Absolute calibration in solar scattering polarization measurements with ZIMPOL

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Calibration workshop, Zurich, 23-24 January 2013

outline

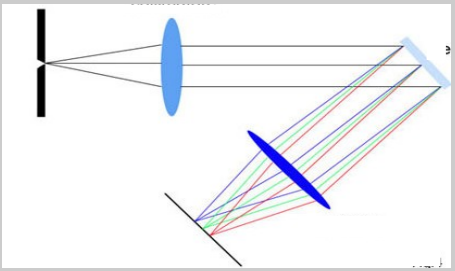
- Introduction about instrumentation
- Scattering polarization observations
- Continuum polarization
- Measuring the zero level polarization

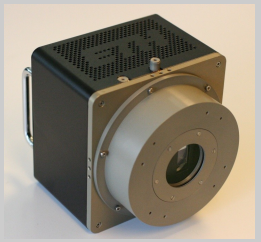
Polarimetry at IRSOL, method

Measuring 2D solar image (spectral image or Fabry-Perot)with high polarimetric resolution (~10^{-5}) we have to take into account that we are faced with a “dancing” image (due to atmospheric seeing, up to ~300 Hz). Our solution: high frequency modulation.

MODULATOR

POLARIZER





Telescope | Analyzer | Spectrograph | Camera

ZIMPOL

Previously developed at Institute of astronomy, ETH Zurich, in the group of Jan Olof Stenflo (initial idea of Hans Peter Povel),

Since 2008 home-base at IRSOL; maintenance and further development in collaboration with SUPSI (University of Applied Sciences of Southern Switzerland)

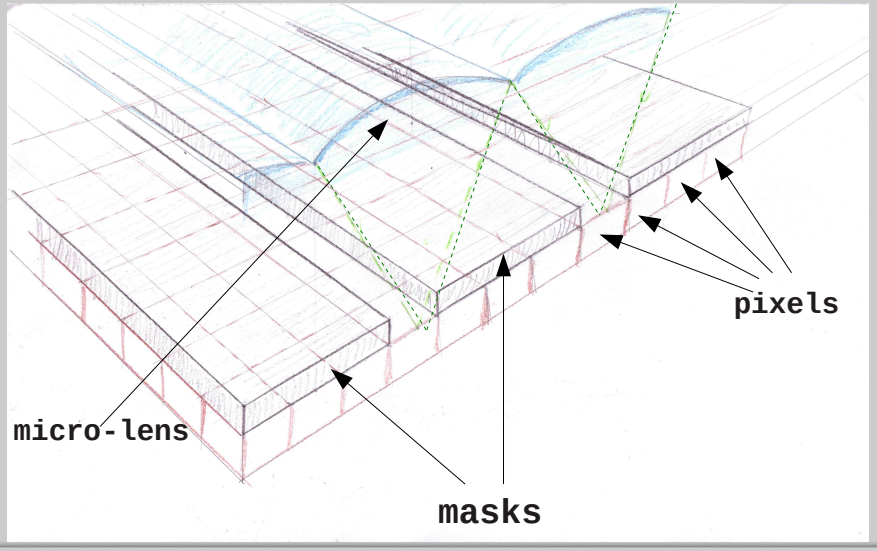
Modulators used:

photoelastic modulator (PEM) 42 kHz or

ferro-electric liquid crystal(FLC) 1 kHz

Demodulation:

achieved using the charge shift method on a masked CCD chip

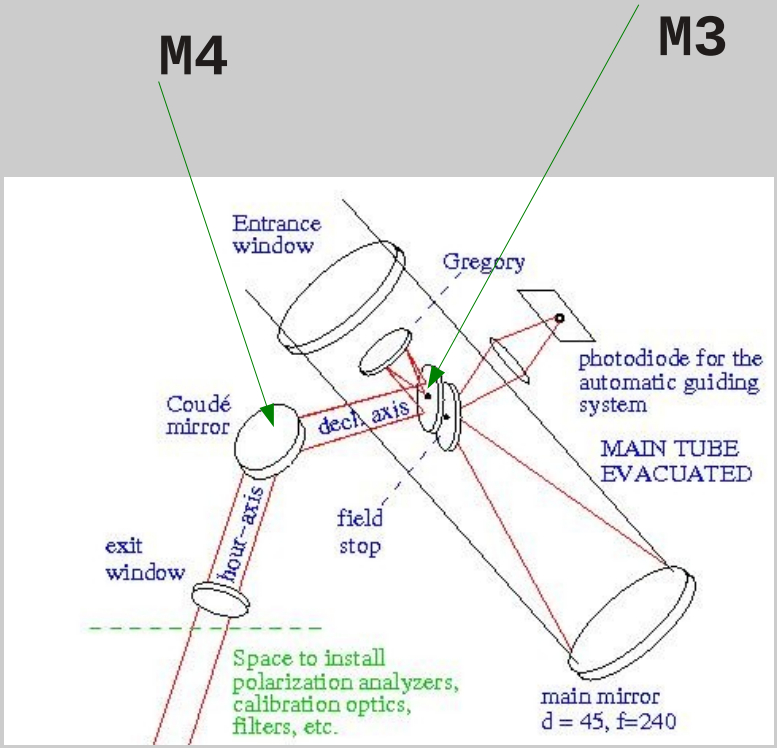


Telescope at IRSOL

Polarimetric properties:

The folding mirrors M3 and M4 introduce instrumental polarization and the resulting Muller matrix is a function of declination only (equatorial mounting). It is almost constant over the day.

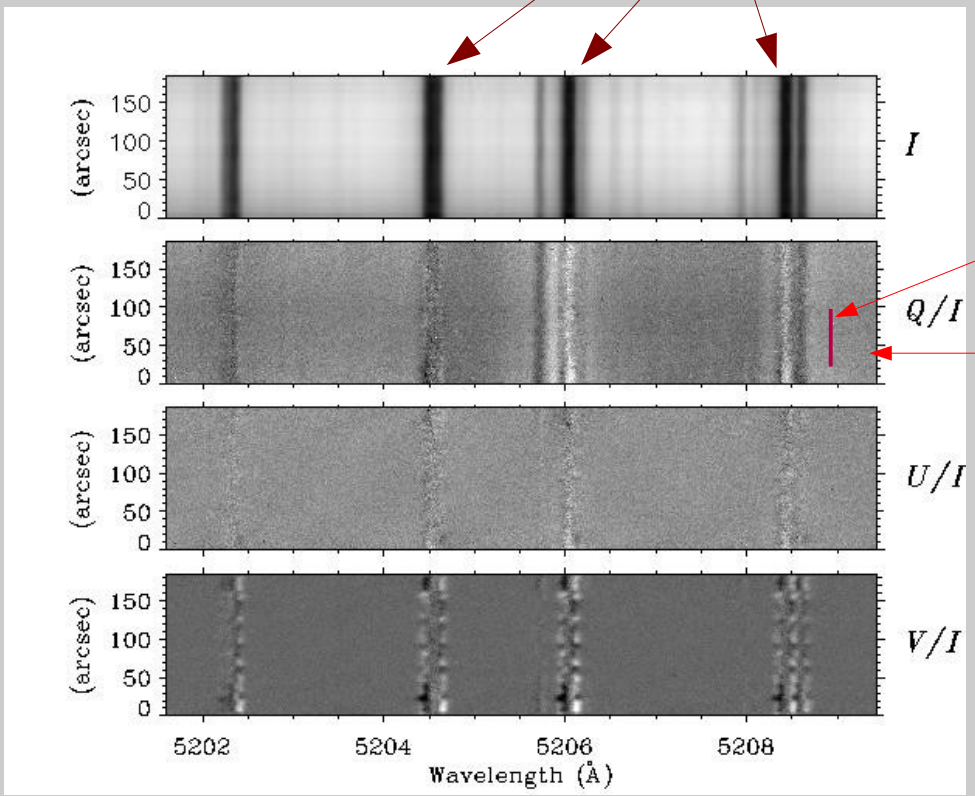
It is one of the telescopes with the best characteristic for polarization measurements (being THEMIS the best one).



