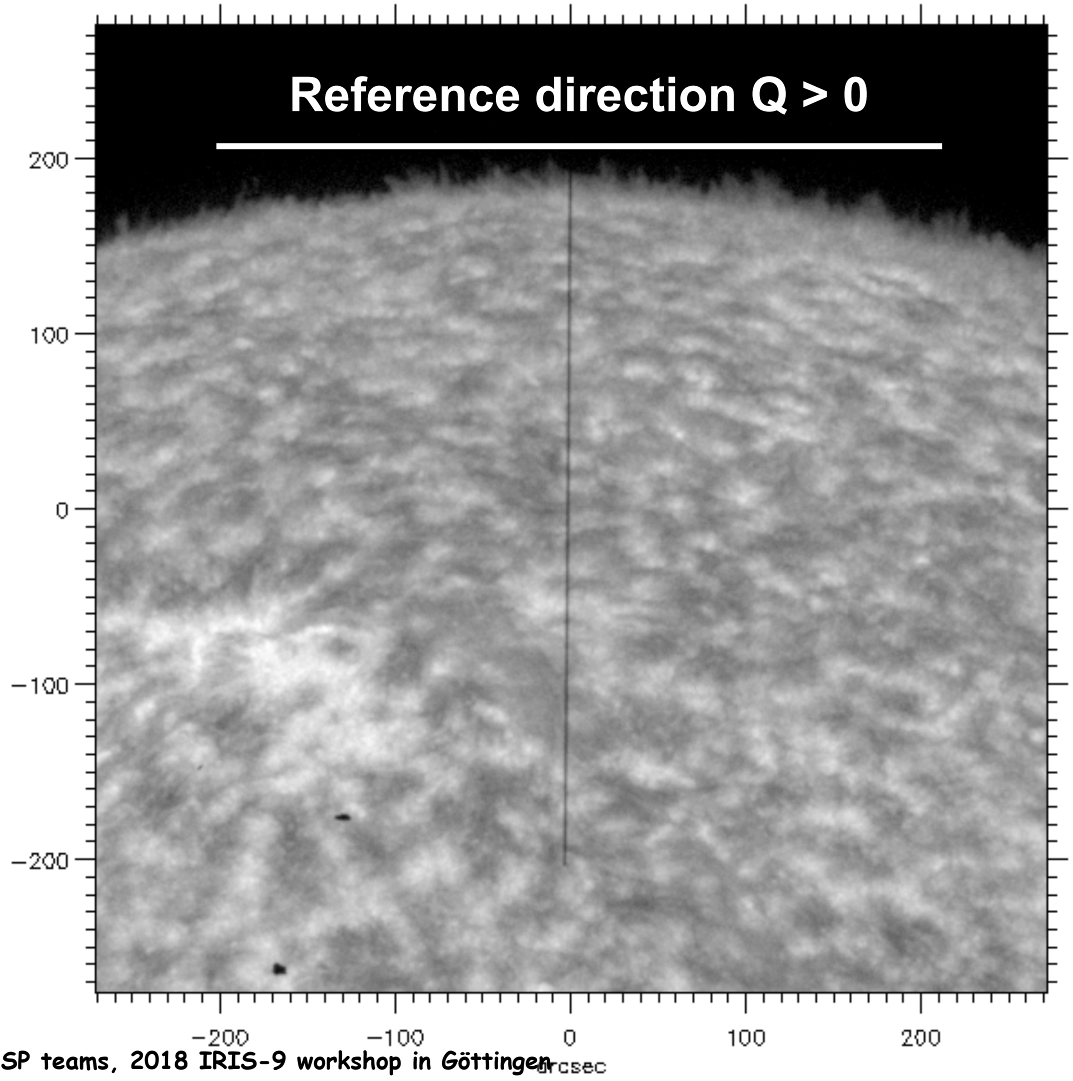
Spectro-Polarimeter	Narukage et al. (2015, Applied Optics)	
Optics	Inverse Wadsworth mounting	
Wavelength	121.567 ± 0.61 nm	
Slit	1.45’’ (width), 400’’ (length)	
Grating	Spherical constant-line-spacing, 3000/mm	
CCD camera	512×512 pixel	13μm/pixel
Plate scale	0.0048 nm/pixel	**1.11’’/pixel**
Resolution	**0.01nm**	3’’
Sensitivity	**0.1%**	

Launch of CLASP, 3rd September 2015

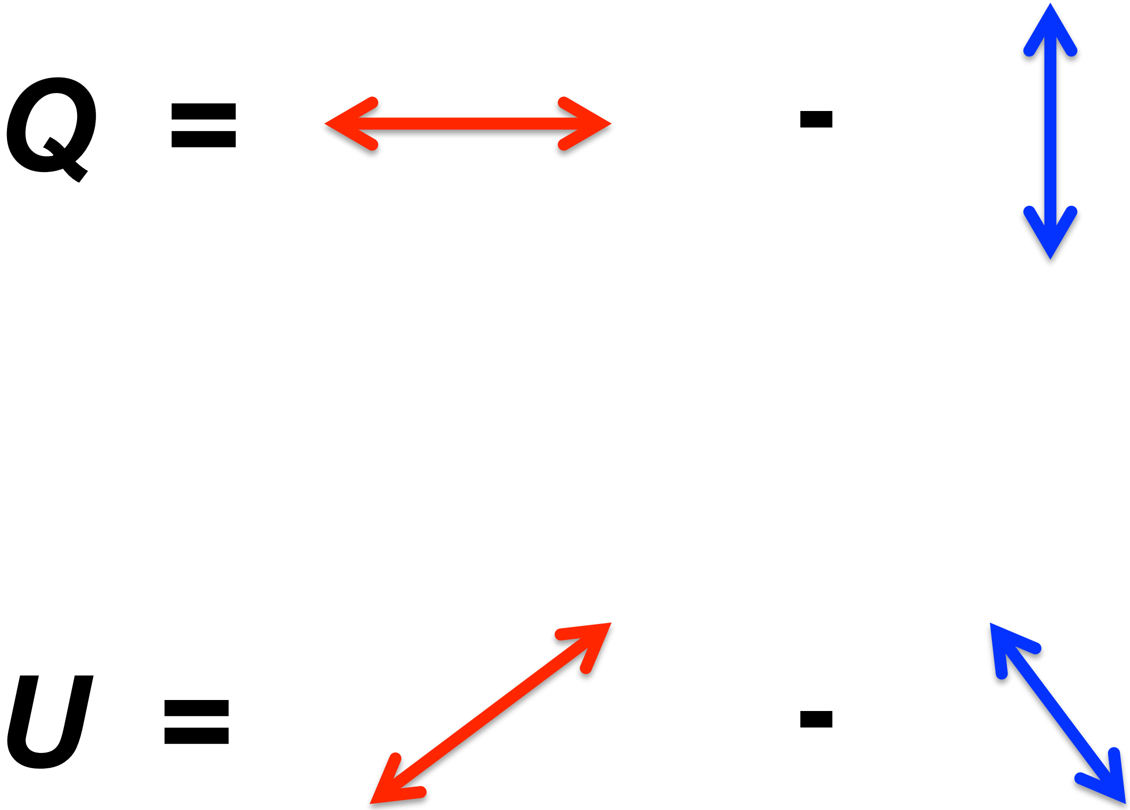
J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

Summary of the CLASP observations

Kano, Trujillo Bueno, Winebarger et al. (2017; ApJ Letters)



J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen



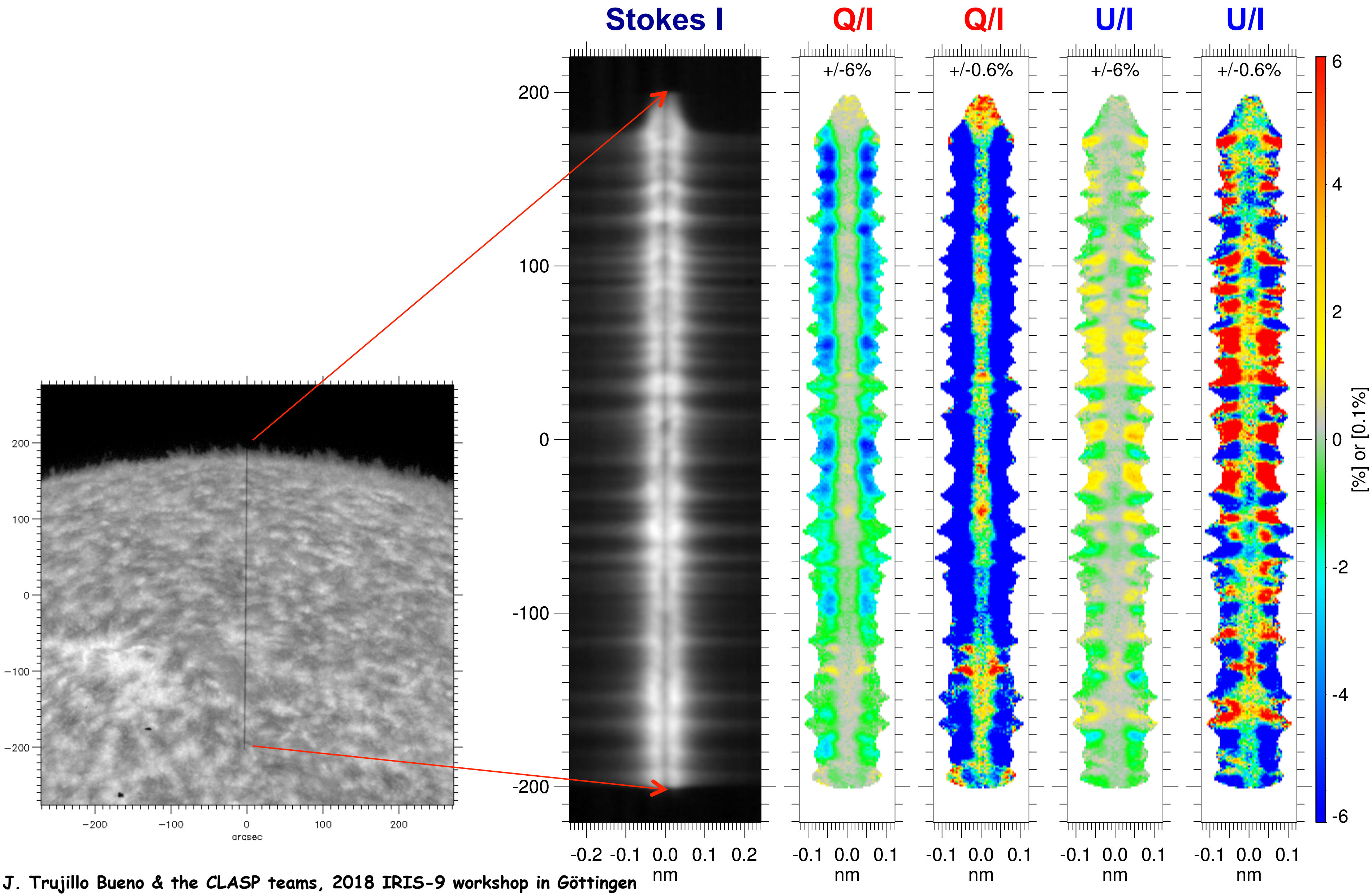
Q = -

U = -

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

Discovery of scattering polarization in the Ly-alpha line of the solar disk radiation

Kano, Trujillo Bueno, Winebarger and the CLASP team (ApJ Letters, 2017)



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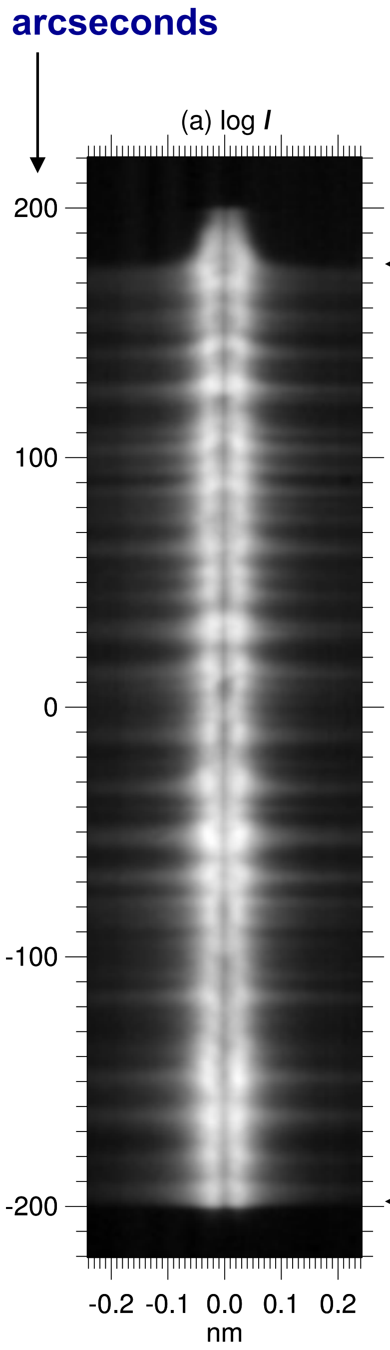
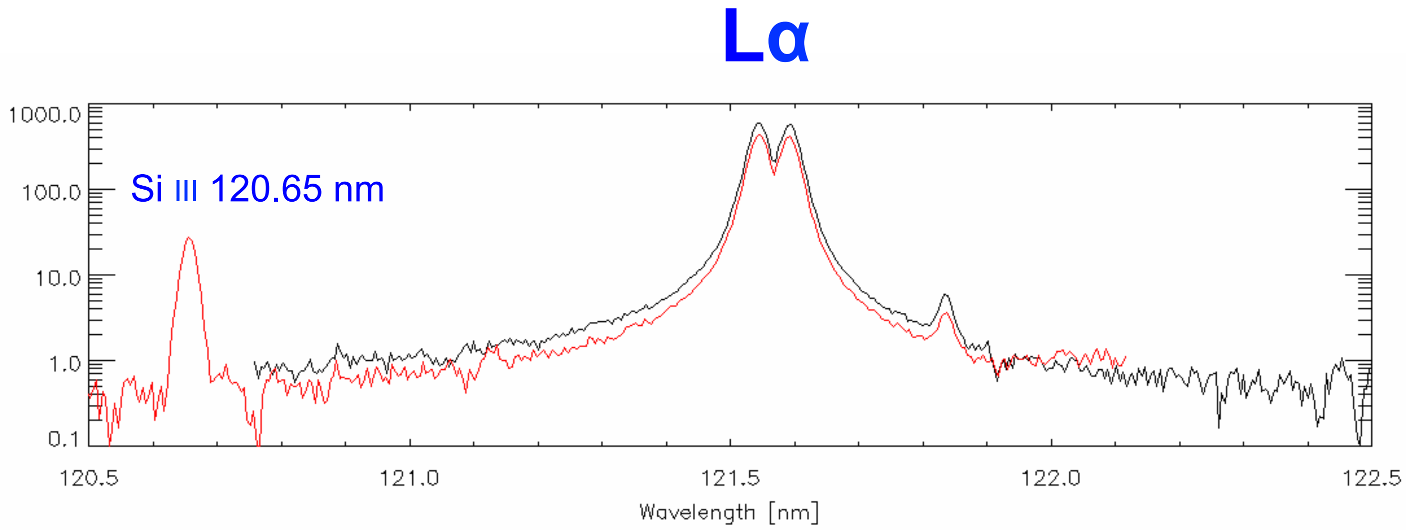
CLASP observations: Stokes I



