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Istituto Ricerche Solari Locarno: Instrumentation and Scientific Projects in Polarimetry

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Abstract. The Zurich IMaging POLarimeter (ZIMPOL) developed at ETH Zurich and installed permanently at Istituto Ricerche Solari Locarno (IRSOL) allows to reach a polarimetric accuracy down to 10^{-5} and thus to investigate new aspects of solar physics like solar scattering polarization and the action of the magnetic fields through the Hanle effect. As example an observation in the Ca I 4227 Å line is reported. The IRSOL facility is briefly described. The main scientific results and projects are mentioned.

Key words. Sun: magnetic fields – Instrumentation: polarimeters – Astronomical instrumentation, methods and techniques

1. Introduction

Istituto Ricerche Solari Locarno (IRSOL) (Figs.1,2), located in the Italian speaking part of Switzerland, was constructed in 1960 as external observatory by the Universitäts Sternwarte Göttingen (USG) Germany. In 1984, after USG moved its observational activity to the facilities in Tenerife, a local foundation acquired the institute in Locarno. The partially dismantled instruments were rebuilt and improved, in collaboration with USG, University of Applied Sciences in Wiesbaden, Germany, and Institute of Astronomy at ETH-Zurich. The scientific collaboration with ETH-Zurich allowed to start at IRSOL an important polarimetric observing program, first with a beam exchange polarimeter and then with ZIMPOL. Observation campaigns included for instance the measurements for the first two volumes of the ”Second Solar Spectrum Atlas” (Gandorfer 2000, 2002), the investigations of the Hanle effect in the quiet chromosphere (Bianda, Stenflo, & Solanki 1999; Trujillo Bueno, Shchukina, & Asensio Ramos 2004; Stenflo 2004), in prominences and spicules (Ramelli, & Bianda 2005; Ramelli et al. 2005), and the observation of polarization signatures of molecules in sunspots (Asensio Ramos et al. 2004; Berdyugina et al. 2006). A recent example of an observation of scattering polarization at the limb in the Ca I 4227 Å line showing Hanle effect signatures will be discussed in this paper.

With a Fabry Perot interference filter system and an adaptive optics system recently installed at IRSOL it will be possible to start several new projects in the next years.

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Fig. 1. IRSOL building with offices, guest rooms, a mechanical workshop, and the custodian apartment. The institute is located 500 m above sea-level over the city of Locarno near Lago Maggiore.

Fig. 2. IRSOL Observatory. In the left side of the building there is the observing room, while the spectrograph room is in the underground. All is white painted with titanium dioxide.

2. Instrumentation at IRSOL

The IRSOL telescope (Fig. 3) is a 45 cm aperture Gregory Coudé with 24 m effective focal length. The field stop at the primary focus allow a 200″ disk image to go through rejecting 99% of the sun light. This reduces mirrors heating and scattered light. This last point is of particular advantage when observing low intensity structures like sunspots, spicules and prominences. The relative angle between the two folding mirrors M3 and M4 (Coudé) changes only with declination and at the equinoxes is orthogonal. As a consequence the instrumental polarization, originated by non-perpendicular reflections, is almost constant over the day and virtually vanishes during the equinoxes. A Gregory Coudé telescope is thus a superlative instrument for polarimetric measurements.

An automatic guiding system developed by the University of Applied Sciences in Wiesbaden (Küveler et al. 1998) is also available.

The Czerny Turner spectrograph with 10 m focal length is based on a 180 × 360 mm grating with 300 lines per mm and 63° Blaze angle. A prism based predisperser allows to select the bandwidth entering in the spectrograph and to avoid orders overlapping.

Imaging observations of the solar surface will be performed using the recently installed Fabry Perot filter in collimated configuration (Feller et al. 2006). The filters are based on temperature controlled lithium niobate etalons of CSIRO with an aperture of 50 mm. The wavelength transmission can be selected modifying electrically the refractive index of the etalon medium, varying the temperature, or tilting the etalon. The measured bandwidth is around 30 mÅ. The system is currently being adjusted and it is planed to be available for scientific observations during 2006.

An adaptive optics (AO) system based on a tip-tilt mirror and on a 37 actuator deformable mirror is currently being installed and tested in collaboration with the University of Applied Sciences of Southern Switzerland, SUPSI and ETH Zurich. The system follows the design of the infrared AO system installed at Kitt Peak (Keller, Plymate, & Ammons 2003).

Two polarimeters are available. The oldest one operating at IRSOL is the two beams exchange device based on a Savart plate and on rotating quarter and half wave retarder plates (Bianda, Solanki, & Stenflo 1998). A polarimetric precision of a few 10^{-4} can be reached, but it can be affected by seeing induced cross-talks, because the technique requires two exposures taken at different times. The second polarimeter is ZIMPOL (Povel 1995; Gandorfer et al. 2004) which is installed permanently at IRSOL since 1998. The main advantage of this instrument is that it is free form seeing induced effects thanks to its high

Fig. 3. The 45 cm aperture Gregory Coudé vacuum telescope.

modulation rate: 42 kHz (with a piezoelastic modulator) or 1 kHz (with ferro-electric liquid crystal modulators). Another advantage is that the same pixel of the CCD ZIMPOL sensor is used to measure all Stokes parameters avoiding problems related to different gains. The ZIMPOL polarimetric accuracy depends primarily on the photon statistics. With a long exposure time it has already been possible to reach an accuracy of about 10^{-5}.

