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The project of installing a ZIMPOL_3 polarimeter at GREGOR in Tenerife

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Abstract. A project of collaboration between Kiepenheuer Institut für Sonnenphysik, KIS, and Istituto Ricerche Solari Locarno, IRSOL, includes the installation of a ZIMPOL_3 high resolution polarimeter at the 1.5 meter aperture solar telescope GREGOR in Tenerife. Important scientific topics are expected to be investigated, in particular in the case of events showing faint amplitude polarization signatures like scattering polarization effects, and the Hanle effect. This project has also a technical importance, this combination can be used as test bench for future polarimeters to be installed on the new generation solar telescopes.

Key words. Instrumentation: polarimeters – Sun: surface magnetism

1. Introduction

ZIMPOL (Zurich Imaging Polarimeter) is a polarimeter allowing high polarimetric resolution in solar observations (Povel et al. 1991; Gandorfer & Povel 1997; Ramelli et al. 2010). ZIMPOL, developed at Institute for Astronomy at ETHZ, was already used for international campaigns at large solar facilities (Kitt Peak, Sac Peak, La Palma, Tenerife). Since 1998 it is based permanently at IRSOL for scientific observations and for technical implementation. The last version ZIMPOL_3 is currently managed and developed by IRSOL and University of Applied Sciences and Arts of Southern Switzerland, SUPSI. The polarimetric resolution, down to few 10^{-5}, allows to investigate scientific domains that would be unreachable without these sensitivity. In particular we cite the opportunity to measure signatures in the order of parts of 10^{-4} produced by the Hanle effect. That allows the direct measure of the turbulent magnetic field (e.g. Stenflo 1982). High polarimetric resolution also allows to investigate elusive quantum mechanics interference effects in scattering processes, for example see Stenflo (1980), Smitha et al. (2011, 2012).

The scientific successes reached with ZIMPOL observations at IRSOL, using the 45 cm aperture Gregory Coudé telescope, and in international campaigns show that combin-

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ing a ZIMPOL_3 system with a telescope allowing good spatial resolution it would be possible to investigate unexplored domains in solar physics. At IRSOL the best spatial resolution reached in high polarimetric resolved spectra is about 2″. A better spatial resolution is expected to furbish more information about several topics like the geometry of solar atmospheric features, or about the behavior of the magnetic field.

Based on these considerations KIS and IRSOL decided to start a research project foreseeing the installation of a ZIMPOL_3 system on GREGOR in Tenerife (Schmidt et al. 2012). The system should be operating in 2014.

2. ZIMPOL_3 polarimeter at GREGOR

The principle of ZIMPOL can be seen as single beam polarimetry. Polarized signatures are transformed in modulated intensity by an analyzer (modulator and polarizer), the single beam at the exit of the spectrograph is demodulated in the CCD camera. The demodulation is obtained shifting, synchronized with the modulator, the charges on a masked CCD chip. Typical frequencies are in the kHz domain (Povel et al. 1991). That allows measuring the solar polarization signatures, unperturbed by seeing effects and by the polarization properties of the instruments located between analyzer and camera.

The results obtained are amazing, allowing precisions down to few 10^{-5}.

Installing ZIMPOL_3 on GREGOR we have to take into account following

- The calibration optics will be the already existing one, placed in an ideal location, on the telescope axis, before any folder mirror, thus in a point were the instrumental polarization is expected to be negligible.
- ZIMPOL will be installed on the spectrograph.
- The analyzer, composed by a modulator based on ferro-electric liquid crystals, FLC, and a polarizing beam-splitter, will be set just before the spectrograph slit. Thus folding mirrors, deroatator, and adaptive optics are located between calibration optics and analyzer.
- There will be the choice to use TIP (Tenerife Infrared Polarimeter) or ZIMPOL. Just few optical components need to easily be removed from or inserted in the optical path.
- The ZIMPOL camera will be placed near the TIP camera; inserting an appropriate folding mirror it will be possible to feed the desired camera.

The modulator of the analyzer is based on FLC modulators; four components are assembled, in order: FLC modulator, zero-order quartz quarter-wave-plate, second FLC modulator, second zero-order quartz quarter-wave-plate. The components are chromatic, but they are adjusted in such a way, that for each wavelength the four intensity values measured after the linear polarizer can be converted by an appropriate linear combination (defined during the calibration procedure) in the usual Stokes parameters, see Gisler (2005), chapter 6.3. That allows using the polarimeter as a perfect achromatic system.

2.1. Scientific motivation

High polarimetric resolution requires collecting a large number of photons being the noise proportional to the square of this number. That requires long exposure times, because the source is observed in high spatial and spectral resolution. For instance at IRSOL often exposure times of about 30 minutes are required. GREGOR has a larger aperture compared to the instrument in Locarno, but in Tenerife we have a better spatial resolution (and we will use a different spatial scale: arcseconds per millimeter) , thus the two effects partially compensate, and exposure times in the order of several minutes are expected. At small spatial scales solar structures can evolve quite fast, already in this order of times. That will give limits to the combination: spatial, polarimetric, spectral and temporal scale measuring solar structures. The real limitations will be explored by real observations, when it will be possible to really measure the instrumental problems introduced by the still unexplored optical configuration.

Scientific topics to be explored with this instrumental configuration has to be thought taking account the points above. As possible real topics we can try to list. Observations at IRSOL are giving important hints to local anomalies in scattering polarization signatures that could be related to spatial variations of the illumination anisotropy, that could be used to better investigate the atmosphere geometry (Shapiro et al. 2011; Sampoorna et al. 2009). The measure of scattering polarization coming from small scale structures (for example granulation) is expected to reveal important physical properties of the solar atmosphere and magnetic field (Trujillo Bueno et al. 2004). Forward Hanle effect scattering polarization (Trujillo Bueno 2001) is a tool allowing direct measurement of the chromospheric magnetic field (Anusha et al. 2011). The better spatial resolution of GREGOR will allow to better investigate the reachable limits of these technique, being aware of the limits introduced by the fast evolution of many structures in the chromospheric magnetic field. As usual, unexpected signatures and phenomena could also be expected to be revealed observing in the new resolution boundaries.

2.2. Technical interest

Besides the evident immediate scientific interest related to the opportunities of measuring with a ZIMPOL_3 system at GREGOR , we also would like to point out the technical interest. There will be the opportunity to test on a big solar telescope an already successful polarimeter allowing high frequency modulation (1 kHz with the FLC modulator). The particular configuration with the image rotator and the adaptive optics located between calibration optics and analyzer is particularly challenging for achieve high quality results, but we expect that the thus winned know-how will be very helpful for a next generation of polarimeters.

3. Conclusion

The installation of a ZIMPOL_3 polarimeter on GREGOR, requires solving challenging technical problems related to the presence of an image derotator and the adaptive optics system between calibration optics and polarization analyzer. The Muller matrix of these optical devices is changing in time. The scientific expectations of exploring the solar atmosphere with the combination of high: spatial, spectral and polarimetric resolution are nevertheless significant. The solar community should win from this project technical know-how, and will have the opportunity to use ZIMPOL_3 on a large instrument. Once the system will be fully operating at GREGOR (probably in 2015), we plan to devote time also to external applications (in terms to be already defined).

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