

# The Hanle and Zeeman Effects in Solar Spicules

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in collaboration with

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# Summary

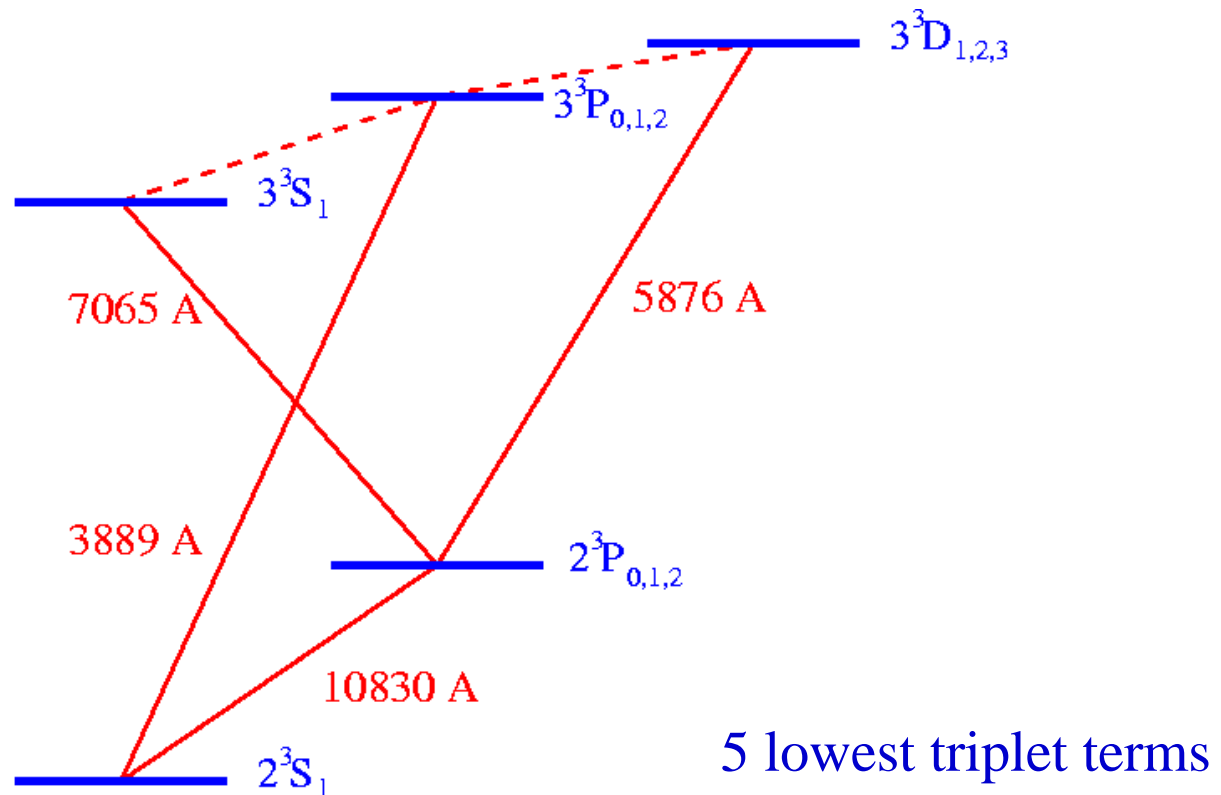
- ? Preliminary results about **observing campaign on Spicules in the He-D3 line** at IRSOL, Locarno
- ? 53 full-Stokes spectropolarimetric measurements during 15 days
- ? **Goal:** magnetic field diagnostics via inversion of the Stokes profiles based on the quantum theory of the Hanle and Paschen-Back effects.

