The polarization of the Hα line in the quiet solar chromosphere

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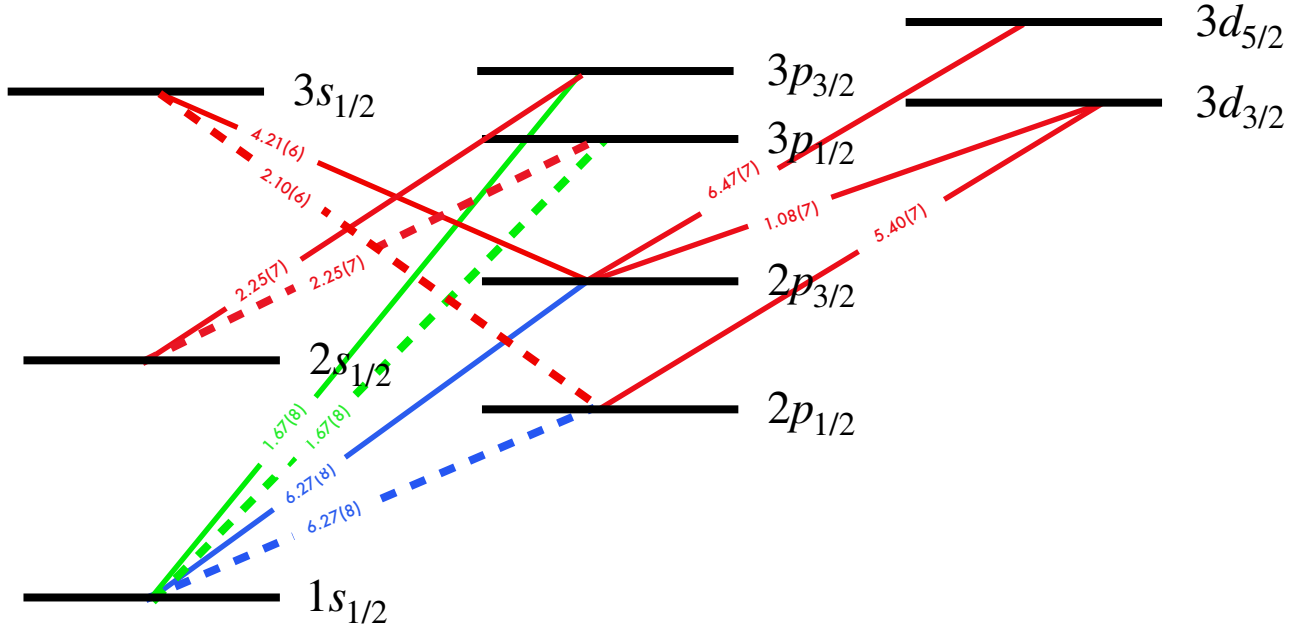
ABSTRACT. ***One-dimensional radiative transfer (RT) calculations suggested that the scattering polarization profiles of the Hα line are very sensitive to the strength and structure of the chromospheric magnetic field. Here we present unprecedented spectropolarimetric observations of the Hα line obtained with ZIMPOL-3 at IRSOL. The linear polarization profiles show a rich variety of shapes and amplitudes, as well as an interesting spatial variability. We confront them with the theoretical scattering polarization profiles we have obtained by solving the complex RT problem of the Hα polarization in a 3D model from MHD simulations, highlighting the impact produced by the model's magnetic and velocity field. This investigation reveals the great interest of the Hα polarization in the present new era of large-aperture solar telescopes.***

1. Introduction

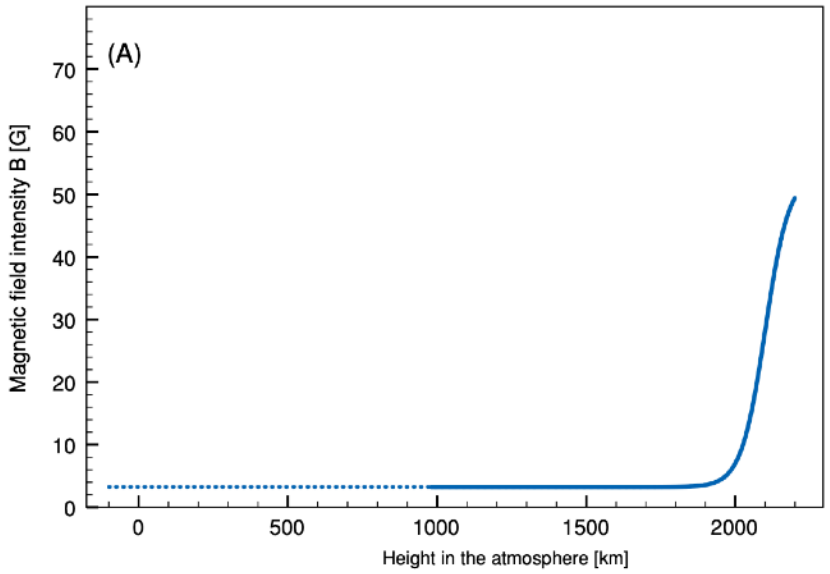
The atomic model used has 9 fine-structure levels. Hα results from 7 blended radiative transitions (red lines). Due to their different formation heights, through the Hanle effect the emergent Hα profiles are sensitive to magnetic fields at different heights.

