



# First successful deployment of the ZIMPOL-3 system at the GREGOR telescope

by

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## Abstract

Since several years the Zurich Imaging polarimeter (ZIMPOL) system is successfully used as a high sensitivity polarimeter. The polarimeter system, which is mainly based on a fast modulator (PEM or FLC) and a special demodulating camera with a masked CCD, has been continuously improved. The third version of the system (ZIMPOL-3) is routinely used at IRSOL, Locarno. The fast modulation allows to "freeze" intensity variations due to seeing, and to achieve a polarimetric sensitivity below  $10^{-5}$  if the photon statistics is large enough. In October 2013 the ZIMPOL system has been brought and installed for the first time at the GREGOR telescope in Tenerife for a spectropolarimetric observing campaign. There, the system configuration took advantage from the calibration unit installed at the primary focus of the GREGOR telescope, while the analyzer was inserted in the optical path just before the spectrograph slit after several folding mirrors. This setup has been tested successfully for the first time in this occasion.

## Introduction

The Zurich Imaging Polarimeter (ZIMPOL) [1] allows to obtain solar observations with high polarimetric sensitivity ( $<10^{-5}$ ). It is thus possible the exploration of a wealth of phenomena that generate a low amount of polarization such as elusive quantum mechanics interference effects in scattering processes and the Hanle effect. This gives a deep insight in the complex structures of the solar magnetic field.

The high polarimetric sensitivity is obtained thanks to fast modulation in the kHz regime followed by a synchronous demodulation obtained with a special camera with a masked CCD sensor. This allows to avoid spurious effects induced by intensity variations due to seeing.

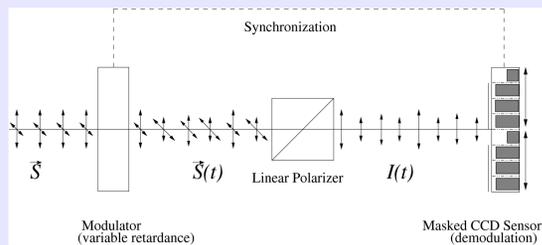


Fig 1: ZIMPOL measurement principle

## The first observing campaign of ZIMPOL@GREGOR

The observing campaign with ZIMPOL at the GREGOR telescope described here has been carried out from 21. to 31. October 2013. Its main goal has been to test the setup from the technical point of view and to learn about its capabilities. This has been the first step of a collaboration between IRSOL and the Kiepenheuer-Institut für Sonnenphysik (KIS) that aims at bringing a full ZIMPOL system permanently at the GREGOR telescope. This will allow to combine high spatial resolution with high sensitive spectropolarimetry mainly in the visible and in the near UV.

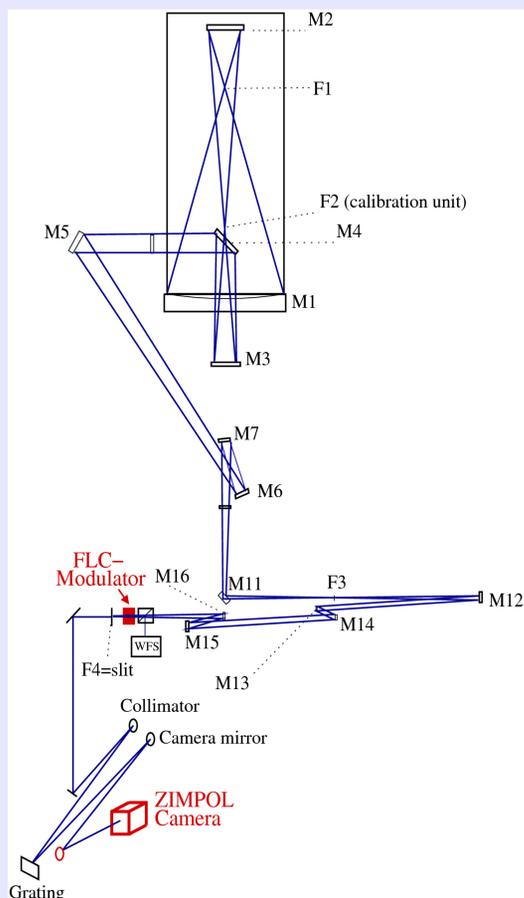


Fig. 2: The ZIMPOL setup at the GREGOR telescope.