# Outline

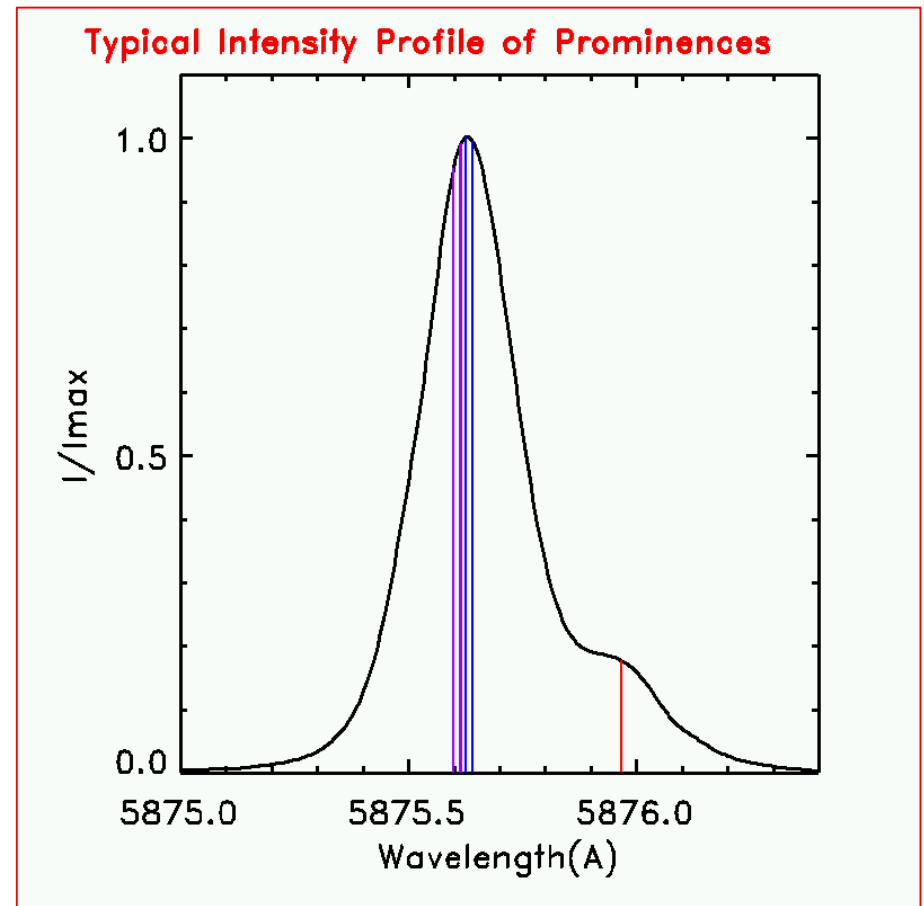
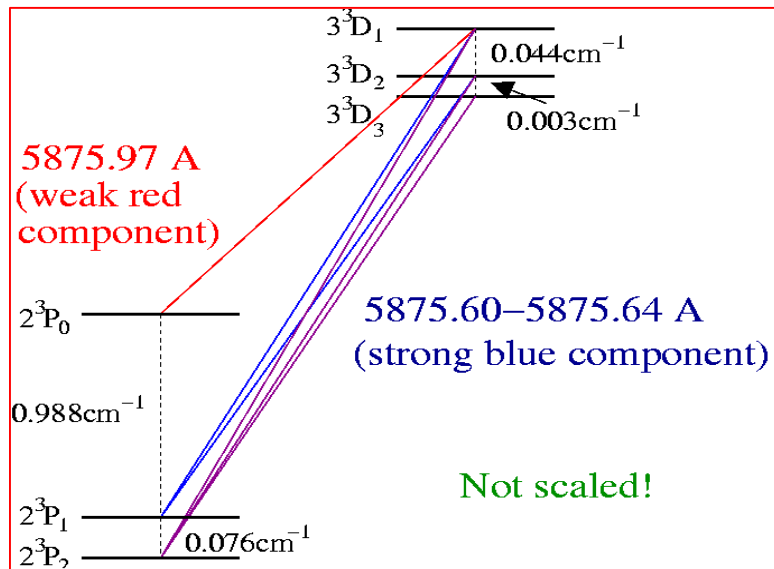
- ? Theoretical Modelling and Inversion
- ? The instrumentation
- ? The observations
- ? Preliminary results
- ? Conclusions

# The Theoretical Model and the Inversion Method

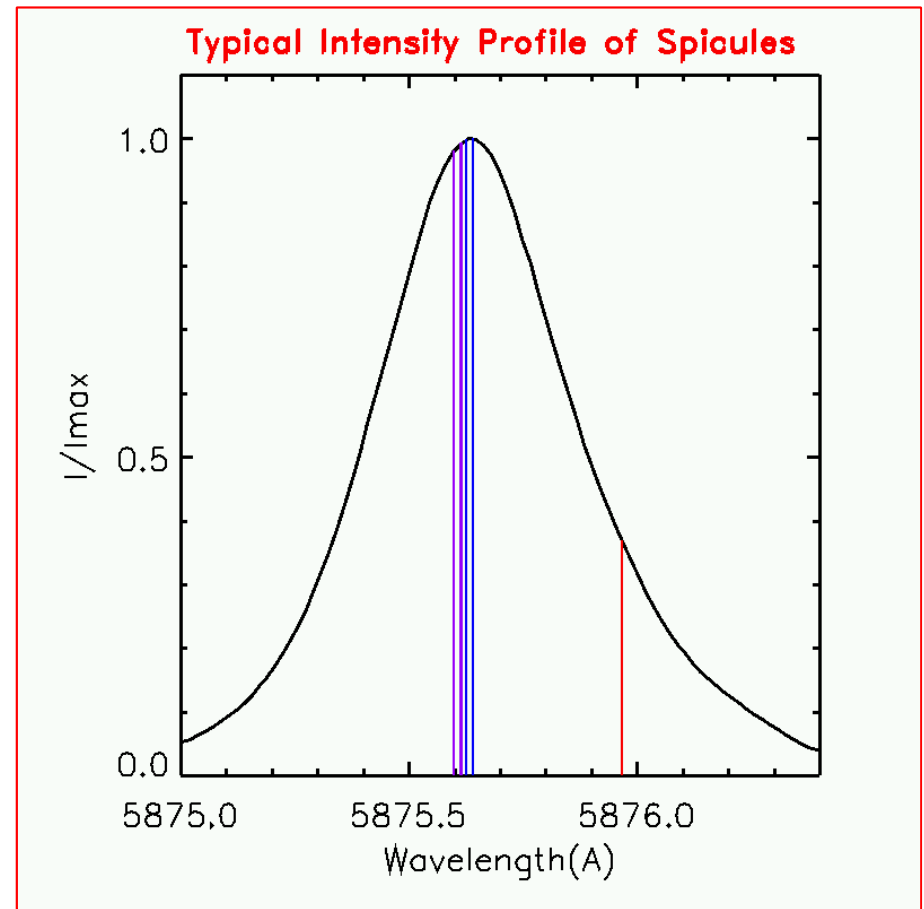
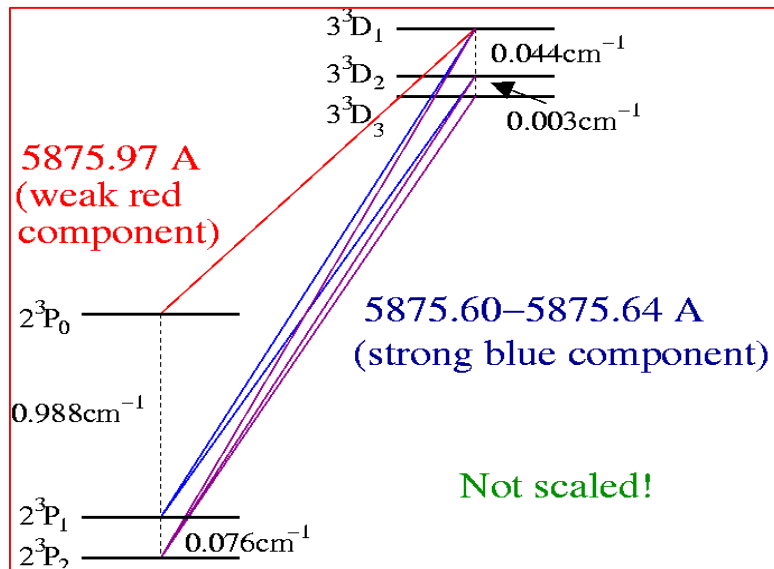
## The Model Atom for Helium