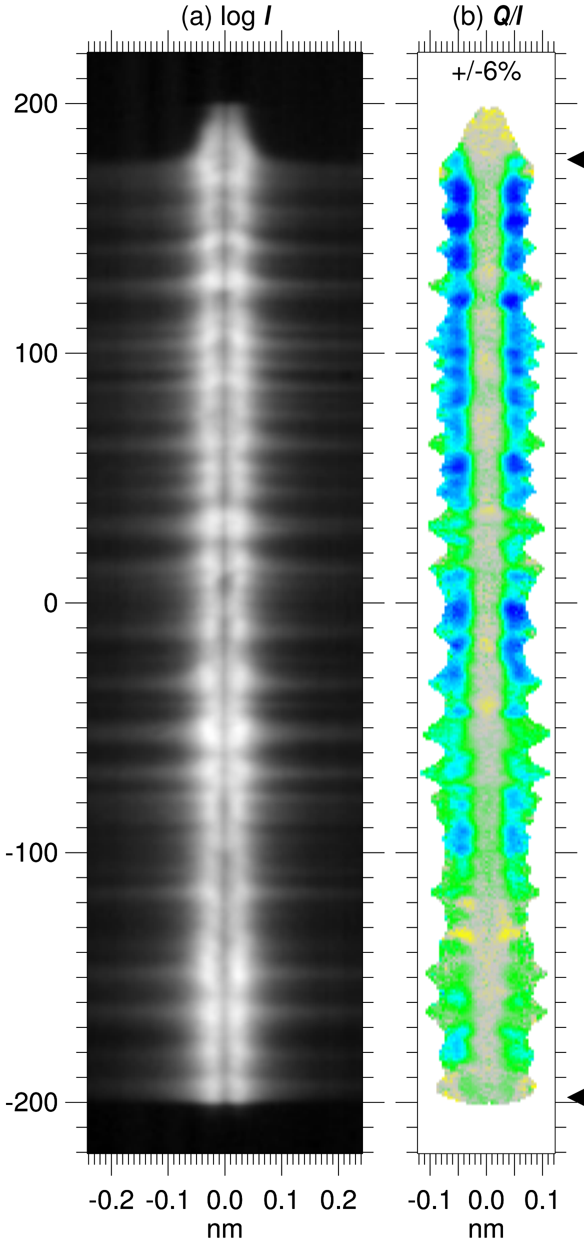
Solar LIMB

Near DISK CENTER



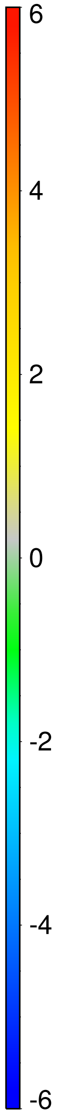
CLASP: Q/I wings

Q/I WINGS

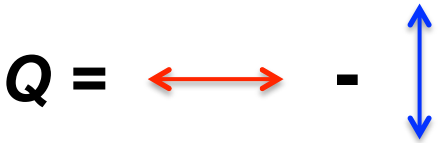


Solar LIMB

NEAR DISK CENTER

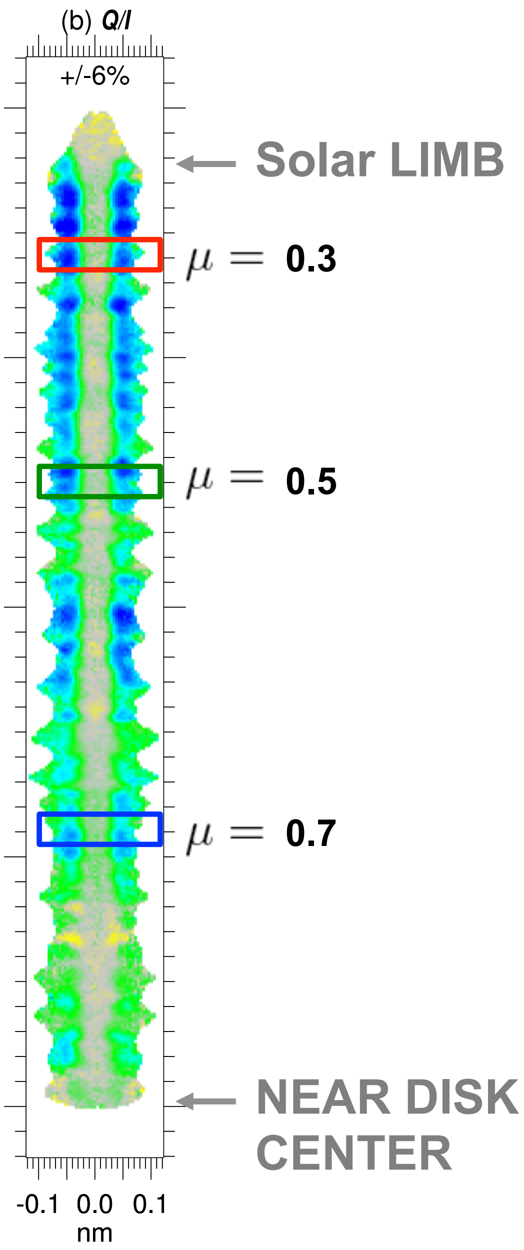


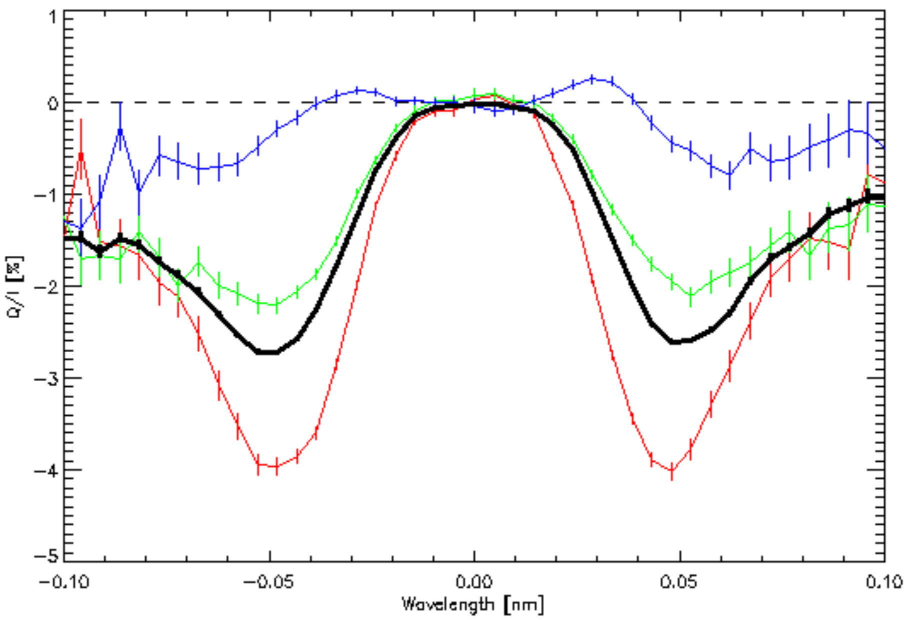
%



CLASP: Q/I wings

Q/I WINGS



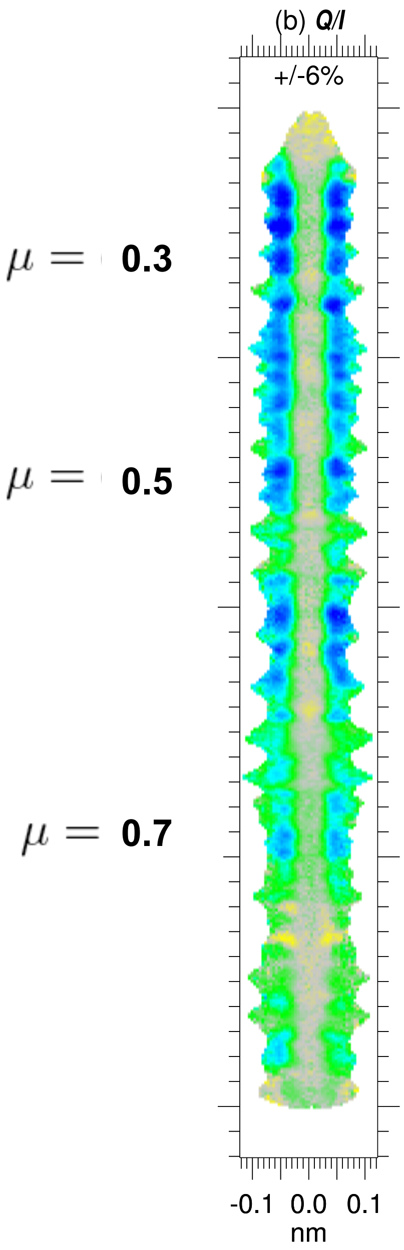


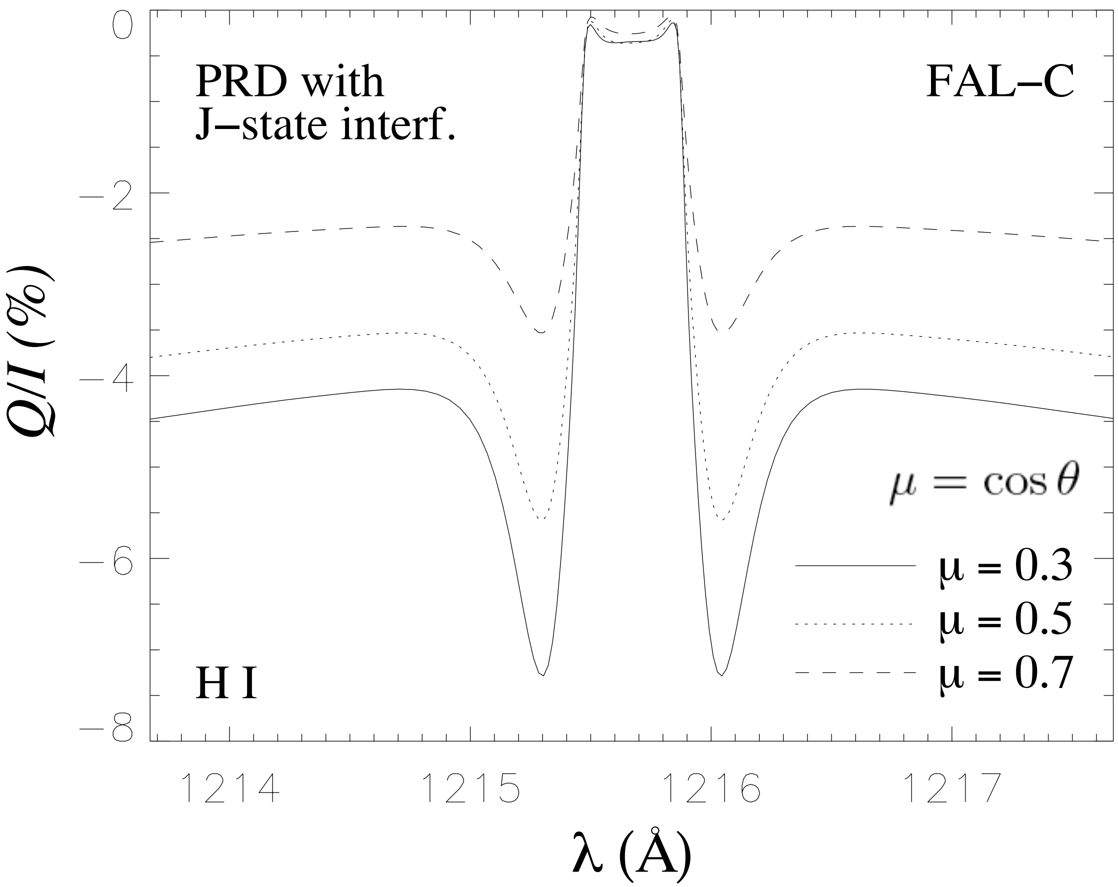
Note the large Q/I signals in the Ly-alpha wings, along with their negative sign and CLV, in agreement with our theoretical predictions.

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

Theoretical prediction for Q/I wings: CLV

Q/I WINGS





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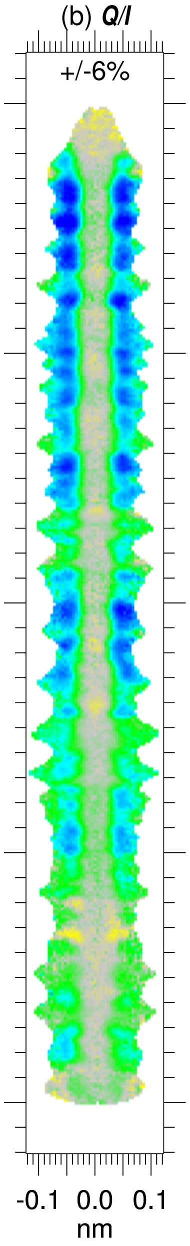
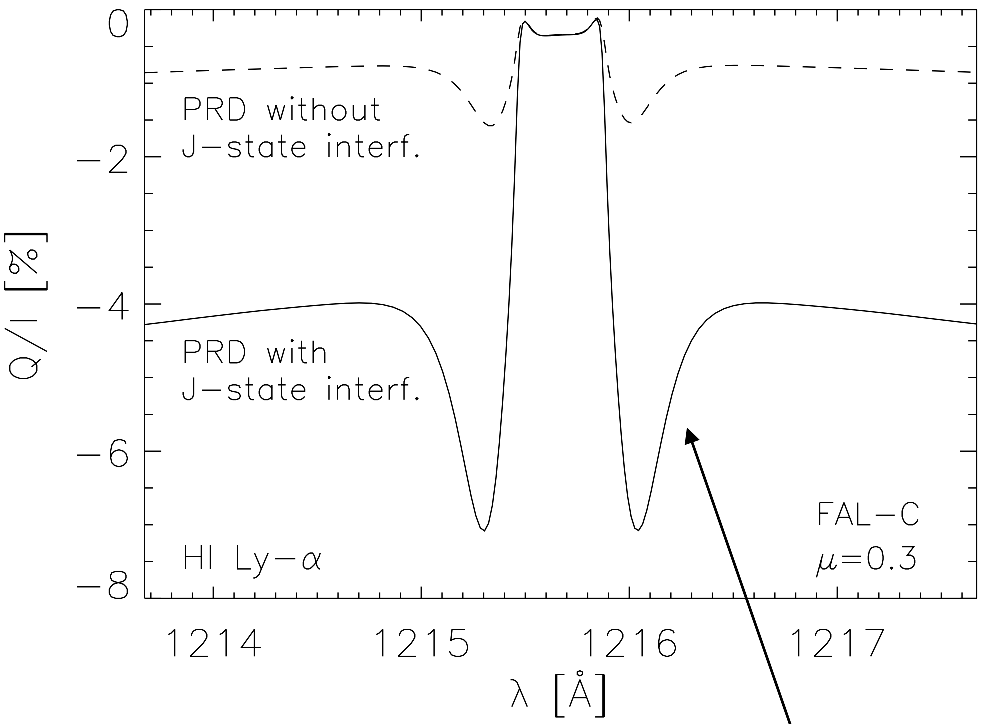
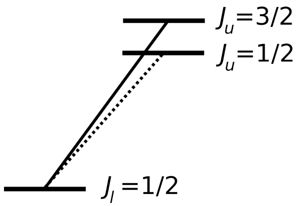
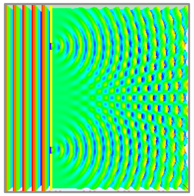
Q/I WINGS



Theoretical prediction for Q/I wings > 1%







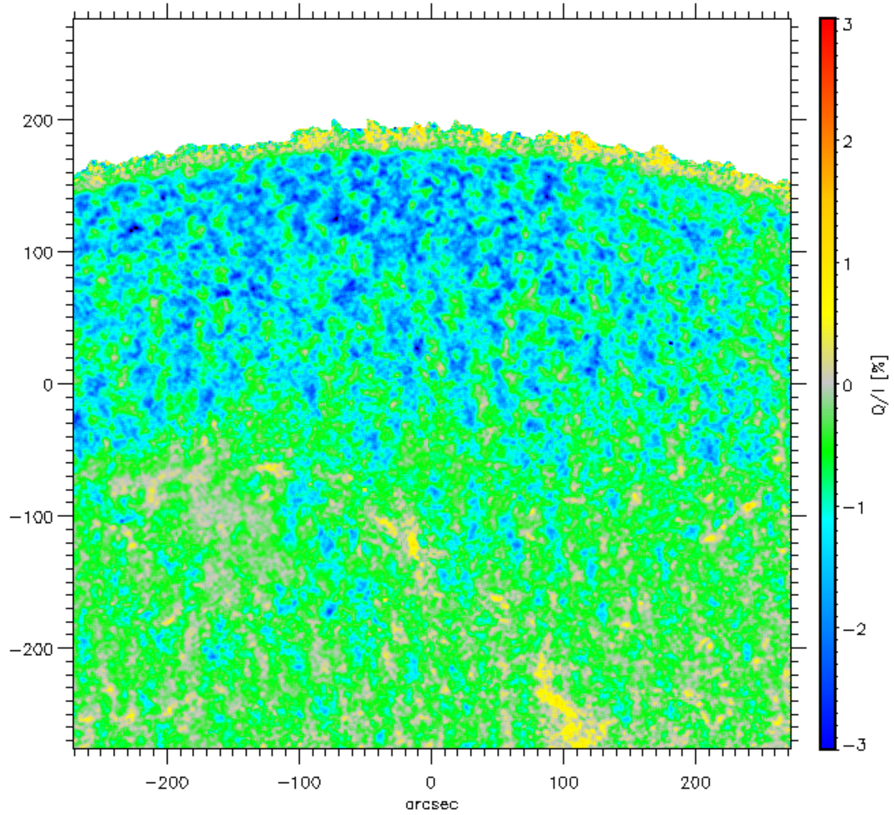
CLASP has confirmed that J-state interference plays a key role in producing the Ly-alpha wing polarization

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

Filter polarimetry of the Lyman-alpha line

Kano, Trujillo Bueno, Winebarger et al. (2017; ApJ Letters)