High polarimetric resolution, I

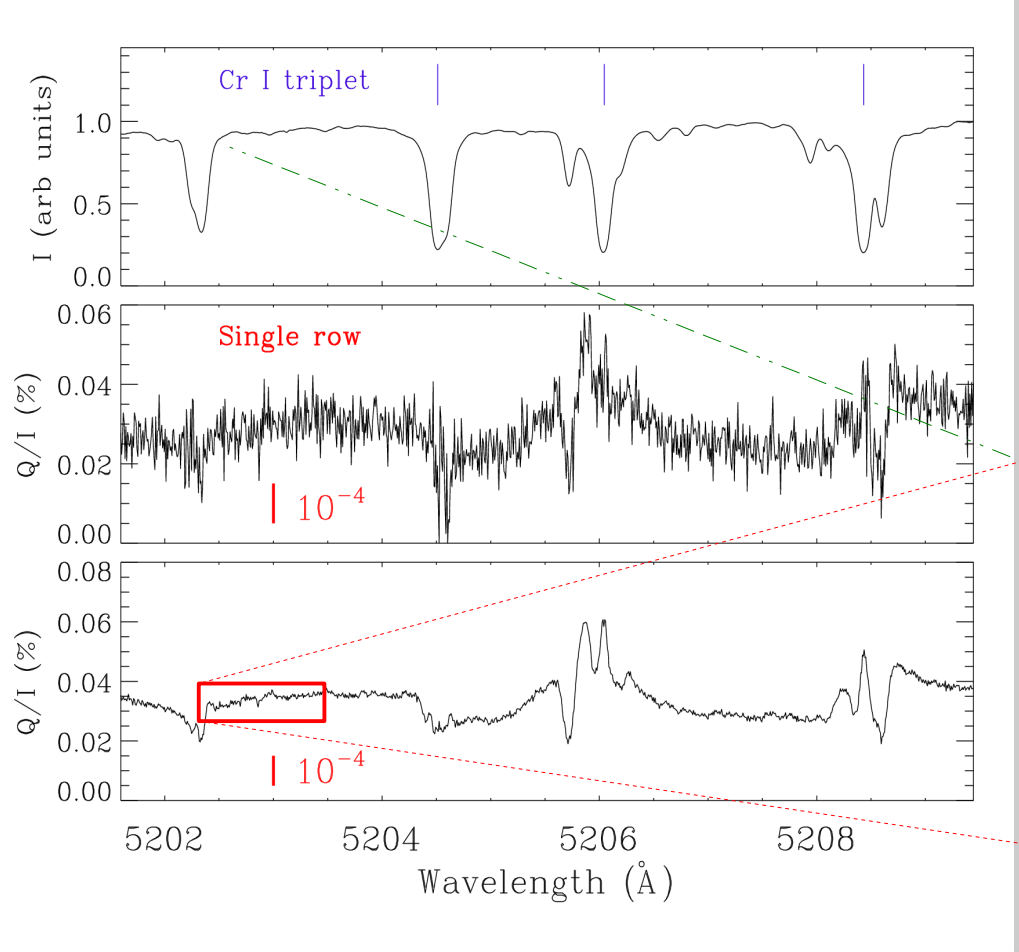
Example: scattering polarization of the Cr I 5207 Å triplet