# The Helium D3-multiplet



# The Helium D3-multiplet



# Theoretical Model: basic features

- ? Atomic polarization due to the anisotropic illumination induces emission of polarized radiation
- ? In particular, coherences between fine-structure levels within each atomic term are completely accounted for, allowing for the treatment of both the Hanle and Zeeman regimes, including level crossings (incomplete Paschen-Back effect).

See, e.g., Landi Degl'Innocenti & Landolfi (2004)

- ? Spicules are assumed to be optically thin.

# The inversion

- ? Database containing profiles for different magnetic field orientations and strengths is created for a given limb distance
- ? The best fitting theoretical profiles are carefully searched in the database



# Instrumentation

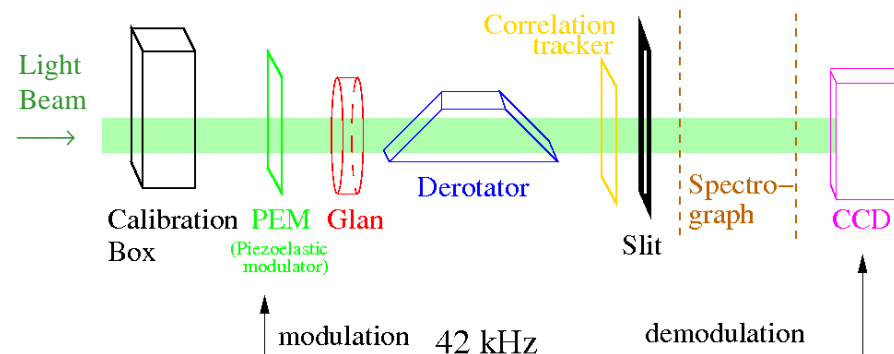
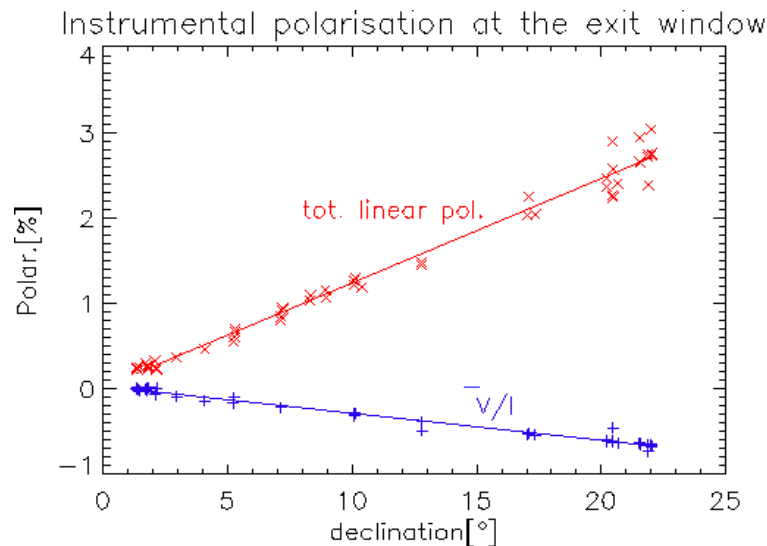


- ? **Telescope:** Gregory - Coudé, evacuated
  - Diameter of primary mirror: 45 cm
  - Total focal length: 25 m



- ? **ZIMPOL2-polarimeter** (*Zurich Imaging Polarimeter*, developed at ETH-Zurich) allows precise measurements free from seeing induced spurious effects (modulation 42 kHz).
- ? **Limb tracker** keep constant the distance between the spectrograph slit position and the limb.
- ? **Instrumental polarization** is small and almost constant over one day of observations (easy to correct)

## ZIMPOL 2 - setup



# The observations

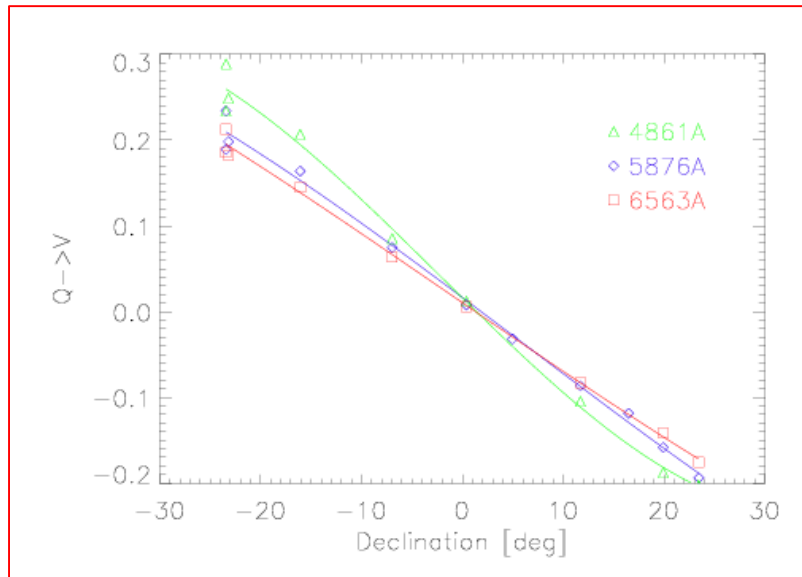
- ? 53 measurements during 15 days from November 2004 to June 2005.
- ? Different positions and limb distances.
- ? Total integration time per measurement from 10 to 50 minutes.