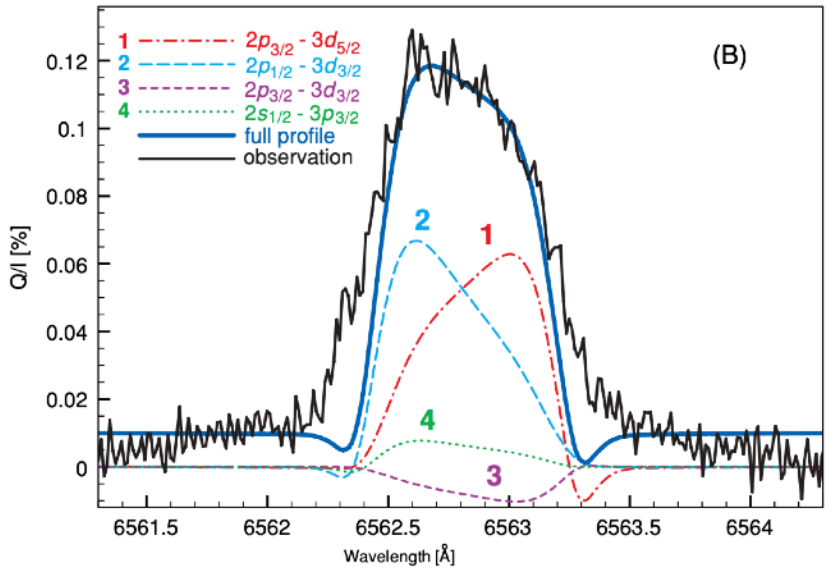
Table 1
Hanle Critical Field of the Hydrogen Levels

Level	Landé Factor	B_H (G)
$2p_{3/2}$	1.33	53.5
$3p_{3/2}$	1.33	16.2
$3d_{3/2}$	0.80	9.2
$3d_{5/2}$	1.20	6.1



Theoretical and observed Q/I profiles for a LOS with μ=0.1





1D radiative transfer modeling suggested that the Hα scattering polarization is sensitive to the presence of magnetic field gradients in the upper chromosphere.

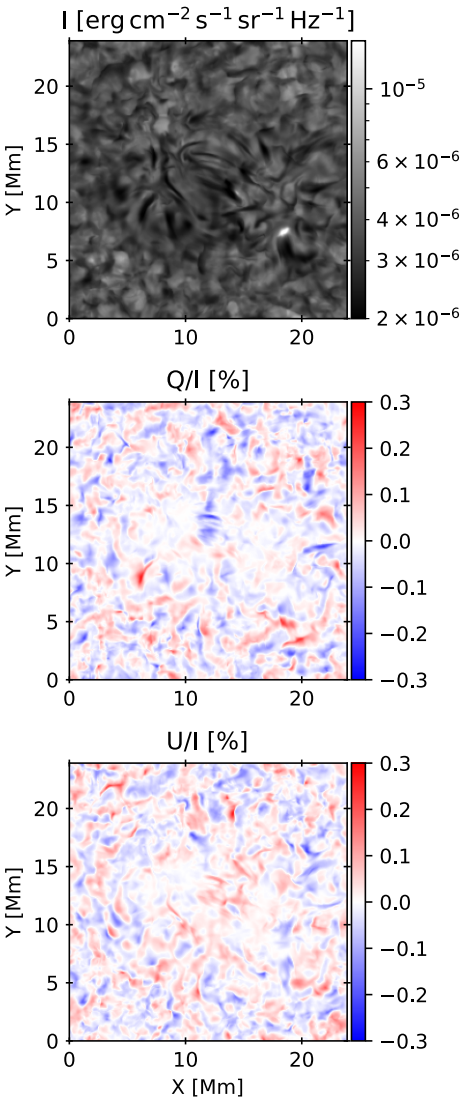
Štěpán & Trujillo Bueno (2010)

