JOSO ANNUAL REPORT 2002-2003 - Switzerland

Werner Schmutz

Institute of Astronomy, ETH Zurich
Istituto Ricerche Solari Locarno (IRSOL)

ZIMPOL, the instrument system for high-precision imaging polarimetry that has been developed at the Institute of Astronomy of ETH Zurich, was used during 2003 for solar observing programs at Kitt Peak, La Palma, and IRSOL (Locarno). The Kitt Peak observations at the McMath-Pierce facility were made in the spectrograph focus to record 2-D spectra of the four Stokes parameters with the UV-sensitive version of ZIMPOL. The aim was to explore the scattering polarization and the Hanle effect in various spectral windows and regions on the Sun. Strongly polarizing spectral signatures of rare elements were found and studied, like from europium, yttrium, samarium, and rutenium. The molecular scattering polarization and Hanle effect of C_2 and CN were recorded in various magnetic regions near the solar limb. Horizontal chromospheric magnetic fields in the central portions of the solar disk were detected via their Hanle signatures in forward scattering in the Ca I 4227 and Na I D_2 5890 Å lines. Particularly strongly polarizing lines of chromium and titanium were studied.

At the Swedish La Palma observatory we observed simultaneously with two different ZIMPOL II systems, separated from each other by a dichroic beam splitter. With help of the adaptive optics system monochromatic images with narrow-band filters were recorded of the four Stokes parameters with the highest possible spatial resolution. One of the ZIMPOL systems was used with two ferrolelectric liquid crystal modulators to record vector magnetograms in the Fe I 6302 Å line, while the other ZIMPOL system was used with a 1.5 Å Ca II K 3933 Å filter to record chromospheric magnetic fields via the Hanle effect, in forward scattering near disk center, and in large-angle scattering near the limb.

Since many years the observed signature of scattering polarization in the Na I D_1 5896 Å line has remained an enigma, since standard quantum mechanics predicts that this line should be intrinsically unpolarizable. Theoretical attempts to explain this in terms of optical pumping of the ground state of the hyperfine structure multiplet have failed, since the predicted polarization has the wrong symmetry and an amplitude that is two orders of magnitude too small. To clarify if the solution to this problem is to be found within solar physics or within quantum mechanics, a laboratory experiment was set up to measure the scattering polarization at sodium atoms for 90° scattering angle. These measurements show very clearly that the scattered radiation from the D_1 transition is polarized, in agreement with the solar measurements but in disagreement with standard quantum mechanics. We therefore now know that the problem lies in quantum mechanics, not in solar physics, but a solution has yet to be identified. An explanation in terms of optical pumping can be ruled out, since the light source used in the laboratory experiment was far too weak to optically pump the sodium atoms in the cell.

The polarimetric observations at IRSOL have during the year addressed different scientific topics, in particular the search for impact polarization in solar flares, vector polarimetry of prominences in the He I D_3 line, and explorations of turbulent magnetic fields with the molecular Hanle effect of the C_2 molecule. The impact polarization program, using vector polarimetry in Hα in combination with an automatic flare recognition system, has now accumulated a considerable statistical material of many different flares, in particular of one of the largest X-class flares in October 2003. Not a single case of significant impact polarization was found, in contradiction to the many claims and reports on observed impact polarization in the literature. As the ZIMPOL system has much higher accuracy and is free from the various sources of systematic errors as compared with all the other systems in the world that have been used, we are now in a position to definitely rule out the existence of impact polarization on the Sun (above a level of about 0.1%).

Work has started at IRSOL to build and implement an adaptive optics system to be used in combination with the ZIMPOL vector polarimetric observations to significantly improve the spatial resolution. Another major program that has just been started is to develop and implement a fully tunable universal filter system with a passband of about 30 mÅ, based on two lithium niobate Fabry-Perot etalons that have been acquired by ETH Zurich in 2003 from CSIRO, Sydney.