# Corrections: Crosstalks

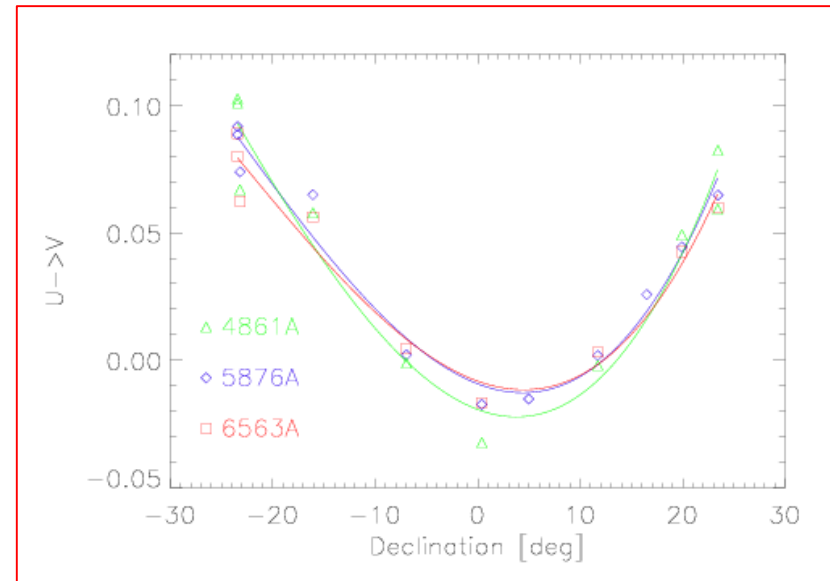
$I \rightarrow Q, U, V$  determined through measurements in quiet regions at the center of the solar disc

$Q \rightarrow V$  and  $U \rightarrow V$  measured with a linear polariser sheet applied at the entrance window of the telescope.

$Q \rightarrow V$



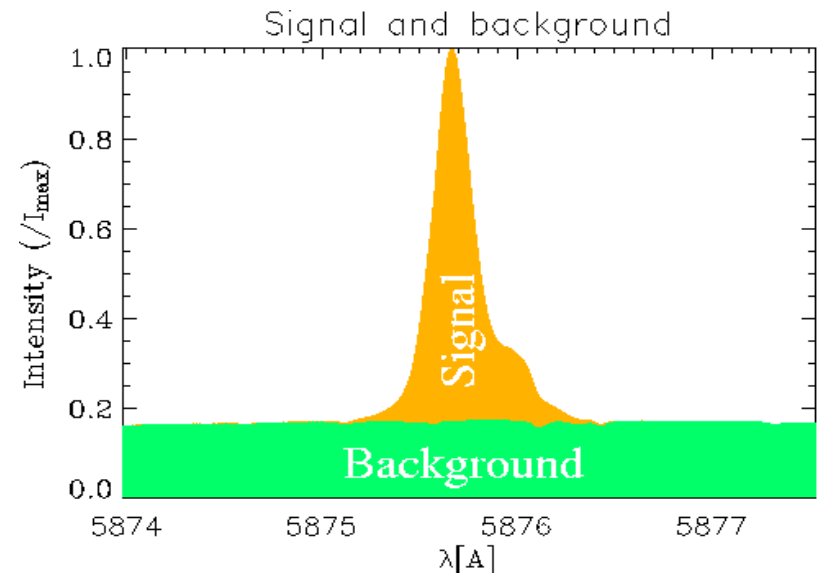
$U \rightarrow V$



$V \rightarrow Q$  and  $V \rightarrow U$  deduced from the symmetries of the theoretical Müller Matrix and the  $Q \rightarrow V$  and  $U \rightarrow V$  measured crosstalks.