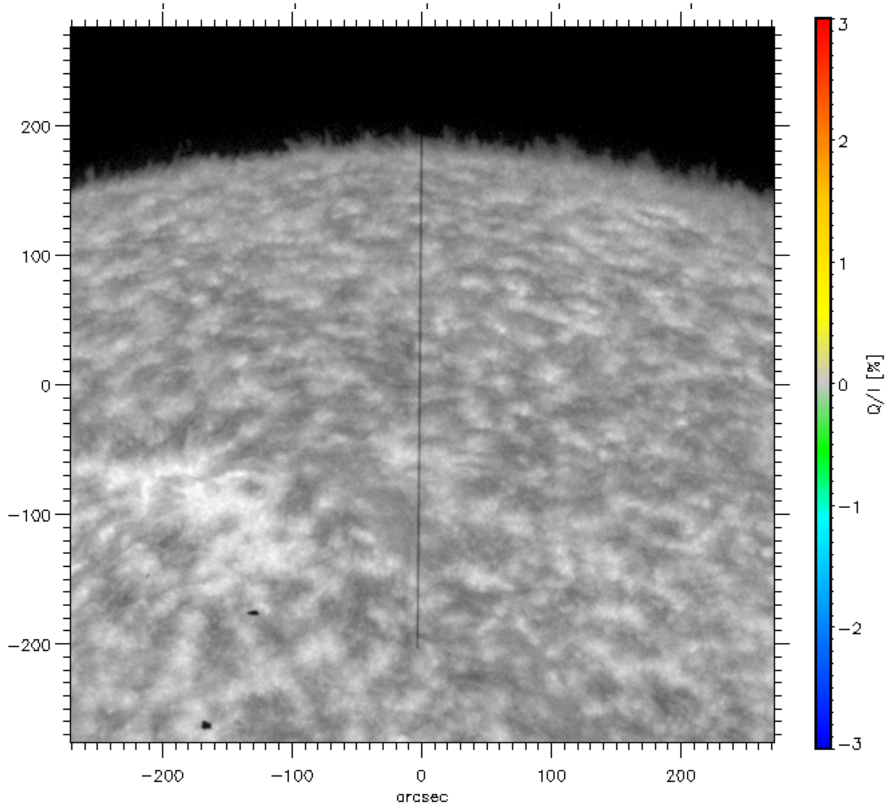
Q / I



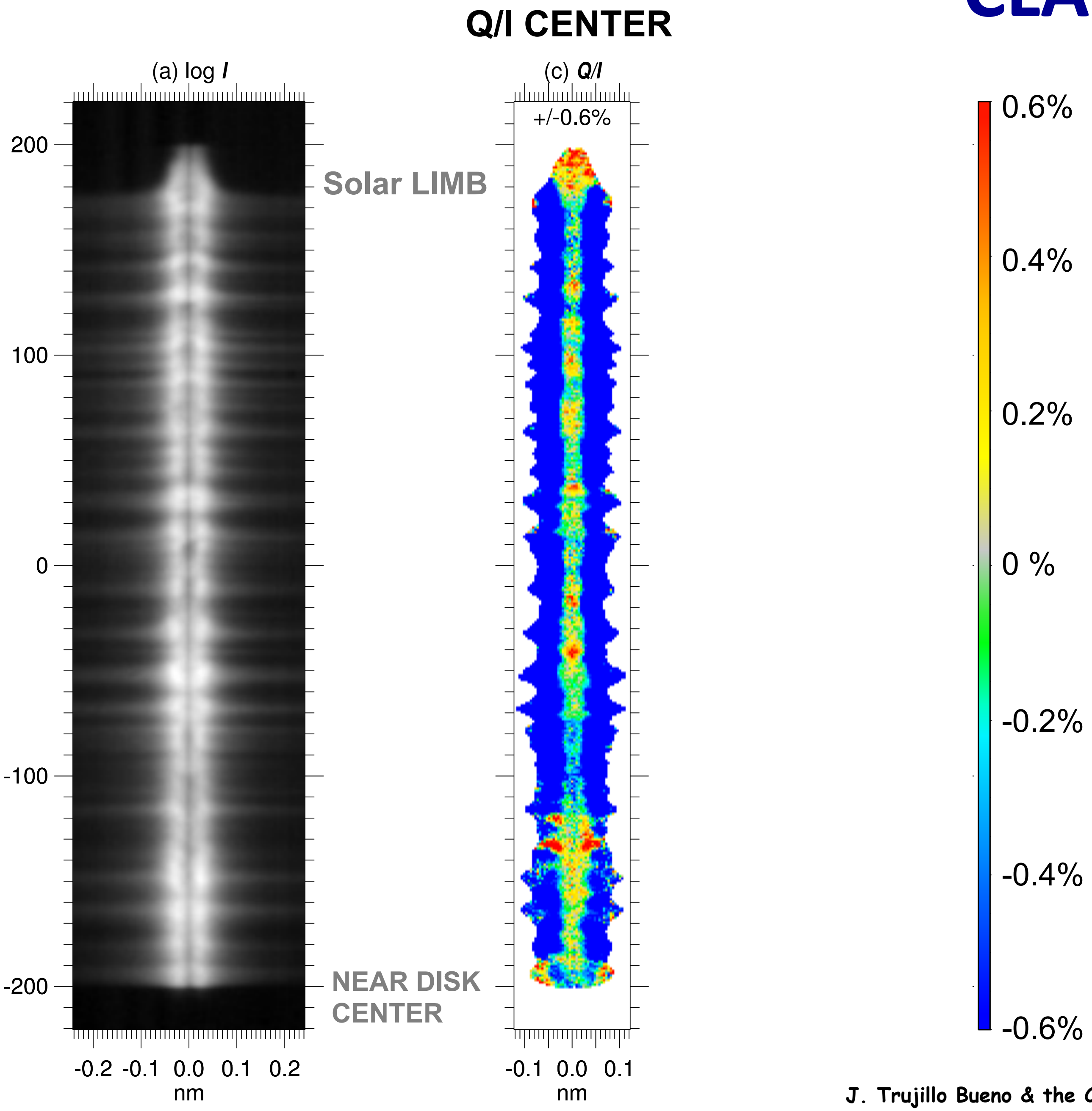
Filter polarimetry of the Lyman-alpha line

Kano, Trujillo Bueno, Winebarger et al. (2017; ApJ Letters)

Stokes I



CLASP: Q/I center



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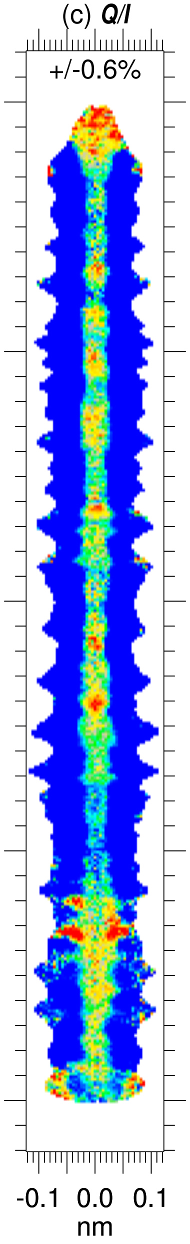
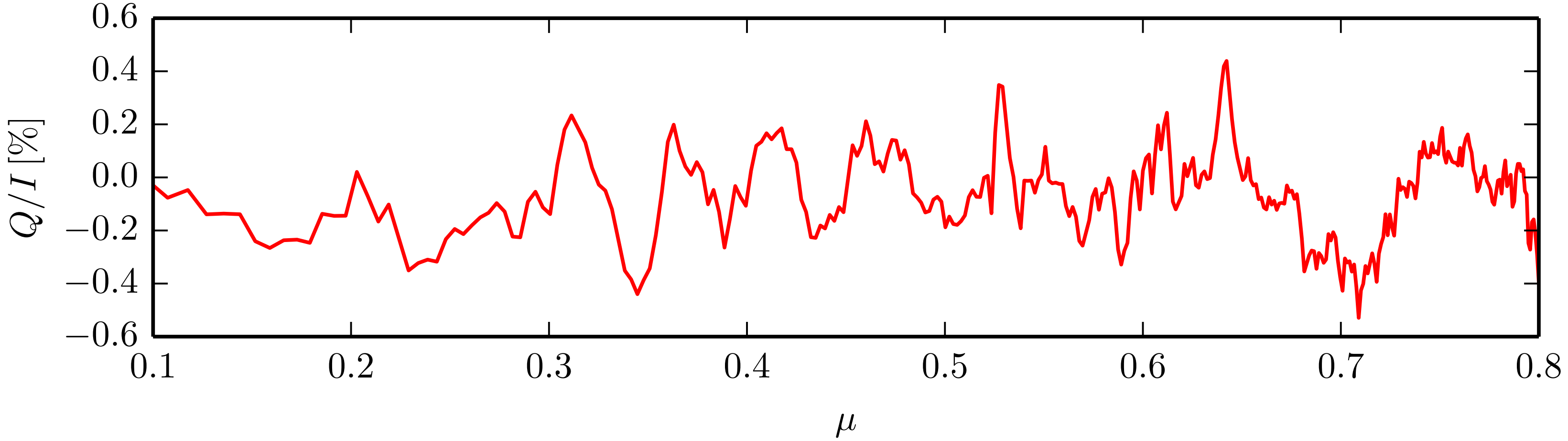
Q/I CENTER



CLASP: Q/I line-center signal



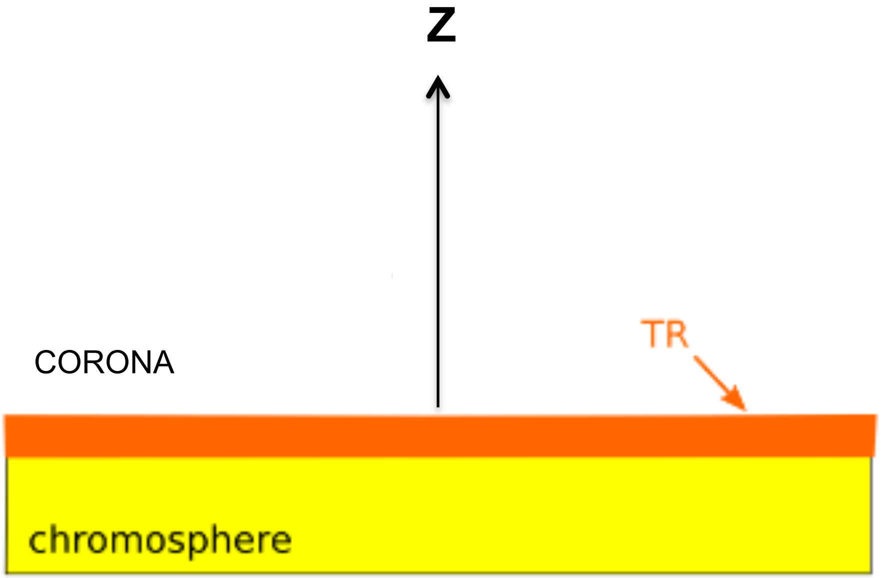
Very interesting surprise:

The observed Q/I line-center signal does NOT show any clear CLV

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

1D

Cylindrically symmetrical



The Lyman-alpha line-center radiation originates in a very narrow TR, with strong gradients along **Z**

1D plane-parallel models

1D

Cylindrically symmetrical

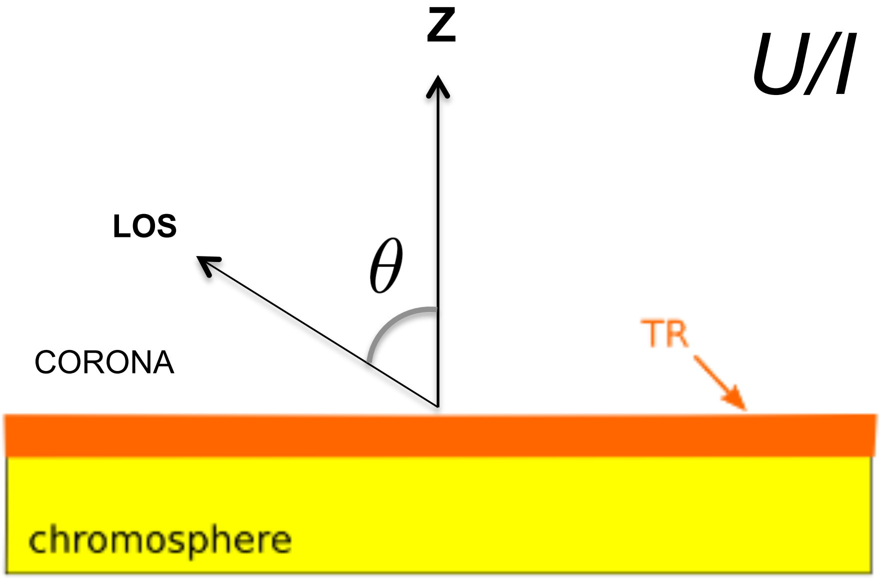
$$\frac{Q}{I} \approx \frac{1}{2\sqrt{2}}(1-\mu^2)\,\mathcal{H}\,\frac{\bar{J}^2_0}{\bar{J}^0_0}$$

$U/I = 0$

$\mu = \cos\theta$

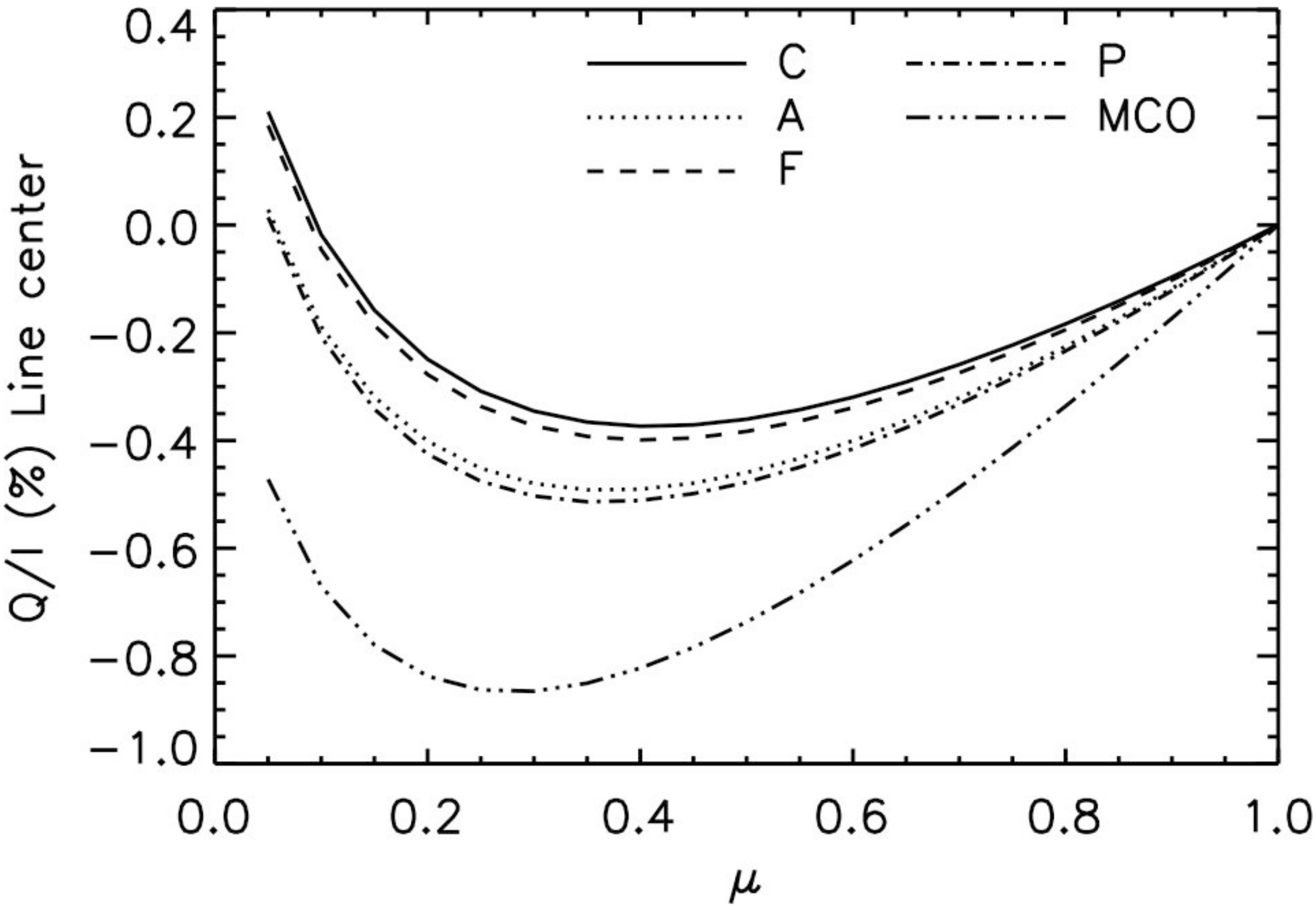
Hanle depolarization factor due to B at the TR