2. 3D Calculations

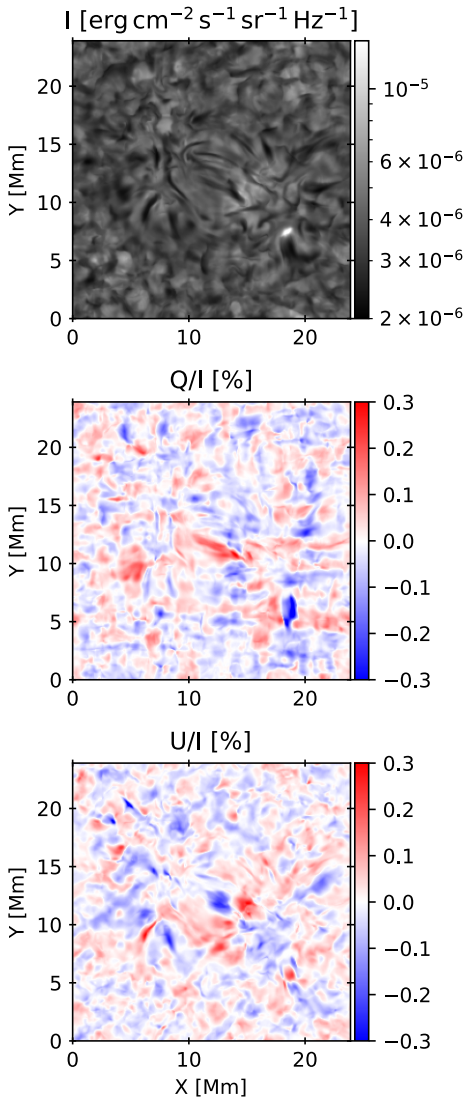
- 3D model of enhanced network (Carlsson et. al. 2016)
- 3D radiative transfer code PORTA (https://gitlab.com/polmag/PORTA)
- Complete frequency redistribution (CRD)
- Hanle effect regime (line-width much larger than the Zeeman splitting)
- Multilevel model atom:
  - 9 fine-structure levels
  - 11 blended radiative transitions
  - “Weakly inelastic” collisional rates (Sahal-Brechot 1996) between fine-structure levels of a given level *n*.
  - Inelastic collisions between *n* levels (Przybilla & Butler 2004)
- Several numerical experiments: with/without magnetic field, with/without velocity field, using the 1.5D approximation, etc.

Stokes maps at Hα line-center

With magnetic field



Without magnetic field



4. Observations

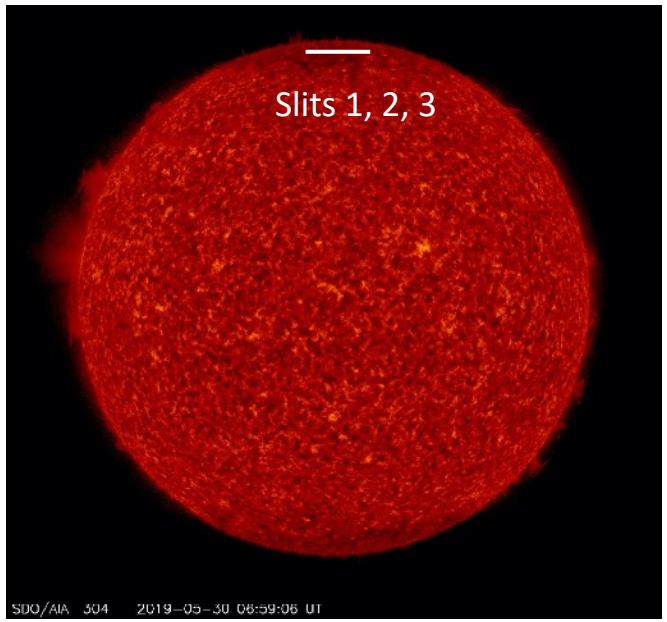
ZIMPOL-3 at IRSOL

Low spatial res.: >10”