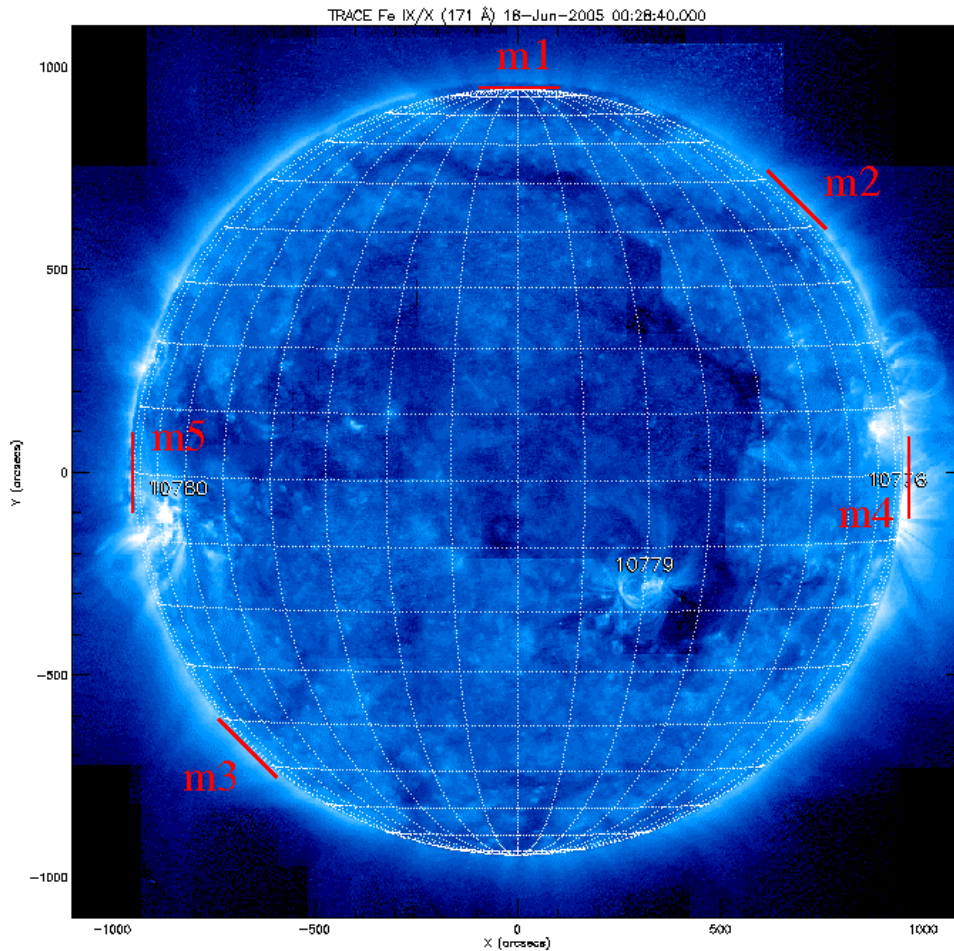
# The scattered light

- The emission intensity profile of spicules (**signal**) has to be separated from the **scattered light (background)**
- An intensity spectrum measurement is taken on the solar disc (usually near the measured spicules) and we assume that the scattered light has the same shape (approximation)
- The scattered light may be slightly polarized (linear polarization usually  $\sim 10^{-3}$ ). Corrections are applied in the data analysis assuming that the degree of polarization (P/I) of the scattered light is wavelength independent.
- **Sources of scattered light:**
  - **Earth atmosphere** → influenced by meteorological conditions and zenith angle, but practically unpolarized
  - **Telescope** → scattered light may be polarized



# The Results (preliminary)

Example: The observations of the 18<sup>th</sup> June 2005

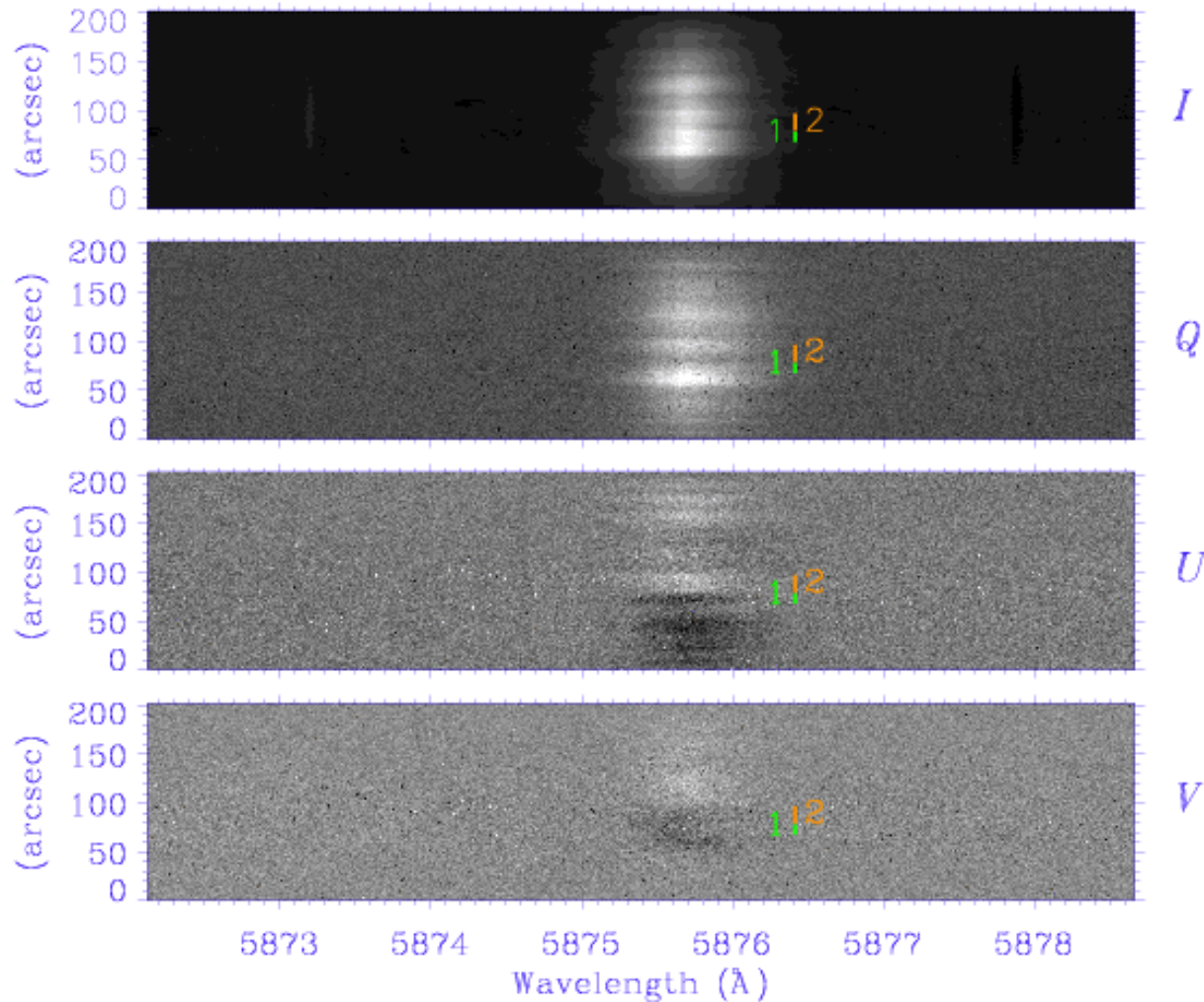


- Very good observing conditions (clear sky and good seeing)
- Exposure time for each measurements about 30 minutes
- Measurements at  $\sim 3$  arcsec from limb