Anisotropy of the Ly-alpha radiation at the TR



1D plane-parallel models

The CLV in 1D semi-empirical models



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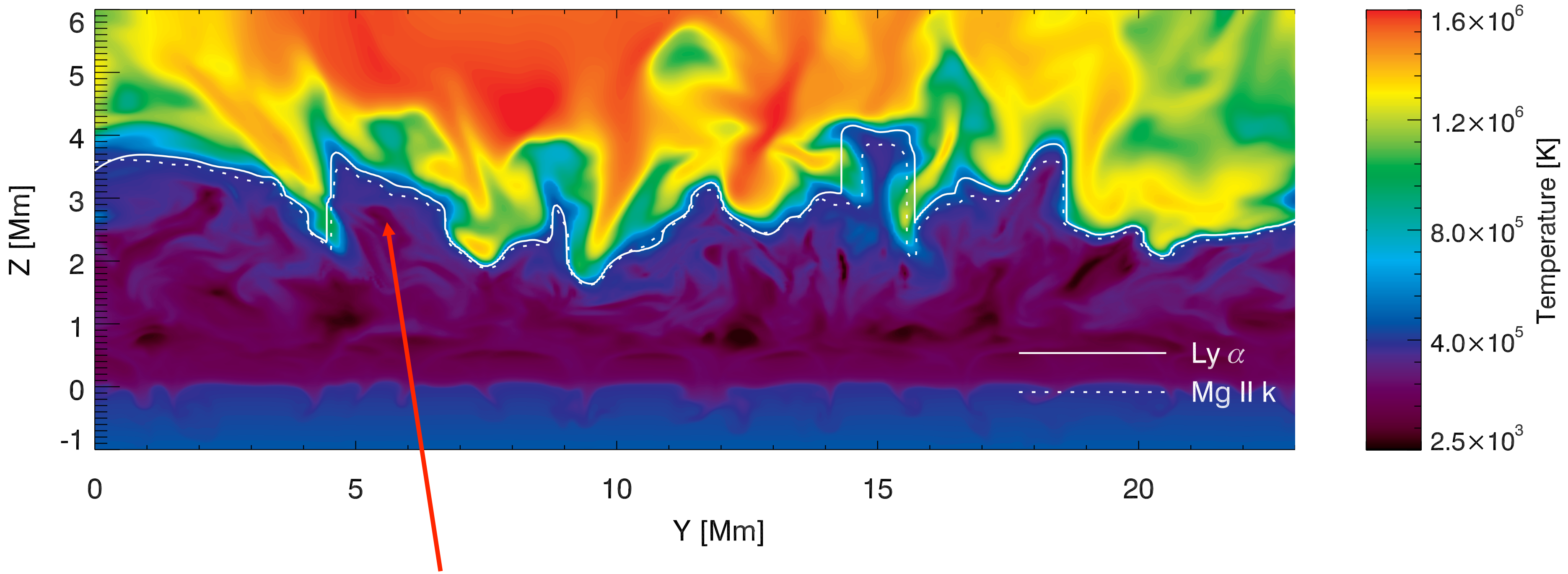
3D model of the chromosphere-corona TR

(see Carlsson et al. 2016)



Atmospheric heights where the line-center optical depth along the LOS is unity

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

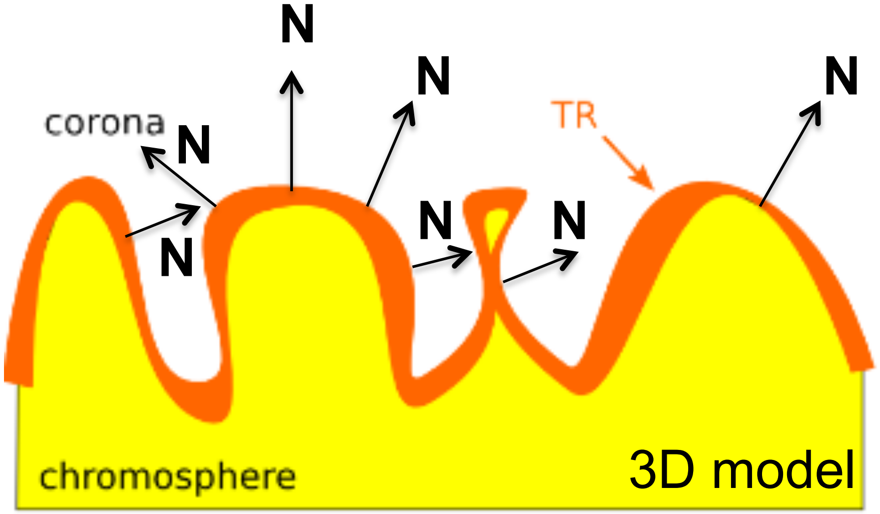
Locally:

3D

Symmetry breaking

$$\frac{Q}{I} \approx \frac{1}{2\sqrt{2}}(1-\mu_{\rm N}^2)\,\mathcal{H}\,[\frac{\bar{J}^2_0}{\bar{J}^0_0}]_{\rm N}$$

U/I = 0

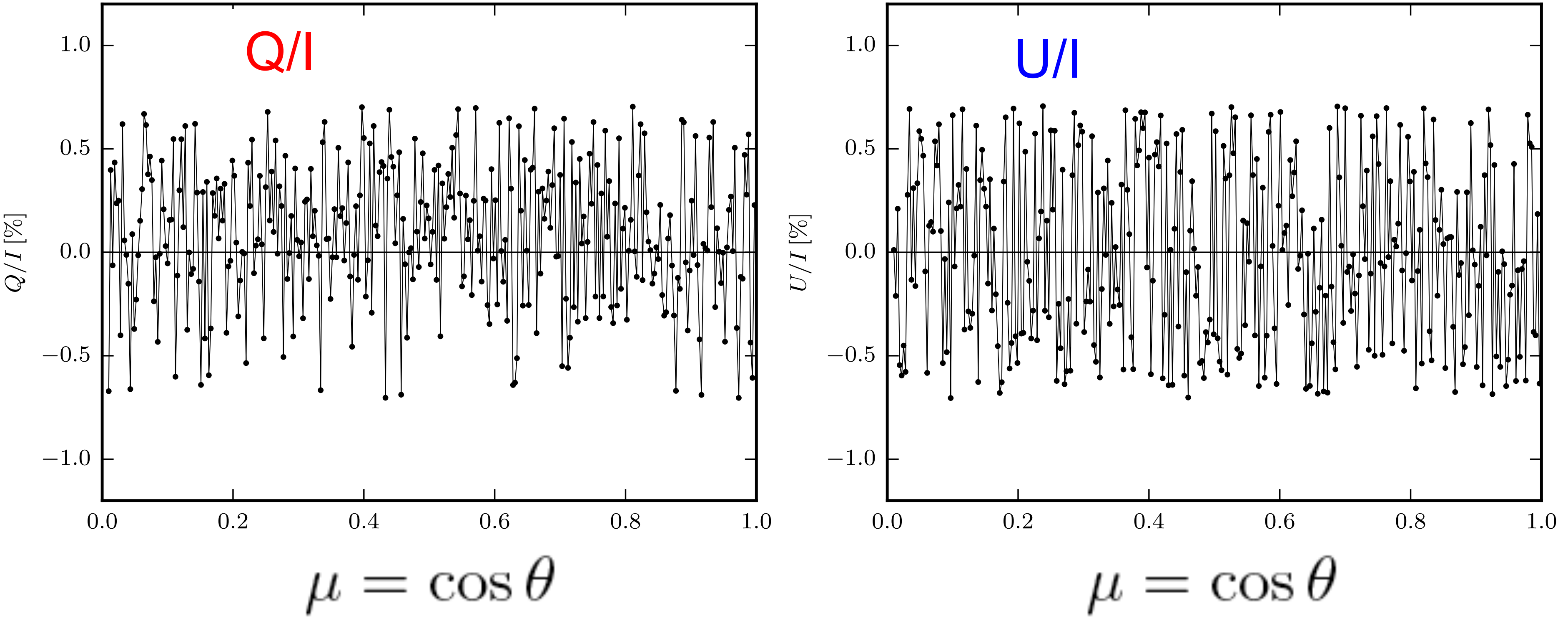


N = local NORMAL vector to the TR

The CLV in corrugated TR models

Stepan, Trujillo Bueno et al. (2018; ApJ)
Trujillo Bueno, Stepan et al. (2018; in preparation)

θ_{N} = random

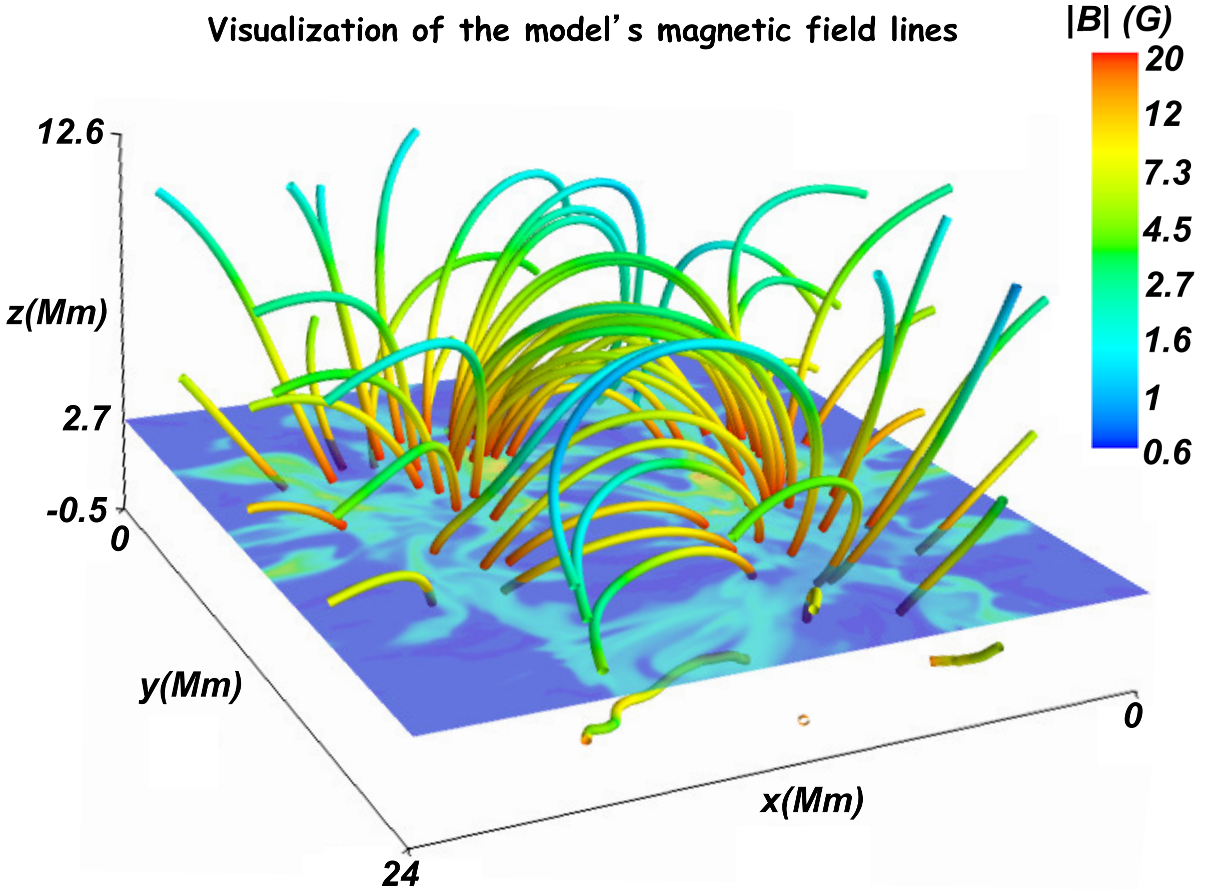


The scattering polarization of Ly-alpha in a 3D MHD model

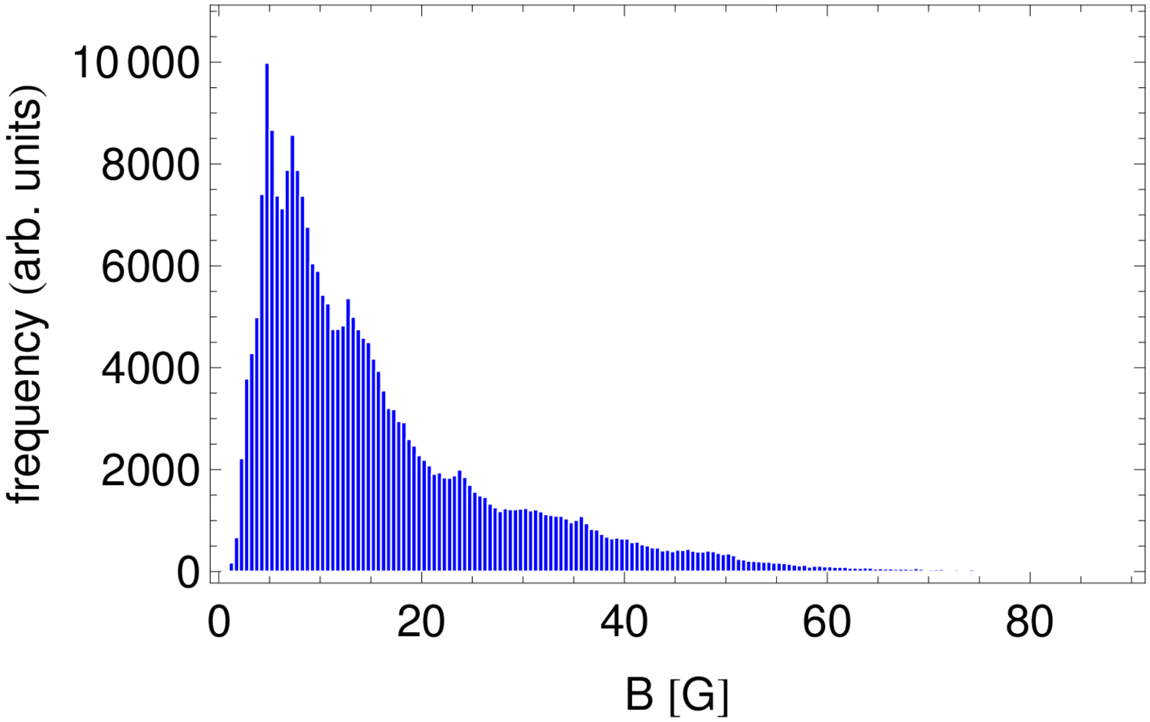
3D model of an enhanced network region, resulting from a MHD simulation with Bifrost (see Carlsson et al. 2016).

3D radiative transfer code **PORTA** for modeling the line-center polarization (Stepan & Trujillo Bueno 2013)

Visualization of the model's magnetic field lines



The magnetic field in the model's chromosphere-corona TR

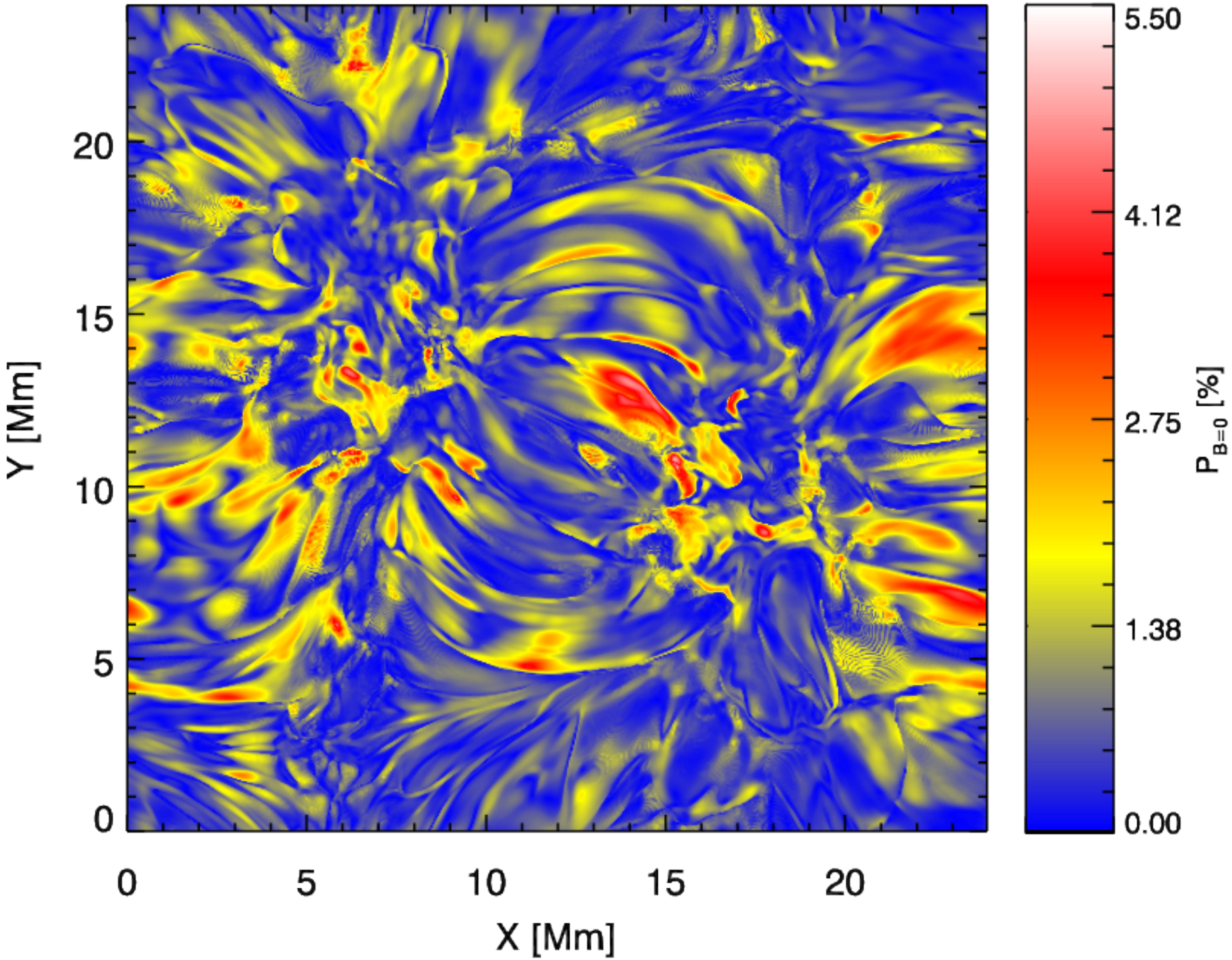


The mean magnetic field strength is <B> ~ 15 gauss
at the corrugated boundary that delineates the Transition Region (TR)