High spectral res.: 20 mA

Very low noise: 5×10^{-5} I_{cont}

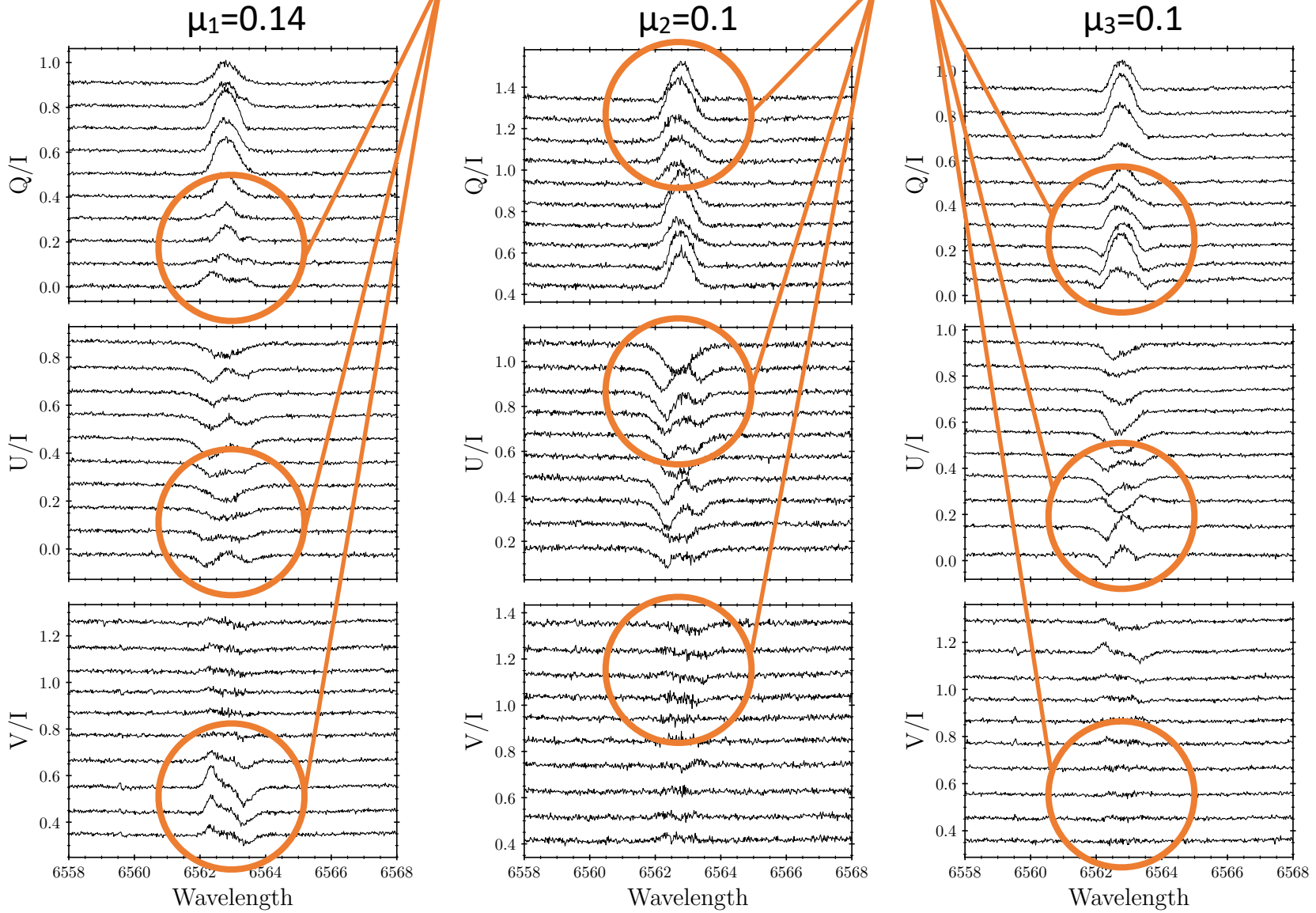
Integration time: 7 min



Spatial profiles averaged every 10 pix along slit direction (ofset between them for better visualization)