Observation at cos(θ)=0.15, heliographic North pole

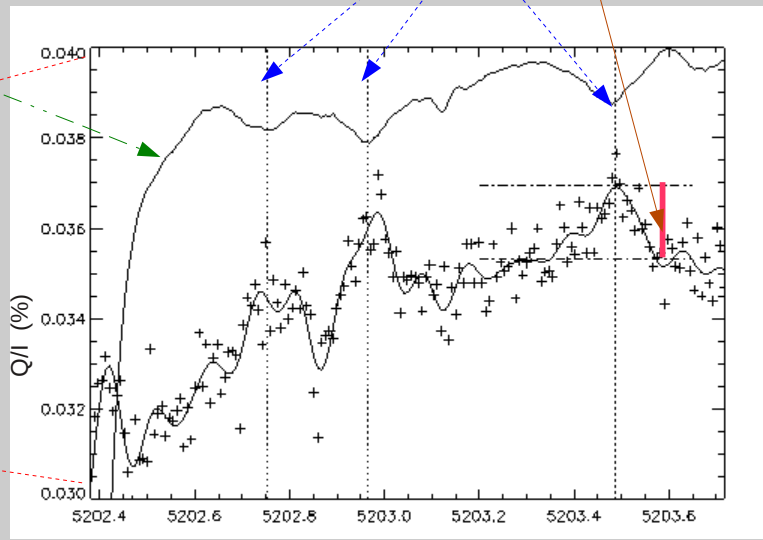


High polarimetric resolution, II

Profiles from the previous images



Scattering polarization peak of a MgH line with an amplitude of $1.6\ 10^{-5}$



Relative and absolute accuracy

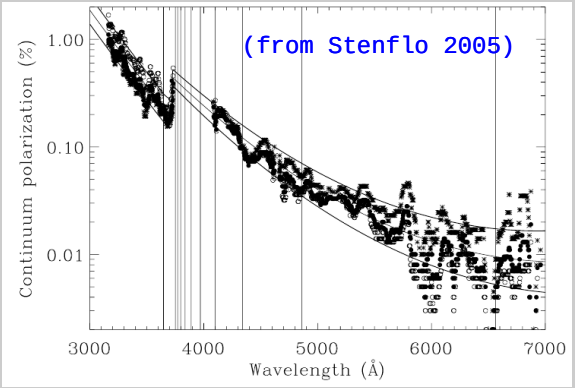
- With long exposure times, in the order of 30 minutes or even more, it is possible to reach a high relative polarimetric accuracy (see previous slide)
- It is not possible to reach the same results in the direct measurement of the absolute zero polarization level. The zero polarization value in a single measurement is affected by instrumental effects
- Previous attempts to just take into account the value measured in a solar region where a zero polarization result is expected (example, continuum polarization at disc center) failed
- For Q/I measurements of the scattering polarization near the solar limb (Second Solar Spectrum), the polarization of the continuum is/was used to determine the absolute zero polarization level

Continuum polarization

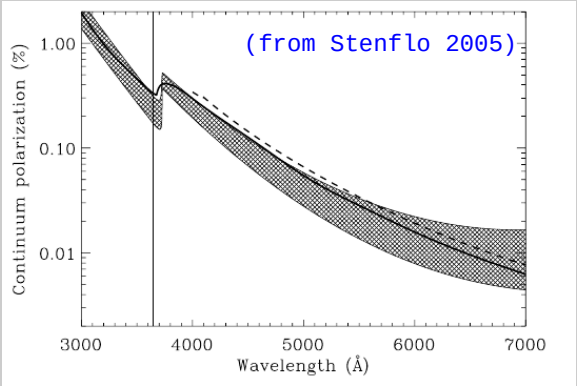
The continuum measured close to the solar limb is polarized (scattering of photons at neutral hydrogen atoms plus Thompson scattering)

This value is/was used to calculate the zero level polarization, based on theoretical models of Fluri & Stenflo (1999) and Stenflo (2005)

An atlas of the measured center to limb variation, CLV, of the continuum polarization as function of wavelength and position on the sun ($\mu = \cos\theta$), is still missing



data at $\mu = 0.1$ derived in an indirect way by the atlases of Gandorfer



Models of Fluri & Stenflo (1999) and Stenflo (2005) at $\mu = 0.1$

Determining the Q/I zero level

Sources of error measuring the zero level of linear polarization

- the telescope instrumental polarization
- the optical path before the CCD device can slightly change with time
- maintaining the precise position of the solar image on the spectrograph slit plane during the time required to measure (till 30 minutes) is critical