# Measurement in a quiet region (m2)

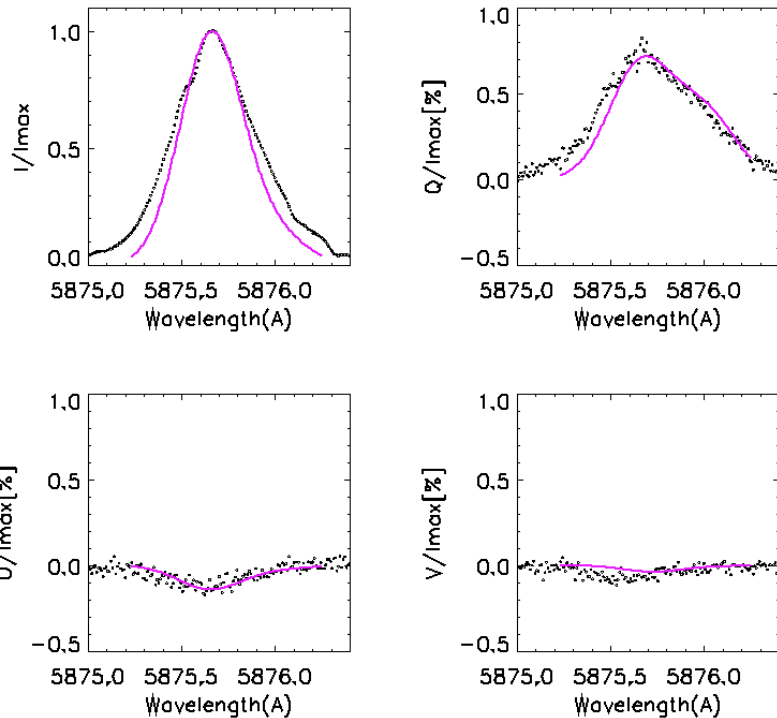
Spicules at ~2.5 arcsec from N-W limb (quiet region) 18 June 05