The TOTAL fractional linear polarization for a disk-center observation

$$P = \sqrt{Q^2 + U^2} \; / \; I$$

B = 0 gauss



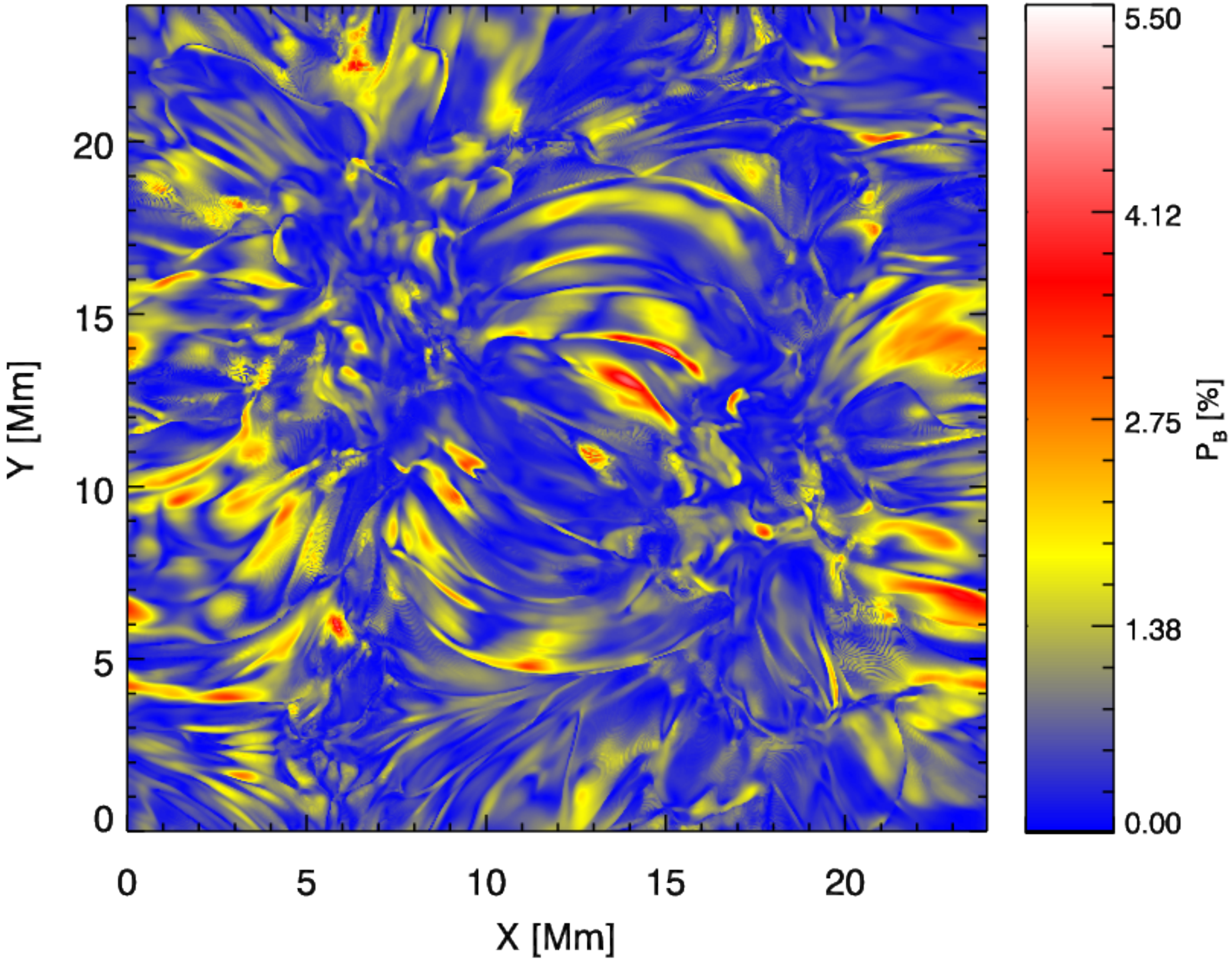
Ly-alpha

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The TOTAL fractional linear polarization for a disk-center observation

$$P = \sqrt{Q^2 + U^2} \;/\; I$$

B = model's B



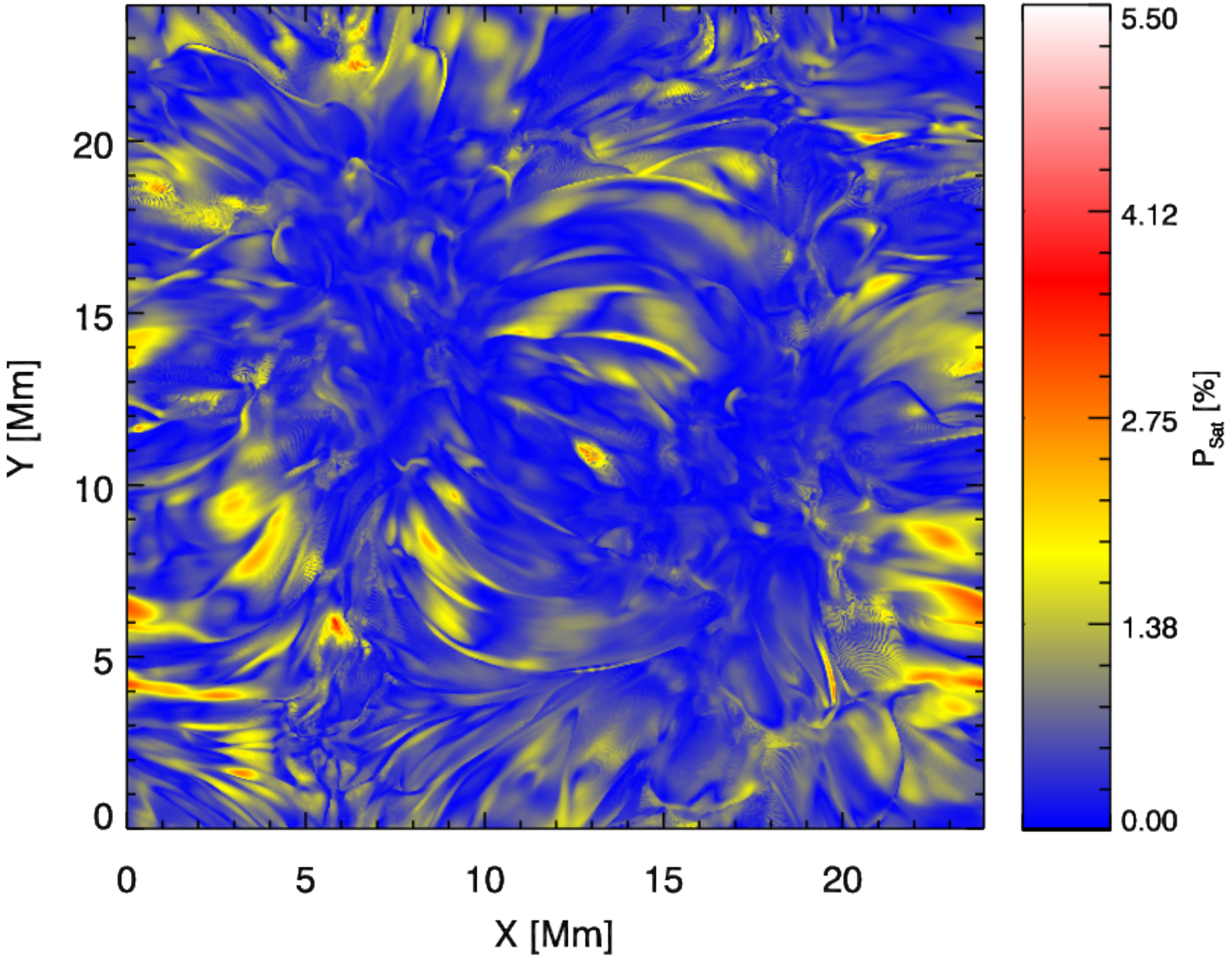
Ly-alpha

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The TOTAL fractional linear polarization for a disk-center observation

$$P = \sqrt{Q^2 + U^2} \;/\; I$$

B > 100 gauss



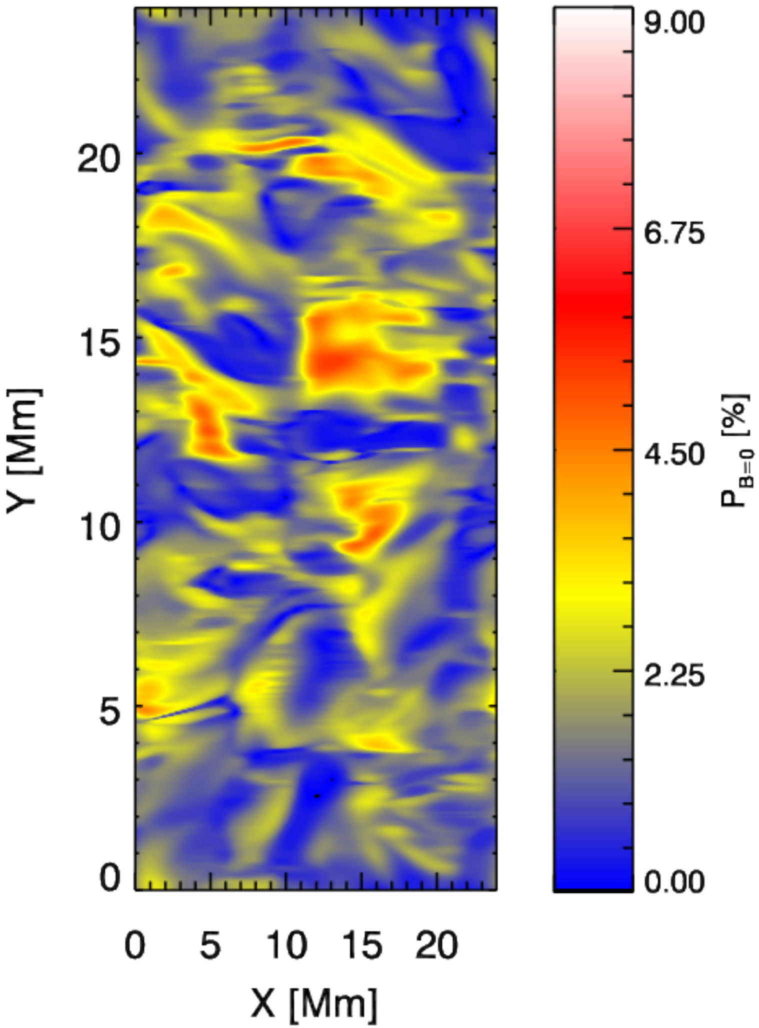
Ly-alpha

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The TOTAL fractional linear polarization for mu=0.4

$$P = \sqrt{Q^2 + U^2} \; / \; I$$

B = 0 gauss



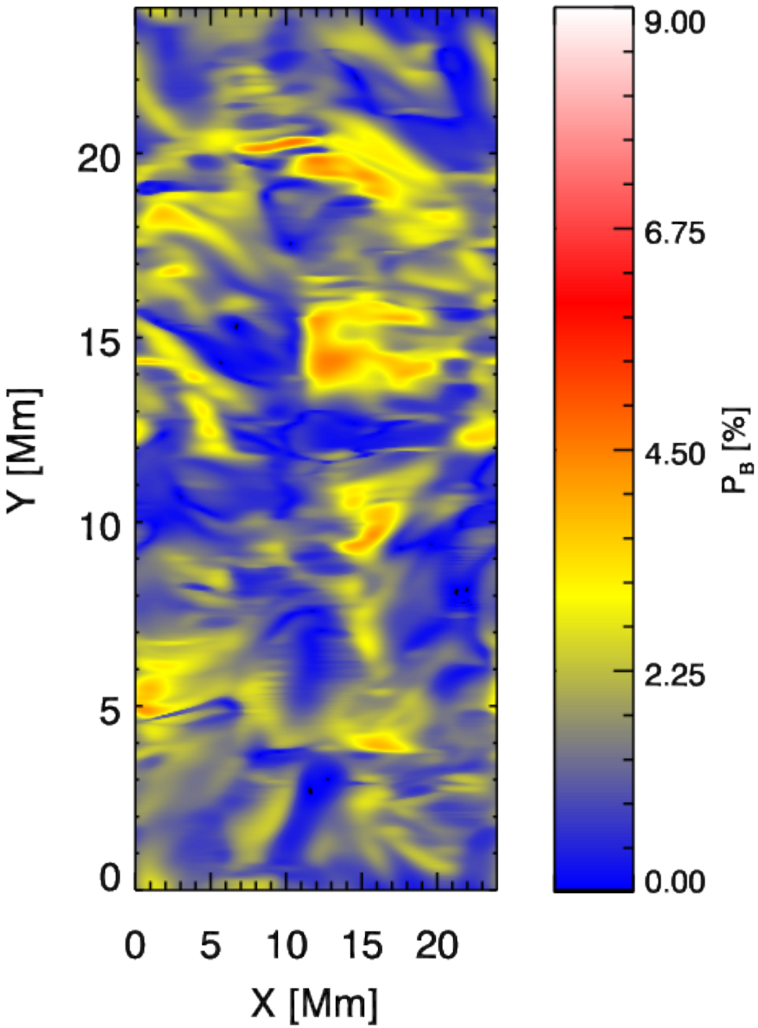
Ly-alpha

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The TOTAL fractional linear polarization for mu=0.4

$$P = \sqrt{Q^2 + U^2} \, / \, I$$

B = model's B



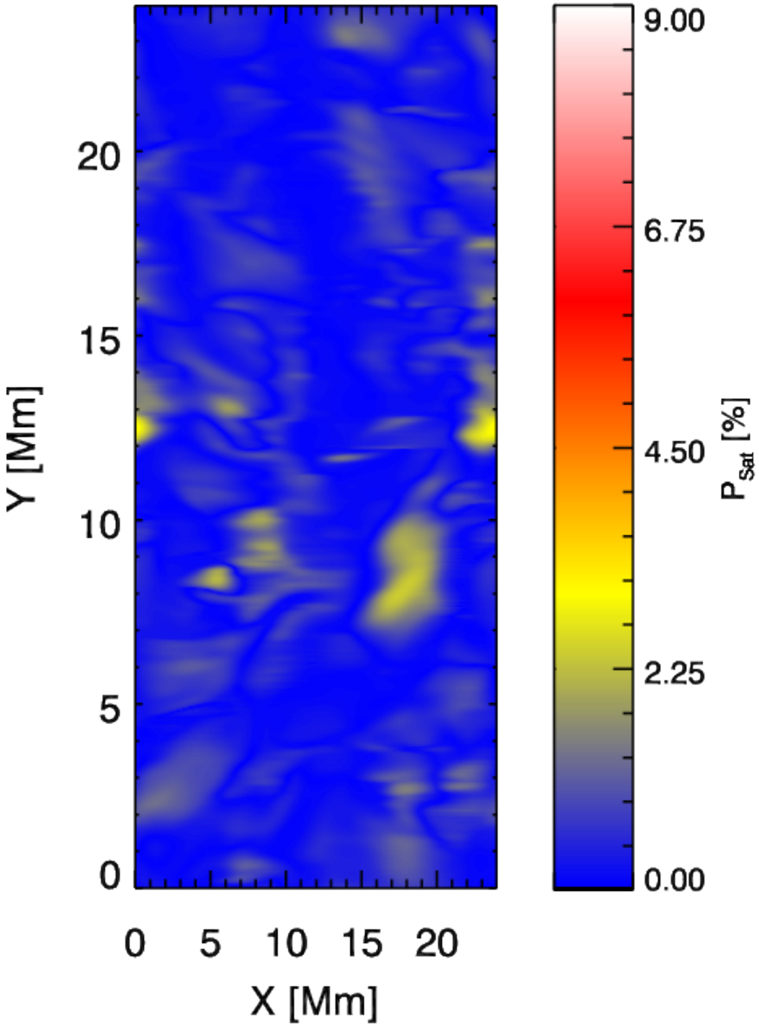
Ly-alpha

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The TOTAL fractional linear polarization for mu=0.4