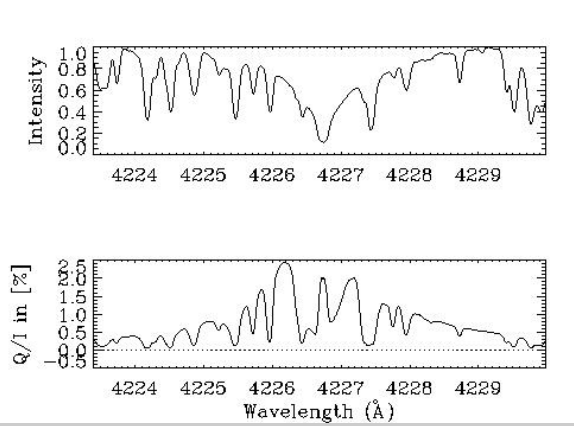
Instrumental improvements at IRSOL to measure it

- Precise adjustment of the orientation of the analyzer optics taking into account ephemeris data
- Tilt-plate (or AO) to improve the accuracy of the limb – spectrograph slit distance ($\mu = \cos\theta$ value)
- better accuracy in the adjustment of all optical devices.
- Compensation of the linear instrumental polarization

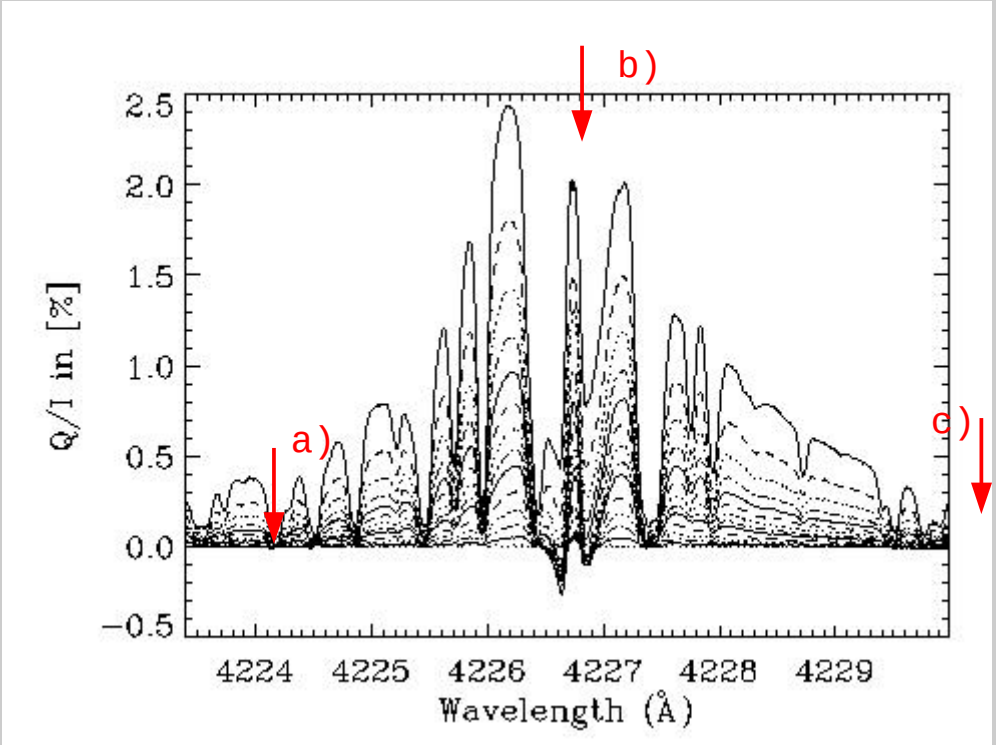
Results I

Example: center to limb variation (CLV) of the scattering polarization of the Ca I 4227 Å line

The zero level of Q/I is determined just comparing to disc center!