# Stokes profiles

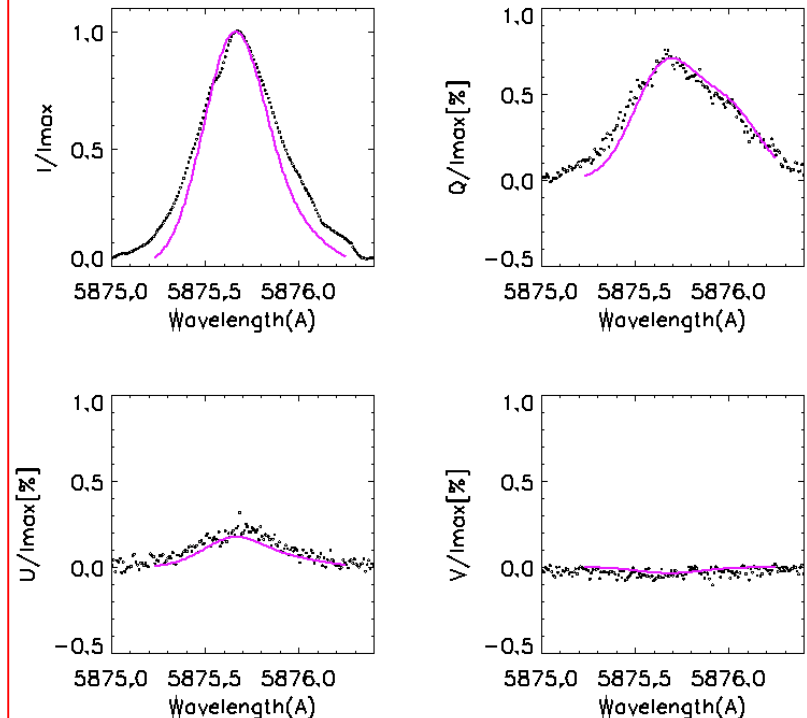
## Region 1

Fitted profile:  $B = 7$  Gauss,  $\theta = 58^\circ$ ,  $\phi = -101^\circ$



## Region 2

Fitted profile:  $B = 6$  Gauss,  $\theta = 54^\circ$ ,  $\phi = -90^\circ$

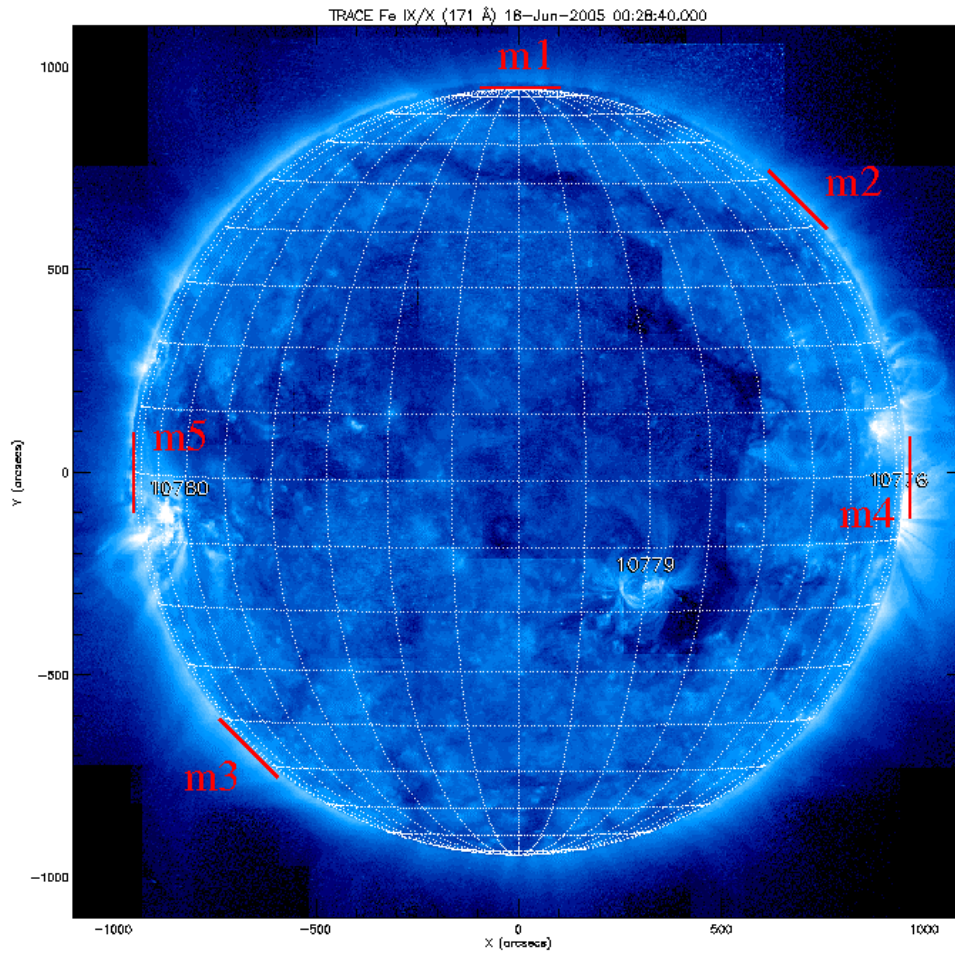


**~ 10 gauss**



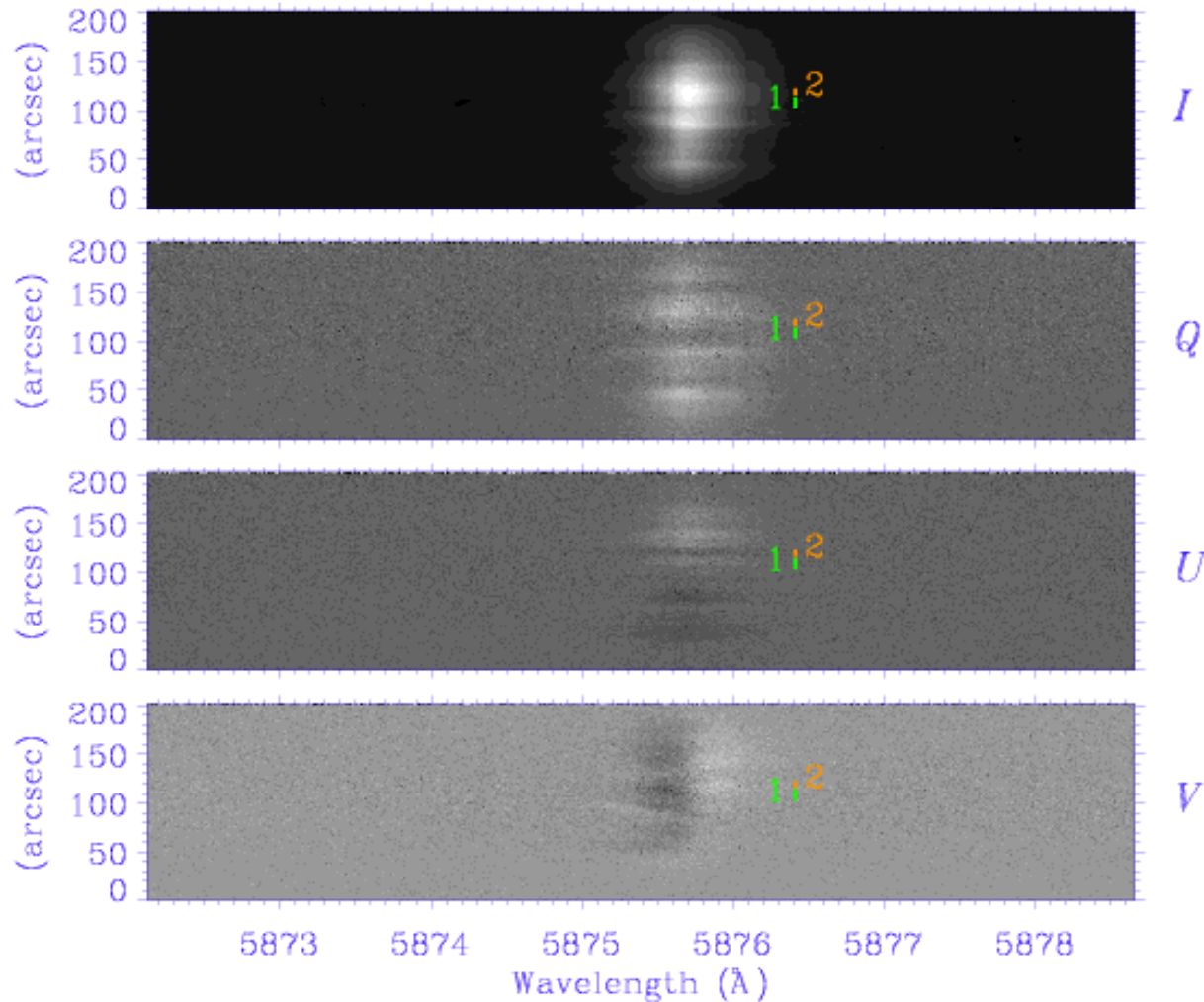
**Also all other analyzed Stokes profiles obtained from measurements in quiet regions indicate  $B \sim 10$  gauss** (in agreement with the results obtained by Trujillo Bueno et al. (2005) via the He I 10830 multiplet)