$$P = \sqrt{Q^2 + U^2} \; / \; I$$

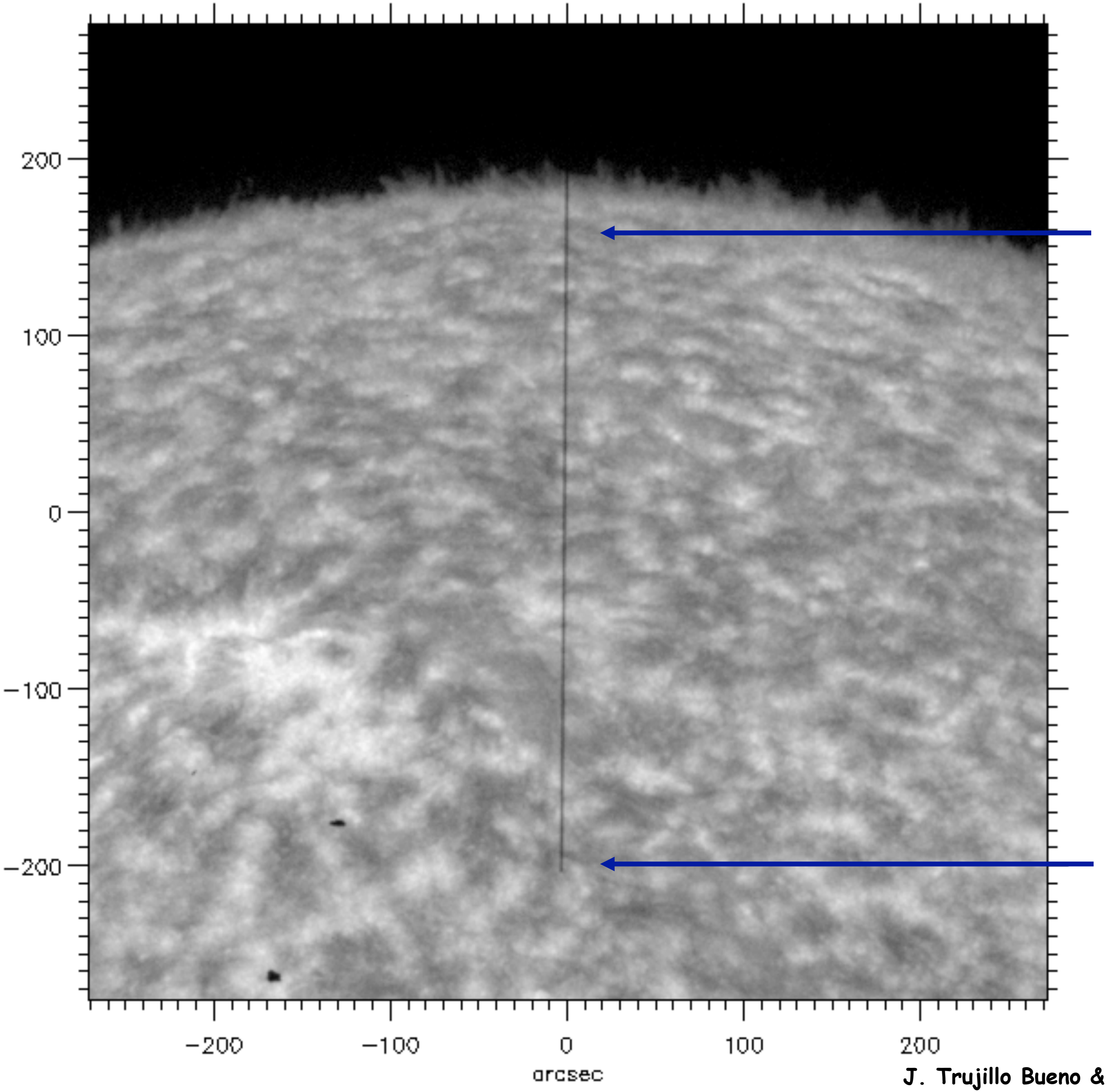
B > 100 gauss



Ly-alpha

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

CLV of the Q/I line-center signal in the 3D model



$\mu = \cos\theta$ **= 0.1**

$\mu = \cos\theta$ **= 0.8**

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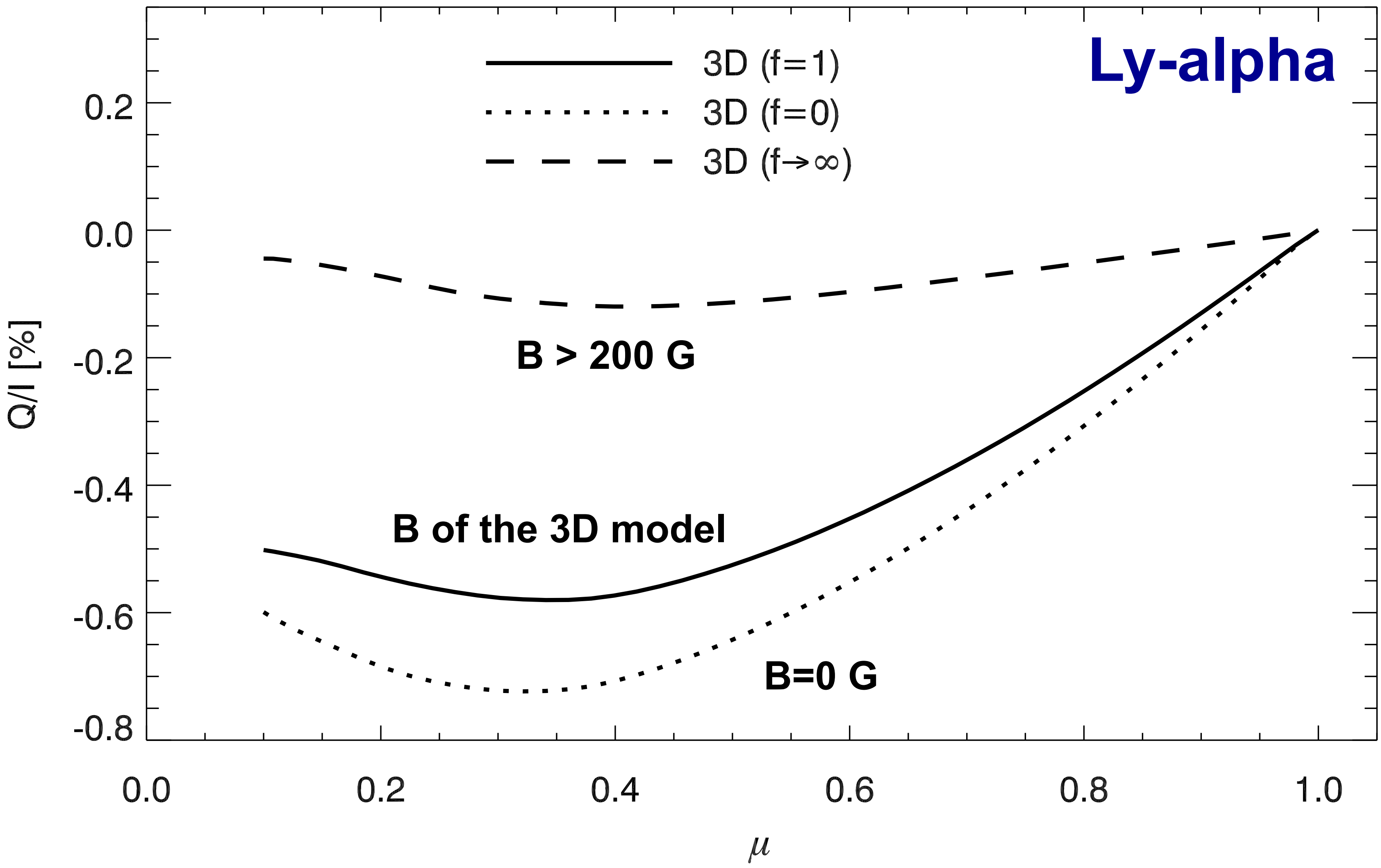
The spatially-averaged CLV of Q/I calculated in the 3D model



Summary

- The Ly-alpha line-core polarization observed by CLASP encodes valuable information on the 3D structure of the chromosphere-corona TR and on its magnetization.

- **Our investigations suggest that the TR plasma is magnetized and that its geometrical complexity is substantially larger than in the available 3D models.**

Stepan, Trujillo Bueno et al. (2018)
Trujillo Bueno, Stepan et al. (2018)

We need

“Realistic” 3D models with SPICULES !

Refereed CLASP-1 publications (after the launch)

- Kubo et al. (2016; ApJ)
- Giono et al. (2016; Sol. Phys)
- Kano et al. (2017; ApJ Letters) → Lyman-alpha
- R. Ishikawa et al. (2017; ApJ) → Si III at 120.6 nm
- Giono et al. (2017; Sol. Phys)
- S. Ishikawa et al. (2017; ApJ)
- Schmidt et al. (2017; ApJ)
- Stepan et al. (2018; ApJ)
- Trujillo Bueno et al. (2018; ApJ, in prep.)

CLASP 2

Chromospheric LAyer SpectroPolarimeter

CLASP-2: measure I, Q, U, V of Mg II h & k with a vacuum UV telescope and a spectropolarimeter launched by a NASA sounding rocket

Rocket + CCD cameras

USA

D. Mc.Kenzie (MSFC, PI)
L. Rachmeller (MSFC)
K. Kobayashi (MSFC)
A. Winebarger (MSFC)
B. De Pontieu (LMSAL)
C. Bethge (USRA)

France

F. Auchère (IAS, Co-PI) ‡ **GRATING**

Telescope + Polarimeter

Japan

R. Ishikawa (NAOJ, Co-PI)
M. Kubo (NAOJ)
N. Narukage (NAOJ)
R. Kano (NAOJ)
H. Hara (NAOJ)
T. Sakao (NAOJ)
S. Ishikawa (ISAS)
Y. Suematsu (NAOJ)

Theory & Modeling

Spain

J. Trujillo Bueno (IAC, Co-PI)
A. Asensio Ramos
T. del Pino Alemán

Switzerland

L. Belluzzi (IRSOL)
E. Alsina (IRSOL)

Czech Republic

J. Stěpán (ASCR) ‡

Norway

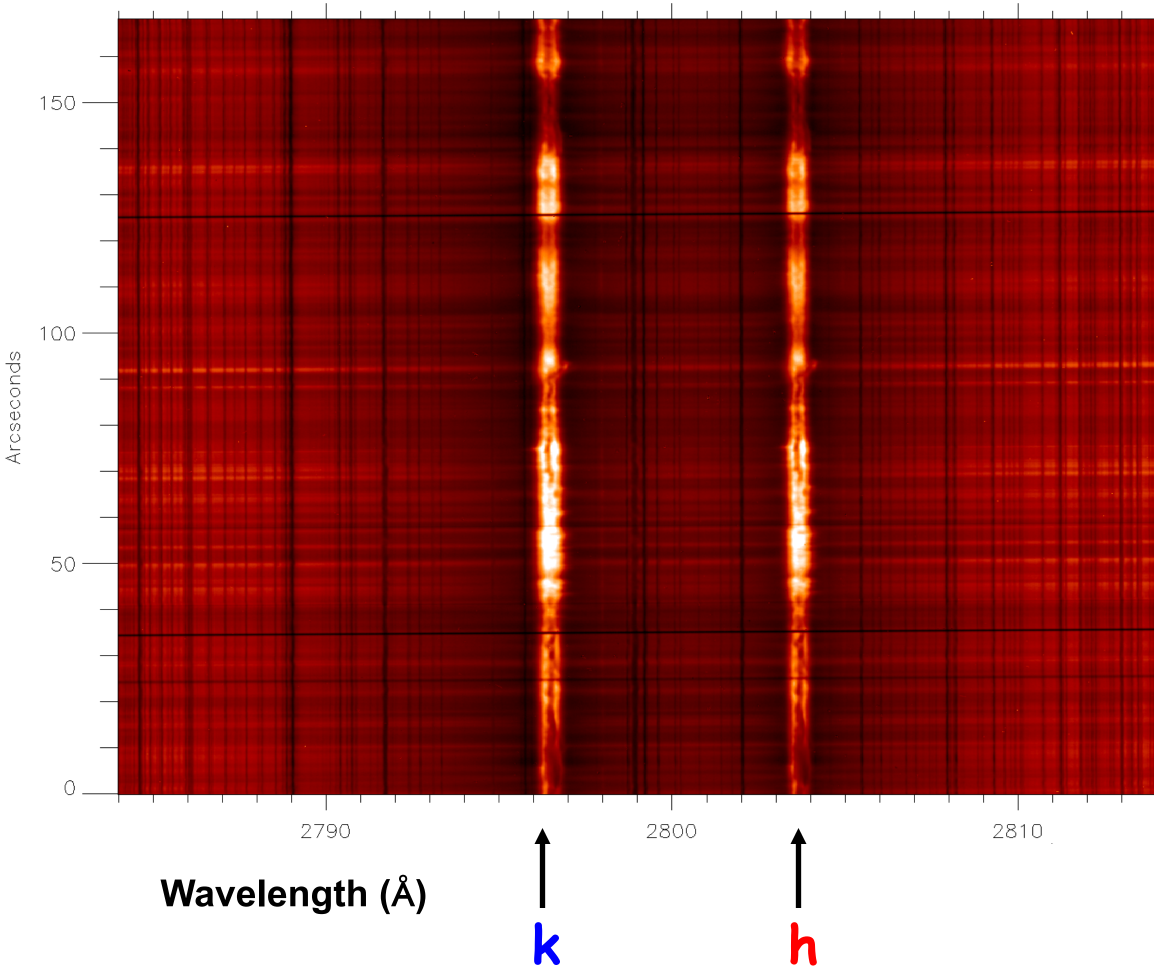
M. Carlsson (Univ. of Oslo) ‡

Sweden

J. Leenaarts (ISP)

The INTENSITY of the Mg II h & k lines

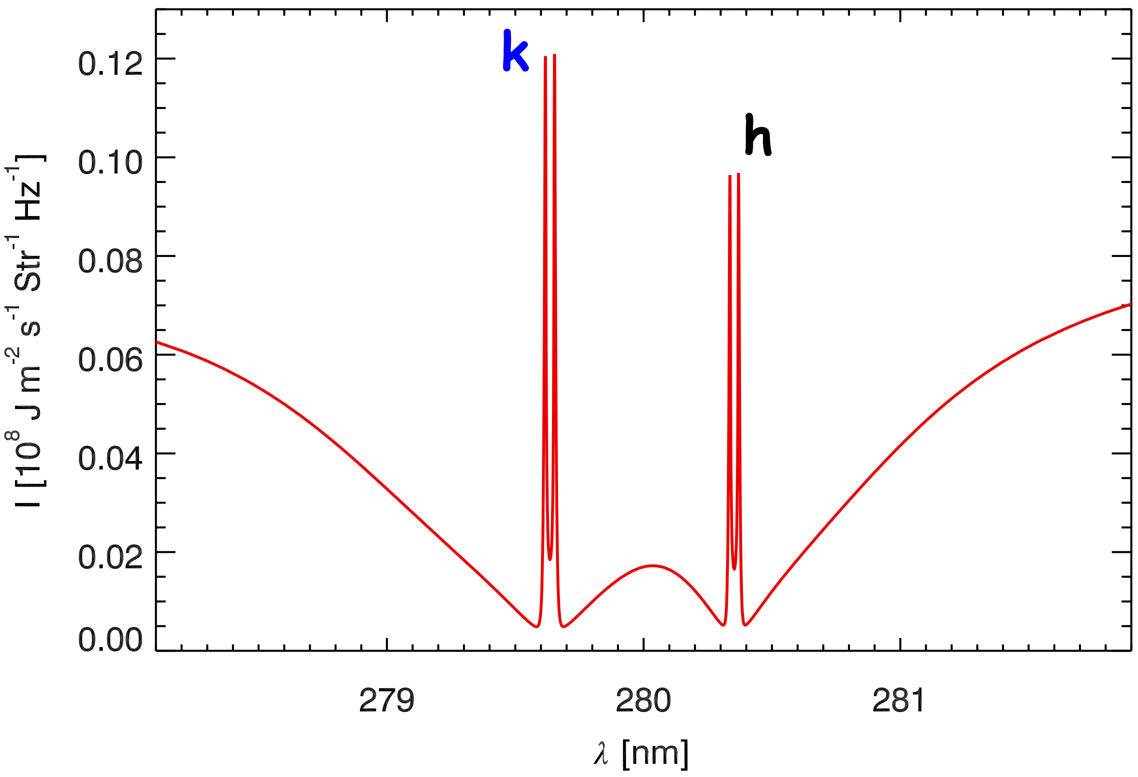
OBERVED Stokes-I profiles
Interface Region Imaging Spectrograph (IRIS space telescope)

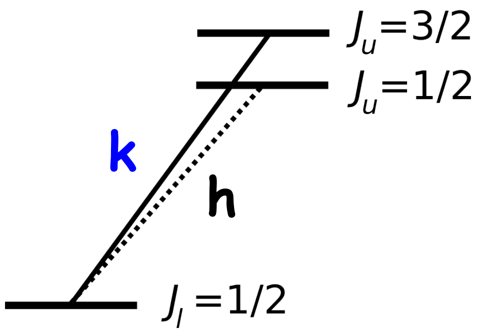


J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The INTENSITY of the Mg II h & k lines

Calculated Stokes-I profiles





J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

The polarization of the Mg II h & k lines

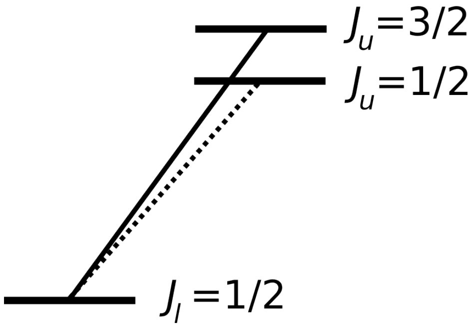
Belluzzi & Trujillo Bueno (2012; ApJ Letters)

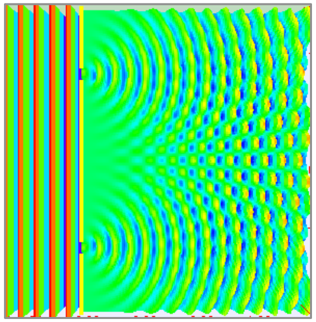
Alsina Ballester et al. (2016; ApJ Letters)

del Pino Alemán et al. (2016; ApJ Letters)