3. Solar scattering polarization observation

Linear polarization in scattering processes in the solar atmosphere is quite low, typically signatures are in the 10^{-3} regime. However the physical information connected to it is very rich, so that the solar physics community decided to define it as the ”second solar spectrum”. A very interesting application considers the action of the Hanle effect on the ”second solar spectrum” as diagnostics tool for turbulent weak magnetic fields, to which the Zeeman effect is blind. The Hanle effect (Hanle 1924) manifests itself when acting on the polarization caused by coherent scattering of the solar atmosphere radiation. An exhaustive overview of this effect and its use in astronomy can be found in the monograph of Stenflo (1994).

We present an example of observation in the Ca I 4227 Å line obtained with the ZIMPOL polarimeter. It was performed within a project we started with K.N. Nagendra and M. Sampoorna (Indian Institute of Astrophysics, Bangalore) intended to explore unexplained Hanle signatures in the line wings reported by Bianda et al. (2003). This calcium line forms in the low mid chromosphere and shows the strongest signature in the second solar spectrum in the visible, with ampli-

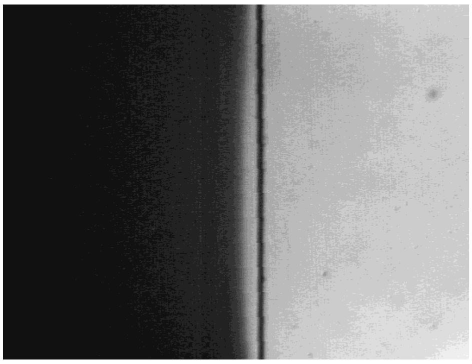

Fig. 4. Part of the slit jaw image, 190″× 140″, at low resolution corresponding to the measurement shown in Fig.5.

tudes reaching 4%. The first detections of the Hanle effect in the solar atmosphere were obtained with this line, first in an active region (Stenflo 1982) and then in the quiet atmosphere Bianda, Solanki, & Stenflo (1998).

The observation reported here was registered on the 15th September 2005. The spectrograph slit was set parallel to the limb at West equator, about 5″ inside the disc (Fig. 4). The slit subtended 200″ and was 1″ thick.

The four Stokes images of a spectral interval around the calcium line are shown in (Fig. 5). The positive Stokes Q is defined as the linear polarization parallel to the solar limb. In the intensity image we observe the broad Ca I chromospheric line at 4226.74 Å blended with several lines in the wings (most of them are iron lines). The Q/I image shows several structures. In the line core and the wings of the Ca I line scattering polarization can be seen, and can be explained in terms of anisotropy of the radiation field and partial frequency redistribution effects (Holzreuter, Fluri, & Stenflo 2005). The vertical dark shapes in correspondence with the blending lines, are depolarization features. In the calcium line core we note irregular features, changing along the spatial direction. These can be explained as Hanle depolarization signatures originated by magnetic fields in a regime of a few Gauss (Bianda, Solanki, & Stenflo 1998). Also in the U/I image we can see clear signatures in the line core. These are indications of the presence of oriented magnetic fields which rotate the plane of polarization induced by scattering processes. This is a typical manifestation of the Hanle effect. The nature of wing signatures would be discussed in detail in a forthcoming paper. No appreciable V/I value can be detected other than a very faint Q to V instrumental cross-talk.

In the solar atmosphere similar behavior can be observed in other strong polarizing lines like the sodium D2 line (Stenflo et al. 1998).

4. Conclusions

At IRSOL it is possible to obtain solar observations with high polarimetric and spectral resolution taking advantage of the high performances offered by the ZIMPOL polarimeter which is unaffected by seeing induced spurious effects. We are now starting an imaging polarimetric observing program using a Fabry Perot interference filter system. To improve the spatial resolution an adaptive optic system is being installed.

The technical improvements achieved in polarimetry allow high quality investigations of scattering polarization and a better understanding of solar magnetism.

Acknowledgements. Fig. 5 reports an observation connected to a project started with K.N. Nagendra and M. Sampoorna (Indian Institute of Astrophysics, Bangalore). We are grateful for the financial support that has been provided by the Canton Ticino, the city of Locarno, ETH Zurich, the foundation Carlo e Albina Cavargna.

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ZIMPOL has been developed at Institute of Astronomy, ETH Zurich, (H.P. Povel).