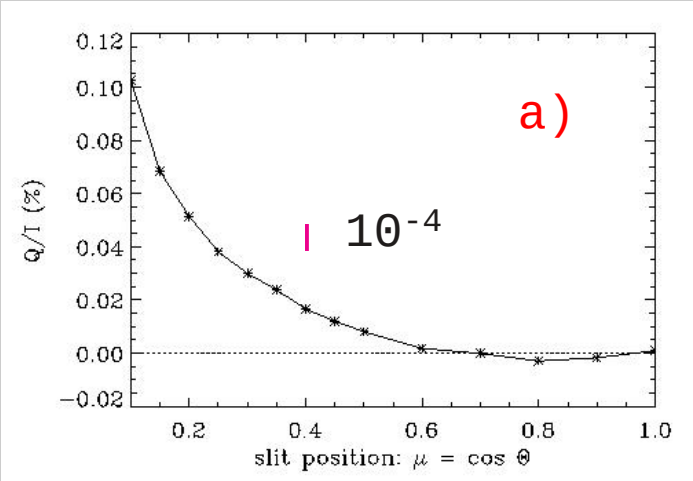
Scattering polarization measured at μ=0.1 (October 16, 2012)

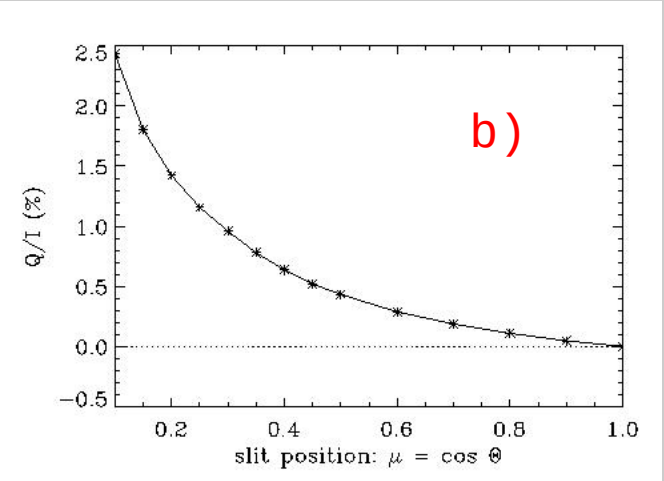


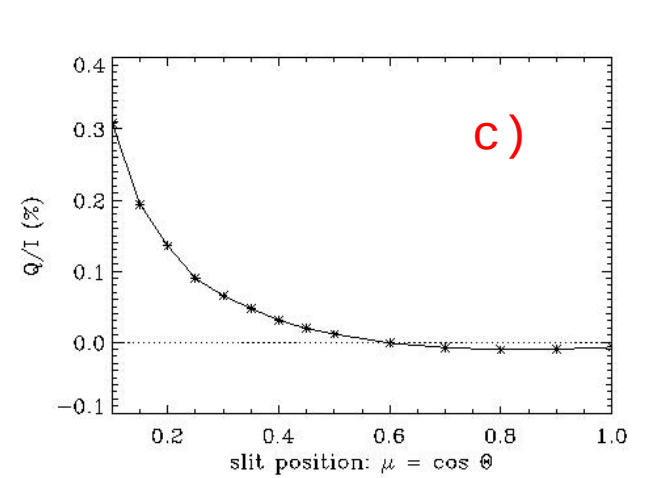
CLV of the scattering polarization, different profiles in function of μ are over-plotted

Results II

Q/I center to limb variation at three wavelengths, see previous slide







The uncertainty of the zero polarization level is about ~0.5 10^{-4}!

Conclusions

- One of the difficulties connected with high accuracy solar polarimetry, particularly measuring the Second Solar Spectrum, is the determination of the zero polarization position
- Improvements at IRSOL permit to measure that value with an accuracy of ~0.5 10^{-4}
- To acquire higher accuracy based on measured values, an atlas of accurate center to limb variation, CLV, of the scattering polarization of the continuum measured at different wavelengths is required