PRD → frequency correlations between the incoming and outgoing photons

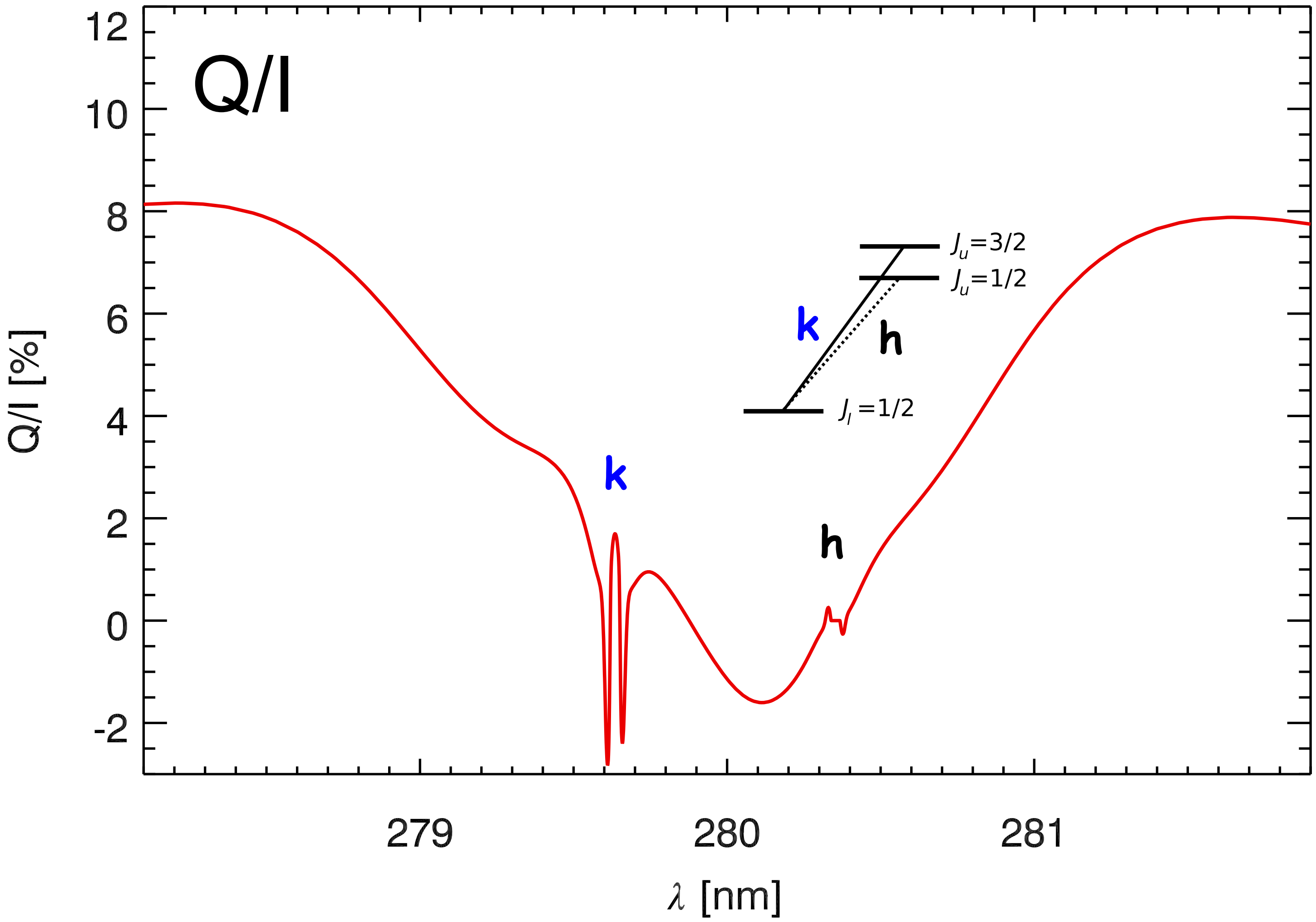
J-state interference →





The calculated Q/I pattern **WITHOUT** magnetic fields

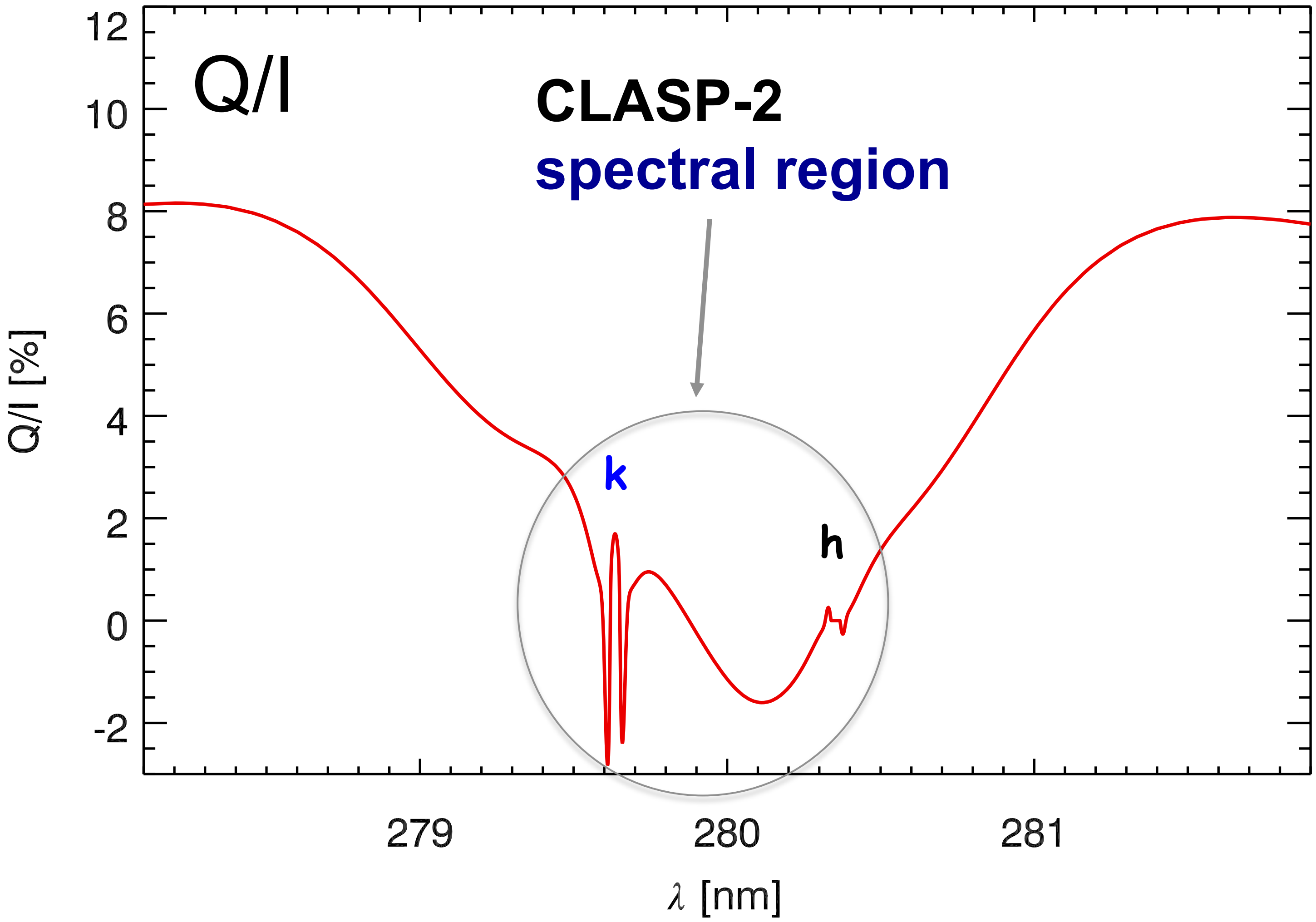
Belluzzi & Trujillo Bueno (2012)



J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

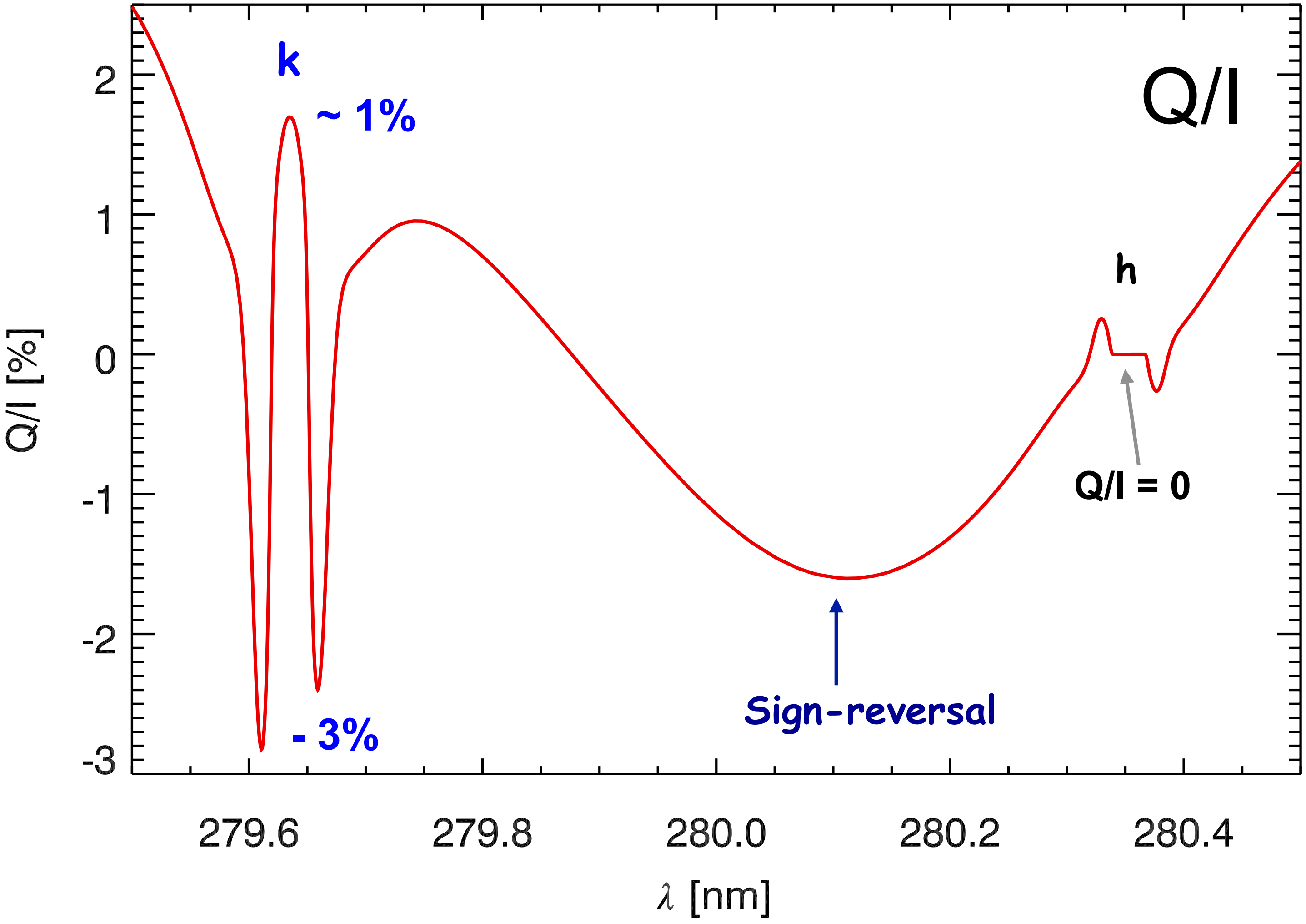
The calculated Q/I pattern **WITHOUT** magnetic fields

Belluzzi & Trujillo Bueno (2012)



The calculated Q/I pattern **WITHOUT** magnetic fields

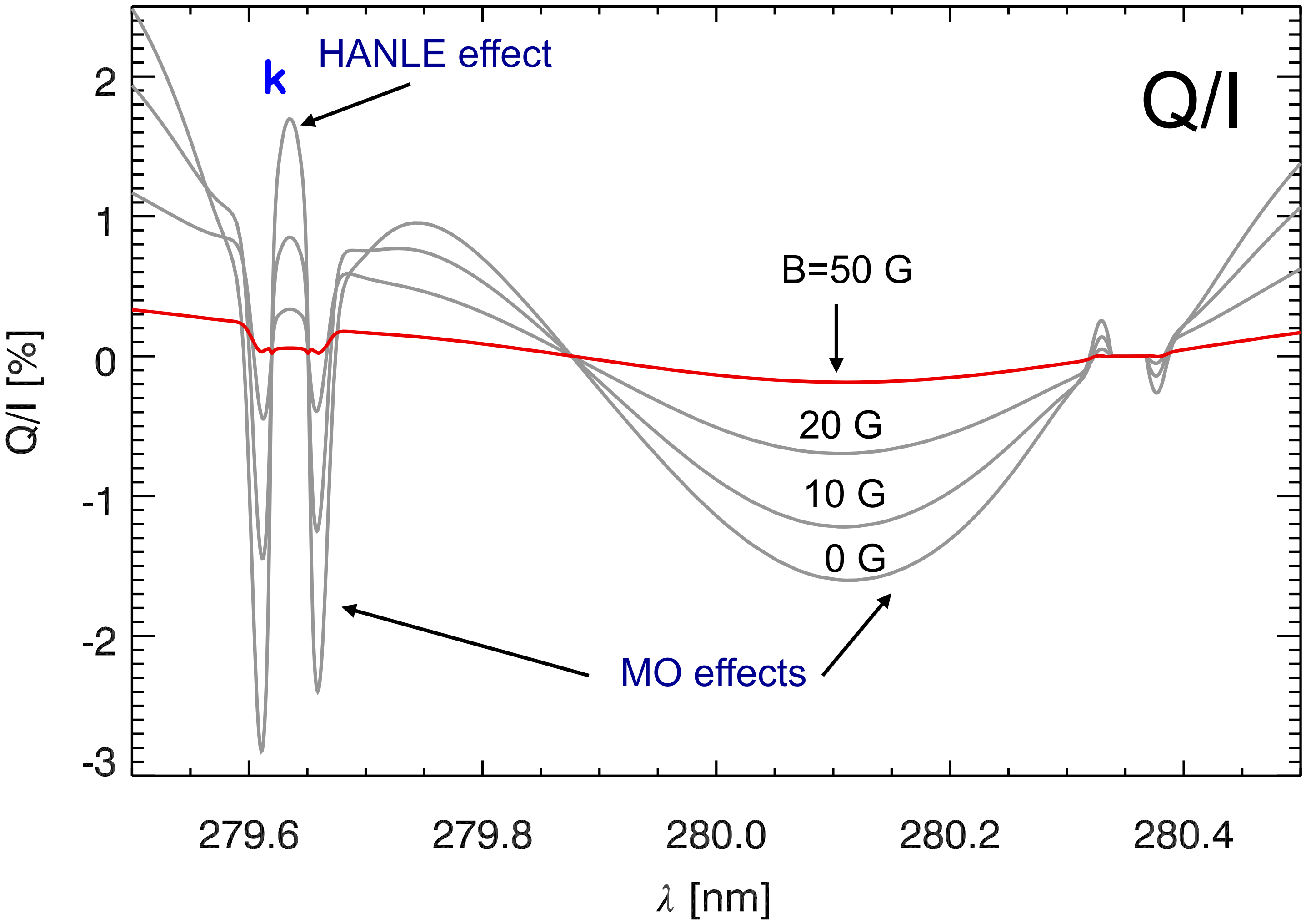
Belluzzi & Trujillo Bueno (2012)



The calculated Q/I pattern **WITH** magnetic fields

(Horizontal field pointing almost towards the observer)

del Pino Alemán et al. (2016)



MO term that couples Q and U

See Alsina Ballester et al. (2016) and del Pino Alemán et al. (2016)

$$\frac{\mathrm{d}}{\mathrm{d}s}\begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix} = \begin{pmatrix} \varepsilon_I \\ \varepsilon_Q \\ \varepsilon_U \\ \varepsilon_V \end{pmatrix} - \begin{pmatrix} \eta_I & \eta_Q & \eta_U & \eta_V \\ \eta_Q & \eta_I & \boxed{\rho_V} & -\rho_U \\ \eta_U & \boxed{-\rho_V} & \eta_I & \rho_Q \\ \eta_V & \rho_U & -\rho_Q & \eta_I \end{pmatrix} \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