## Example: The observations of the 18<sup>th</sup> June 2005



# Measurement near active region (m4)

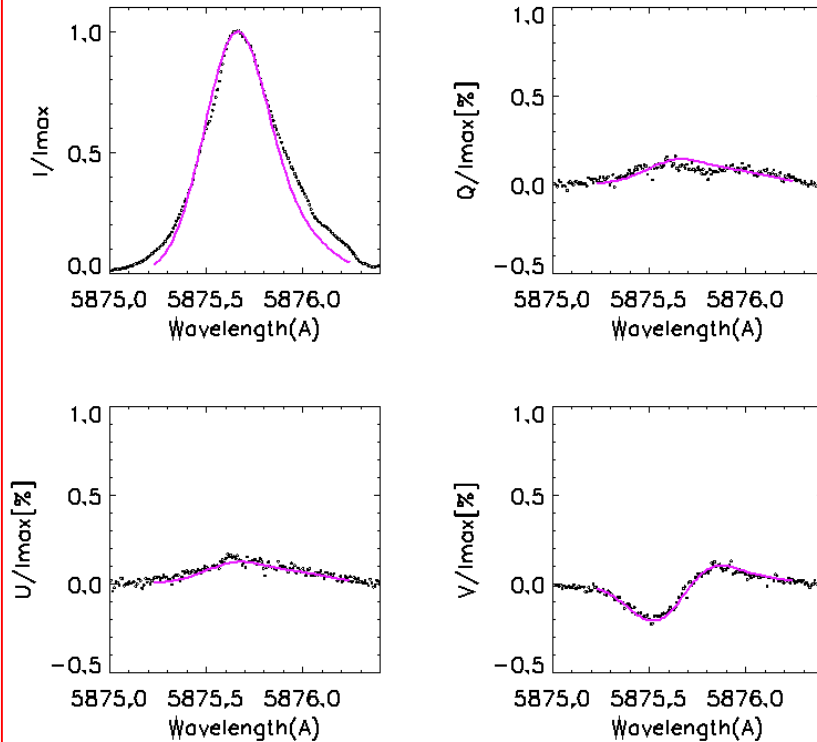
Spicules at  $\sim 2.5$  arcsec from W limb (active region) 18 June 05



# Stokes profiles

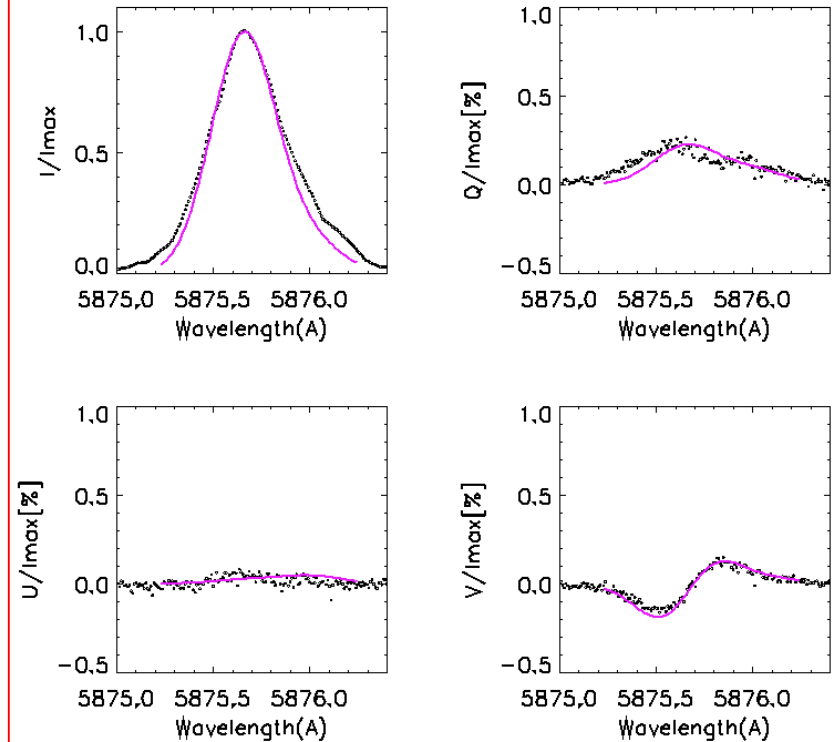
## Region 1

Fitted profile:  $B = 57$  Gauss,  $\theta = 55^\circ$ ,  $\phi = 57^\circ$



## Region 2

Fitted profile:  $B = 48$  Gauss,  $\theta = 51^\circ$ ,  $\phi = 45^\circ$



**Near active region we found  $\sim 50$  gauss !**

# Conclusion

- ? At IRSOL, we could obtain several interesting full-Stokes spectropolarimetric measurements of Spicules in the He-D3 line with ZIMPOL2.
- ? Inversions of the Stokes profiles observed in spicules near quiet regions give  $B \sim 10$  gauss
- ? In one case (near active region) we obtained  $B \sim 50$  gauss
- ? Analysis is preliminary:
  - Not all data have been fully analyzed yet
  - Ambiguities are under study
  - We shall improve the model to account for the broadening of the intensity profiles in the wings.