References

Asensio Ramos, A., Trujillo Bueno, J., Bianda, M., Manso Sainz, R., & Uitenbroek, H. 2004, ApJ, 611, L61

Berdyugina, S., et al., 2006, in preparation

Bianda, M., Solanki, S. K., & Stenflo, J. O. 1998, A&A, 331 , 760

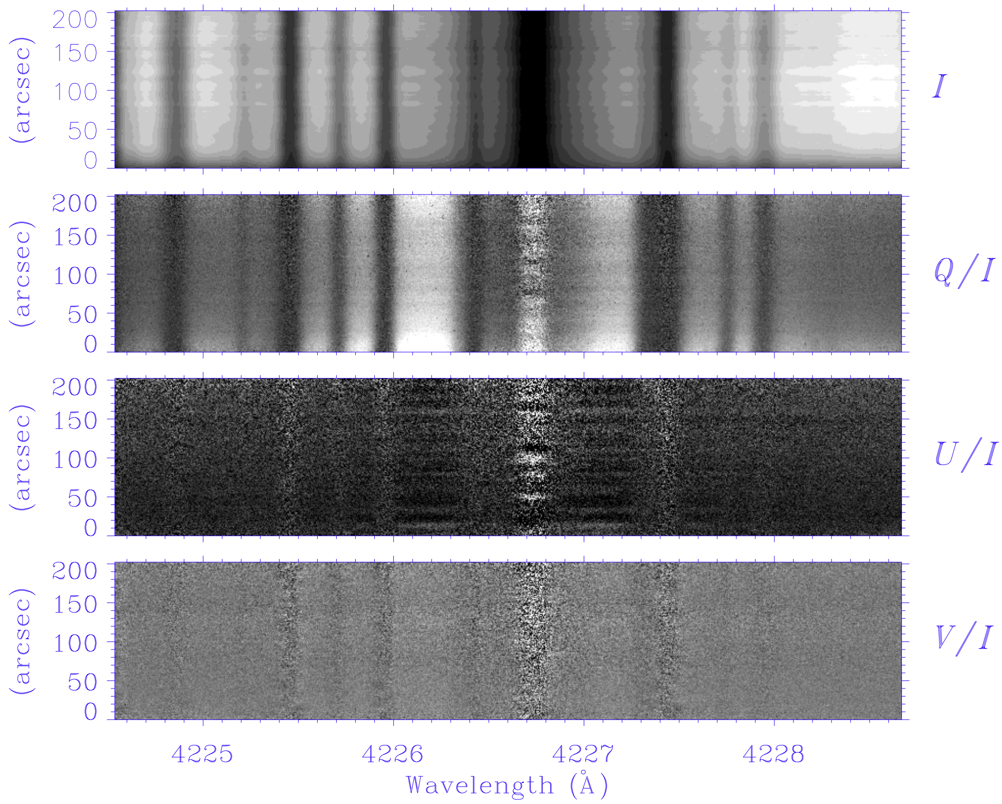

Fig. 5. Four Stokes images registered with the ZIMPOL polarimeter in the Ca I 4227 Å line close to the West equator limb in the region shown in Fig.4. No smoothing technique has been applied to the polarization images.

Bianda, M., Stenflo, J. O., & Solanki, S. K. 1999, A&A, 350 , 1060

Bianda, M., Stenflo, J. O., Gandorfer, A., & Gisler, D. 2003, in ASP Conf. Ser., 286, 61

Feller, A., et al., 2006, in Proceedings of the Fourth Solar Polarization Workshop, Boulder 2005, ASP Conf. Ser., in press

Gandorfer, A. 2000, The Second Solar Spectrum, A high spectral resolution polarimetric survey of scattering polarisation at the solar limb in graphical representation, Vol. 1: 4625 Å to 6995 Å (Zurich: vdf, ISBN 3 7281 2764 7)

Gandorfer, A. 2002, The Second Solar Spectrum, A high spectral resolution polarimetric survey of scattering polarisation at the solar limb in graphical representation, Vol. 2: 3910 Å to 4630 Å (Zurich: vdf, ISBN 3 7281 2844 4)

Gandorfer, A., et al. 2004, A&A, 422, 703

Hanle, W. 1924, Z. Phys., 30, 93

Holzreuter, R., Fluri, D. M., & Stenflo, J. O. 2005, A&A, 434, 713

Keller, C. U., Plymate, C., & Ammons, S. M. 2003, in Proceedings of the SPIE, 4853, 35

Küveler et al. 1998, Sol. Phys., 182, 247

Povel, H. 1995, Opical Engineering, 34 1870

Ramelli, R., & Bianda, M. 2005, in Astronomy and Astrophysics Space Science Library, vol. 320, Solar Magnetic Phenomena,

(Dordrecht: Springer), 215
Ramelli, R., Bianda, M., Trujillo Bueno, J., Merenda, L., & Stenflo, J. O. 2005, in ESA SP-596, Chromospheric and Coronal Magnetic Fields, (Noordwijk: ESA Publications Division)
Stenflo, J. O. 1982, Sol. Phys., 80, 209
Stenflo, J. O. 1994, Solar Magnetic Fields - Polarized Radiation Diagnostics (Dordrecht: Kluwer)
Stenflo, J. O., Keller, C. U., & Gandorfer, A. 1998, A&A, 329, 319
Stenflo, J. O. 2004, Nature, 430, 304
Trujillo Bueno, J., Shchukina, N., & Asensio Ramos, A. 2004, Nature, 430, 326