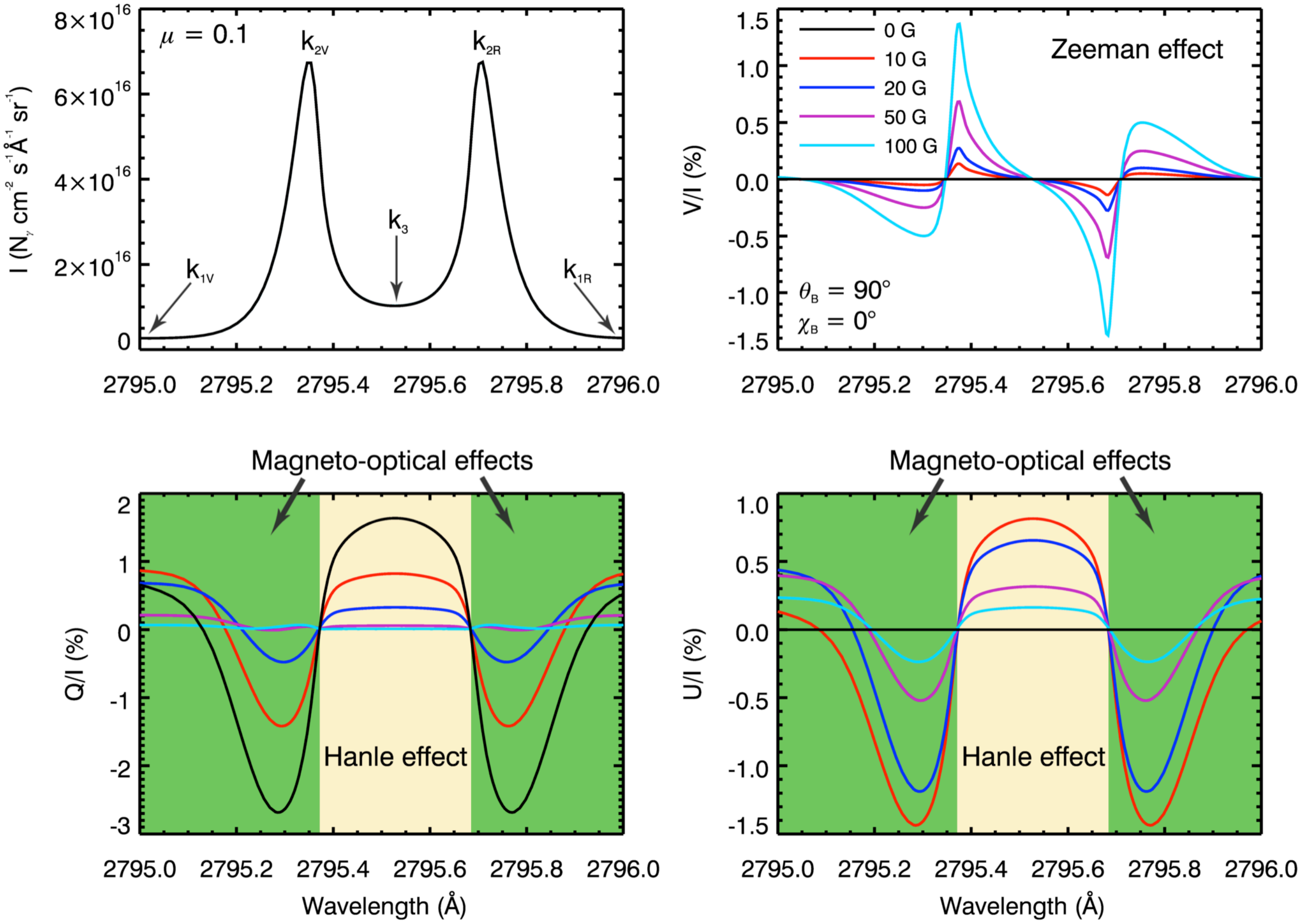
WITH the key Magneto-Optical (MO) term

$$\frac{\mathrm{d}}{\mathrm{d}s}Q \approx [\epsilon_Q - \rho_V\, U] - \eta_I\, Q$$

$$\frac{\mathrm{d}}{\mathrm{d}s}U \approx [\epsilon_U + \rho_V\, Q] - \eta_I\, U$$

In 2019 we will launch CLASP-2 to probe the magnetism of the solar chromosphere via the polarization caused by the joint action of the Hanle, Zeeman and MO effects in the Mg II h & k lines

Alsina Ballester et al. (2016)



J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen

Second flight of CLASP (CLASP 2)

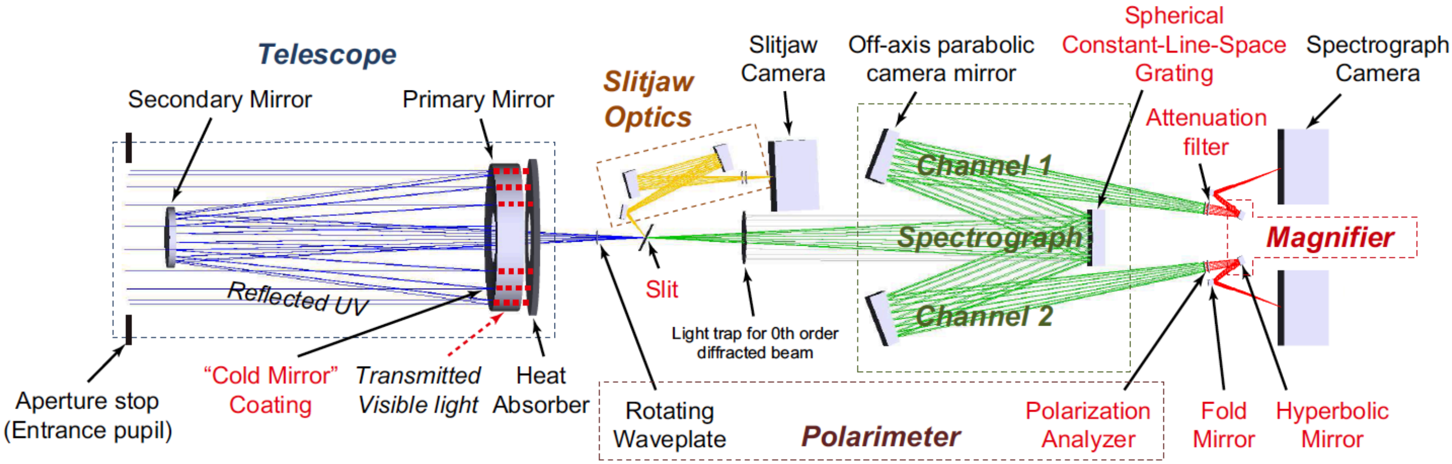

CLASP instrument was successfully recovered!

- Mission accepted by NASA, and scheduled to fly in **2019** spring

- **Full stokes** spectro-polarimetry of **Mg II h & k** in quiet and active regions

	CLASP 1	**CLASP 2**
Observables	Stokes-I, Q, U	Stokes-I, Q, U, **V**
Spectral Lines	Lya (1216 Å) & Si III (1206 Å)	Mg II h & k at 2800 Å
Resolutions	0.1 Å (wavelength), 3” (spatial)	**0.1** Å (wavelength), **2”** (spatial)
Slit Length	400”	200”

CLASP-2



Selected by NASA in 2016

Launch date → 2019

Measure the four Stokes profiles across the Mg II h & k lines.

Targets: quiet and active regions of the solar disk.

Telescope	
Type	Cassegrain
Aperture	ø270 mm
Eff. Focal Length	2614.0 mm (F/9.68)
Primary Mirror	ø300 mm, K=-1, Curvature radius 2054.5 mm
Secondary Mirror	ø123 mm, K=-5.27, Curvature radius 1243.0 mm
Visible Light Rejection	"Cold Mirror" coating on primary mirror

Slit	
Slit Width	7 μm (0.55 arcsec)
Slit Length	2.5 mm (200 arcsec)

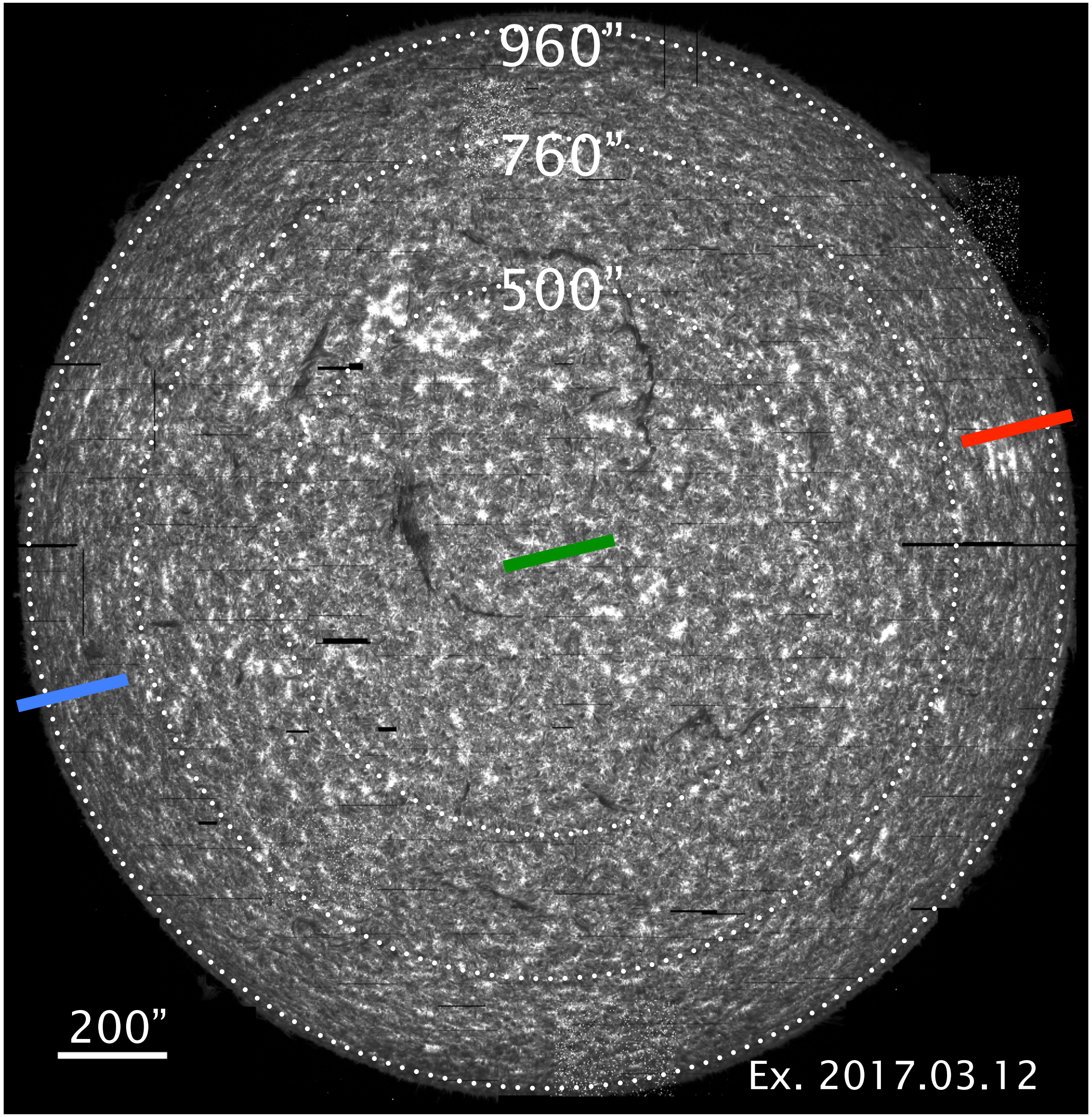
Slitjaw Imaging System	
Wavelength	Lyα (band-pass filter)
Optics	- Fold mirror with multilayer coating - Off-axis parabola x 2 - Lyα filter x 2
Detector	512 x 512 CCD, 13μm pixel
Plate Scale	1.03 arcsec / pixel
Resolution	2.9 arcsec (spot RMS diameter)
Magnification	1.00
Field of View	527 arcsec x 527 arcsec

Polarimeter	
Measurements	Stokes I, Q, U, V
Capability	Simultaneous measurement of orthogonal polarizations
Optics	- Rotating waveplate - Polarization analyzer x 2

Spectrograph	
Spectrograph Type	Inverse Wadsworth mounting
Grating Type	Spherical constant-line-space with 1303 mm^{-1} groove density
Grating Size	ø106 mm (clear aperture)
Wavelength	Optimized for MgII h & k (280 nm)
Resolution	1.1 arcsec (spatial; RMS diameter) 0.01 nm (spectral; RMS diameter)
Magnification	1.87
Field of View	200 arcsec (determined by slit) 1.5 nm (to cover 279.45 - 280.35 nm)

Spectrograph Cameras	
Detector	512 x 512 CCD, 13μm pixel
Exposure Time	0.2 sec (nominal)
Plate Scale	0.55 arcsec / pixel (spatial) 0.005 nm / pixel (spectral)
Readout area	512 (spatial) x 300 (spectral) pixel

Observing Targets

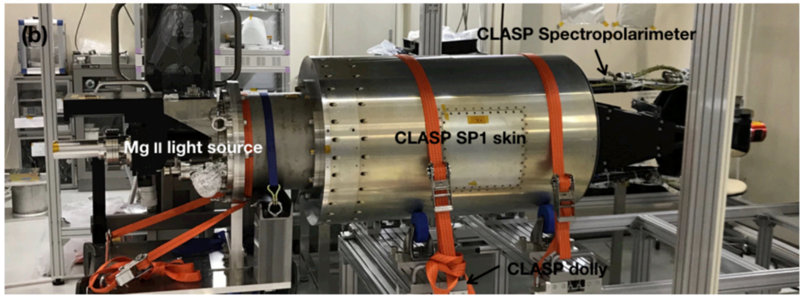


Ex. 2017.03.12

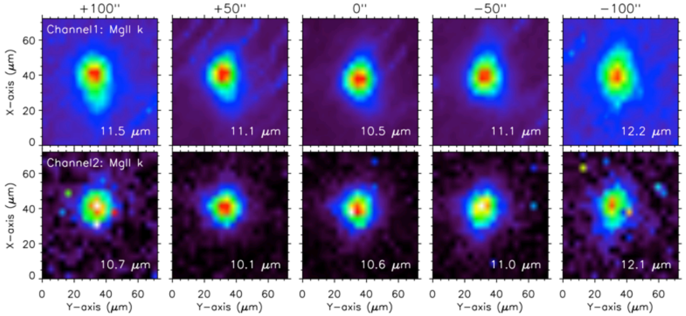
- QS @ disk center (15 sec): pol. cal.
- Plages (155 sec): Zeeman, Hanle and MO effects
- QS near the limb (50 sec): CLV

CLASP 2 I&T

SP alignment completed (except for CCD focus)



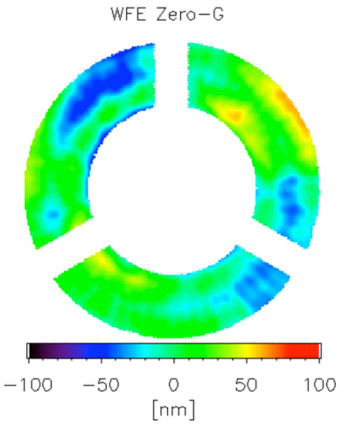
Song et al. (2018; SPIE)



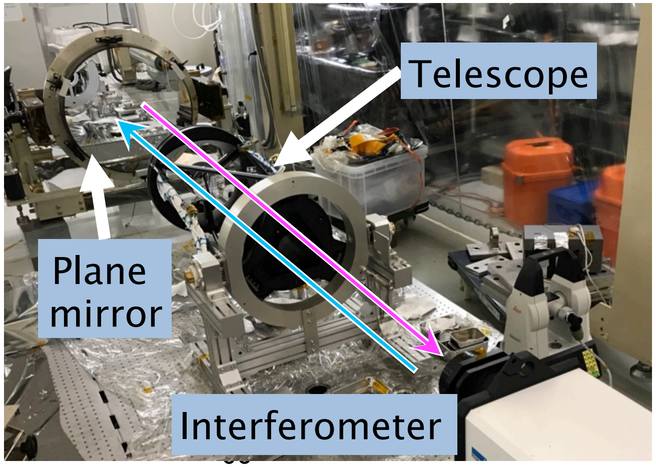
Remaining work:

- Flight CCD focus adjustment
- Polarization calibration of SP
- E2E test in VL and UV
- Installation of flight avionics and E2E test

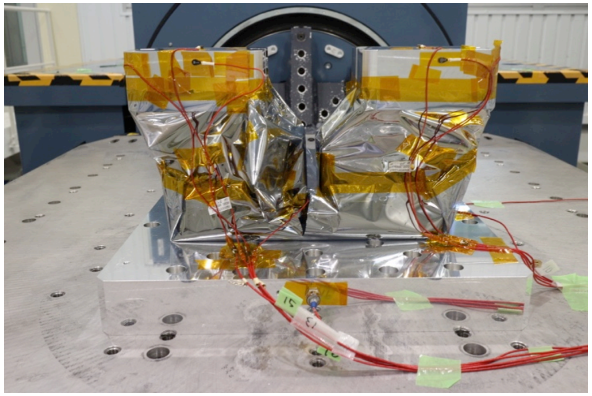
Yoshida et al. (2018; SPIE)



Telescope alignment completed (with improved analysis)



Vibration test of new components completed



Concluding comments

- Spectropolarimetry in UV lines can only be done from space. However, we must pursue this goal because UV polarimetry is a key gateway for exploring the outer atmospheres of the Sun and of other stars.

CLASP is being a successful international collaboration between Japan, USA and Europe !

The Spanish contribution receives support from the European Research Council (ERC) through ERC Advanced Grant agreement No 742265

http://www.iac.es/proyecto/polmag/

J. Trujillo Bueno & the CLASP teams, 2018 IRIS-9 workshop in Göttingen