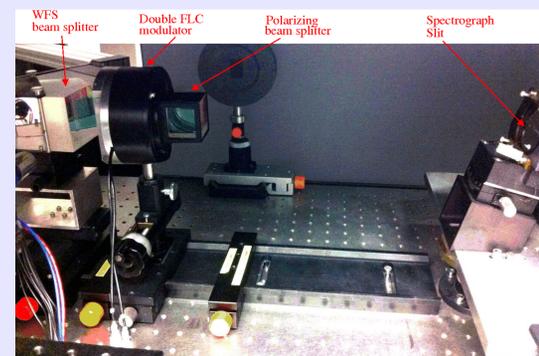


Fig 3: The ZIMPOL FLC modulator package consisting of a double Ferroelectric liquid crystal modulator and a polarizing beam-splitter installed before the spectrograph slit and after the beam-splitter feeding the wave front sensor of the adaptive optics system.

## Example of observational results

During the observing campaign we could perform several observations in different spectral regions and on different targets (e.g. solar limb, sunspots, prominences). Figure 4 shows, as a representative example, the four Stokes images of an observation recorded around the SrI 4607Å line on 30 October 2013. The measurement has been obtained near the solar limb with a total exposure time of 1 minute. The sharpness of the structures seen in the spatial direction, indicates how the observing conditions allowed to reach a high spatial resolution, also thanks to the usage of the adaptive optics system. The solar limb is located in the bottom direction, while the horizontal bright line in the I-image corresponds to a facular region. Positive Stokes Q is defined parallel to the nearest limb point. It is interesting to see how the scattering polarization signal in the Stokes Q/I image is increasing noticeably when approaching the limb, as expected from the theory. In the magnetic regions, clear signals from the Zeeman effect can be seen as symmetric patterns in the linear polarization (Stokes Q/I and U/I) and as antisymmetric patterns in the circular polarization. The lowest polarization signal detectable in the image has an amplitude of 0.01%.

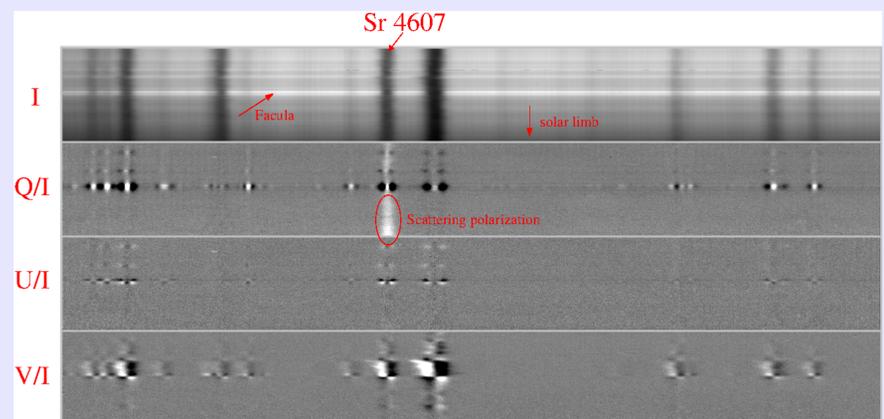


Fig.4: Example of full-Stokes observation taken around the SrI 4607Å line. During this observation the adaptive optics system was in closed loop.

## Conclusion

This first observing campaign has shown that the ZIMPOL-3 system works very well at the GREGOR telescope. The installation of the system did not present any difficult technical problem. We found, that the setup with the polarimetric analyzer just before the spectrograph slit in combination with the calibration unit at the focal point F2 installed before any folding mirror was very convenient. The calibration allowed to obtain observations where Zeeman effect signals did not show any evident sign of crosstalk from circular to linear polarization and vice-versa.

While the aim of the first observing campaign with ZIMPOL was mainly to test the instrumental capabilities, in 2014 we are planning a new campaign more oriented on selected scientific topics. In the near future we plan that a ZIMPOL system will be permanently available at GREGOR. We expect also to benefit of further developments of the instrumentation at GREGOR such as the slit jaw scanner and the image derotator that will give the possibility to perform scientific observations involving longer exposure times.

## Reference:

[1] Ramelli, R., Balemi, S., Bianda, M., Defilippis, I., Gamma, L., Hagenbuch, S., Rogantini, M., Steiner, P., and Stenflo, J. O., "ZIMPOL-3: a powerful solar polarimeter," in SPIE Conf. Ser. 7735 (2010).