Q/I, U/I and V/I spatial variations detected **Hanle effect ?**

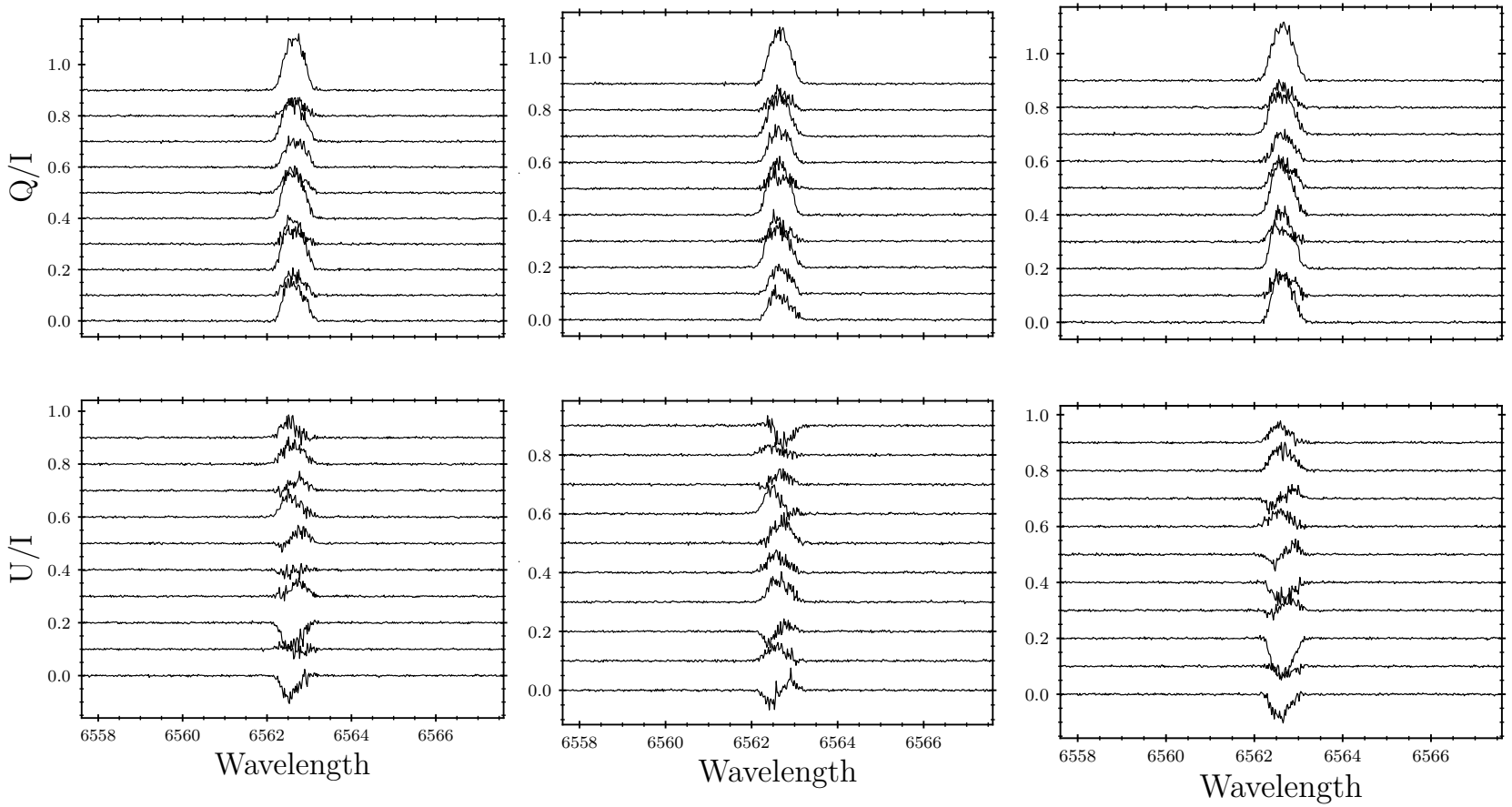
No V/I detected but Q/I and U/I spatial variations **Hanle effect ?**



3. Theoretical profiles

Same degradation than previous observations

- Degraded Q/I and U/I profiles at μ=0.1 simulating slit-based observations with ZIMPOL at IRSOL.
- Radiative transfer calculations in only 1 snapshot —> time evolution is not considered.



5. Ongoing work & conclusions

- To apply machine learning techniques to classify the theoretical Q/I and U/I profile shapes in order to relate them with the plasma properties of the model.
- To relate similar spatial variations in the calculated emergent linear polarization profiles with magnetic or velocity field gradients.
- To simulate slit-based observations taken with the new generation of solar instruments, like ViSP at DKIST.
- Spectropolarimetric observations of the Hα line with ViSP at DKIST are being planned, because they may help to better understand the solar chromosphere.